BABY BUOY

Group 22

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1.0 Executive Summary

Throughout the United States, drowning is the number two cause of death among children between the ages of 1-4. According to the Center for Disease Control, approximately 800 children drown every year throughout the United States. Most of those drownings occur in our very own backyard swimming pools. Four main components that influence this death toll include failure to wear life jackets, lack of swimming capabilities, lack of supervision and lack of barriers to prevent water access while unsupervised.

In today's market, there are numerous devices to aid parents in need of extra pool safety and or supervision. One of these devices is the pool alarm. Most of these devices have a loud alarm that goes off once it detects large ripples of water from a child falling into the pool. However, there are some disadvantages based on user reviews, including short lifespan of some devices and the sensitivity of the motion sensor being too high. It is observed that the lifespan of most of these devices is limited from a few weeks to a few months before they begin to break down or stop functioning. Also, some users report many false alarms that may be provoked from filter pumps, wind, and small animals.

In our project, we constructed a “buoy” like device that countered these disadvantages and overall was more efficient for those investing in pool alarm systems. Our device included features such as a sounding alarm to alert individuals that there may be trouble in the swimming pool. We also developed a mobile application that works with the buoy. The mobile application communicated with the system as long as the buoy was connected to the WiFi, and the user’s phone has internet. The mobile application contained information such as logs from when the the alarm was triggered, and underwater images of what was detected when the alarm was triggered. To maintain and sustain battery life, we added solar capabilities. We also implemented a two-step verification, to reduce any false alarms from filters, wind, or any other miscellaneous objects that might disturb the surface of the water.

One of the critical features of our buoy device was first encounter verification. This was implemented with an efficient surface sensor to detect motion surrounding the pool top. The surface sensor was a PIR sensor that uses infrared radiation to detect heat. The sensor had a dome that focused the heat into the actual sensor component. The second verification method was an accelerometer to detect if there is any change in the surface of the water. If an object or a baby falls into the water, the ripples was caught by the accelerometer. As long as both the PIR sensor and accelerometer were triggered, then the user was notified. Additionally, there was an underwater 2MP camera to capture images when both sensors were triggered. All components were mounted onto a 3D printed board inside the electronics housing. The electronics housing was held by a adjustable arm, so the user could adjust it’s height and rotation since every pool is slightly different.

A pool alarm is crucial to have if you are a parent of adventure-seeking children between the ages of 1-4. Swimming pools are great fun in the backyard, but they also pose a threat to those too young to know the difference between life and death.

2.0 Project Description

The following section was written to illustrate the motivations, as well as the goals and objectives of pursuing this project. The dangers of having a swimming pool, specifically in the state of Florida, was highlighted to allow the reader to better understand our concerns and the overall concept behind investing in a pool alarm. Lastly, an overview of the projects requirement specifications to complement the goals and objectives will be present in the following passage.

2.1 Motivation

In the sunshine state of Florida, it is almost always summer-time. Having approximately 392,000 swimming pools throughout the state; scattered between civilian homes and community clubhouses, Florida holds second place in the nation with the most amount of swimming pools. Nevertheless, Florida takes lead in the nation for the number of child fatalities due to drowning. According to the USA Swimming Foundation, in 2017, there was a total of 51 children that passed away due to drowning in pools or spas. This was a 20 percent increase from the figures that were analyzed in the previous year, 2016. Based on the profiles recorded by the USA Swimming Foundation, 80 percent of those fatalities involved children between the ages of 1-4, and 20 percent being kids 15 and younger.

Our goal with this project was to construct a buoy with sensors to alert any parent that may have curious children that roam near the pool if or when they take a harmful, unsupervised step into the pool. The main objective of this project was to reduce the number of child fatalities that occur every year in the sunshine state known as Florida.

2.2 Goals & Objectives

The following section will cover some of the specifications that are implemented in the design of the Baby Buoy. The listed specifications below will be discussed in detail throughout the report.

- System shall have a maximum power consumption of ≤ 5W
- System shall cost ≤ $250
- System shall have an electronic housing no larger than 23*10*7 in. (L*W*H)
- System shall have a wireless communication range of ≤ 115 ft
- System shall have 16 hours of battery life between charging

2.3 Requirement Specifications

The following section will cover some of the requirements that are implemented in the design of the Baby Buoy.

- System shall have an IP58 rating
- System shall have 2-step verification

    - PIR Sensor and Accelerometer
- System shall have a mobile application to monitor the system
- System shall sound an alarm when triggered
- System shall capture an image and send it to the user via the mobile application
- System shall have solar power capabilities to sustain battery life

2.4 Related Work

Currently, there is a company named “cFloat” that has a pool system with similar features. However, based on multiple user reviews, it is reported that the device is too technical, not very user-friendly, and not worth the cost. The main goal for our device was to maintain a safe environment for children around the swimming pool. Our vision is to keep everything user-friendly, cost-competitive and not too technical that it strays away from the general purpose.

2.5 House of Quality

The marketing requirements of the Baby Buoy included reliability, durability, ease of use, battery life, compactness, and cost. The design focused on increasing all the requirements except cost, which was minimized whenever possible. The engineering requirements included waterproofing, power consumption, WiFi range, dimensions, redundancies, and cost. The Baby Buoy was partially submerged in water; therefore the device must be waterproof to ensure a long life and reliable operation. Since the device was self-powered by solar energy stored in a battery pack, power consumption must be minimized. Pools are usually outdoors and relatively far from household routers, therefore the WiFi range of the Baby Buoy must be maximized to ensure data transmission is uninterrupted. The device must be portable and easily put away when the alarm system is not needed, for this reason the dimensions are minimized as much as possible. The design increased redundancies to prevent false alarms from wasting battery power and the user’s time. Finally, cost was minimized to keep the device competitive in the market.

Waterproofing the device increased reliability and durability but negatively affected cost. Since the device housing was tightly sealed, the WiFi range was also negatively affected. Decreasing power consumption positively affected the battery life and required smaller solar cells and battery capacity which reduced the cost. However, it had negative impacts on redundancies and WiFi range. Redundant systems require power to operate, decreasing the power did limit the use of these systems. Increasing WiFi range increased reliability and ease of use but also increased cost which should be minimized. Reducing the device dimensions increased compactness but had negative effects on battery life, redundancies, and cost. Since the available space is smaller, more compact and expensive batteries were used and less area for redundant systems. Reducing cost negatively affected all aspects of the design except power consumption.

The targets for engineering requirements were selected as follows: IP58 is the Ingress Protection rating for dust protection and resistance to temporary submersion in water.

Water resistance can be demonstrated by submerging the buoy in water for several seconds and inspecting it for leakage. A 5 W power consumption is comparable to WiFi enabled wireless security cameras in the market today. The power consumption can be measured over time to confirm the specification has been met. Depending on the battery capacity selected, the power consumption can be calculated by how long it takes drain the battery. A 115 ft WiFi range is a common distance for current household routers. The Baby Buoy can be gradually moved farther away from a wireless receiver until data is unable to be transmitted, then that distance can be measured to find the WiFi range. The dimensions are flexible, as they may change through the design process, 23”x 10”x 7” is a sensible, non-intrusive size for a pool accessory. The dimensions can be demonstrated with a measuring tape during the presentation of the project. Two-factor verification is part of the design, an above water PIR sensor system sensed the motion of potential targets and the underwater camera verified the object being tracked has been submerged. This specification can be demonstrated by tracking a baby doll as it drops into a small pool. Finally, the target price of $250 places the product at the higher end of the market for similar products. The price requirement can be demonstrated by divulging the cost of each component used in the device.

The house of quality diagram shown in Figure 1 summarizes the relationships between marketing and engineering requirements. It also shows the effect each engineering requirement has on the others. One arrow pointing up represents a positive correlation while an arrow pointing down is a negative correlation. Double arrows in either direction represent stronger effects on those requirements. The plus and minus signs next to each requirement determines whether the design tried to maximize or minimize that particular requirement. Marketing requirements are shown horizontally in green while engineering requirements are vertical in a tan color. Finally, Targets for engineering requirements are shown vertically at the bottom in blue, aligned with their respective engineering requirements.

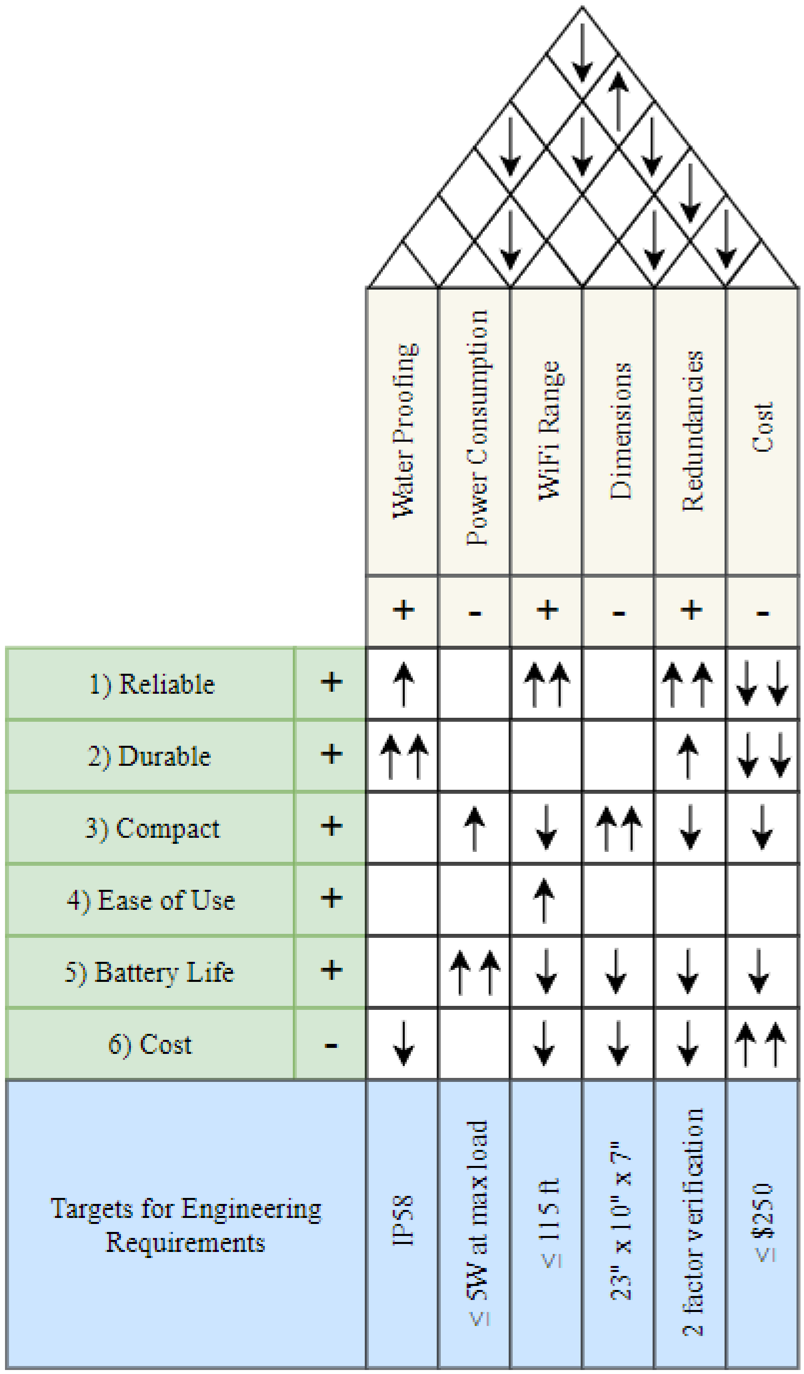

Figure 1: House of Quality trade-off table

2.6 Block Diagram

The following is the block diagram for the baby buoy. The PIR sensor detected if a human was walking near the pool, while the accelerometer was checking to see if a person or object fell into the pool. If it is a positive reading, then it will trigger the camera to detect capture an image of what's going on in the water. Additionally, with a positive reading the user would be alerted via their phone, while also having a sounding physical alarm on the system. The WiFi module is an external antenna that will allow the microcontroller to communicate with the users' phone via a mobile application. The user could use the mobile application to view a log of images and alarm triggers. If a reading is incorrect, then the user would not be notified. The battery will be supply power to the whole Baby Buoy system, while also providing solar charging capabilities via solar panels to sustain battery life.

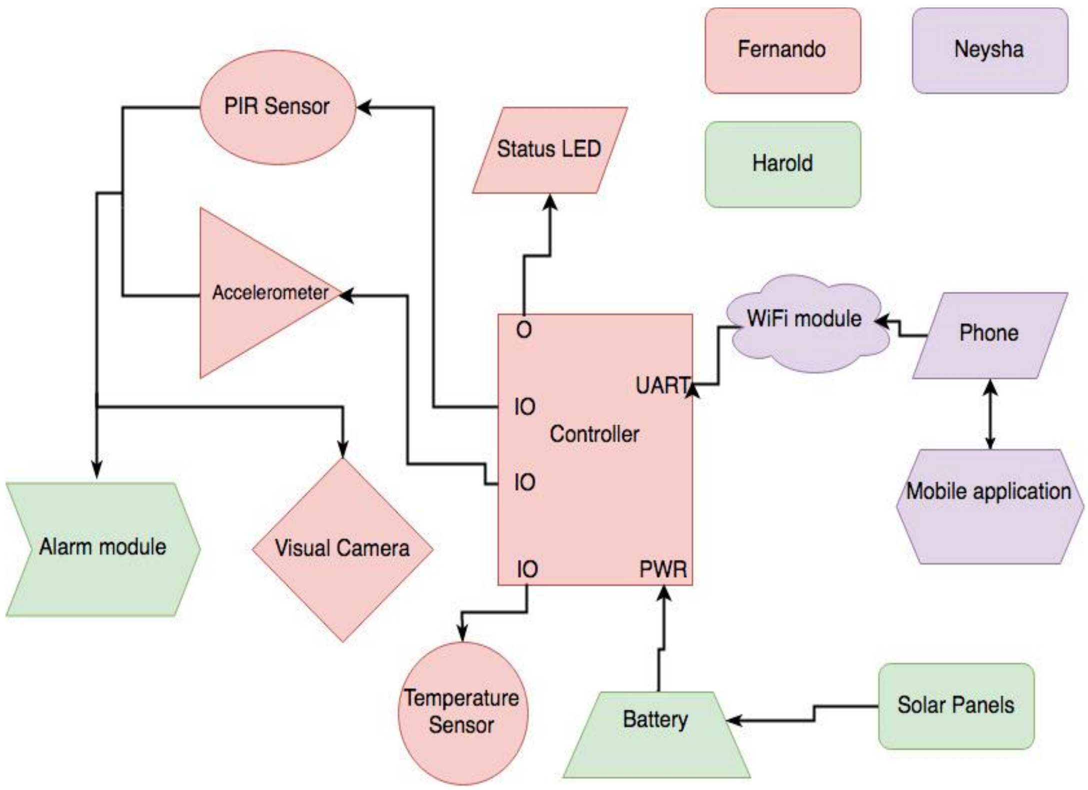

Figure 2: Project Block Diagram

Block status

Visual Camera: Acquired
Alarm module: Acquired
PIR Sensor: Acquired
Accelerometer: Acquired
Controller: Acquired
Status LED: Acquired
WiFi module: Acquired
Phone: Acquired
Mobile application: Acquired
Battery: Acquired
Temperature Sensor: Acquired
Solar Panels: Acquired

Diagram Legend:
Visual Camera: Secondary system to provide visuals of an object falling into the water.
Alarm module: Component that creates a sound if a correct object has been detected.
PIR Sensor: System that detects motion above the water.
Accelerometer: System that detects if an object or human has fallen into the pool.
Status LED: Component to notify the user that the system is running.
Temperature Sensor: Component to notify the user of the pool water temperature
Microcontroller: Controller that interacts with all the components.
WiFi module: External antenna that communicates with a WiFi signal.
Phone: User device needed for a mobile application.
Mobile application: Application needed to confirm if an object has fallen in the water.
Battery: Component that powers everything up.
Solar Panels: Component that maintains battery life.

3.0 Research

The following section will dive into examining various ways of accomplishing the requirements and specifications of our product. This was complemented through extensive research in the implementation of software and hardware components. There was an examination on existing products with similar functions or appearance that envisioned our baby buoy. Furthermore, comparison and considerations of various devices, framework, and material that may seem fit to be implemented on the baby buoy was completed.

3.1 Similar Projects

This section is a deep dive into some existing products and their architectural design and implementation, that influenced the style/design of the baby buoy.

3.1.1 cFloat Pool System

This product demonstrates several key components that were achieved in our final baby buoy product. Some features to take away from this item would be the mobile device connectivity. The cFlout is capable of connecting to cell phones and tablets of any carrier through the users Wi-Fi network. Within the mobile application users can interface with the device, and display data such as water temperature, pH levels, battery life, etc. that is being collected from the cFloat. The device also contains a motion sensor that kept an eye out for any motion that is being detected from the surface of the pool. Unfortunately, the device itself does not have an audio alarm built into the actual cFloat, but it comes with a separate "home" unit that is rechargeable through a micro-USB port. This "home" unit is also connected to the Wi-Fi of the user as well as cFloat, so that it may activate and set an alarm that will amplify through the house if there is ever any danger in the pool.

Figure 3: cFloat pool alarm system [43]

For the Baby Buoy, a mobile application was developed to collect data from the device out in the pool at a range of up to 115 feet. Some of the information that the baby buoy captured was from the temperature sensor, as well as motion from the PIR sensor. Through its Wi-

Fi connection, the Baby Buoy was able to send a push notification to the user to check up on the pool when the system was triggered. All the sensors were monitored through the mobile application, just like that of the cFloat. The cFloat system costs $399 via the PoolWarehouse website.

3.1.2 SafeFamilyLife by SafetyTech Pool Alarm

This product is simplistic in design but has a powerful delivery. The SafeFamilyLife pool alarm has mounting capabilities on any border of the pool's edge. Made of plastic, it is capable of keeping all electronic components inside the housing dry, making it waterproof. Another feature that the SafeFamilyLife has is an alarm that is built into the unit itself. This alarm is set off once there is any detection of a water level change, like that of someone falling into the pool. This sensor may be adjusted based on the level of the water.

Some key features that was reflected on the Baby Buoy was its capability of having the device mounted on the border of the pool. A waterproof housing was crucial to making sure none of the electrical components got damaged, such as the MCU and the cameras. The SafeFamilyLife pool alarm costs $139.99 via Amazon. The figure below shows the SafeFamilyLife pool alarm product.

Figure 4: SafeFamilyLife pool alarm system [44]

3.2 Mobile Application Development

The following section will break apart the differences between iOS and Android applications. Research on mobile application development will be conducted on which is the best programming languages, based on the platform. A detailed description of the UI of the mobile application along with expected widgets were interactive with the Baby Buoy.

3.2.1 iOS VS Android Application

In this section research on the very much debated topic of Android versus iOS development, will be crunched down and analyzed to what was best fit for the Baby Buoy project. Analyzation on both platforms will range from the user interface (UI), different mobile device compatibility, programming language, and longevity of publishment on the devices store.

3.2.1.1 iOS Platform

Mobile application development for iOS has its pros and cons. One of the biggest highlighted pros comes from how user-friendly applications developed for iOS are. Based on multiple user reviews, the App Store for iOS is very aggressive when it comes to choosing what apps may be showcased in their store. This is due to iOS being a closed platform, where Apple designs all of their software and hardware. One of their guidelines is creating having a "user-friendly" interface for everyone, something that is appealing, attractive to the eye and easy to get around. Which leads to a con, the app store is very strict with applications that are attempting to be published onto the actual App Store. This results in many rejections. Throughout the years many users have been able to find a suitable framework to reduce the number of rejects, by having the framework already set to fit a large majority of the needs that the App Store looks for in their published applications. Due to the fact they have only a limited number of apps that make it to the App Store, most app are able to load up fairly quickly and run smoothly without any lag or long wait times. Most submitted mobile applications get evaluated within four to five days before getting a notification on the status of the app.

A great feature about iOS development is that there are only 20 different types of mobile devices that are compatible with the iOS platform. This limited number of devices gives developers a shorter development process being that they consider dimensions from only the 20 different mobile devices. iOS uses a programming language called Swift, which is created to handle Apple's framework. Taking on the preexisting framework of apple, swift is practically identical from that of objective C. Apple first started development using the objective C language but has advanced to create its own type of programming language as time has passed.

The likelihood that the Baby Buoy team would be implementing an app on the iOS platform was not high. Due to the lack of objective C knowledge, aggressive and strict regulations on new apps, and wait time for application approval, iOS was less fit for the Baby Buoy project.

3.2.1.2 Android Platform

Android application development is much more popular based on the number of different devices that can support these applications. Developing for the Android platform can be rather challenging. The Android platform is an open source software that allows developers to extend to the furthest depth of their imagination when it comes to creating an application.

An open-source platform allows flexibility, custom frameworks, and freedom to have full creative power over the functionality and features of the application.

Although, from the large number of mobile devices that can sustain the Android operating system it suffers from fragmentation, which leads to having a different user experience from device to device. This is very challenging to the Android app developer, as they must optimize per individual operating system and screen dimensions, thus driving up cost in development. A great perk about having an open source software is that there are limited regulations that developer must adhere by. This creates a great turn over when it comes to launching and publishing an app on the Google Play Store. The wait time for must submitted mobile applications ranges from 30 minutes to five hours, to receive an acceptance or rejection. The Android platforms utilizes Java as its programming language for all app development.

The Baby Buoy team developed its mobile application for use on Android devices, for these reasons: The main programming language, Java is a more universal language that has derived much of its syntax from C and C++, two languages that the team is also familiar with. Having the ability to submit an application into the Google Play Store for evaluation and having it evaluated in less than five hours is a great advantage. This allowed more time to fix and update the app so that it may be published properly on the Google Play Store. Although the team dealt with optimizing for several different devices, that was a small price to pay to have the flexibility to be creative and construct a mobile application that was most suitable for our users' needs.

3.2.3 Wireless Communication Methods

There are numerous ways of accomplishing wireless communication between multiple devices. Wireless communication has taken lead in the past few years, having multiple types of information travel through waves, rather than through cables. In the following subsection, a detailed description will be made between the two most popular ways of wireless communication, Bluetooth and Wi-Fi. These two forms of communication will be broken down to evaluate which would be the better form to take on in the construction of the Baby Buoy.

3.2.3.1 Bluetooth

Bluetooth connectivity can be seen in devices such as headphones, keyboards, automobiles, and a few other small day-to-day devices. It operates at 2.4GH with a low bandwidth of 800Kbps. This is great when it comes to pairing perhaps, one or two devices at a time but it will eat up its bandwidth when it's paired with more than that. This will take a toll on the performance and create lag on any information that is being transmitted between all the devices. With that in mind, with the low bandwidth and frequency, Bluetooth will tolerate a range from five to 30 meters between the main device and the connected consoles. Although Bluetooth may not be very compatible with a large range or connectivity of many devices in a single moment, it's very cost effective. Bluetooth is very power friendly, drawing as little as 2.5mW and at most 10mW. This power consumption is determined based on the device your Bluetooth is paired with. Large devices like a speaker with an amp would draw more power in comparison to a wireless headphone.

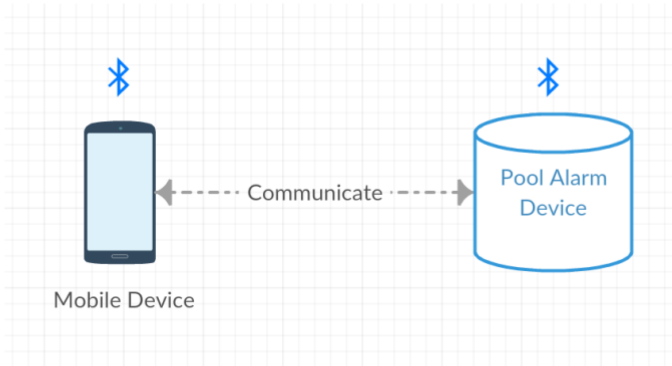

Figure 5: Wireless Communication through Bluetooth Model

3.2.3.2 Wi-Fi

Wi-Fi operates via radio frequencies very much like Bluetooth, but one of the biggest differences is how large the range of use is for Wi-Fi. Wi-Fi can operate as far as 300 feet. Depending on the Wi-Fi network that the user may have, its frequency can take up to 60 GHz bands. This is great to be able to receive and send information very quickly. With such a large frequency tolerance, Wi-Fi also has a high bandwidth ability of approximately 11 Mbps. With so much bandwidth, the user may also connect numerous devices at the same time with no lag or performance loss. Wi-Fi compatibility is seen through gadgets such as Desktops, Laptops, TV, and even mobile devices. All these features come at a price.

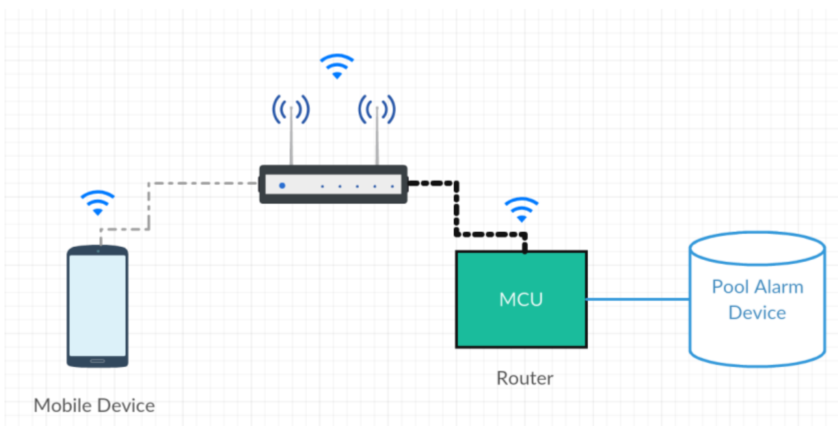

Figure 6: Wireless Communication through Wi-Fi Model

Wi-Fi is very expensive because all Wi-Fi must have a router. To have a router the user must hire someone to install the router. Wi-Fi also is very thirsty for power. It will continuously use approximately 30 mW of power, whether the user is connected to a device transferring data or not. There are a few programmable boards that have Wi-Fi built into them, such as the ESP32 and the ESP8266. Based on the large range and the ability to have multiple devices connected with ease, Wi-Fi was the best method of wireless communication.

3.3 Microcontroller

The Baby Buoy system used one microcontroller unit, which acted as the “brain” of the whole system. The MCU (microcontroller unit) had a major task of deciphering the data given to it by any subsystem and choosing what to do with that data. The MCU controlled the PIR sensor, the accelerometer, the camera, and several other components. The PIR sensor and the accelerometer constantly sent data to the MCU. If both of them were triggered, then the camera would turn on and send an image to the user. The MCU would also need WiFi capabilities, while also being able to connect an external antenna. The WiFi capability allowed for communication with the users' mobile device.

There were several aspects to deciding what microcontroller were best for our system approach. We needed an MCU that would be capable of processing all the data, with a programming language that the team is comfortable with. The MCU would also need to be capable of being connected to the internet to communicate with the user when necessary. More importantly, the cost of the MCU should be within the project budget and consume low power. All MCUs provide memory, a processor core, and programmable input/outputs.

3.3.1 Microcontroller Options

There is a large variety of microcontrollers to choose from. The team decided that an all-in-one inclusive MCU would be the best, since there would be no need for a master and a slave for WiFi capabilities. The ESP32 and ESP8266 were the first and second choices for our system. They have been used in numerous home projects and IoT (Internet of Things) projects. The third choice was the ATWINC1500, since it is also popularly used for home projects. All three microcontrollers were based on the Arduino platform, which utilized C++ programming language.

3.3.1.1 ESP Series

The ESP microcontroller series utilizes a 32-bit CPU with self-programmability and cost-effective in-circuit upgrades. The ESP MCUs are ideal for large amounts of coding and reliable performance in IoT projects. The ESP series also has a vast amount of online resources and tutorials for user related projects. This is a huge benefit as those online resources can be hard to come across for other MCUs. The ESP series is fairly inexpensive which helped the team stay under project budget.

3.3.1.1.1 ESP-WROOM-32U

The ESP-WROOM-32U is a high-performance microchip manufactured by Espressif. The ESP-WROOM-32U has 34 programmable I/O pins, of which atleast 15 pins would be needed for the Baby Buoy project. The ESP-WROOM-32U microchip has operating voltages of 1.8V - 3.6V, and temperature ranges of -40°C - 125°C. The operating voltages and temperature ranges were more than enough for the needs of the Baby Buoy. The ESP-WROOM-32U operates at 3.3V, 25°C (temperature), 160MHz (speed) with an active draw of 80mA (current). This equates to 264mW of power consumption. It also features an external antenna connection was crucial for connecting to the WiFi, given that the electronics housing is essentially a Faraday cage.

The ESP-WROOM-32U microchip has been used for various projects. Given the vast amount of online resources and tutorials, it is expected that this microchip is safe and reliable. The price for the microchip is $3.80 via the Digi-Key website. The most common system based on this microchip is the ESP32. The ESP is a revision of the ESP8266, where certain problems and features have been improved.

3.3.1.1.2 ESP-WROOM-02U

The ESP-WROOM-02U is the predecessor from the ESP-WROOM-02U microchip. The ESP-WROOM-02U provides 17 general purpose I/O pins, 50 KB of SRAM, and a maximum clock frequency of 160 MHz. It runs under the same operating voltages and temperatures of the ESP-WROOM-32U; 1.8V - 3.6V and -40°C to 125°C. Given that the ESP-WROOM-02U is of the same family as the ESP-WROOM-32U, it can be fairly easy to adapt the code from the ESP-WROOM-32U onto the ESP-WROOM-02U. The same online resources can be used, with the exception that the pins of the ESP-WROOM-02U have to be used. The ESP-WROOM-02U has all the major functionalities as the ESP-WROOM-32U, except it draws less power given that it provides less memory, pins, and a lower clock frequency.

3.3.1.2 ATWINC1500 Series

The ATWINC1500 is a series of microcontrollers manufactured by Atmel. It incorporates a 32-bit Cortus APS6 CPU, peripherals and various modes of operation. It integrates LNA, switch, power management, and power amplifier. The module also provides SPI and UART to interface to host controller.

3.3.1.2.1 ATWINC1500-MR210PB

The ATWINC15000-MR210PB is an affordable Wi-Fi controller which is built to consume minimal amount of power. This Wi-Fi module is specifically built to operate and work well with Internet of Things (IoT) applications. The ATWINC1500-MR210PB comes with integrated Power Amplifier (PA), Low-Noise Amplifier (LNA), and Power Management. It has the capability to operate under temperatures ranging between -40°C and 85°C.

The ATWINC1500-MR210PB also operates in voltage ranging from 2.7V to 3.6V. This chip may consume up to 268mA when transmitting, and approximately 61mA when receiving. This chip is less commonly used due to its strict IoT interface. Depending on where you buy from the ATWINC1500-MR210PB can go for as low as $10 and as high as $20. This would make the ATWINC1500-MR210PB a questionable purchasing. Everything would have to depend on what the application is being built for, as it has been addressed that this chip is in better used for Internet of Things application purposes only. It also has a PCB antenna which defeats the purpose of having an all-in-one inclusive MCU.

3.3.2 Microcontroller Comparisons

This section covers the comparisons between the top 3 microcontrollers of choice. The comparisons are based on the cost, power consumption, memory size, clock frequency and operating temperatures of each board. The board required a robust clock frequency and memory size to send images to the user, while maintaining as low of a power consumption as possible.

3.3.2.1 Cost

The cost of each microcontroller was extremely important in deciding which board to use for the Baby Buoy project. We have to maintain budget throughout the project, such that it can still be affordable at the end of the project. The end goal is for the project to be superior and more affordable than the cFloat and SafeFamilyLife pool alarms.

Table 1 shows the unit price of each microcontroller The ATWINC1500 is about 3 times more expensive than the ESP-WROOM-02U and 2 times more expensive than the ESP-WROOM-32U. There was no justification for choosing the ATWINC1500 considering its price point. The ESP-WROOM-02U and the ESP-WROOM-32U had much more affordable prices. Overall, the more expensive the microcontroller is, the more expensive the end product will be.

3.3.2.2 Power Consumption

The power consumption of our Baby Buoy device is not to be expended. The Baby Buoy is always to be attentive to its surroundings once it is powered on. The MCU that was governing our device must be low power consumption while still providing enough power for its subsystems. Having the motion sensor and the accelerometer feeding off of the power, along with the MCU sending and receiving signal throughout the day, power consumption was imperative in deciding which MCU to choose.

Table 1 shows the different microcontrollers and the amount of maximum power each consume individually. Based on the three that are in comparison the, the ESP-WROOM-02U would be consuming the least amount of power, using 612 mW of power based on the voltage and current input. The microcontroller with the most amount of power consumption was the ESP-WROOM-32U at 4320 mW based on the amount of voltage and current input. The ATWINC1500 has a power consumption of 1008 mW

3.3.2.3 Memory Size

The memory in a microcontroller varies depending on the product and what they are meant for. The three microcontrollers are very user friendly. The ESP-WROOM-02U is a microcontroller designed for low power consumption embedded applications and IoT projects. Static Random-Access Memory (SRAM) is the data space that is used for temporarily holding values during normal program execution and lost when the memory is not powered. The more SRAM a microcontroller has, the more temporary information it can hold.

Table 1 shows the SRAM for all three microchips/microcontroller boards. The ESP-WROOM-32U has the most SRAM, compared to the other microcontroller boards and microchips. It is apparent that the ESP-WROOM-32U is the strongest competitor in terms of memory, which was critical for all the image processing necessary to send bytes of data to the Amazon EC2 server.

3.3.2.4 Clock Frequency

The clock frequency is the rate of instruction execution for a microcontroller board. The higher the clock frequency, the faster the CPU can handle and perform tasks. It is important that the Baby Buoy system have a large clock frequency in order to perform all the image processing necessary to capture an image and send to the user. Without a large clock frequency, we wouldn't be able to perform all the tasks that the CPU had to handle due to these algorithms. The ArduCAM 0V2640 camera performed as the live image capture for when a human is detected by the PIR sensor and a fall is detected by the accelerometer. We needed to ensure that the CPU could handle all the tasks of all the subsystems as well. The clock frequency was one of the most important factors in deciding which microcontroller board to choose.

Table 1 shows the clock frequency for each microcontroller. It is apparent that the ESP-WROOM-32U has the highest clock frequency. The ATWINC1500 has the lowest clock frequency, while the ESP-WROOM-02U is in the middle. The ATWINC1500 has a maximum clock frequency of 48 MHz, the ESP-WROOM-02U has a maximum clock frequency of 160 MHz, while the ESP-WROOM-32U has a maximum clock frequency of 240 MHz. This is considerably faster than its counterparts, which is a superior increase in terms of computing power. The ESP-WROOM-32U has an exceptional clock frequency, which was necessary for the tasks of the project. The ATWINC1500 and the ESP-WROOM-02U microcontrollers have a clock frequency that is far too low for the needs of the Baby Buoy system.

3.3.2.5 Operating Temperatures

The operating temperature on a microcontroller depicts that a device will be operating efficiently within the given range of temperature. This range is varied based on the devices function and application use. There is typically a minimum operating temperature that is the coldest a microcontroller can be and still operate. There is also a maximum operating temperature which is the hottest it can operate at any given moment in time without malfunctioning, or force shutdown.

For the Baby Buoy project, a board that is capable of taking on a large heat tolerance is very much in need. Being that the device was mounted on the side of a pool, outside, it endured large amounts of continuous heat throughout the day. At night, it must be able to take on colder temperatures since temperature drops from daytime to nighttime.

Table 1 goes over the temperature ranges that each microcontroller board and microchip can operate in. Based on the research, the ESP-WROOM-02U and the ESP-WROOM-32U microchip have the largest operating temperature ranges. The low temperature value is how cold it can operate, and the high temperature value is how hot the board can operate before it malfunctions. The ATWINC1500 has the lowest operating temperature.

3.3.3 Microcontroller Choice

After comparing the features of all the microcontrollers, the ESP-WROOM-32U was the optimum choice for the Baby Buoy project. Of the three microcontrollers, the ESP-WROOM-32U offers the best processing power needed for the project, at the most cost efficient price. The ESP-WROOM-32U microchip costs $3.80, which is considerably cheaper than the ATWINC1500 that costs $8.08. The ESP-WROOM-02U costs the lowest at $2.80.

The ESP-WROOM-32U has a very low operating power consumption that is extremely important in being able to run the Baby Buoy system continuously for more than 1 day. The 5000mAh Li-Po battery was more than sufficient for the needs of the microchip and the Baby Buoy system. The operating temperatures for all the microcontrollers are more than enough for the environment that the system will be placed in. It wasn't the biggest factor in deciding which microcontroller to use, considering that the typical weather in Florida is 28°C. The number of pins (34) that the ESP-WROOM-32U microchip offers was more of a convenience than a necessity, since not all of the pins were utilized.

The ESP-WROOM-32U microchip has various online tutorials and documents for learning how to use the board and how to create projects with it. This is relevant since the ESP-WROOM-32U microchip is based on the same family as the popular ESP-WROOM-02U microcontroller. Although there are minor differences between the ESP-WROOM-02U microcontroller and the ESP-WROOM-32U microcontroller, portability is not too difficult. It is also important to note that the ATWINC1500 has a PCB antenna, which defeats the purpose of having an all-in-one inclusive MCU. Table 1 compares the specifications for each microcontroller.

Table 1: Microcontroller Specifications Comparison

Module	ATWINC1500-MR210PB	ESP-WROOM-02U	ESP-WROOM-32U
Board	ATWINC1500	ESP8266	ESP32
CPU	Cortus APS6	Tensilica L106	Xtensa LX6
Wireless Frequency	2.4 GHz	2.4 GHz	2.4 GHz
SRAM	64 KB	50 KB	520 KB
General I/O Pins Count	28	17	34

Maximum Clock Frequency	48 MHz	160 MHz	240 MHz
Operating Voltages	2.7V - 3.6V	2.5V - 3.6V	1.8V - 3.6V
Temperature Ranges	-40°C - 85°C	-40°C - 125°C	-40°C - 125°C
Maximum Power Consumption	1008 mW	612 mW	4320 mW
Built-In Wi-Fi	Yes	Yes	Yes
Price	$8.08	$2.80	$3.80

3.4 Battery

Since the Baby Buoy was solar powered, it required a battery back-up to power it at night and in cloudy days. Batteries are devices capable of storing electrical energy via chemical reactions within their cells. Batteries consist of three main components: the cathode, the anode, and the electrolyte. During discharge, the anode is the negative electrode while the cathode has a positive charge. An oxidation reaction occurs in the anode that releases electrons into the external circuit which are accepted by the cathode, the accumulation of electrons in the anode results in the electric potential of the battery. The electrolyte is a chemical medium that separates the electrodes and transports ions between the anode and cathode. During recharge, an external voltage source causes the flow of electrons to change direction and the anode and cathode polarities are reversed. In the Baby Buoy, the external voltage sources are the solar cells. It is important to note that the flow of current is opposite to the flow of electrons, therefore current flows into the anode and out of the cathode during discharge.

3.4.1 Battery Types and Applications

Batteries are separated into two major types, primary and secondary batteries. Primary batteries cannot be recharged, their chemical reactions are irreversible. They are used when recharging is difficult or impossible, for example, in pacemakers or animal trackers. Alkaline batteries are a common type of primary battery, they are safe and can be stored for prolonged periods of time. However, these batteries have low load current, therefore they can only be used in low current applications.

Secondary batteries are also known as rechargeable batteries, their electrochemical reactions can be reversed by applying an external voltage in the opposite direction of the battery operation. These batteries have a higher current output and are used when it would be impractical and costly to swap out primary batteries regularly. Secondary batteries are used in mobile devices, RC planes, and other high load applications. These batteries are classified into subtypes according to their chemical composition, some of these types include Lithium-Ion, Nickel Cadmium, Lead-Acid, and Nickel-Metal Hydride.

3.4.1.1 Lead-Acid

Lead-Acid Batteries are larger and heavier than other secondary batteries, for this reason, they are not used in portable devices. Lead-Acid are the oldest of the rechargeable batteries and are very reliable and low-cost. These batteries are commonly used in vehicles ignitions due to their ability to generate high current surges. Lead-Acid batteries are low maintenance and have low self-discharge rates. Limitations include environmental hazard due to lead content and low energy density. The life of these batteries ranges between 200-300 recharge cycles, relatively low compared to other rechargeable batteries. They are a good choice for applications that require only occasional deep discharges.

3.4.1.2 Nickel Cadmium (Ni-Cd)

Nickel Cadmium batteries consist of metallic cadmium electrodes and a nickel oxide hydroxide electrolyte. These batteries are also known as NiCad batteries, they have long life cycles and their ability to hold a charge when not in use is excellent. NiCad batteries' best attribute is their ability to deliver their full rated capacity at high discharge rates. They come in a variety of sizes, including AAA to D standard sizes, making them a viable option for portable devices. Some disadvantages of NiCad include its relatively low energy density compared to other rechargeable batteries. Its high self-discharge rate and environmental impact due to toxic metals in their construction. Also, the future capacity is lowered if a partially charged battery is recharged, this is known as the "memory effect". NiCad batteries have an average life of 2000 recharge cycles and an efficiency of 70-90%.

3.4.1.3 Nickel-Metal Hydride (Ni-MH)

Nickel-Metal Hydride are like NiCad batteries, they use the same positive electrode and electrolyte, however the negative electrode is a hydrogen-absorbing alloy. These batteries have higher capacity and energy density, double or triple a similarly sized NiCad. They are also not afflicted by the "memory effect", making them superior to NiCad batteries in that respect. They are more environmentally friendly with only mildly toxic components. Some limitations include low discharge current, high self-discharge rate, and high maintenance to prevent crystalline formation. Ni-MH batteries have wide ranging average life between 180-2000 recharge cycles and efficiencies of 66-92%. They require more complex charging procedures since they generate more heat and longer charging periods than NiCad batteries.

3.4.1.4 Lithium-Ion (Li-Ion)

The most common rechargeable battery used in mobile devices, the lithium-ion battery excels with its high energy density, low self-discharge, lightweight construction and immunity to the memory effect. Li-Ion battery life spans 400-1200 recharge cycles depending on the specific chemistry of the battery and efficiencies of 80-90%. The main disadvantage of Li-Ion batteries is that they cannot be recharged by a regular power supply, a specialized charging procedure must be followed to ensure the battery does not overheat and gets damaged. There are two main phases, a constant current phase and a constant voltage phase. First, the charger applies a constant current, normally between 0.5C and 0.7C, where C is the capacity of the battery being charged, usually given in mAh (milliamp-hour) or Ah (amp-hour). This is done until the battery voltage reaches 4.2V, then the charger turns to the constant voltage phase, maintaining the voltage at 4.2V until the current drops to 0.1C-0.03C, at this point the battery is considered fully charged.

3.4.1.5 Lithium-Ion Polymer (Li-Po)

Lithium-Ion Polymer batteries are a type of Li-Ion battery that has a polymer electrolyte instead of liquid. They have the same advantages and charging procedure as the Li-Ion batteries. The main benefit of Li-Po over Li-Ion batteries is their design flexibility, they can be made thinner and in any shape the manufacturer desires. The price of these batteries is also slightly higher than comparable Li-Ion batteries. They are safer than Li-Ion batteries but have slightly lower energy density. Li-Po batteries can have high discharge rates, which reduces their life to about 300 recharge cycles.

3.4.2 Battery Choice

Below is a table comparing the specifications of each battery, the Li-Po battery was chosen due to its compactness, which surpasses that of similar Li-Ion batteries.

Table 2: Battery Comparison

Battery	Lead-Acid	Nickel Cadmium (Ni-Cd)	Nickel-Metal Hydride (Ni-MH)	Lithium-Ion(Li-Ion)	Lithium Polymer (Li-Po)
No memory effect	✓		✓	✓	✓
Compact		✓	✓	✓	✓
Low self-discharge	✓			✓	✓
Not Toxic			✓	✓	✓
High discharge rate	✓	✓		✓	✓

3.5 Alarm System

The alarm system is a key feature that was implemented on the Baby Buoy project. Being that Baby Buoy is an advanced pool alarm, the sound that it emitted may be the difference between life and death. As described in "Similar Projects", Baby Buoy had an alarm mounted on the actual device that was installed on the side of the pool.

3.5.1 Piezo Buzzer

The Piezo Buzzer was the perfect element to creating a loud pitch sound to alert anyone of danger around the pool or inside the house. Piezo Buzzers come in many different sizes and models and are very commonly used in alarms. The great thing about this buzzer is how small it is. Throughout the different models, the size of the horn stays fairly small which is perfect for the compact style of the Baby Buoy. The Piezo Buzzer was great for outdoor use having the operation temperature range between -30°C to approximately 85°C. This temperature range is the same through all Piezo Buzzer models. The large temperature range that all Piezo Buzzers have was perfect for the indoor units as well. The pitch of sound the Buzzer is capable of outputting very well depends on the model. For the Baby Buoy project, the team is going to be installing a buzzer that is anywhere in between 60-90 dB. The number of decibels may be manipulated by the amount of voltage that is given to the buzzer. The higher the voltage the louder the sound it emits, the lower the voltage the softer the sound.

The Piezo Buzzer was very easy to install only needing two wires and a power supply. The power supply may be found on a programmable board or a battery. In the case of the Baby Buoy, the alarm was attached on the programmable board, which was powered by the battery. The Piezo Buzzer was set to sound off if it passes certain test case within the program. If all test cases output to be "true" the Buzzer sounded alerting anyone in the perimeter of danger. This is the logic that was exercised in the code. This test cases lessened the number of false alarms, or even eliminate any possibility of false alarms.

Figure 7: Piezo Buzzer [46]

3.6 Image Processing

Image processing is a form of signal processing where the general input would be an image and the output might be an image, feature, particular color, characteristic, that is associated with the input image. This type of technology is rapidly growing in most recent years. Image Processing may be found in airport security as well and home security. Most security camera systems come with image processing integrated in the software. There are two main forms of image processing, analogue and digital image processing. Digital image processing techniques are very useful in manipulating digital images through the use of a computer. Being using digital techniques, there are three phases that data must go through. Those being pre-processing, enhancement, and display. All three phases must be completed properly so that information is extracted properly from an image.

So that an image may be digitally processed, a image function f(x,y) is constructed so that the amplitude and the spatiality of the image is being put into consideration. This is done by converting data into digital form which can be done either through sampling or quantization. The spatial resolution of the digital image is determined by the sampling rate and quantization determines that amount of grey levels is found within an image. The levels of quantization must be very high so that the human eye can depict details of shading within an image. The collection of data is all towards enhancing the image so it can be recognizable and interpreted by humans. Based on the human biology, our vision is much more sensitive when it comes to dark colors that contrast in comparison to lighter colors that illuminate. Therefore, taking into consideration the quantization, which makes a collection of the grey scale within an image in very important in depicting the overall image.

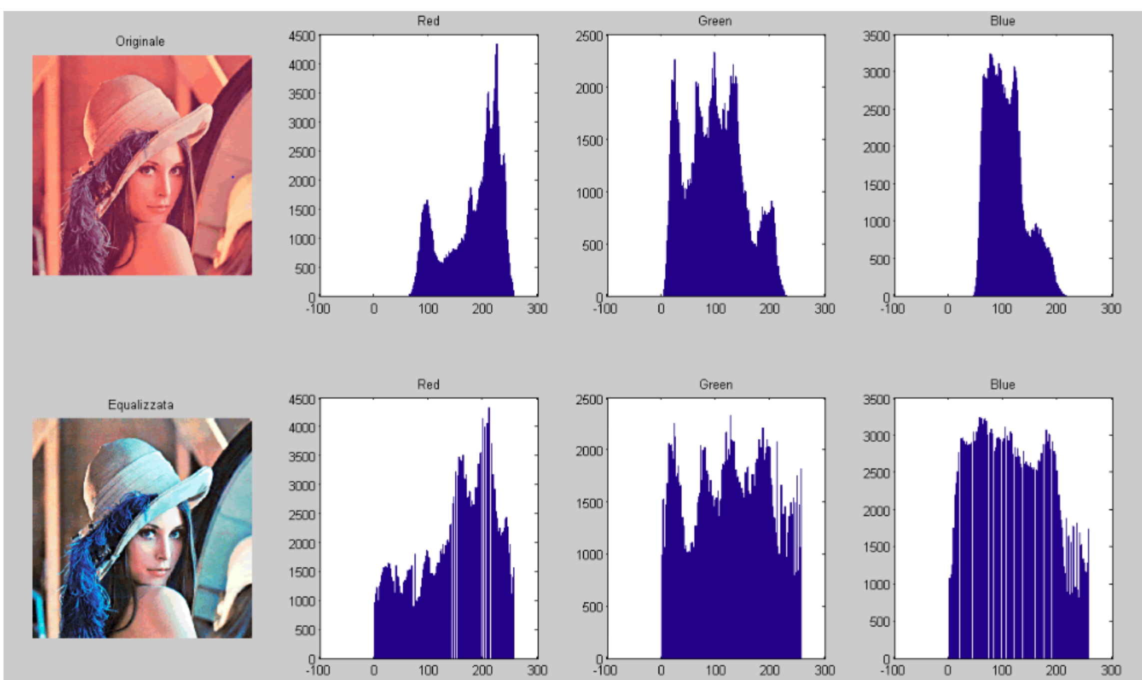

Figure 8: Image Processing Data Exhibition [47]

Figure 8 illustrates an image of a woman to the left and how the image is processed and broken down into the primary components red, green and blue (RGB). On the top left corner is the original image that was captured. One can see that it is very pink or red after development. Therefore, you can visually see the spike of red in the graph to the immediate right of the original image. There is also a fairly large spike in blue that can be visually seen from here outstanding hair. In the green graph there can almost be a linear line that can be draw from the base of green that there are in the image. The image below is seen to edited to make the original look more realistic. From the edit, you can see from in the RGB graphs that this image is more balanced throughout the scope which makes it more pleasing and realistic as a result.

3.7 Solar Cell

Solar Cells, otherwise known as photovoltaic cells, are capable of converting light directly into electricity due to a material property known as the photoelectric effect. Materials that exhibit this property will absorb photons and release electrons, which can be captured to produce an electric current. Solar cells come in a variety of shapes and sizes, selecting the right panel depends on the project at hand. Photovoltaic cells are not very efficient at converting solar energy into electricity, current commercial panels have efficiencies between 15-18%. Solar cell current is a function of light intensity; therefore a cell will only reach its rated current when a light threshold is met. This limits the operation of solar powered devices to peak sun-hours, unless battery back-ups are used. Most solar panels used for power grid applications store their energy in Lead-acid batteries that are then converted to AC to power homes. In order to select the correct solar cells to charge the Baby Buoy, a battery capacity must be calculated for the LiPo battery used. Also, the current from the cells is too unreliable to be used to power the device, the only function of the solar power was to charge the battery.

3.8 Voltage Regulation

Most microcontrollers have operating voltages ranging from 3.3-5V. However, some peripheral digital inputs will only work at 5V. On the other hand, most lithium-ion batteries used in portable devices have rated voltages of 3.7V. The use of voltage regulators comes from the need to normalize the input voltage of the system to a constant value that will be able to power all peripherals. There are two main types of voltage regulators, linear and switching. These can be either DC or AC depending on the specifications.

Linear regulators are also known as step-down regulators, they can only create a constant DC output voltage that is lower than the input. Their operation is based on voltage division where one of the resistors is variable to maintain a constant output over a range of input voltages. A transistor is used as the variable resistor by operating it in the linear region, depending on the base (BJT) or gate (MOSFET) voltage, the resistance value changes. An operational amplifier is used as a negative feedback controller to regulate the voltage to the transistor base. Linear regulators need the input voltage to be higher than the output by a certain amount in order for regulation to occur, this voltage difference is known as the dropout voltage. There are three basic types of linear regulators: Standard, low dropout

(LDO), and quasi LDO regulators. The main difference between these types is the dropout voltage.

Linear regulators are simple but not very efficient. Since the input current is almost equal to the load current, the change in voltage across the regulator times the current is power dissipated as heat. Other advantages of these regulators include fast response to changes in load voltage and no switching noise. Bypass capacitors are sometimes used parallel to the input voltage and load to maintain low AC impedance paths to ground. A very common linear voltage regulator used to teach about these devices is the LM7805, which drops voltages down to a constant 5 V output. The precision of these voltage regulators depends on the resistors creating the voltage divider, picking high precision resistors is necessary if the voltage needs to be within a certain tolerance. Linear regulators are also cheaper due to their simplicity.

Switching regulators operate by carefully opening and closing transistor switches using pulse width modulation (PWM). The circuits have inductors and capacitors that are charged and discharged to regulate the voltage. These regulators are more efficient than linear regulators, however, they have more electrical noise, added complexity, and are more costly. There are three types of switching regulators: buck converter, a boost converter, and buck & boost converter. Buck converters create a constant output voltage that is lower than the input. They are also known as step-down converters and are similar to linear voltage regulators.

Boost converters have a constant output voltage that is larger than the input. Since power must be conserved, the output current is lower than the input. They use the same components as the buck converter but in a different configuration. These regulators are also known as step-up converters. Finally, the buck & boost converters can produce constant output voltages that are either higher or lower than the input voltage. These converters have more than one switching component. They are very useful in battery operated devices when the initial charge of the battery might be more than is needed so the converter steps-down the voltage, but when the battery starts losing its charge it can step-up the voltage to maintain a constant output.

3.9 Two-Step Verification

A unique feature of the Baby Buoy pool alarm that the team implemented is a two-step verification system. In similar projects researched, it was discovered through user reviews that pool alarms out in the market have a bad reputation for giving out false alarms of an object falling into the pool. To combat this issue, the team is implementing a two-step verification. The two-step verification eliminated, or reduce, the number of false alarms that the device may capture.

This was implemented by using a motion sensor above the waters surface and an accelerometer to detect a fall. Additionally, a visual camera was place below the water so the user can see what’s underneath the water. The motion sensors purpose it to capture any motion within the scope of the devices range of vision. Once the motion detector is set off and the accelerometer detects a fall, it activated the underwater visual camera and sent the image to the user via the mobile application.

3.9.1 Raspberry Pi Camera v2

The Raspberry Pi camera v2 is an 8 megapixel Sony IMX219 sensor specifically designed for the raspberry board. This camera can take on images at 1080p30 and videos. This camera is very commonly used in security cameras to for image processing and motion detection. It also has the ability to perform time lapse photography depending on its program settings. The Raspberry Pi camera is an add no feature for any Raspberry Pi board capable of functioning with 5 volts. This limits the scope of possible microcontrollers that can be used by with this camera.

After extensive research this camera was an option for the Baby Buoy project. Is very limited in the options for programmable controllers. It is fair in price standing in the market for approx. $30, which is a very competitive rate from other cameras. Its high-quality resolution though was a large turn down factor for the final project. With its high resolution, when active, it consumed a large portion of current from the microcontroller. This visual option as an underwater camera has been turned down due to its limitations on implementation and current consumption.

3.9.2 ArduCAM OV2640 2MP

The Baby Buoy utilizes the popular ArduCAM OV2640 for capturing images underneath the surface of the pool. The ArduCAM features a 2MP camera that has several image processing capabilities in the included library. Color saturation, hue control, exposure control and more are programmable through its interface. This camera is low powered, cost competitive and extremely effective in capturing images as opposed to other cameras that aren't capable of communicating with the ESP32, are more expensive, or are TTL Serial cameras.

The ArduCAM was be triggered by the ESP32 when the system detects motion and a fall. The ArduCAM took a picture of the person underneath the water and stored it into an external server. The mobile application communicated with the external server to pull the image and show it to the user via a picture gallery in the application. The user can either delete or keep the image. The image resolution can be changed in the code, but for the Baby Buoy system, a 320*240 resolution was used. The image resolution is adequate for distinguishing between a human or an object.

The image should minimize any false alarms for the user, since it allows them to see what the surface of the water is underneath, as opposed to other pool alarms that have no image capabilities. The ArduCAM OV2640 was the optimum choice for capturing images underneath the surface of the water. Below is an image of the ArduCAM OV2640.

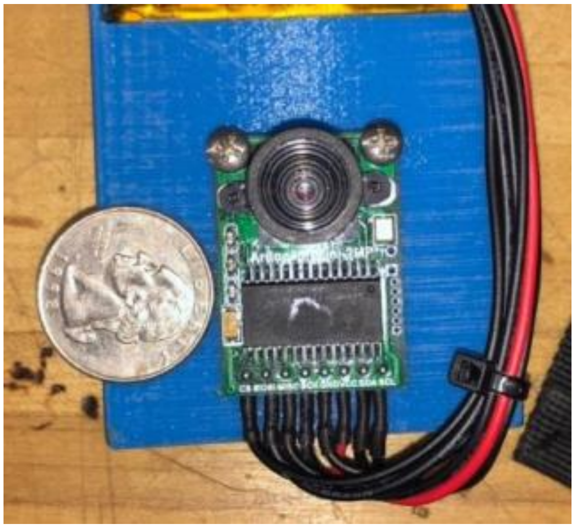

Figure 9: ArduCAM OV2640 2MP

3.9.3 MMA8451

The MMA8451 is an accelerometer from Xtrinsic. Accelerometers are normally used to detect motion based on its normal pivoting axis. If the module was tilted in any way from a motion, it sended an output signal to the microcontroller that there was a change in pivoting axis. The MMA8451 is very economic, listed in the market for approximately $8 dollars. It is low current and low power, so it would not cause a load of stress on the microcontroller. It operated through I2C, which is very common in most microcontrollers.

The accelerometer was housed into an external buoy so that it would lay on the surface of the pool water. For an accelerometer to function properly, we needed it to be external so that it can detect changes in waves due to acceleration. The team decided that this was the best component as we only needed something simple, not too complicated, and low power consumption. It is considered as the second step of verification for when a human fall into the pool.

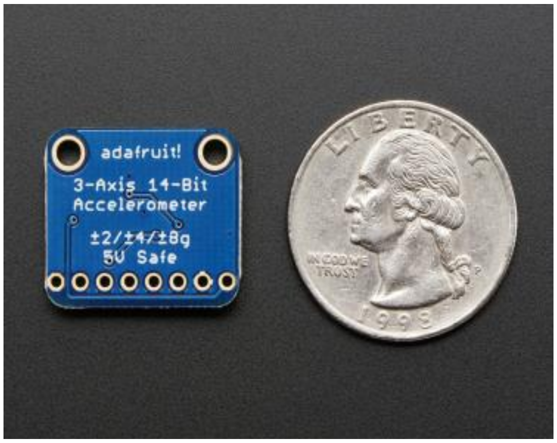

Figure 10: MMA8451 Accelerometer [15]

3.9.4 Passive Infrared Sensor

Passive Infrared (PIR) sensors are very common motion detectors that can be seen throughout many homes and facilities, in order to catch movement outside of their doors. They are usually implemented in a compact casing that may be mounted on a wall and a small camera for user visuals. With their small compact shape, they are very energy efficient and normally don’t wear out. PIR sensors operate with a vision scope that rang 100 degrees by 70 degrees and up to 20 feet away. They maintain a low power consumption between five volts and 20 volts, with the actual operating voltage of 5V. They are cost effective, at approximately $2 per sensor. The PIR sensor works by comparing the differences between heat that is detecting within the sensitivity range. If a human were to walk in front of the sensor it would detect the difference in heat from the surrounding environment. Once it senses the change in environment it would send out on output signal to the main board. Most PIR sensors come with a special edged sphere. This sphere is specially built to amplify the vision of the general sensor. The dome alone is what gives the sensor the range of vision; as it splits the output wave from heat detection.

For the Baby Buoy project, the team used a PIR sensor as the first step in detecting motion around the perimeter of the pool. Once the PIR sensor detects motion around the perimeter of the pool, an output signal will be sent out that will commence the second verification step; the accelerometer. The team believes that the PIR sensor was a great feature that kept the cost of the device to be competitive with other pool alarms in the market. The PIR is considered the best choice for above water motion detection. Below is a figure of a PIR sensor.

Figure 11: PIR Sensor [46]

3.10 Software Utilities

In today's resourceful technology, there are numerous tools found on the internet that may be utilized to optimize communication, organization, and design. With the proper use of such tools group projects will endure fewer headaches throughout the development stages of that said project.

3.10.1 Staying Connected

There are various tools that can be used as a platform for communication. Throughout the early stages of development, exchanging thoughts on where to collaborate and organize ourselves is extremely crucial. Essentially, this would be the foundation of where your brainstorming stage begins. The following are some of the tools that were utilized for communicating and developing the Baby Buoy.

3.10.1.1 GroupMe

GroupMe is a messaging application, that is owned by Microsoft. The general purpose of the application is to give users the ability to send group or private messages from their computer or phone using Wi-Fi. With GroupMe, the user has the option of creating an account with them by either the use of Facebook, Microsoft/Skype, or their own personal email address. Through the processes of signing up, the user has the option of syncing their contacts into the application as well as sharing their location to be able to be found by other nearby users with the GroupMe app. A very fun addition being utilizing this application is the preinstalled emojis and GIFs that can brighten conversation that one may have by using the app. A useful tool that comes with the application would also be the ability to create calendar events, share photos, and videos through a simple user interface. These are very basic features that the application has to offer but if used in the proper manner they may go a very long way.

3.10.1.2 Google Drive

Google Drive is simply a storage cloud for all your personal or private files. This service is a synchronized service that is provided by Google and can be utilized by simply having a Gmail account. In the Google cloud, you can share, view, and edit file with whomever you decide to send an invitation to. Besides sharing documents, Google Drive has built in office applications, such as sheets, docs, and slides that are extremely useful and free to use. By creating a simple Gmail account, you can utilize these tools and be given 15 GB of storage for free. This is a must in your tool box for developers to exercises the ability to share, collaborate, with others in their team, as well as, organize each step of the development process.

3.10.1.3 Github

Github is one of the biggest platforms to help developers solve problems by building software together. After making an account through their website you will have the freedom to store source files of any language and even share them with others. Github is a central location for any and all coding that is done within a project. Whether you are linked in a project with others or working independently, Github contains several tools that are to the user's disposal. One of these tools is the ability to create a separate branch independently from the main source code, therefore to not corrupt files in the middle of editing and testing. Another feature is the ability to keep track of everyone's commits and contributions towards the project. Currently, Github is an open source platform allowing users the freedom to innovate without boundaries, making it a most have in your tool box.

3.10.2 Development Tools

In a world of constant innovation, there are multitudes of tools that can be found online and utilized for free. These tools are created to better assist the developer and create simplicity between user and source code logic. This section will cover the developmental tools that was used to develop the Baby Buoy system.

3.10.2.1 Draw.io

Draw.io is a free tool found online, that may assist you in creating custom charts and diagrams with ease and simplicity. Draw.io provides the ability to share and save your creations in your local drive, dropbox, OneDrive, or Google drive. It contains several features such as templates for UML diagrams, flowcharts, general shapes, and arrows, to help you illustrate the necessary functions. This is a free tool available for anyone without the need to create an account. This tool was very useful in constructing diagrams and flowcharts that are seen throughout this document.

3.10.2.2 Visual Studios

Visual Studio is a dynamic IDE that is powered by Microsoft. Visual studio is free for any individual or collaborative use within small teams. It can compile code written in C#, visual basic, C++, HTML, JavaScript and many more coding languages that are built into the platform. It also can download addons onto the platform that will allow Visual Studios to performer compilations of languages such as Python, Ruby, M, and Node.js. With the ability to connect source code with multiple accounts, this is a very powerful IDE capable of collaborating with multiple languages through the cyber world.

3.10.2.3 Creately

Creately helps you draw diagrams of all kinds and collaborate with others. It can be easily used to illustrate your ideas, plans and work with your team. Creately can run on your desktop or your browser. Everything is synced via the cloud, so you collaborate with other in real time. Creately has a library of assorted templates that you may choose from to help you begin your diagram. The user interface is very user-friendly and colorful to help beginner navigate through all its features. Creately has a smart AI interface that will predict what type of diagram you are constructing, in order to better assist you in finishing your project in a timely hassle-free manner. This is a paid product but can be used for five free diagrams to be saved on its cloud storage without purchasing one of its packages.

3.10.2.4 Android Studio

Android Studio is the official IDE (Integrated Development Environment) for developing applications for Android operating systems. Android Studio is a free software created by JetBrains IntelliJ that can be used on several different computer operating systems such as Linux, Windows, and macOS. Different team members have different operating systems of choice, which makes it a huge convenience to be able to have this IDE, since mobile application development won't be strained onto only one developer of the team. Applications can be developed in Java, Kotlin, or C++. Being able to develop applications using Java is great, since several team members have experience with that programming language. The team also has experience using Android Studio since previous classes required by the College of Engineering and Computer Science have required a mobile application to be developed throughout the course. This would be more particular to the Computer Engineers of the team.

3.10.2.4.1 Android Studio Features

Android Studio offers various features for developing mobile applications. Considering that it is the official IDE, it means that there is constant support from the creators to make it run smoothly. Constant updates shows that the creators are concerned for the end users, since bugs can be patched with an update. Another feature is the Advanced Code Completion that it offers. The code completion that Android Studio offers for the Java language is exceptional. Code completion essentially completes the code for you depending on what you are trying to do with your code. It knows when a variable has previously been declared, which will allow it to auto complete if chosen based on the first few letters that you type out. Code completion also helps reduce the amount of time used when typing every letter out. Code completion is also more based on the development of mobile applications, since that it is the main purpose of the IDE.

Navigating through Android Studio is easy once you learn where all the buttons are, and what they do. The UI (User Interface) for Android Studio is very effective for mobile application development since it was built purposely for Android, as opposed to another IDE where the purpose is in being the best all-purpose IDE. Project organization is great since Android Studio creates modules to manage and organize the code modules.

3.10.2.5 EasyEDA

EasyEDA is a browser based electronic computer aided design tool that allows teams to collaborate in the design of board schematics and PCB design. The website has an open source library of components which include pinout of IC components as well as PCB pad and pin mappings for most components. Schematics can be converted to PCB layouts fairly easily with the built-in functionalities. EasyEDA is partnered with an online store for electrical components called LCSC as well as a custom PCB manufacturer by the name JLCPCB. These partnerships make EasyEDA very convenient since components can be selected from the design and bought simultaneously, and once the PCB design is done, it can be sent out for manufacturing, the only thing they will not do is place the components on the PCB, which can be done with a pick-and-place machine or manually soldering.

3.10.2.6 Multisim

Software created by Electronic Workbench, now owned by National Instruments, used for electronic schematic capture and circuit simulation. Multisim is a powerful tool with an extensive library of components and analysis tools. During simulation, the circuit can be probed using digital multimeters and oscilloscopes, the simple interface makes it ideal as an academic aid for students to learn electronics without the need for breadboards and expensive equipment.

3.10.2.7 Eagle CAD

Eagle is an Autodesk software package used to design electronic schematics and PCB layouts. The software has a free package that is available for students. It has a comprehensive library of components to ease the schematic design process and a powerful converting tool to turn the schematic into a PCB design. Eagle has a large community and plenty of online resources to get started, including how-to tutorial videos in youtube among other things. The program is an electronic design automation (EDA) tool much like EasyEDA. However, the paid software is more powerful than EasyEDA and more commonly used in industry.

3.11 Pulse Width Modulation

In the topic of buck and boost converters, the term pulse width modulation (PWM) was used. PWM is a method for generating analog signals from a digital source by precisely regulating when the signal turns on and off. Digital signals are limited to only two discrete states, on or off, usually 5V for on and 0V for off. Analog signals are continuous and time-varying, they can have any value. The Duty Cycle represent what percentage of time the digital pulse is on during a period, or the inverse of frequency. The brightness of LEDs can be controlled by adjusting the duty cycle of a digital signal, which parallels an analog current adjustment. Pulse width modulation has a variety of uses from servo control, telecommunications, power delivery, audio control, and voltage regulation as previously stated. In modern RC servos, the duty cycle of the pulse determines the angle of rotation, with pulses traveling at 50 Hz or 20 ms. In telecommunications, the pulse width is used to encode the amplitude of transmitted signals.

3.12 Printed Circuit Board

Printed circuit boards (PCB) are a part of every electronic product in the market today. The need for smaller and cheaper electronics devices led the evolution of circuits from point-to-point wiring, to vacuum tubes and relays, and eventually to silicon and integrated circuits on PCB. Printed circuit boards have metal lines, also known as traces, and pads to connect components together in any required configuration. Solder is used to make electrical connections between components and the PCB, it also serves as a strong mechanical adhesive since it is a metal, usually consisting of tin and lead.

The PCB consists of several different layers, including the silkscreen, soldermask, copper, and substrate. The silkscreen is the outermost or top layer, its main purpose is to add symbols and labels to facilitate assembly and make it easier to understand for other people. This layer is usually white, but any color can also be used. The soldermask gives the PCB its color, it is usually green. The purpose of this layer is to insulate the copper traces and expose the pins and pads that will be used for soldering. The copper layer is a foil that is laminated to one or both sides of the substrate depending on whether it is a one sided or double-sided PCB. Currently, it is common for more sophisticated PCB designs to have 8 copper layers or more. The circuit traces and ground are located in this layer, its thickness is commonly 1 ounce of copper per square foot, but it can be made thicker if the device consumes higher power. Finally, the substrate is the core of the PCB, it provides thickness and rigidity. The substrate is most commonly made from FR4 which is a type of fiberglass with a fire-resistant epoxy resin binder, although flexible high temperature plastics such as kapton are also used.

PCB design requires knowledge of the terminology used to describe the topology of the board. The following list defines these terms.

- **Wave solder** - A soldering technique for through hole components in which the board is passed over a standing wave of molten solder which connects the components to the board.
- **Via -** Holes in a board that allow signals to pass from one layer to another. Sometimes the via is under the soldermask to protect it from unintended soldering, this is called tented vias.
- **V-score -** Is used to tear off boards from a panel, similar to mouse bites. The perimeter of the board is partially cut to make it easy to snap off.
- **Trace -** A path of copper within the board that is used for circuit interconnections, it replaces wires in older circuit designs.
- **Thermal -** Small trace that connects a pad or annular ring to a plane, it is used to allow the connection to reach a high enough temperature for a good solder joint.
- **Surface mount -** Components are soldered to pads on the PCB instead of passing through holes in the board. It is the most common method used to place components on a board.
- **Solder jumper -** Refers to shorting two or more adjacent pins with solder on a PCB. It can be done on purpose to connect pins without the need for wires or new traces, but it can also be an error if too much solder is used on a pin.
- **Solder pot -** A pot containing molten solder, it's used to quickly hand solder boards by dipping them in the pot, creating solder joint on any exposed pads.
- **Solder paste -** Small solder particles are suspended in a gel medium which is applied with the paste stencil. When the paste is heated, reflow occurs and the solder particles melt, serving to connect components to the PCB.
- **Slot -** A hole in a PCB that is not round, they may be plated or not.
- **Reflow -** Refers to melting solder to connect components to PCB pads.
- **Pogo pin -** A tool used to penetrate the solder mask to make temporary connections for testing purposes.
- **Plated through hole -** Is used to connect through hole components or as mounting holes for the PCB. It is a hole with an annular ring that goes through the board.
- **Plane -** Also known as pour, it's a sheet of copper in the board that is defined by borders instead of a path, it is most commonly used for the ground terminal of the PCB.
- **Pick-and-place -** A machine used to place components on the PCB board to solder. It uses suction to hold on to components and places them on the board pads, which are heated so the components are instantly soldered.
- **Paste stencil -** The copper pads on the PCB are covered with solder paste to facilitate soldering of components in the pick-and-place machine. The paste stencil is a mask

that goes over the PCB with holes where the pads are to deposit the solder. Stencils are thin metal or plastic sheets.

- **Panel -** A collection of boards in the same substrate that can be broken apart after manufacturing into individual boards. Having a panel of boards is more efficient since automated handling equipment doesn't need to change boards as frequently and it's also easier to handle larger panels.
- **Pad -** The exposed metal on the board that is used to solder components.
- **Mouse bites -** A series of clustered drill hits along a path to create weak spots for separating boards from a panel with multiple copies. The boards can be broken off by hand or with pliers, making sure not to bend the board too much or the traces might be damaged.
- **Finger -** Used to connect two separate circuit boards together. They are exposed metal pads along the edge of the board, commonly seen in GPU units and RAM sticks.
- **Drill hit -** Locations where holes should be drilled in a PCB design. Dull drill bits can result in errors in the drill hits, this is a common issue in manufacturing.
- **DRC -** Stands for design rule check. The design is reviewed using software to make sure there are no trace shorts, incorrect trace thickness, or incorrect hole diameters, among other possible errors.
- **Annular ring -** The ring of conductive material, commonly copper, around a plated through hole in a board.

Some manufacturing requirements to ensure a working PCB include the dimensions of pins, pads, traces and layers in relation with each other. The pad sizes must be 0.010" larger than the finished hole size for vias and 0.014" larger for component holes. Recommended hole sizes are 0.015", with the minimum allowed size of 0.008". Copper trace width of 0.005" are recommended with spacing between traces of 0.008". The minimum silkscreen width is 0.005". For power circuitry, the trace widths are larger than for logic circuitry, this width is a function of the current going through the traces. The following table relates trace width to maximum current ratings.

Table 3: Guidelines for trace current capacity. Source: Armisted Technologies

Temperature Increase	**10 ℃**	**20 ℃**	**30 ℃**
Width	**Maximum Current (A)**		
0.010"	1	1.2	1.5
0.015"	1.2	1.3	1.6
0.020"	1.3	1.7	2.4
0.025"	1.7	2.2	2.8
0.030"	1.9	2.5	3.2
0.050"	2.6	3.6	4.4

0.075”	3.5	4.5	6
0.100”	4.2	6	7.5
0.200”	7	10	13
0.250”	8.3	12.3	15

In the case when there is not enough space in the PCB to increase the trace width for a higher current capacity, a common technique is to leave the traces exposed after the solder mask is deposited and add solder to the top of the trace, increasing the trace weight and current carrying capacity. The Baby Buoy will have a PCB design inside the main housing that will include the MCU, battery charging IC, and voltage regulator IC, with all the corresponding passive components and switches for the inputs and outputs as required.

3.12.1 PCB Partitioning

Another important factor of PCB design is the electromagnetic compatibility (EMC), which refers to the ability of the whole electronic system to work with no errors caused by electromagnetic interference (EMI). To prevent or reduce interference, a few design criteria should be followed. The circuit loop must be minimized to prevent it from acting as an antenna for EMI. Also, only a single reference plane should be applied in a system. If the PCB has both digital and analog signals, or mix-signal, the ground planes should be separated, one for analog, the other for digital, in order to isolate them. Failure to do so will greatly increase EMI and signal crosstalk.

4.0 Design Constraints and Standards

All projects that take on a form of engineering contain certain constraints and limitations that play a role in the completion of the engineering project. These constraints range from being technological, some sort of legal constraint, or even financial. Whichever the case may be, all constraints must be handled appropriately and in a timely manner to ensure success in the development of the project. The following section goes over several design constraints and standards that affected the development of the Baby Buoy device.

4.1 Constraints

In the development process of the Baby Buoy device, various design constraints played a role in implementation. Thus, in this section the design constraints was highlighted for the overall system.

4.1.1 Economic Constraints

The overall cost of development plays a major constraint. The Baby Buoy team was funding the entire project themselves. This meant the team had to conduct extensive research on the part that was put in the final design of the Baby Buoy. The research was crucial for team, since it means that they weren't able to have the freedom to perform trial and error in pursuit of determining which components would best work for the Baby Buoy system. By buying multiple components in an effort to create a trial and error scenario will only increase the cost of the prototype as well as lead to a financial burden on the team.

The manufacturing cost for the Baby Buoy must also stay as low as possible to be able to compete with other similar products out in the market now. The Baby Buoy must be affordable and for all users in whichever wedge group they may pertain to. Keeping the cost low helped in marketing our product to the ideal user. In an ideal case, the Baby Buoy team would take advantage of having the freedom to test and explore different components in a trial and error scenario. But due to the Financial constraint, the team must find the finite balance between cost and quality.

4.1.2 Health and Safety Constraints

The team's top priority when developing and designing this product is the health and safety of the end user as well as the Baby Buoy team. The purpose of the Baby Buoy project is to save the lives of children by alert a parent or guardian if there is any child near or in the pool. Therefore, attention was invested into what the needs to be considered and what needs to be accurate in order to accomplish this safety constraint.

Careful programming and development is taking into action when it comes to the motion sensing and the Wi-Fi connectivity. The Baby Buoy device contained two types of sensors on board, plus the visual camera. Even with both cameras operating, a lag or lack of programming in the software to advise the camera that there is a child in the perimeter may lead to a life-threatening situation. The lack of proper programming may lead to the alarm not sounding or the parent or guardian not being notified with time. This also applies to the Wi-Fi connectivity of the device. If the camera is detecting motion in the perimeter but the

Wi-Fi connectivity is not strong enough to reach the user from 300 feet away or the Wi-Fi has poor connection, these are errors that will lead to life treating situation.

All the dangers stated above are very much possible if these features fail, but the may also be caused by the faulty hardware. A bad sensor which happens to stop working after installment or faulty wiring with a poor connection may lead to safety hazards. To avoid the described scenario above, the team is being very thorough when it comes to testing the components of the device before installing them on the PCB board. Although, all the components will be aggressively testing before installation, malfunctions will still be a possibility, which is the sour truth of computer components. In attempts to keep the malfunctions in the eyes of the user, data will be collected in the form of logs in order to check on the features in on the device.

Powering the device is also something that the Baby Buoy team is putting up as a high priority. Every component in the device will need power to operate efficiently. Thus, the team is using a lithium battery that is calculated to power all the components as well as solar panels to be able to help the battery and maintain it. For the natural environment of the device, obtaining solar power will not be an issue being that it is belt for outdoor use. In general, the team is studying on a library of lithium batteries and solar panels that are in the market today, so to best choice one that would power all components. The Baby Buoy team will practice caution when handling both solar panels and lithium batteries as the both contain hazard chemicals and materials that are harmful to the human body.

The Baby Buoy device, as implied by the name, involve the monitoring of children. Having the device outside and accessible to the children that the device is monitoring. The housing of the device must be secure and inaccessible to the children. Inside the device there are many small hazardous components and chemicals that maybe harmful to small children. This device is to only be operated by adults. To combat this issue the solar panel will be encased in a transparent box outside the pool and small components will be secured in a deionized aluminum frame. Even though these protective measures are put into effect, the device is still to be operated by adults only with caution.

4.1.3 Social Constraints

The purpose of the Baby Buoy was to increase the safety surrounding the average user's home pool. In order to achieve this, the team strived to keep the cost of the product low, so that it may be available to many users, rather than a select group of users. Another social constraint is the ease of device installment. This is being put into consideration when it comes to the designing and testing of the device. Being that are device has many built in features, such as Wi-Fi connectivity and motion detection, when it comes to the installation method, the team is striving to make it very friendly to the ideal user.

4.1.4 Sustainability Constraints

The team is envisioning the device to sustain a life span of up to 16 hours without recharging the battery. The sustainability constraints is derived from the harsh environments that the device will be placed under once finalized.

The Baby Buoy device needed to withstand extremely hot and cold environments. During the warmer climates the components and general device itself, must be able to withstand the warm southern climates of the United States, and the cold climates of the northern states. This will be very well thought out by the team, as the device exhibited an aluminum frame in order to protect the components inside, such as the cameras and MCU. After careful research, the team has come to terms that the pool alarm will sustain an ideal temperature to maintain all the component healthy by having a portion of the device submerged in water. This will automatically keep the aluminum frame cool throughout the summer seasons. For the winter months, the team has been very specific with the selection of components and has made sure that all components that will be within the housing, may withstand extremely harsh cold environments. Having all electrical components inside the aluminum frame and also constructing a see-through casing for the solar panels will guarantee protection from other unforeseen climate changes such as strong winds, rain and snow.

Besides the alternative climate changes throughout the fiscal year, the electronics housing needed to be 100% waterproof. To ensure this, the team implemented waterproof electrical wiring sockets. The sockets prevented water from coming into the unit at all cost and ensured a dry environment for all the electronics.

4.1.5 Time Constraints

The time constraints were the most important constraint. The Baby Buoy team was given a period of approximately eight months to accomplish the desired product. The time constraint was the driving factor to many design decisions. The team was given till the end of Senior Design 2, or 8 months to accomplish the product. The team must’ve taken into consideration this time and kept the design of the product optimal but within scope of the time frame. There were various features that could’ve implemented into the final Baby Buoy product, but they were considered out of scope. Thus, the team did not consider those features at the time.

To achieve maximum performance from all team members, a schedule was created to take on the two-semester time constraint. In the process of managing time, the construction of the PCB was considered by the Baby Buoy team. It was to the team's knowledge that the PCB required excessive attention to detail. Once the PCB was constructed, it must’ve been shipped off for testing, which may have led to a redesign of the PCB and further testing. The teams schedule can be seen in the administrative section under project milestones.

4.1.6 Presentation Constraints

The Baby Buoy team was limited when it came to showcase the product and testing. This is due to the fact that the system was developed for outdoor use, specifically in swimming pools. To showcase the device, the Baby Buoy team planned on having several recorded test results, which were conducted outside of campus.

The team had reached out to friends and neighbors that were willing to lend the team time to access their property in order to test the prototype. The access was limited due to it being at the teams' friends and/or neighbors' convenience. An advantage to that case was having the possibility of testing our device against several different size pools of different dimensions and lengths.

4.1.7 Manufacturability Constraints

When analyzing the components that took part in the final product for the Baby Buoy device, the team ensured that the components chosen were in the market for some time and that they weren't exclusive components. This could've posed a manufacturing constraint. Every piece that was ordered to take part in the final product was checked for the number of units in stock that are available and how long that it has been available to the general consumer. This was placed at a high priority because the team must ensure that they have some sort of insurance when it comes to relaying on parts from manufacturer.

4.2 Standards

In the following section, several hardware and software standards are brought to light for better examination. While these standards are analyzed, there will also be discussion on how it relates to our project. In this section, discussion on general safety procedures and concerns will be touched on to further ensure the safety of the group in their specific design implementation.

4.2.1 IPC PCB Standards

The Association Connecting Electronics Industries, or IPC, is a trade association determined to standardize the manufacturing process of electronic equipment. This association has published many standards that are used by commercial PCB manufacturers to ensure reliability in their products and uniformity within the market. The IPC-2221 is the generic standard on printed board design that establishes the requirements for component mounting and interconnecting structures. Other standards include IPC-2615, which covers printed board dimensions and tolerances. IPC-ET-652 for guidelines and requirements for electrical testing of PCB with no components. IPC-A-600 describes the acceptability of printed boards in inspection settings. IPC-A-610 for acceptability of electronic assemblies. Some material specification standards include IPC-4562 for metal foil for printed wiring applications and IPC-4202 for flexible base dielectrics for use in flexible printed circuits. IPC standards range from general topics to design specifications, materials, performance, and inspections.

The Institute for Printed Circuits was originally founded by six individual printed circuit board manufacturers but in 1957. After 20 years, in 1977 the six manufactures officially changed the name of the institution to the Institute for Interconnecting and Packaging Electronic Circuits (IPC). Since then the institution has been able to publish several standards for when it comes to building a circuit from scratch. The IPC has gone into depth on design specifications, material specifications, performance and inspection documents, flex assembly and materials standards, and general documentation. It is recommended to uses the IPC standards when it comes to building your own custom circuit.

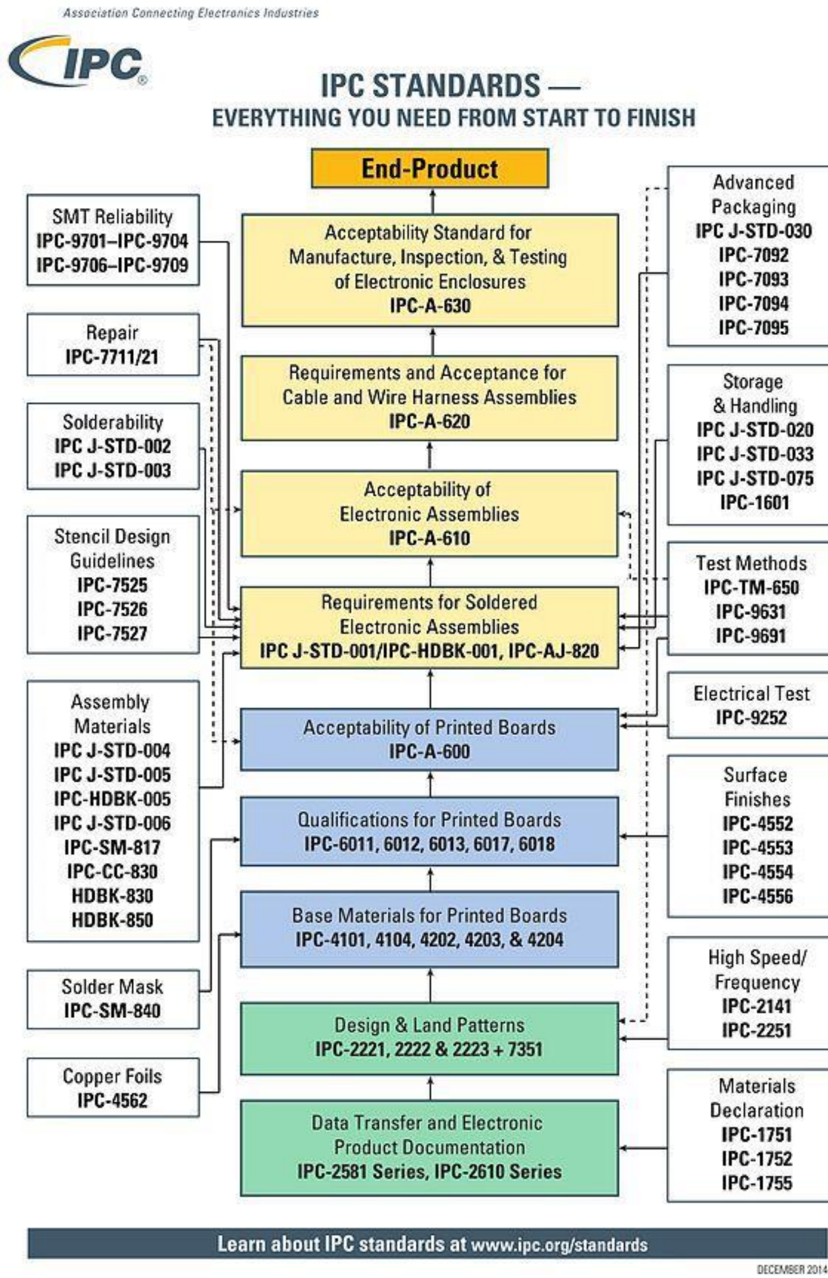

Figure 12: IPC Standards [48]

In the Baby Buoy project, the team manufactured their own PCB board. It was important for the team to follow several guidelines that are stated within the IPC standards. As illustrated in the image above, the IPC standards are step by step documents that thoroughly go into detail on what are some of the expectation for getting a PCB to be checked out properly, how to add components through soldering, and what type of flux to use to create the best joint. Throughout the building process. The team went back through the IPC standards to insure an accurate and efficient board for the Baby Buoy.

4.2.2 IEC 60950-1

The safety of information technology equipment standard is applicable to battery-powered equipment and office electronic devices with rated voltages under 600V. It's main purpose is to prevent hazards such as fire, electric shock, and mechanical instability. It divides equipment into three main classes. Class 1 equipment protects from shock by basic insulation and protective earth grounding. In other words, if the insulation of a conductive segment fails for any reason, the conductor is also connected to a protective earth conductor. Class 2 equipment requires no ground for protection since it uses double or reinforced insulation. Finally, Class 3 equipment operates from a safety extra low voltage (SELV) supply circuit, which inherently protects from electric shock since the equipment is unable to generate a hazardous voltage. Some definitions are required for the complete understanding of the standard:

- **Hazardous Voltage:** Any voltage over 42.2 VAC or 60 VDC without a limited current circuit
- **Extra-Low Voltage (ELV):** A voltage in a secondary circuit under 42.2 VAC or 60 VDC that is separated from a hazardous voltage by at least insulation.
- **Safety Extra-Low Voltage Circuit (SELV):** A secondary circuit unable to reach a hazardous voltage. SELV circuits must be separated from hazardous voltages by two levels of protection such as double insulation.
- **Limited Current Circuits:** Are designed to output safe currents even in the case of shorts or any fault conditions. For frequencies lower than 1 kHz, the steady state current cannot surpass 0.7 mA AC or 2 mA DC. For higher frequencies, the 0.7 mA limit is multiplied by the frequency in kHz without exceeding 70 mA.
- **Limited Power Source (LPS):** Designed with a set output voltage, current, power, and short circuit current limit.

4.2.3 IEC 60529

The International Electrotechnical Commission (IEC) 60529 is a standard that goes over what would classify an object to be protected from environmental elements. This standard is also known as the Ingress Protection Marking. These standard rates a device based on the degree of protection from dust, intrusion, accidental contact, and water. The Ingress Protection (IP) has its own grading scale in order to classify devices that are claiming to be protected for a environmental element.

In the grading scale format is as follows "IP##". The "IP" would stand for it being officially graded by the Ingress Protection. The first number or digit would tell the user the intensity of the object's protection from a solid surface. The second number is how resistant the device is to water. The higher the rating the more protected the device is. The Ingress Protection goes through aggressive and extensive testing to scale the protection of devices. No other company can mimic what they do, therefore no other company can create their own grading scale to classify the protection of their own device or that of others.

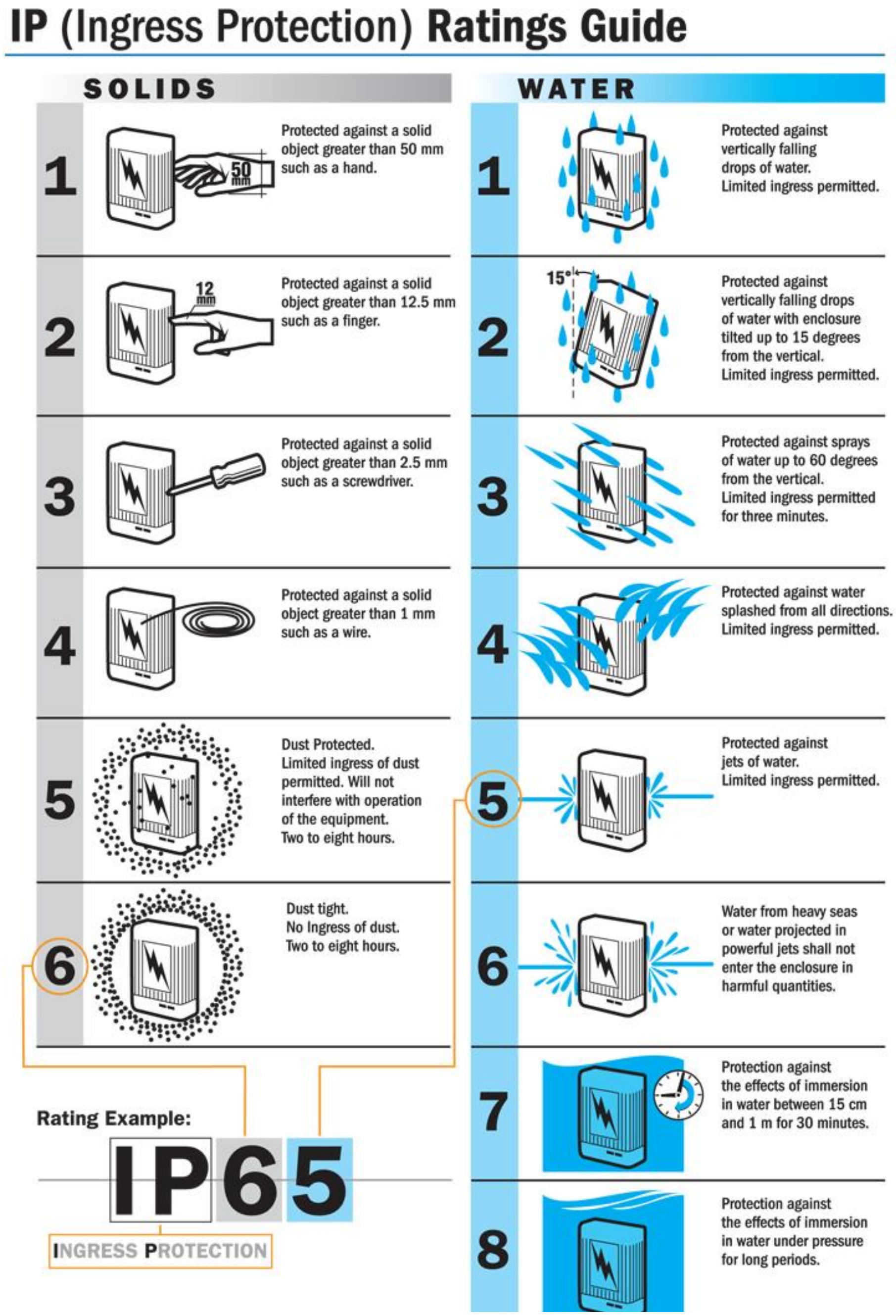

Figure 13: IP Rating Chart [49]

The highest level of waterproof that the IP has to offer is IPX9K which means that the tested device is able to resist high-pressures and, high temperatures sprays at close range. This high rating is very rarely used in day to day market devices. A more commonly seen rating would be the IPX8, which is more commonly used in modern day technology such as mobile phones. This rating states that the device is capable of being submerged under water for more than one meter. The exact depth of testing can be changed based on the manufacture needs.

For the Baby Buoy pool alarm, the team created a device that was water-resistant with a rating of IP58. This classification shows that the product is water resistant from any direction. Due to the fact the team does not plan on making this project a marketable device we are setting this rating as a goal. From lack of time and budget the team did not reach out to contact with the International Electrotechnical Commission to ask for an IP marking. Although the IP marking of certified protection was not received from our device, we still achieved water-proof from any direction.

4.2.4 Frequency Band Standards

This section covers the various frequency bands available for wireless internet signals, particularly the 2.4 GHz and 5 GHz frequencies using the 802.11n standard.

4.2.4.1 The 2.4 GHz Band

The 2.4 GHz frequency band is the most common frequency available. It has become a well establish standard, given its popularity and low cost. The 2.4 GHz frequency has certain limitations that the 5 GHz doesn’t have. 2.4 GHz frequency is overcrowded, providing more interference from external devices that use the same 2.4 GHz frequency such as cordless phones and microwaves. This reduces the theoretical internet speeds that the frequency can provide, while also negatively impacting a user’s router and access points. Below is a table of theoretical vs actual distance and internet speeds using the 2.4 GHz frequency.

Table 4: Theoretical vs Actual Distance and Internet Speeds with 2.4 GHz frequency

Theoretical Distance	Actual Distance	Theoretical Internet Speeds	Actual Internet Speeds	% Increase or Decrease from Theoretical to Actual
820 ft	410 ft	300 Mbps	150 Mbps	50% decrease for distance and internet speeds

Table 4 shows the theoretical and actual distance and internet speeds that the 2.4 GHz frequency should provide using the 802.11n standard. It can be seen that there is about a 50% decrease from the theoretical numbers and the actual numbers. Theoretical distance goes from 810 ft to 410 ft, while theoretical internet speeds goes from 300 Mbps to 150 Mbps. 2.4 GHz is more susceptible to interference while providing lower data rates, but it is much better at covering large areas of a home or store since it is great at penetrating solid objects.

4.2.4.2 The 5 GHz Band

The 5 GHz frequency band is far less common in homes. Unless you decide that you want to upgrade your internet speeds from the ISP (Internet Service Provider), it is difficult to justify upgrading from a 2.4 GHz router to a dual band router that provides 2.4 GHz and 5 GHz frequencies. Although the 5 GHz provides clearer signals and more channels that can be combined for higher speeds, it lacks in area coverage. Below is a table of theoretical vs actual distance and internet speeds using the 5 GHz frequency.

Table 5: Theoretical vs Actual Distance and Internet Speeds with 5 GHz frequency

Theoretical Distance	Actual Distance	Theoretical Internet Speeds	Actual Internet Speeds	% Increase or Decrease from Theoretical to Actual
460 ft	230 ft	900 Mbps	450 Mbps	50% decrease for distance and internet speeds

Table 5 shows the theoretical and actual distance and internet speeds provided by the 5 GHz frequency, using the 802.11n standard. It can be seen that the 5 GHz frequency also has a 50% decrease for theoretical vs actual distance and internet speeds. Theoretical distance goes from 460 ft to 230 ft, while theoretical internet speeds goes from 900 Mbps to 450 Mbps. Due to the lack in distance that a router can provide using the 802.11n, it is hard to justify needing a 5 GHz frequency band router where we won't need the actual internet speeds that it can provide, and the microcontroller that was used didn't support that frequency.

4.2.5 Lead Solder Safety

The Baby Buoy Team used a high purity alloy such as Sn63Pb37, which is composed of 63 percent tin and 37 percent lead. The soldier must be high priority so that the solder joint may be properly joined with the board. The use of lead and lead byproducts poses a danger to the human body. This is well known from the continuous studies of modern science, and therefore require cautions actions when working with lead. Lead poses numerous chronic health effects due to its neurotoxic composition. Some of these side effect include (but are not limited to), muscle and joint pain, concentration problems, digestive problems, reproduction problems,and many more. Therefore, the Baby Buoy team took precautionary steps when it came to handling lead when soldering.

When it comes to soldering in general, one of the first dangers comes from the soldering iron. In order to solder, the soldering iron must be approximately 750 degrees Fahrenheit to melt and manipulate the solder paste. With such extreme temperatures, there is a possibility of getting burnt. Therefore, when handling the soldering iron, it was crucial that the team handled the iron with respect and caution. This may be practiced by soldering little bits at a time and having the iron only out if needed. If not needed, to have it be placed in the cradle and far from human touch. Throughout the building of the PCB board, there was minimal human interaction with the iron. Another instance that is common to occur is the product coming off the line, such as a misaligned part. In order to fix this issue, hand soldering will be the resolution.

There are various factors that must be placed into perspective when it comes to handling anything that may contain lead. The first and utmost important is the user's health. As stated in the beginning of this section the dangers and side of effects of lead have been well documented in the scientific community. However, based on these documents, there are numerous applications, which includes ours, that lead will not necessarily pose a threat human health. It would take a large amount of lead to be ingested so that it poses a threat to the human body. The handling of lead was in accordance to RoHS compliance, which will be further touched on in section 4.2.6. The RoHS Directive states that there are certain elements and chemicals that must be handled in accordance to specific guidelines if that said product is being shipped abroad. In the case of our product, this was not be something of concern. Currently, the 37 percent of lead is not decent for what we created. Being that is at a lower percentage it is easier to manipulate and work with when making the joints. Soldering is very precise when it comes to the temperature gradient each paste may need a Fahrenheit in order to blend well. With this solder, that will not be an issue. The solder the team plans on using is very friendly and easy to overcome. Although it contains a dominant portion of tin, it is found it work well with small projects as this one.

Another concern that comes from soldering is the solder fumes when working with lead. At Carnegie Mellon University, it has been documented that safety precautions for these fumes must not be taken lightly. The documents at Carnegie Mellon University state that when soldering it would be advised to solder in a well-ventilated area or at least work under an exhaust fan of some sort. They also advise in wearing protective attire when soldering in the lab, which includes but is not limited to; closed toe shoes, eyewear, and a mask. When certain parts of the product are being cooked in the heating oven, the fumes will not pose a threat, as the oven is equipped with an exhaust fan built in. The use of safety equipment is still advised while the lab is in use.

As a general summary when taking on project that involves soldering in some way, there are specific safety precautionary steps that must be followed. In this paragraph, there will be discussion of these said safety procedures. To begin handling lead, there will always be the production of fumes from the flux that contains rosin. To combat this issue, one must be in a well-ventilated area whether it is an open area, or the area contains equipment such as an exhaust fan. A good example of such an area would be the UCF TI lab, which is a very open and even is equipped with a soldering station that gives good ventilation. It is also very important to never touch the soldering iron when heated as it may cause severe burns. A soldering iron may reach heat indexes more than 750 degrees Fahrenheit. Therefore, it is critical to ensure that the iron is unplugged and on a stable surface, given that the cradle may easily fall and leaving the iron plugged my lead to unforeseen dangers. While a member is using the lab, it is critical that they are following lab safety wear protocols. This includes and is not limited to wearing eyewear and closed toe shoes. It is also important to wash your hands thoroughly after the use of the soldering iron to eliminate any chances of lead exposure through the hands. Although it has not been discussed in thorough detail in this passage, it is of utmost important to never solder when the circuit is live. One must ensure that the circuit is not plugged to any sort of power source when soldering. This is done for several reason. One being the safety of the parts on the board and the safety of the user, by avoiding electrocution.

With any type of soldering, there will be waste. In the case of soldering with lead, there will be waste created that must be disposed of properly. This waste will be packaged in a metal container and properly labeled as hazardous waste and properly disposed of. This is done in efforts to avoid having any remains of lead go into landfills which is very harmful to the environment. In the UCF TI lab, there are bins which are used to dispose of any waste that is produced by soldering with lead. The UCF EHS also provides specific labels that are to the student disposal so that they may properly label the waste they are disposing.

If the statements above are followed properly it will ensure safety in the lab environment when handling lead and soldering. Any further question in regard to handling and disposing of waste may be answered by contacting the Environmental Health and Safety (EHS) at UCF, with phone number (407) 823-6300.

4.2.6 RoHS Compliance

RoHS, stands for the Restriction of Hazardous Substances Directive. Short for the restriction of use of certain hazardous substances in various electrical and electronic components. This Directive was adopted in February 2003 by the European Union. The RoHS lists approximately ten substances that are to be limited. These ten items being: mercury, lead, cadmium, polybrominated biphenyls, polybrominated diphenyl ether, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, dibutyl phthalate, hexavalent chromium, diisobutyl phthalate. RoHS is associated with WEEE, which is the Waste Electrical and Electronic Equipment Directive. WEEE main purpose is to set the standards on the collection, recycling, and recovery standards for various electronic goods. There intentions are to remove harmful substances, such as lead, from electronic devices. The RoHS is not required to contain special stickers to ensure that the order is complaint under the RoHS regulations, however they due require special restriction when it evolves shipping to various locations abroad.

The only concern that the Baby Buoy team had from the substances that the RoHS covers was Led. Lead is often found in solder paste. Having that the team will be constructing our individual PCB, soldering will be required. Therefore, the team will be RoHS compliant. Based on the specifications of RoHS 1 < 1000 parts/millions of concentrations must be maintained over the board at all times to ensure compliance. A very common alternative to lead would be a 98 percent tin solder, but tin does not produce a high-quality solder joint and is more likely to be rejected in examination. Therefore, the team will be compiling with the RoHS regulation when it comes to soldering the PCB together.

5.0 Design

After conducting extensive research on several different products and material on hardware and software features that are relevant toward the Baby Buoy, the following section goes into specifics on components that have been selected. All selections were made with the requirement and specifications in mind. Components that are shown and described below were researched to be the best choice for the Baby Buoy based on affordability and simplicity of design.

5.1 Hardware Design

The Baby Buoy consisted of two main bodies, the solar cell housing and the electronics housing. The solar cell housing was made of clear plexiglass to let light through to power the cells. This housing included the buzzer alarm to help propagate its sound farther. Furthermore, it acted as a counterweight to keep the electronics housing suspended in the water. An aluminum rod extended out of the solar cell housing over the edge of the pool to hold the electronics housing in the water. A junction box used as a buoy holds the accelerometer inside, it was attached to the electronics housing with a cable. This accelerometer floated in the water, detecting ripples formed by potential falls. An articulating arm was used to connect the two bodies together, this arm made it possible to adjust the electronics housing height so half of it was submerged in the pool. This is done so that the PIR sensor can stay above water while the camera is submerged. The articulated arm used for this project is shown in Figure 14.

Figure 14: Articulated arm produced by CAMVATE.

The electronics housing was made of anodized aluminum to prevent oxidation in the water. It contained the PCB, PIR sensor, camera, battery pack, and thermal sensor. It also had a switch to turn the system off when not in operation to save battery life. To hold all the components inside in an organized and consistent manner, a 3D printed base was constructed with blue PLA plastic, Figure 15 shows this base with all components installed.

Figure 15: 3D printed base for components

The electronics housing was divided into three parts: the body, the top cap, and the bottom cap. Figure 16 depicts the main housing in detail. The body is a cylinder 150mm high with an inner diameter of 60mm, it has two windows for the PIR sensor and camera. The upper window is the PIR lens that comes with the sensor, it was attached to the body with hot glue, the lower window was made of the same clear acrylic as the solar cell housing and was used for the camera. The top cap included an indicator LED, a threaded hole to attach the articulating arm, a hole for wires to enter the housing, and an external antenna for WiFi since the aluminum body of the electronics housing acts as a Faraday cage. The bottom cap is mainly used for easy access to the body from the lower side, it also has a small hole for the thermal sensor to measure the temperature of the pool water. Silicon holds the sensor in place, but since the hole doesn't go through the cap, there is no danger of water leaks. Each cap was secured to the body by three 3mm screws, there is also a standard 2.625" neoprene gasket to keep the caps waterproof. The gasket groove was designed to have a width 20% greater and a height 20% smaller than the ring's cross-sectional diameter to ensure a good seal, some grease was also added to further improve the seal.

Figure 16: Main housing body and caps.

Since the wire passing from the solar cell housing to the electronics housing had to be kept waterproof as well, cable glands were used. Cable glands hold on to wires by compressing them from all directions, creating tight seals. Figure 17 gives an example of what a cable gland looks like. The wire used between the two housings needed to deliver power from the solar panels down to the voltage regulator in the control and also feed power to the buzzer alarm system, for this reason, a four-wire cable was used. Two wires to deliver power from the cells and the other two for the buzzer. Since the current did not exceed 800 mA from the solar cells and the cable length was less than half a meter, a small gage could be used safely, a 20 AWG wire was used for this project to keep a high margin of safety.

Figure 17: Cable Gland [46]

An aluminum rod was secured to the bottom of the solar cell housing with three 5mm screws, it protrudes out into the pool. The end of this rod has a threaded hole for the articulated arm that holds the electronics housing. The solar cell housing has four rubber legs to keep it from making contact with the ground and to prevent it from slipping on wet surfaces. The Baby Buoy is a compact system that can be removed at any time from the side of the pool, it is not attached with clamps or screws, only the weight of the solar cell housing. The solar cell housing dimensions were 355x232x85mm and contain two 165x135mm solar cells, as seen in Figure 18.

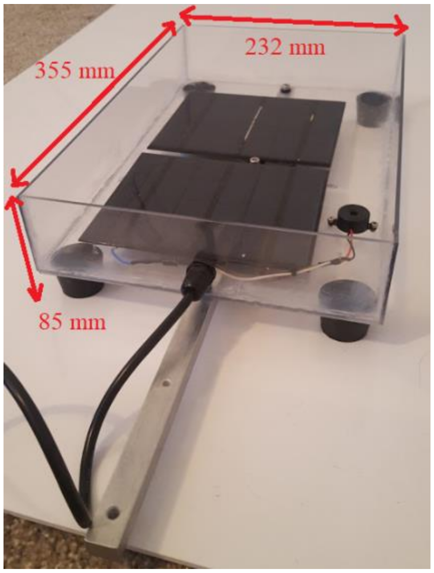

Figure 18: Solar cell housing dimensions

The buoy that held the accelerometer was a junction box with a hole made to pass the cable that connected it to the PCB from the electronics housing, it had a gasket to make it water resistant, additional silicon was used to make it waterproof. Figure 19 shows the accelerometer buoy with dimensions.

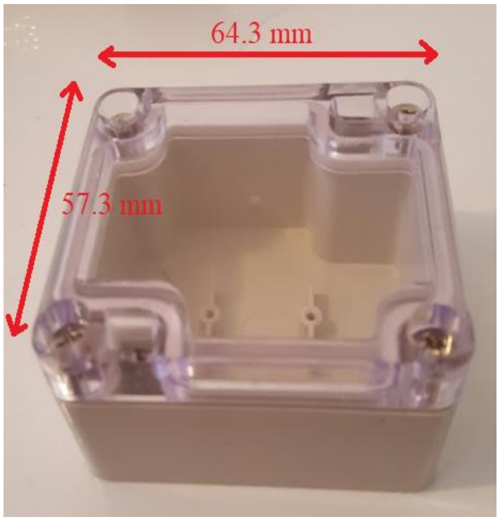

Figure 19: accelerometer buoy dimensions

Finally, Figure 20 depicts the whole Baby Buoy assembly. Some of the smaller details are not shown, this SolidWorks assembly demonstrates how all the components look when put together.

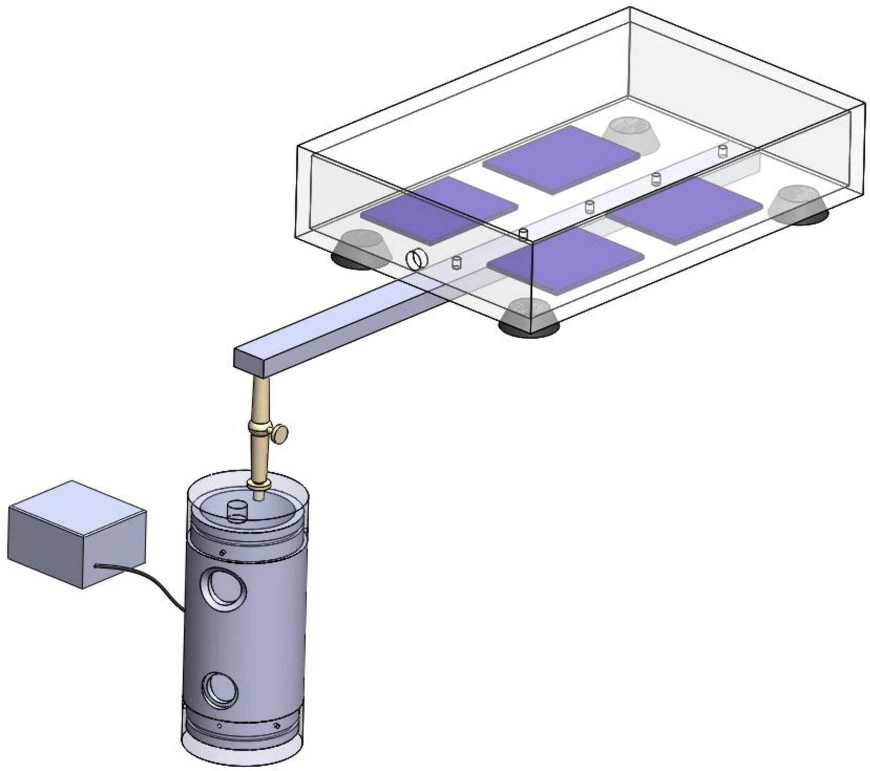

Figure 20: The Baby Buoy full assembly.

5.2 Battery Selection

The Baby Buoy required a battery capable of powering a microcontroller, camera, WiFi module, PIR sensor, accelerometer, LED, temperature sensor, and a piezo buzzer alarm system. The microcontroller selected for the design was the ESP-WROOM-32U, which has a maximum power consumption of 80 mA at 3.3 V. The WiFi modules was not needed since the MCU included this functionality. The camera used for this project is the ArduCAM OV2640, which consumes 70 mA at 3.3 V. The PIR selected for this project is the HC-SR501 system, which requires 65 mA to operate at 5 V. The accelerometer selected was the Adafruit MMA8451 that uses 0.165 mA at 5 V. The temperature sensor TMP36 requires 0.05 mA at 5 V also. The green LED uses 30 mA at 3.3 V. Finally, the piezo buzzer has a voltage range between 3-24 V and current consumption of 30 mA. At maximum current load, the Baby Buoy would consume about 245 mA, which meant the battery had to have a large capacity to power the device for the majority of the day. The camera was kept in idle mode and only turned on when the PIR sensor detected motion above the water and the accelerometer on the water surface. The piezo also sounded at that time. Considering some components were idle or off during normal operation, the operating current of the system when not in alarm mode was calculated to be around 195 mA.

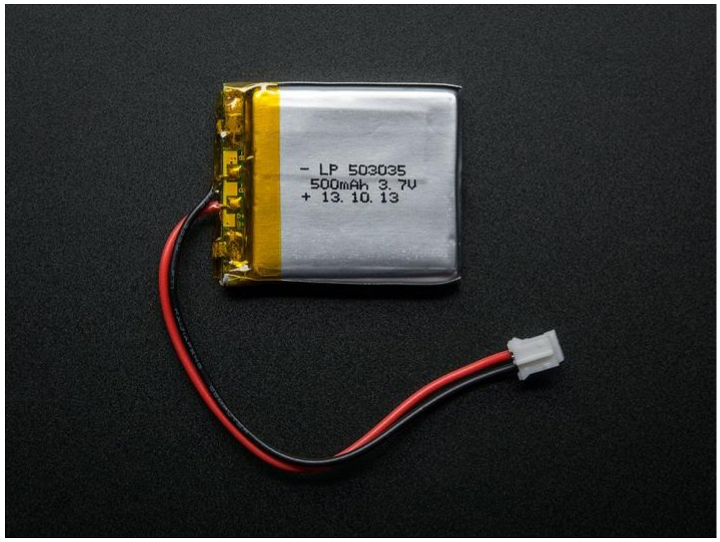

Figure 21: 5000 mAh 3.7V Li-Po battery used. [50]

Since the battery was charged by solar cells, the Baby Buoy must run on battery power alone during night time, dusk, and twilight, when light intensity is not enough to power the device. Since peak sun-hours are typically between 9AM to 5PM, the device ran on battery for 16 hours out of the day, at 195 mA, the battery capacity had to be at least 3120 mAh. The battery also had to be impervious to the memory effect since charging occurred irregularly, disregarding the current charge. Finally, the battery had to be compact, the Baby Buoy's main body has a width of 60mm and a length of about 80mm for battery space. Since the battery had to have a large energy density, high discharge rate, and immunity to the memory effect, a Lithium-Ion or Lithium-Ion Polymer battery was selected. After some research, the Adafruit 328 battery was chosen, this Li-Po battery has a capacity of 5000 mAh and nominal voltage of 3.7V. The battery dimensions are 59 x 54 x 11mm. With this battery the device was able to run for close to two days without solar assistance, providing an increased safety margin for charging.

5.3 Electrical Design

The first step in making sure the Baby Buoy operated correctly was to fully charge the 5000 mAh battery in the 8 hours of peak sunlight of the day. For this task we needed the solar cells to provide at least 625 mA and around 5 V. Since the output of solar cells drops drastically due to clouds or any type of shade, about double the required current was chosen as a desired current input to charge the battery. This way, if the solar conditions were perfect, with 1.2 A the battery would be fully charged in about 4 hours, if the day was cloudy, the added current might be enough to fully charge it in 8 hours as needed. After some research, two solar cells with ratings of 600 mA and 6 V from AMX3d were chosen to charge the battery. These cells were arranged in parallel to gain the desired output current of 1.2 A. Figure 22 shows the selected solar cells. Knowing the input voltage and current, an appropriate LiPo battery charger IC was selected. The BQ2104DBVR was chosen, it had a programmable output charging current up to 800 mA and maximum inputs of 1.25

A and 30 V. To set the output current to 800 mA, a 680 Ω resistor was added between the Iset pin and ground. This battery charger IC was also able to power the system with any extra current available.

Figure 22: AMX3d 165mm x 135 mm 6.0V 600mA solar cell.

The Baby Buoy had two main voltage levels, 5 V and 3.3 V, to operate the microcontroller and all other components. The PIR sensor, piezo buzzer, accelerometer, and temperature sensor were operated at 5V. The MCU and camera ran on 3.3 V. Since the voltage from the battery was 3.7 V, both a boost converter and a buck converter were needed to power all components. Noting that the maximum current load was calculated to be 245 mA, an appropriate switching boost converter was selected. The TPS613222A boost converter IC was chosen, it had a maximum output current of 500 mA, more than double the amount needed, to provide a wide safety margin. It's output voltage was fixed to 5 V and had an efficiency of about 95%. Next, the buck converter to power the camera and MCU was selected. To minimize electrical noise, a linear converter was chosen, the AZ1117E-3.3.

This buck converter had an output voltage of 3.3 V and 1.2 A maximum current. In addition to the solar cells, a USB charging option was added to the PCB for development purposes to be able to charge the battery while programming the microcontroller. Since both the solar cells and USB could power the battery charger IC, safety diodes were added in series with each power supply to prevent reverse current from damaging any components. Figure 23 shows the diode used in series with the solar cells. Also, a power switch was added between the battery and the system to preserve battery power when the device was not in use. Finally, the maximum current rating of the ESP32 microcontroller pins was 40 mA, therefore bypassing switches were needed to power the PIR, buzzer, and camera since they exceeded that rating or ran with 5 V instead of the 3.3 V provided by the MCU. Two dual N-channel MOSFET's were selected for this task, the BSD840, with a drain current of 880 mA and a turn on voltage of 1.8 V.

Figure 23: 1N5822 Schottky diodes

Figure 24 outlines the whole electrical system, including solar cells, diodes, battery charger, battery, and voltage regulators. The linear buck converter was placed in series with the switching boost converter because of its dropout voltage of 1.1 V. The linear converted required at least 4.4 V at the input to operate properly, therefore it could not be powered by the 3.7 V from the battery.

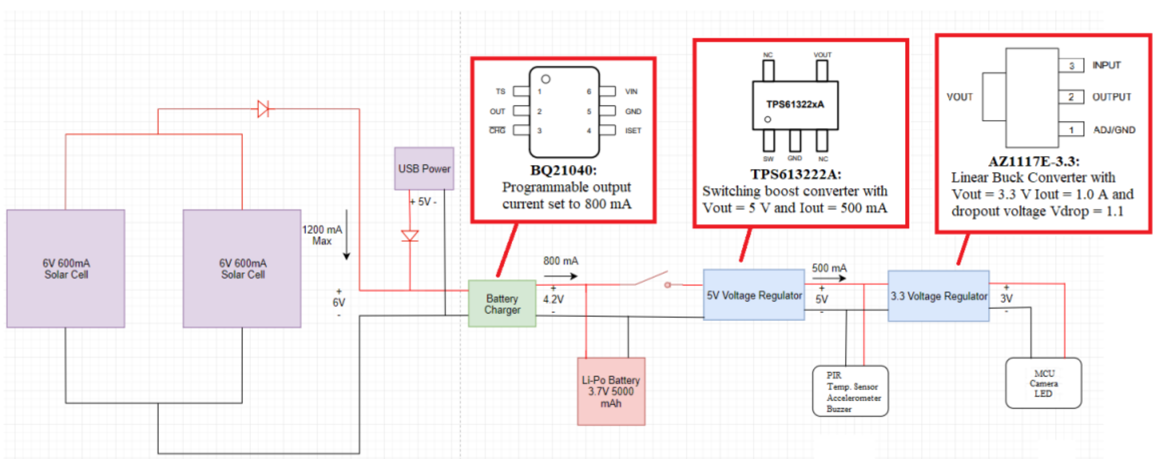

Figure 24: Electrical system layout.

5.3.1 Electrical Schematic

EasyEDA was used for the schematic design. All the IC components, including the BQ21040 battery charger, TPS613222A boost converter, AZ111E-3.3 buck converter, and ESP-WROOM-32U were available in the program's open source libraries with the pinout and PCB footprint included for ease of use. For the battery, solar cells, and all sensors, generic 0.1” header pins were used to simplify the design. In addition to all the required IC’s and accompanying passive components, two push buttons were added for programming, a reset button and a flash button.

The schematic began with the solar cell header pins and optional USB charger, the ZX62R-B-5P USB connector was selected for this design, only the GND (pin 1) and Vcc (pin 5) were connected since it was not used for data transfer. From the USB Vcc, a DFLS140-7 schottky diode was placed for reverse current protection. The BQ21040 battery charger IC had six pins, the power from the solar cells and USB entered through pin 6, Vin. A 1µF decoupling capacitor was connected to this pin as well, as specified in the component’s datasheet. Pin 4 was Iset, which had the 680 Ω resistor to ground as explained in the previous section to provide an output current of 800 mA, Pin 1 was a temperature sensing terminal for the battery, it was disabled with a pull down resistor of 10 kΩ. Pin 3 was an optional charging LED that was left floating, and Pin 2 was the output to the battery and system, also using a 1µF decoupling capacitor.

The TPS613222A switching boost converter had 5 pins, with pins 3 and 5 not serving any function. Pin 1 connected to the battery through a 2.2 µH inductor. Pin 2 was connected to ground and Pin 4 was the output voltage of 5 V. Between pins 1 and 4, there was a CUS08F30 schottky diode in parallel to a 5 Ω resistor and 560 pF capacitors in series. The AZ1117E-3.3 linear buck converter had 3 pins, pin 1 is the ground and both pins 2 and 4 are the output. Pin 3 is the input from the boost converter. Both the input and output have 1µF decoupling capacitors. The ESP-WROOM-32U had 38 pins with a grounding pad on the bottom labeled pin 39. Pins 1, 15, 38, and 39 were the ground pins. Pin 2 was the input voltage 3V3 pin, 3 capacitors were placed in parallel with this pin to reduce electrical noise from the voltage regulator, a 0.01µF, 0.1µF, and 10µF tantalum capacitor. Pin 3 was EN, it connected to the reset button and a pull-up 10 kΩ resistor to 3.3 V.

Pin 7 was connected to the output signal from the temperature sensor, it had to be set up as an analog input to read the data from the sensor. Pin 8 turned on the camera by activating the gate of one of the N-channel MOSFET’s. Pin 10 turned on the PIR by activating the gate of another MOSFET. Pin 11 powered the indicator LED, a 62 Ω resistor between the pin and LED limited the current to the desired amount. Pin 12 was the digital signal from the PIR sensor. Pin 14 turned on the buzzer through another MOSFET. Pin 25 connected to the FLASH button and a pull-up 10 kΩ resistor of 3.3 V. Pin 29 connected to the SC pin of the camera. Pin 30 to the SCK of the camera. Pin 31 was MISO from the camera. Pin 33 to both the SDA pins of the camera and accelerometer. Pin 34 to the TX pin of the programming header. Pin 35 to the RX pin of the programming header. Pin 36 to both the SCL pins of the camera and accelerometer. Finally, Pin 37 connected to the MOSI pin of the camera.

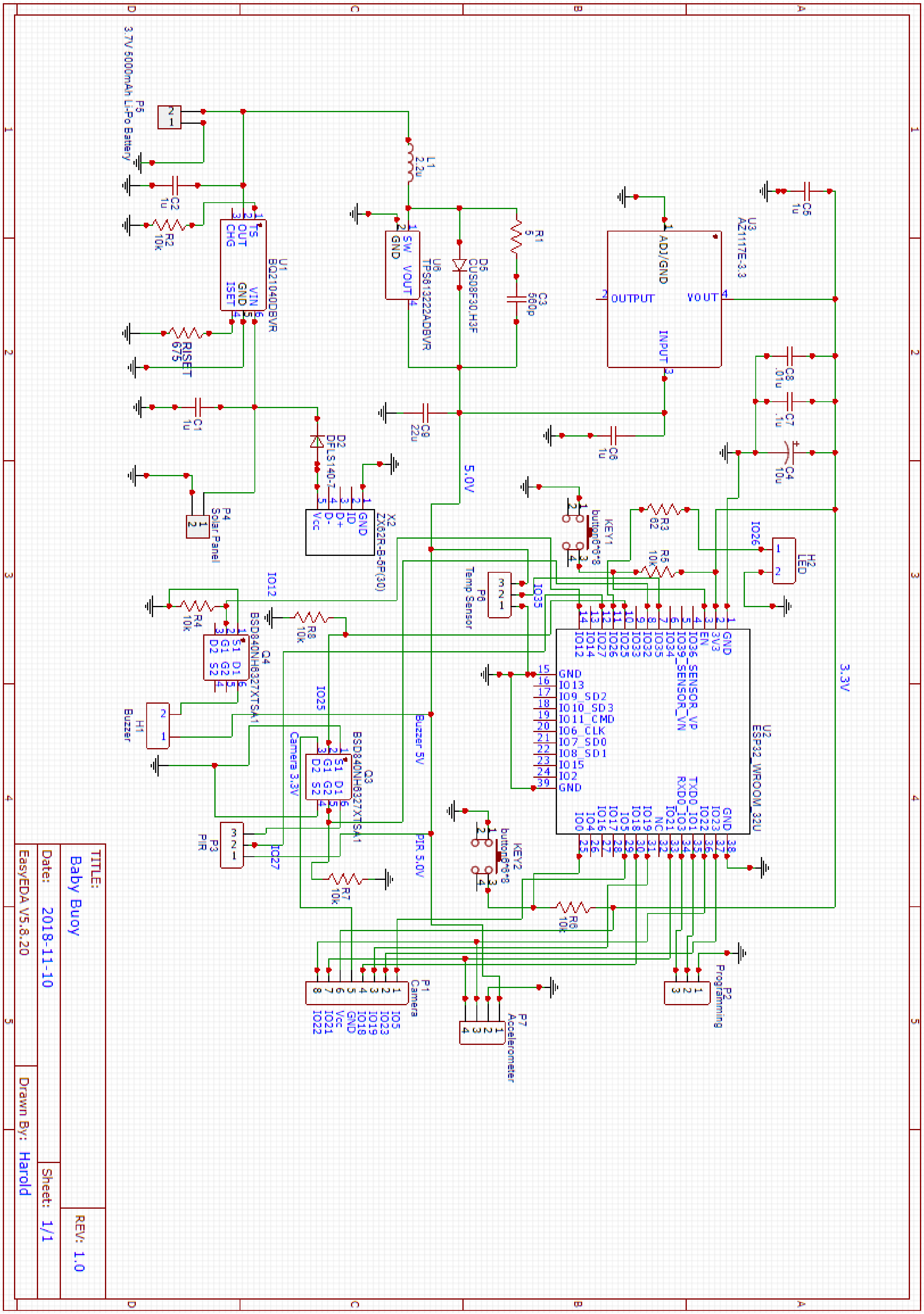

Figure 25: Schematic diagram

5.3.2 PCB Design

The PCB was also made using EasyEDA's software. The physical dimensions were 54 mm long by 45 mm wide. It had four 4 mm holes in the corners to hold the board to the 3D printed base. The PCB has two layers, with ground planes on both. All the power traces were 20 mil wide while signal traces were 10 mil. Power IC's such as the battery charger, voltage regulators, and USB are all isolated on the left side of the board as seen in Figure 26. The ESP32 was centered on the board while all the sensor headers and buttons are on the right side of the board. The two N-channel MOSFET's are labeled Q3 and Q4. The silkscreen includes labels for all resistors, capacitors, inductors and IC's. As well as labels for the battery header, solar header, USB, and all sensor headers, including Pin labels to connect them in the correct orientation. All the components were surface mounted, except for the sensor pins. A stencil was also ordered with the PCB to facilitate the soldering process. Vias were added by the ground pad under the MCU to promote heat transfer through the two ground planes. The PCB was ordered in the traditional green color from JLCPCB, a manufacturing company based in Shenzhen, China.

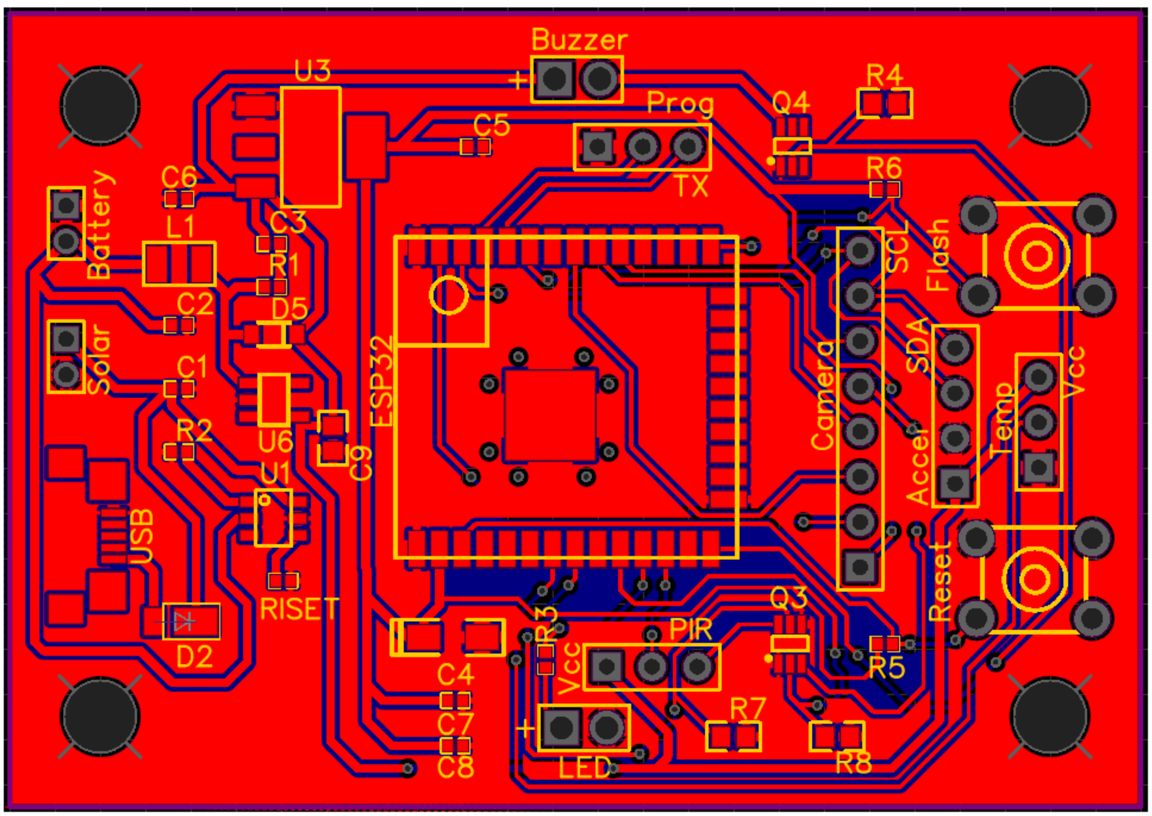

Figure 26: PCB layout

5.4 Software Design

The software design of this device is very critical. Both the embedded programming and software programing have to coexist in the most proper merger in order to construct high-class design. In order to do so in the final design there was a collaboration of three main components. These components being Firebase Realtime database, Amazon EC2 server and the Google cloud. In the diagram below you may see the collaboration between these three services with the mobile application and the physical device.

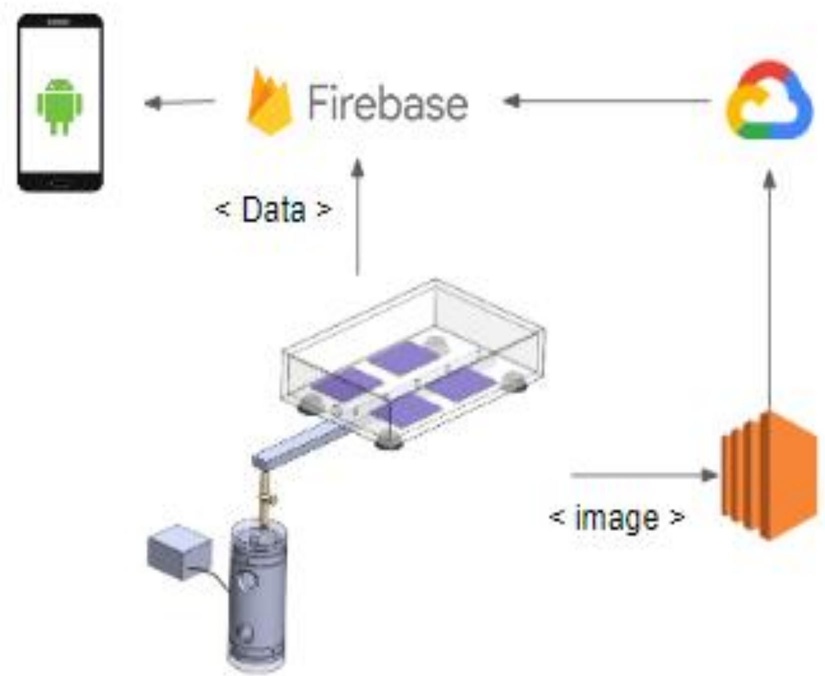

Figure 27: Main Software Components

As seen above, all binary and integer values are passed from the physical device to Firebase Realtime database. The embedded programming within the device was constructed using the Arduino IDE which has some built in libraries that developers may use to tie together Firebase database with all the outputs being received from the sensors within the device. All outputs being sent from the device are being received Realtime as soon as they are tripped and send to the mobile application. Images that are being captured from the underwater camera are a little more complicated than binary data. Images are seen as an array of integers of all the individual pixel colors being captured from the image. This type of data is harder to process and cannot be sent directly to the Realtime database. We instead send it out to a virtual server using Amazon EC2 and collect the image from there. Once in the server we found issues transferring directly into the Realtime database from the EC2 server. So, what we ended up discovering was the Google cloud which through a php algorithm is able to connect the EC2 to the cloud where firebase may easily grab the image and display in the mobile application.

5.4.1 Online Services

In the following section we discuss some of the online service that we implemented throughout the creation of the software design. This included Firebase Realtime database, Amazon EC2 server and the Google cloud. All of these services are crucial in the operation of sending and receiving data to the device and the user.

5.4.1.1 Firebase Realtime Database

The Firebase Realtime database lets you store and sync data between users and Realtime. this makes it easy to access their data from web or mobile and it lets users collaborate. Whenever data is updated in the Realtime database its stored in the cloud and it simultaneously notifies all interested device within milliseconds. The real time database is optimized for offline use. whenever a user loses connecting, the database SDK uses a local cache within the device to serve and store changes. Therefore, when the user gets back online, data is automatically synchronized. The firebase database is hosted for all individuals through the cloud, so there is no server maintenance or operations. There are SDKs available for Android, iOS and JavaScript.

5.4.1.2 Amazon EC2 Server

Amazon EC2 provides a range of instance types designed for different use cases. They can range from small and economical instances that are a great choice for low volume applications all the way up to cluster compute instances designed for high performance computing workloads and cloud-based supercomputing on demand. Amazon EC2 provides instances optimized for compute, memory, storage and GPU processing to enable you to find the right price and performance combination for whatever workload you want to run. It’s also really easy to resize your instances if your business or application requirements change. They offer a choice of flexible pricing options, which allows you to play only for what you need.

5.4.1.3 Google Cloud Platform

Google Cloud products provide infrastructure and services for storage, computing, big data, and machine learning. The Google Cloud Platform provides several options for deploying and managing Windows, SQL servers and .NET workloads. The Google cloud is an easy to use and access platform. Being a google service it is also very easy to integrate Firebase Realtime database in order send and retrieve data.

5.4.2 User Diagram

The original basic interface of the mobile application can be illustrated in Figure 28. The class diagram establishes the classes and operations in a basic structure, in efforts to illustrate the relationship amongst objects.

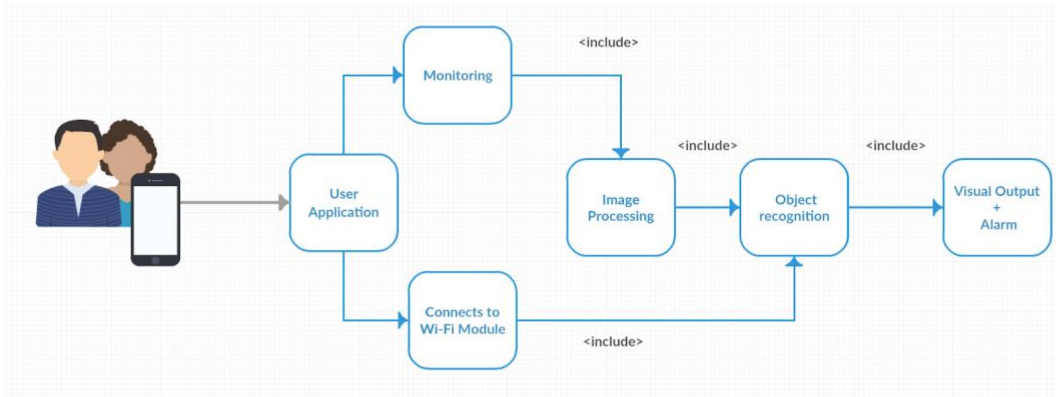

Figure 28: Original Basic Class Diagram of Software

Based on the illustration above, a user will have a friendly interface to operate and manage the device from the use of a mobile application. The application itself will have the abilities to manage the general setting for Wi-Fi connectivity that will lead it to having the capability of monitoring and view images from the onboard cameras of the Baby Buoy device. In the software that will be encrypted within the PCB board, image processing calculation will run through any video feed that is being received by the on-board cameras that are monitoring the surface of the water and underneath. From collecting analyzing the image and turning it into pure data, the computer vision, that will also be programmed into the PCB board, will draw up a decision on if the object that it is visualized in danger or if it is false accusation. After drawing up a conclusion, based on the conclusion, the on-board computer will decide if to stay dormant or to set the alarms and send out a notification to parent or emergency personal.

However, this model is no longer implemented in the final design of the device. After performing testing and modifying the implementation of the Baby Buoy, there was an extra motion sensor added. The extra motion sensor will act as the two step notification to prevent excessive alarms as well as add an extra layer of protection and security in the pool. In the image displayed below will be depict the model that we have implemented in the final design of the Baby Buoy.

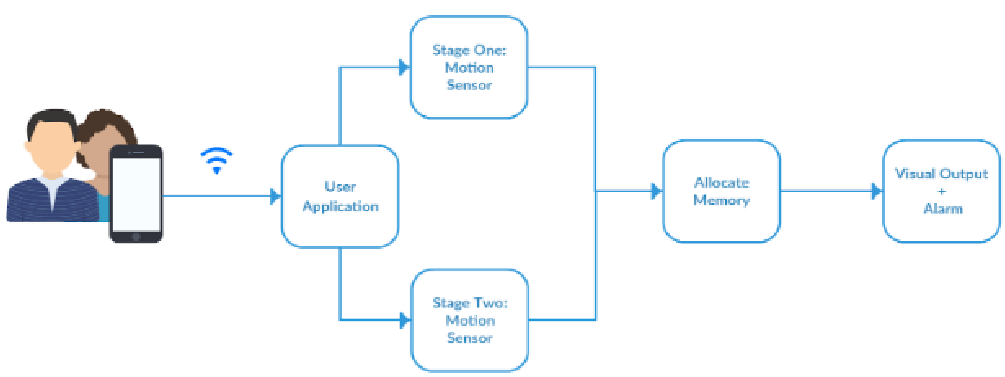

Figure 37: Improved Basic Class Diagram of Software

This is a very basic high-level class diagram, in the following sections we will go more in detail on what actual class and function are being stored in each the classes that are being created in efforts to master the mobile application and its software development.

5.4.1 Software Class Diagram

The image below illustrates the high-level design of the Baby Buoy mobile application. This class diagrams goes into a descriptive detail of the individual headers and probable structures that a play a role within each class. This high level design will integrate an ease of functionality between the user and the device visuals.

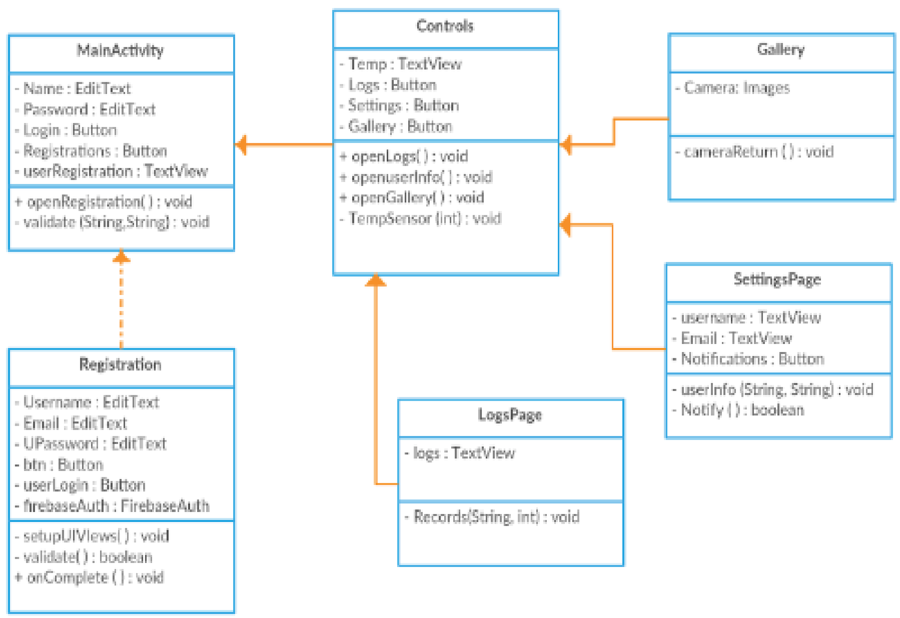

Figure 29: High-Level Class Diagram of Software

In the following design the main activity class is essentially a friendly sign in home page. It will check the authentication of the user against information found in the database. From the main the user can also be redirected to the registration class where they can sign up to create a profile with their individual Baby Buoy. They may also access the database and change their password from the main activity. In the registration screen the potential user will be able to register to the database. After restructuration the user will have access to the control panel and where they may navigate through the different features of the Baby Buoy. In the LogsPage class the user my find the time and date where the sensor was most recently triggered. In the Gallery class they may see the image captured from underneath the water, and the setting page class the user can modify and change their setting from directly from the database.

Previously, in the drafted design, the high-level class diagram had a main class that would essentially be the image processing of a video feed that was going to stream in through the camera in the housing of the Baby Buoy device. This video streaming was not going to be on, in efforts to save power. Therefore, it was discussed to be in a loop that would conduct a perimeter check every so often in attempt to save some battery life. This loop interview was a very small period that was not affected by the actual functionality of the device. In this same perimeter check, the program was going to check if there was a strong wireless connection between the board and outside connected devices, allocate memory to store the video footage, and keep track of the time based on the on-board clock to give an accurate feed on the user's interface.

Figure 29 is a much higher-level design and one can visually see what some of the elements are that will be tracked and checked while the sensors are monitoring the surface of the pool.

5.4.2 MCU Software Interaction

To obtain an accurate depiction of the video stream from our installed cameras, time and date will be put into consideration. This action will be done by the "on-board" module that contains this information. The base idea is to pull the video stream feed from the current time and date and send that to the Wi-Fi module on the microcontroller to have it be received on the user application.

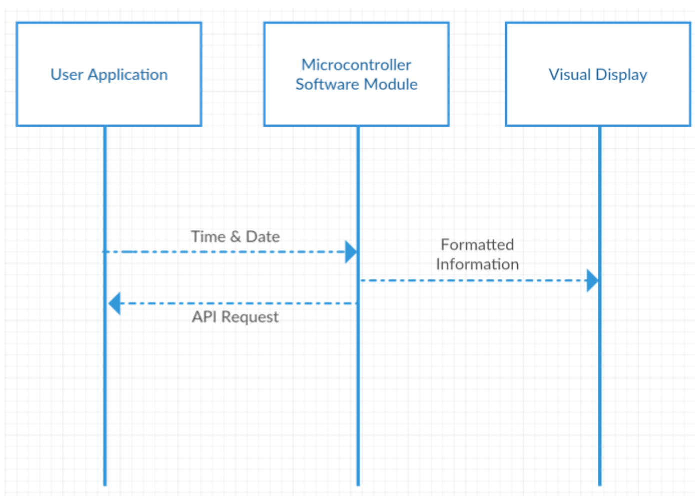

Figure 30: Microcontroller Software Diagram

Figure 30 illustrates the interaction that the all application have with each other. The user application on any mobile device will be retrieving the time and date from the on-board clock in the microcontroller. The microcontroller in return will interact with the mobile device through the application program interface (API). From the visual display, the microcontroller will be extracting the image data and converting it into data that can be interpreted by the Microcontroller and deciphered using computer vision.

5.4.2.1 PIR Sensor Communication

The microcontroller is communicating with the PIR sensor via a digital pin. The PIR sensor has 3 pins; VCC, OUT, and GND. VCC in this case is 5V, which can come from the voltage source, GND is connect to ground, and OUT is connected to a digital pin on the microcontroller. From the digital pin, the microcontroller will communicate with the PIR sensor to send a HIGH signal or a LOW signal. A HIGH signal means that the PIR sensor has detected motion, more important an object or human that contains heat. After the high signal, the PIR sensor will remain HIGH until the object is gone. At this point, the PIR will set its output too LOW for about 3 seconds. For our project, the MCU will send a signal to the accelerometer when a HIGH signal is triggered from the PIR sensor. With the HIGH signal, the accelerometer will be activated to detect if an object or a human has fallen into the water. The PIR sensor is crucial in the 2-step verification method that the Baby Buoy system has. This will allow for reduced false alarms and low power consumption.

5.4.2.2 Accelerometer Communication

The PIR sensor will be in direct communication with the accelerometer in order to be switched from low power mode to high once it is triggered. The accelerometer is the second sensor to the two-step verification. Once in full power mode, it is scanning to detect any aggressive motion on the surface of the water. If there is any movement detected, the accelerometer will switch to high and send a signal to the underwater camera to capture the image below the surface for verification.

5.4.3 User Interface (UI)

The user interface of a mobile application is crucial to creating a mutual relationship between the device and the user. Having the ability to read any directional text and to see any pictorial images crisp and clear, gives the user a clarity of how-to best maneuver throughout the app without assistance. The application for this project is very user-friendly. With sharp images and visual text, so that the user does not place strain in their eyes. Figure 31 illustrates what the mobile application looks like; this is tied together via Wi-Fi with the Baby Buoy device.

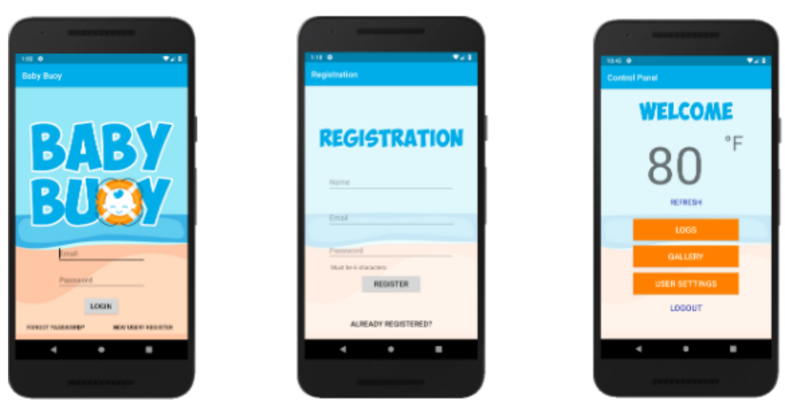

Figure 31: Mobile Application UI

Figure 31 also illustrates the UI that demonstrates some key features that the team is implementing. At first glance, a user may notice the application is minimalistic as a minimalist design is seen to attack better user mobility as well as clarity.

6.0 Project Testing and Prototype

The purpose of prototyping and testing is to construct a physical model of the Baby Buoy, as well as make sure that all components are running properly. In the following section, tests will be conducted on the hardware as well as the software portion of the project. An in-depth description of prototyping the PCB board will also be included in this section.

6.1 Testing

The following section will cover test procedure that will be conducted in order to ensure that all components within the Baby Buoy device work and operate together properly. Test expectations and potential issues will be discussed as well as test specifications.

6.1.1 Hardware Testing

In the Baby Buoy project there are several hardware components that will require specific consideration when it comes to the final device production. Although it is easy to assume that all parts that are new from factor “work”. It is safer to test the components beforehand on a breadboard or a test board, than to assume the parts work. Once all components are tested and show to be properly working, one may install them onto the PCB board.

Even during installation of components, one is running the risk of damaging the component while it is being installed. Therefore, it is also good practice to plug the final design into the main power, then use a multimeter to test the various nodes that are mentioned in the circuit diagram.

6.1.1.1 Microcontroller Testing

The ESP32 can be easily programmed and tested using the Arduino IDE. The Wi-Fi was tested to ensure that the ESP32 functioned as necessary. Within the Arduino IDE, the ESP32 must be installed into device manager manually. Once the device is installed you must setup the serial port to depending on the programmer that was used. The baud rate was set to 115200 and the frequency to 80MHz.

Figure 32: Wi-Fi Testing

When all the setting to the serial port were configured, a test program that was found on GitHub was uploaded onto the board. This process took a minute. When the upload was complete, the Wi-Fi module began scanning for networks around the area. If the module is not performing the scan, then the ESP32 may not be receiving power correctly. Figure 32 shows when the ESP32 found several WiFi signals near it, and the strength of the signal relative to where the ESP32 is located.

6.1.1.2 ArduCAM OV2640 2MP Testing

The ArduCAM OV2640 camera was easily tested by using the ESP32. Before wiring the OV2640 on a breadboard and ESP32, the tester must download the ArduCAM library that can be found on their website. Once the library is downloaded onto the PC, the Arduino IDE will be able to find the library and install it through the Library Manager. Within the library, ArduCAM has compiled several test to ensure that the OV2640 was working properly. The figure below shows an image that was captured with the camera.

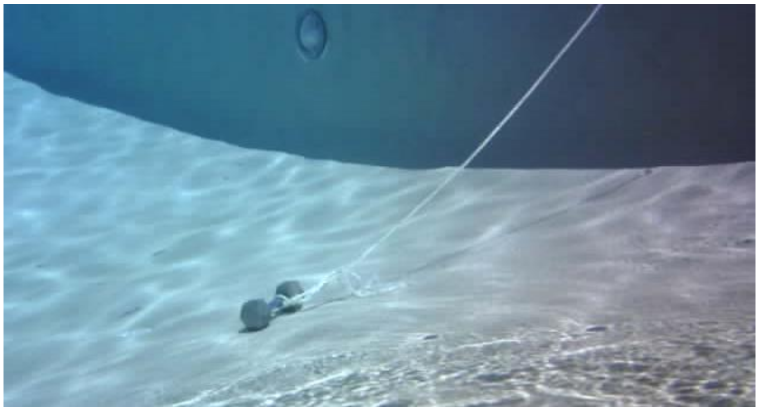

Figure 33: ArduCAM image capture

6.1.1.3 Solar Cell Testing

The two solar cells used for this project were rated for 6 volts and 600 mA, or 3.6 W. Since the cells were arranged in parallel, the maximum expected current is 1.2 A. To test this, the solar cell housing was placed outside under direct sunlight and the output voltage and current were measured using a multimeter.

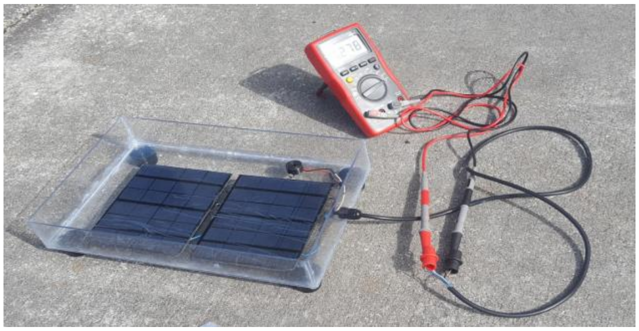

Figure 34: Solar Cell Test with multimeter

Measurements were done every 30 minutes from 8:00 AM to 5:00 PM. The solar cells were tested in two configurations, laying on the floor assuming normal operation and positioned directly facing the sun to get a maximum reading. The following figures show the testing setup and results.

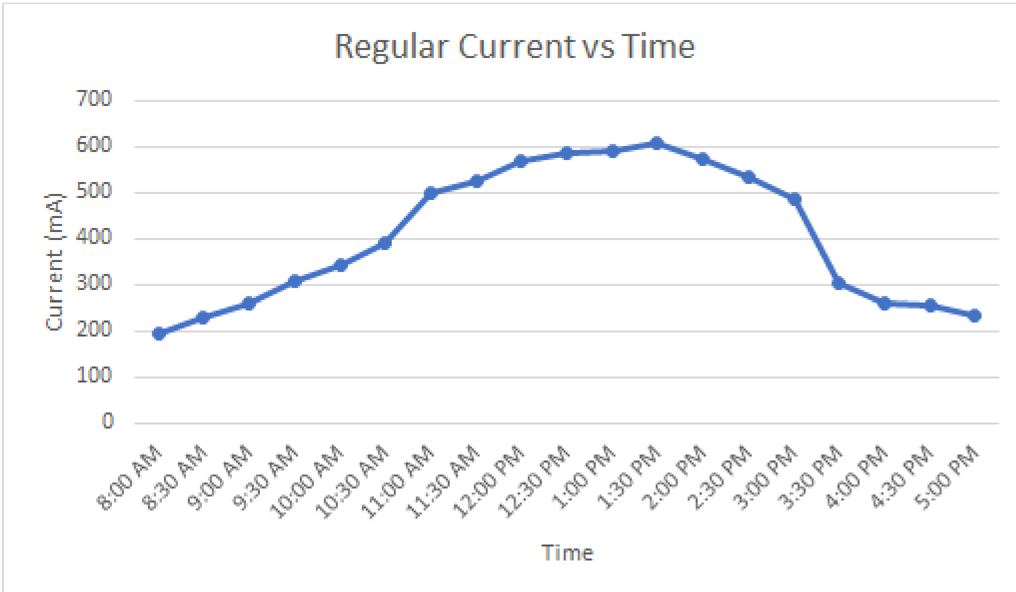

Figure 35: Solar Cell Test regular setup

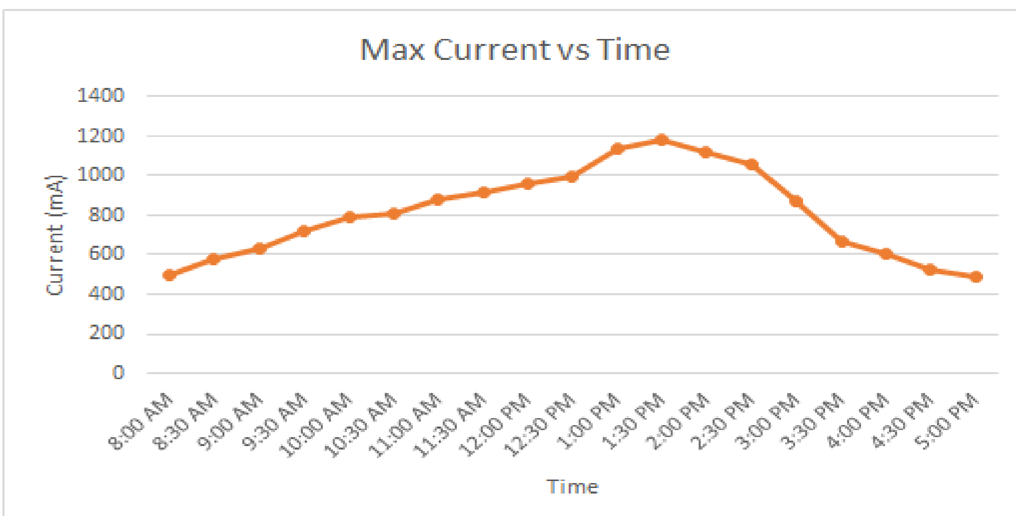

Figure 36: Solar Cell Test aiming cells at the sun

As seen in the figures above, the current supplied by the solar cells fluctuated greatly depending on the position of the sun, the greatest current output occurred in the middle of the day, between 12:00 and 2:00PM. Furthermore, aiming the solar cells at the sun increased their output by roughly double, with the maximum measurement reaching the theoretical 1.2 A ideal output. The voltage was also measured throughout the day, with no load, it remained within 6.5 V to 7.1 V, the voltage remained constant when compared to the current measurements.

The change in current was also drastic when a cloud or any type of shadow covered the cells, the output would drop by roughly 75% when the sun was blocked. Also, the solar cell housing was tested without the top cover which is made of the same polycarbonate as the rest of it, although the cover is clear, a 20 mA drop in output current was noted when it was put on. The fact that the output current varies so much has made us reconsider using it as a power supply for the Baby Buoy, since the cells also need to provide enough current to charge the battery. The alternative would be to have the solar cells only charge the battery and the battery will be the sole power supply for the system.

6.1.1.4 Battery Charger Testing

The battery charger IC chosen for this project was the Texas Instrument's BQ21040 surface mounted charger. The component was too small to test on the breadboard, besides the fact that it is SMD and not a DIP component, therefore small wires had to be soldered to each pin for testing. The charging current was set to 650 mA by placing a 820 Ω resistor in pin #4, this may change to a 675 Ω resistor for 800 mA charging if the solar cells are dedicated to charging the battery.

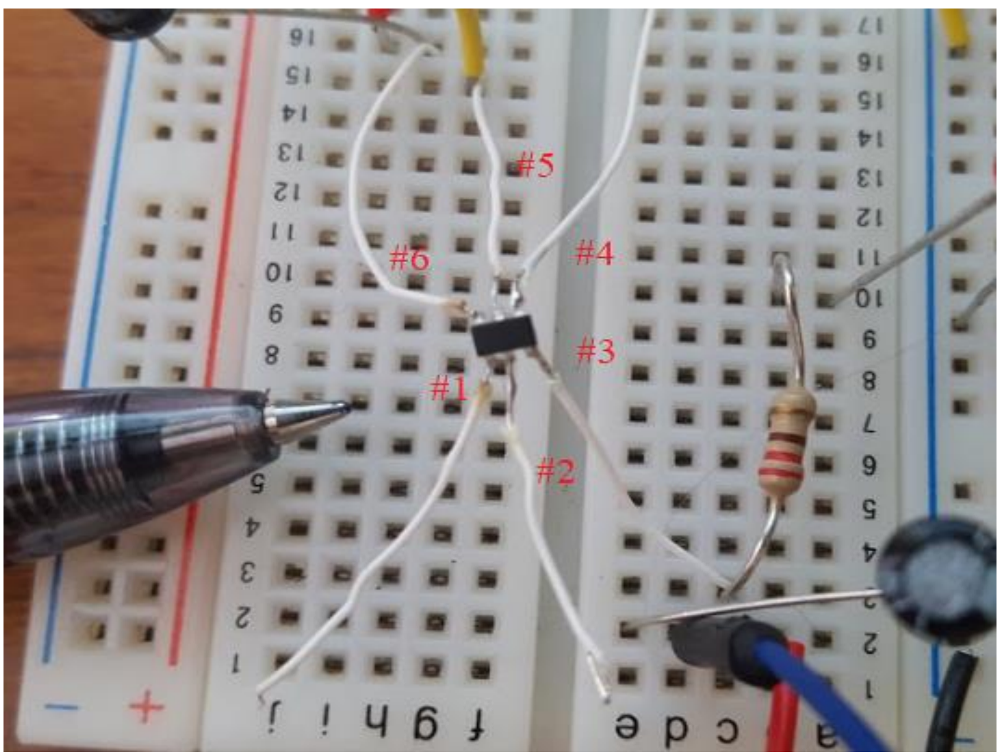

Figure 37: Battery Charger Wiring

The charger circuit was powered by the solar cells around 4:00 PM, charging the battery at around 200 mA. The current was tested by connecting one lead of the multimeter to the output pin #2 and the other lead to the node for the battery's positive electrode, making a series connection to measure current. The charging voltage was also measured, it was 4.1 V which is indicative of the second phase of lithium ion charging where the voltage is kept constant at 4.2 V while the current drops near 0.1C. The battery was already partially charged, this is why charging started at the second phase. The voltage of the solar panels with a load was measured to be 4.4 V, well within the operational specifications of the charger IC. An LED was placed in pin #3 to indicate charging was taking place. However, the LED did not turn on, indicating that maybe the IC determined the battery was fully charged, or the LED was malfunctioning.

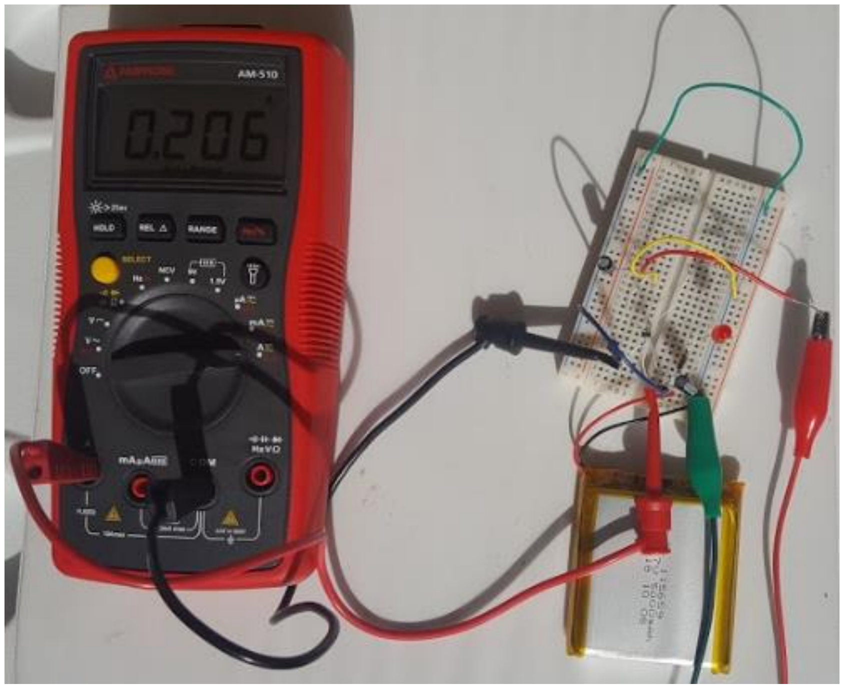

Figure 38: Battery charger output current

6.1.1.5 Voltage Regulator Testing

The TPS613222A boost converter was connected to the battery using the passive components recommended in the datasheet. A breadboard was used to connect the components. As expected, the output voltage was measured to be 5 V with a multimeter. The same process was used for the AZ1117E-3.3, except it was wired in series to the boost converter, not directly to the battery. The output voltage was 3.3 V as expected.

6.1.1.6 Temperature Sensor Testing

The temperature sensor chosen for the Baby Buoy was the TMP36. This sensor takes in 5V and outputs a voltage that is proportional to the temperature around it. This component was tested by plugging it to a DC power supply at 5V and measuring the output pin with a multimeter. The output voltage was then compared to the chart given in the TM36 datasheet. The measured voltage was 0.710 V which, according to the plot, coincides with a temperature of 21 ℃ or about 70 °F. Since the thermostat reading at the time of testing was 72 °F, it can be said the sensor is fairly accurate, especially since the room where the sensor was tested was colder than the rest of the house. The temperature is calculated by starting with an offset of 500 mV for 0 ℃ and then scaling at 10 mV/ ℃.

Figure 39: Testing temperature sensor

6.1.1.7 PIR Sensor Testing

The PIR sensor chosen for the Baby Buoy system was the HC-SR501. The sensor has pinouts for power, ground, and output from the microcontroller. The sensor was tested by powering it up with 5V, connecting it to ground, and having it output with a pin on the microcontroller. The sensor can be adjusted to detect motion from 3 meters to 7 meters. If motion is detected, the time delay can be from 5 seconds to 5 minutes. It also has 2 different types of triggers. Single trigger allows the time delay to begin immediately after motion is detected. Repeatable trigger allows the time delay to be reset after each motion detection (time delay begins with last motion detected). Figure 40 shows the PIR sensor being tested with a separate LED for easy visibility. The LED will be ON when motion is detected and OFF when there is no detected motion.

Figure 41 shows that the PIR sensor is detecting motion and the length of time that motion was detected for. The initial line indicates that the sensor is calibrating and warming up. It needs at least 30 seconds of initialization before it can started detecting motion. After it is done calibrating, the sensor will be activated and ready to detect motion. “Motion detected” is the start of when motion was detected and “motion ended” is when the motion was no longer detected.

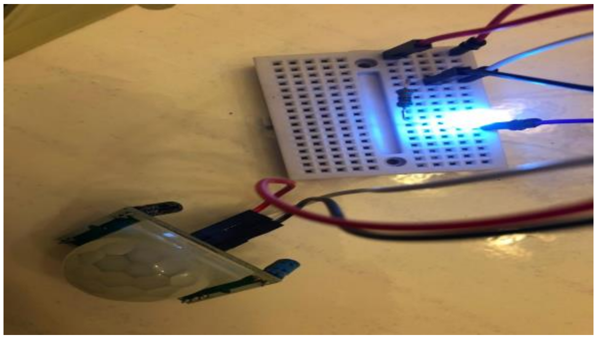

Figure 40: Testing PIR sensor

Figure 41: PIR Sensor Readings

6.1.1.8 Piezo Buzzer Testing

The Piezo buzzer was being tested by inputting a different voltage. The buzzer can operate with 4V to 28V. The higher the input voltage, the louder the buzzer is. The lower the input voltage, the quieter the buzzer is. The Baby Buoy system ran on 5V and 3.3V, therefore the piezo buzzer will have an input voltage of 5V for the project. The figure below shows the buzzer connected to a power source where it functions as it should.

6.1.2 Software Testing

The software implemented in the Baby Buoy project was tested in order to verify that components operated as expected and will continue to operate as expected even after making modifications. This test was conducted on a computer before being transferred to the actual microcontroller.

Unlike hardware, software is very easy to test and manipulate without the need of the actual components. With that being said; software testing will be performed throughout all the stages of development. Therefore, to limit the amount of potential problems.

6.1.2.1 Simulated Testing

Based on the microcontroller that has been chosen, the programming with be written in C. The Arduino microcontroller can accept languages C/C++. Out of experience the team feels more comfortable writing the internal program in C. Through the software development, varies unit test will be performed to push the boundaries of the program and ensured that everything operates correctly.

Unit test are extremely helpful in software development. They are usually written before any lines of code are compiled. Their purpose to make the developer think through the computers logic and determine what needs a unit test and what to test for, which is a very important task. In the long run, performing this brainstorming exercise will prevent more work in the long run. Many large companies such as Microsoft used to have specialized developers that would only test and write unit tests. Unit test are also very useful in tracing the amount of consumed memory within the MCU. This is very important as the team understands that the Baby Buoy project will be allocating large amount of space in order to operate properly. By performing unit tests, we can verify how much memory is being allocated and archived while the program is still being edited on the CPU.

The great thing about software testing is that you do not need the physical devices to perform a test. Software IDE are developed to be able to compile and run test on the CPU without the need to upload onto the physical board. Therefore, software testing is very convenient and can be done anywhere you have a working computer. The tested code will be performing test on verifying inputs, checking for system overrides, and if the display is being updated. All of these are unit test that are performed to construct a test-driven development. This test-driven development is to construct core modules that will allow a smoother user interaction.

Some examples of unit test that the Baby Buoy team performed is in the motion detection above the surface of the water as well as fall detection with the accelerometer. These tests were performed on a computer as well as through user interface, throughout each iteration to eliminate any possible errors.

6.1.2.2 Physical Testing

The physical test for the Baby Buoy project was much harder to troubleshoot, to determine if a module is not working properly. The device had a PIR sensor, accelerometer, camera, a microcontroller, and a buzzer. All of this has been tested physically in order to classify our device as functionable. The PIR, accelerometer and the visual camera was not testable until the ESP32 is sending and receiving information properly. This is because the user has the ability to monitor these modules through the mobile application. Verification of a successful Wi-Fi connection is very important for the physical test.

In order to test that the Wi-Fi is working as intended the tester needed to verify the following procedure. To start turn on the Baby Buoy device and verify to the Wi-Fi is turned on. Once the Wi-Fi is turn on, connect it to your nearest router for internet connection. The user will then have accessed their mobile device and switch the Wi-Fi settings to be connected onto the Baby Buoy device. To best troubleshoot this issue, First verify that the device was successfully connected to the Wi-Fi router, then follow this step by checking the IP address that it is synced to. Once both tests have been performed. The issue is in the program and the tester had to go back into the computer and verify their variables.

If the mobile device was able to connect properly, the tester was able to move on forward and open up the user application. The user application must be tested separately to make sure it is user friendly and easy to navigate. Within the user application all button led to another page. The user is able to access and alter their account information under a settings tab. All transition from various screens must be smooth and efficient with zero lag or wait time.

Within the mobile application the user will be able to monitor the accelerometer as well as the underwater camera. This will be tested individually. The accelerometer was tested by exhibiting motion from shaking the sensor and see that the mobile application sends out a notification. If no notification was sent, the tester can go into the logs with the application and check that there is an entry for the motion. If no entry was made information was never sent out from the device, therefore the accelerometer is not communication to the MCU. This can be due to motion sensitivity settings within the program or the accelerometer not being properly installed in the PCB board. In worst case scenario the sensor was damaged in the midst if installment and is now broken.

In order to verify the camera, the accelerometer must capture movement. Once the accelerometer captured movement the camera turns on. Once the device picks up motion it sends the user a notification and turns on the underwater camera. The visuals are accessible from the mobile application on a specific tab/button. If no visual feed was observed from the user application, the user can check the logs. If there is a no log created for the accelerometer turning on, then there is an issue in the code. If there is a log created the issue is hardware. This is created from improper wiring, wrong installment on the PCB board or in worst case scenario the device was damaged in the installation process.

Once the camera communicates with the trigger of the accelerometer the user tests the buzzer. To test the buzzer the tester simulates a fake fall into the pool. This action activates the buzzer as well as give the mobile device a distress notification. If the buzzer is not activated the accelerometer failed. If in the logs, the accelerometer does output "DANGER" the buzzer is incorrectly installed, or it might be damaged while it was being installed onto the PCB board.

Given that all tests are proven to be valid the device is classified as operational. Due to the long strenuous efforts that are put into the device for it be to be physically tested properly, most testing was done under computer simulations. The following steps for testing have been performed in order to verify successful integration and hardware specific code. With proper testing, the Baby Buoy device exhibits proper device operations and a hassle-free user interface.

6.2 Prototyping

The main design for the Baby Buoy project has been discussed in previous chapters. Now the team will be evaluating the boundaries of the physical circuit board. All major components to the Baby Buoy project have been purchased. In the following section there will be discussion on what are the expectation of the microcontroller as well as potential hardware and software issues.

6.2.1 Hardware Issues

Throughout the making of the Baby Buoy, we encountered a few different hardware issues. This issue would include, the calibration of the accelerometer, transmitting the WiFi signal and noise on the analog reader.

Once testing of the device began the team encountered some difficulties calibrating the accelerometer to fit the need of the pool environment. There are different environmental elements that were triggering the accelerometer. These elements include the rotation of water underneath the surface that was caused by the water filter and the any strong winds that caused ripples on the surface of the pool.

The solution to these problems was not easy to find but we made it so that once there was above ground motion triggered from the PIR the accelerator started detecting motion on the surface of the water. This reduced the sensitivity but did not eliminate it. The team dug further and created an algorithm within the embedded code that would neglect any motion above or below what would be considered an average size wave for a fall. This was tested several times with our outdoor weight testing.

Another issue that we faced was transmitting information via WiFi, by making the housing an aluminum this created a faraday cage that prevented any signal from actually leaving the housing. This was a much easier fix by just adding an antenna outside of the cage that would transmit the signal out of the cage making it possible to send and receive information from outside the housing.

Analog noise was encountered in the ESP32 which caused false readings of data. In order to combat this, we constructed an embedded algorithm that would gather all the possible readings of that said data in a course of a few seconds and average the readings out, based on eh inputting data. This was found to be the best solution as there are many causes found of this exact issue through the web and after testing the solution, we it proves to be correct with low margin of error.

6.2.2 Software Issues

One of the biggest software issues we encountered was sending out images from the physical device to the mobile application, to as close to real time as possible. After weeks of putting in research hours we came up with the best solution to our issue.

Images take up a lot of memory in order to be processed and sent out via WIFI. In order to send out an image we had to first establish a online server to be able to capture that image once it is send out from the physical device. Once captured in the server, we encountered another problem, which was sending out the image to the mobile application as close to real time as possible. The best way to receive an image real time would be through firebase Realtime which is the database the rest of the mobile application uses. After extensive research we found that google cloud was able to send images collected directly to the Realtime database. So the team constructed a php program that would merge the images collected in the server send them to the cloud and have them be saved in the real time database platform.

Although this process requires several hoops one must first go through, it was the best solution that the Baby Buoy team was able to construct in order to collect an image to the mobile application as close to re time as possible.

6.2.2 Housing Issues

Given that the device was constructed to be portable its small compact body caused some issues. These issues being that the main electrical housing is very tight and having it be where everything is mounted it also causes it to be heavier than the solar housing which makes may cause the device to tip over the pool and into the water.

Having all the components in one housing made it very difficult to connect all the wires and electrical component to their desired locations. Although there was no way of physically fixing this issue, being that we wanted a small compact body to begin with to have a potable housing, there are ways to surpass this hardship. One of the best ways we combatted this issue was with simple patience. Patience was the key to taking on the tight housing we created for ourselves. It was not easy, but it was not impossible, all it took was patience.

Having a heavy electrical housing caused the solar housing to tip and potentially fall into the pool, with device and all. The team was able to solve this issue by just adding some counterweights underneath the solar housing to balance out the heavy electrical housing.

7.0 Administrative Content

In the following section information pertaining to the division of labor, project milestones, and overall cost of the project, are documented with descriptions. All group members are responsible on carrying an administrative role throughout the timeline of the project. All information was subject to change under certain circumstances that would prevent the completion of milestones throughout the two-semester period. Engineering and design require a large amount of effort, thus administrative planning is crucial for the success of the team.

7.1 Project Budget/financing

Table 6 shows a preliminary budget for major components of one unit. The list is not a comprehensive itemized list. This list is missing small miscellaneous components, testing equipment, and tools. As overall for our budget we are pushing to stay under $250. To make the device marketable and competitive we will be aiming to lower the cost subtotal. We self-funding the project.

Table 6: Project Budget

Part	**Quantity**	**Price**
PIR Sensor	1	$10
Camera module	1	$40
Wifi module	1	$10
Alarm module	1	$5
PCB	1	$60
Rechargeable Battery	1	$20
Waterproof Housing	1	$80
Articulating Arm	1	$20
Solar Panel	2	$30
Single Unit Subtotal:		**$275**

Table 7 shows the actual amount of money the team actually spent on developing the Baby Buoy system. The project was successfully created under the initial budget from Table 6.

Table 7: Project expenditures

Part	Quantity	Actual Price
ESP-WROOM-32U	1	$3.80
PIR Sensor	1	$1.72
Camera Module	1	$25.99
Alarm Module	1	$1.96
PCB	1	$2.00
BQ21040	1	$1.26
TPS613222A	1	$2.85
AZ111EH-3.3	1	$0.44
TMP36	1	$1.50
Rechargeable Battery	1	$15.99
Main Housing	1	$40.00
Solar Cell Housing	1	$21.98
Articulating Arm	1	$14.98
Solar Panel	2	$21.00
Accelerometer	1	$7.95
ABS Junction Box	1	$6.35
Switch	1	$0.46
External Antenna	1	$5.00
LEDs, resistors, inductors, etc...	1	$6.00
Single Unit Subtotal:		$181.23

7.2 Initial Project Milestones

This section shows the milestones from the beginning of Senior Design 1 to the end of Senior Design 2. These milestones were decided upon as a team in the initial Senior Design Bootcamp. The table below shows the team's project milestones with their completion dates.

Table 8: Project Milestones

Senior Design I	
Milestone	**Date**
Project Idea Assignment	Aug. 24, 2018
Boot Camp	Aug.29, 2018
Divide and Conquer Document	Sept.14, 2018

Half Hour Meeting	Sept. 22, 2018
Update Divide and Conquer Doc	Sept. 28, 2018
60 pg Draft Due	Nov. 2, 2018
60 pg Feedback	Nov. 5-6, 2018
100 pg Draft Due	Nov. 16, 2018
Final Documentation	Dec. 3, 2018
Senior Design II	
Milestone	**Date**
Build a Prototype	Jan 7- February 5, 2019
Test and Redesign	February 9-22, 2019
Finalize Prototype	February 9-March 30, 2019
CDR Presentation	February 8, 2019
Final Presentation	April 16, 2019
Final Report	April 22, 2019

8.0 Conclusion

Throughout the development of this project, our team's goals and motivations were a leading factor in constructing a device that can bring assistance to families in need of extra supervision around the pool area. Our team has taken extra measures to ensure that the child’s safety is our top priority.

In addition, our requirements and specifications that were discussed in our design process helped bring the project to life. The Baby Buoy is made up of a multitude of different components and modules. This includes technologies such as wireless communication, solar power capabilities, motion and fall detection, and a user interface via a mobile application. All components implemented in this device have been properly tested and implemented in order to construct an efficient pool alarm.

Researching the topics corresponding to the device have led the team in broadening their understanding of the procedure and hardware required for the development of this device. Each member has developed unique skills that will help them in finding employment after college. Additionally, this experience has given the group significant insight in cooperating inside a team environment in addition to calling and scheduling each other’s topics and duties. The project was evenly distributed between every member. Each member was allowed to pick their topic and hold each other accountable. This gives each group member experience in organizing and team managing. This can be a critical skill in some companies, and this will give each member a leg up against the competition.

Being a self-funded project, there was a concern with the overall cost of the system. Although the development of the system had to be done within a specific budget, our team was determined in creating a low-cost device to not only be a reasonable purchase to the average family, but to also be competitive with similar devices in the market.

9.0 User Manual

In the following section, we went into detail on how to use and operate the Baby Buoy device. The following steps have been constructed in benefit of the user, please do not skip steps.

9.1 Knowing your device

This device is made up of several components: Solar panels, one motion sensors (in the electrical housing), an external buoy with an accelerometer, a camera, and a mobile application. Follow the next steps in order to properly activate and operate your device.

Figure 42: Baby Buoy Device

9.2 Operating the Device

Please follow these steps consecutively in order to operate your Baby Buoy device.

1. Begin by downloading the “Baby Buoy” app to your android device. Create an account with your device through the application. Once registered continue to the next step.
2. Log in to your application with the newly created user information. Once logged in you will be asked to turn on the Baby Buoy device (there will be an on switch located on the back of the electrical housing).

3. If the device is turned on you will see a blinking LED light on the top. Go back into your application and add your WiFi credentials in order to pair the device with your home WiFi.
4. Once pairing is complete the LED light will turn off for a 15-20 seconds and turn back on once the device is 100% configured.
5. If the LED is on with no interruptions the device has been synced to your home WiFi and may not be monitored with your mobile application.
6. For the best use please place your device in the corner of your pool to grab the largest field of view.

All components of the device should be operational at this moment if you are experiencing issues setting up, please read through the steps once again to make sure you are not skipping any steps.

Appendix A References

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https://cdn-shop.adafruit.com/1200x900/2019-00.jpg

Appendix B Permissions

Jones <jones@poolwarehouse.com> — 10:48 AM (1 minute ago)
to me

Ok!

Thanks!

Jones

Pool Kit Sales Department
Email: jones@poolwarehouse.com
Phone: 800-515-1747 Ex. 1

From: <noreply@zopim.com> on behalf of Zendesk Chat <noreply@zopim.com>
Reply-To: Neysha Irizarry Cardoza <irizarry.neysha@gmail.com>
Date: Wednesday, November 7, 2018 at 10:49 PM
To: "jt@poolwarehouse.com" <jt@poolwarehouse.com>, <jones@poolwarehouse.com>
Subject: Offline Message from Neysha Irizarry Cardoza: Hello, I am a student at the Un

Offline Message from Neysha Irizarry Cardoza

Offline Message left on 08 Nov 2018, 03:49 AM (GMT+0)

Hello, I am a student at the University of Central Florida. I am currently working with a group on our Sr. Design Class to create a pool alarm. I am requesting permission to use your image from the following URL on my research paper https://www.poolwarehouse.com/shop/cfloat-pool-alarm/ Thank You, Respectfully, -- Neysha Irizarry-Cardoza irizarry.neysha@gmail.com Cell : 407-733-5088

Figure 43: cFlout Permission Request

Natalie (Bonanza) <support@bonanza.zendesk.com>
to me

Thu, Nov 8, 6:09 PM (12 days ago)

Hey Irizarry

Good news! An agent has reviewed your request and has provided an update, located below. Feel free to add a comment at any time by replying to this email.

Natalie (Bonanza)
Nov 8, 3:09 PM PST

Hello Irizarry,

Thanks for your email and welcome to Bonanza, an online marketplace connecting buyers and sellers directly where you can find everything but the ordinary in one of the friendliest communities on the internet!

Bonanza does not produce, house or ship any products, so if you have specific questions about an item you've located on Bonanza, you will want to contact the seller directly. On the item description page, you will see a "Send a message" button under the "Add to Cart" button. When you click the "Send a message" button, you will be able to enter a personalized message with any questions you have prior to completing your purchase.

You should be able to purchase an item or make an offer without a Bonanza account, but you will need to register with our site in order to seamlessly contact a seller. Registration at Bonanza is free and very quick; we only require your zip code, email address, and for you to create a username and password. Here is a link to do so: https://www.bonanza.com/users/new

To visit our buyer help pages: http://www.bonanza.com/site_help/offers

May you enjoy your experience at Bonanza, and please do not hesitate to ask any questions or let us know how we can be of further assistance.

Figure 44: SafeFamilyLife pool alarm system Permission

Re: [[Press/Media]] Inbox ×

Adafruit Industries <support@adafruit.com> Thu, Nov 15, 9:15 AM

to me

that is all good! please do.

On Thu, Nov 15, 2018 at 8:44 AM Neysha Irizarry <support@adafruit.com> wrote:

> contactname : Neysha Irizarry
> email address : irizarry.neysha@gmail.com
> message text : Hello,
> I am a student at the University of Central Florida. I am currently working with a group on our Sr. Design Class to create a pool alarm. I am requesting permission to use your image from the following URL(s) on my research paper for illustration purposes:
>
> -https://www.adafruit.com/product/189
> -https://www.adafruit.com/product/3538
> -https://www.adafruit.com/product/3591
> -https://www.adafruit.com/product/2471
> -https://www.adafruit.com/product/2999
>
> Thank You,
> Respectfully,
> Neysha Irizarry
> Client IP: 132.170.253.69

Figure 45: PIR Sensor Permissions

PERMISSION AGREEMENT

This Permission Agreement (this "Agreement") is made and entered into this 14th day of November, 2018 ("Effective Date") by and between Digi-Key Electronics, a Minnesota corporation, 701 Brooks Avenue South, Thief River Falls, Minnesota 56701 USA ("Digi-Key"), and Neysha Irizarry ("Permitted User"). In consideration of the foregoing and of the mutual agreements, promises and covenants contained herein, the receipt and sufficiency of which are hereby acknowledged, the Corporation and the Vendor agree as follows:

1. Digi-Key hereby grants the Permitted Use the right to use the following image(s) and materials provided by Digi-Key Electronics:

https://www.digikey.com/product-detail/en/adafruit-industries-llc/1739/1528-1566-ND/5824413&?gclid=CjwKCAiArK_fBRABEiwA0gOOc7sP7ommxv3Rj1auaGXl7XDBKMaLeZXrfOp4XxURvHvuMWUP1ApXzBoCBcsQAvD_BwE
("Materials") to the extent that Digi-Key has rights in the Materials.

2. The limited scope of the permitted use is as follows: Sr. Design Class research paper for pool alarm creation ("Permitted Use")

3. The Permitted User shall make no use of the Materials beyond the scope of the Permitted Use.

4. Digi-Key grants its permission to the Materials AS IS and EXPRESSLY DISCLAIMS ALL WARRANTIES OF ANY KIND, EXPRESS, IMPLIED, STATUTORY OR OTHERWISE, INCLUDING, BUT NOT LIMITED TO, IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NONINFRINGEMENT WITH REGARD TO THE MATERIALS. Digi-Key shall have no liability to Permitted User relating to Permitted User's use of the Materials. To the maximum extent permitted by law, the Permitted User shall defend, indemnify and hold harmless Digi-Key and its related and affiliated companies and all divestitures, directors, officers, employees, and agents and hold them harmless from all obligations, costs, fees, losses, liabilities, claims, judgments, actions, damages and expenses, including reasonable attorneys fees, suffered, incurred or sustained by Digi-Key, its related and affiliated companies and all their respective directors, officers and employees which arise out of or are related to your use of the Materials.

5. This Agreement is subject to the Terms and Conditions found at the Digi-Key web site (www.digikey.com), and they are hereby made a part of this Agreement, except as expressly modified by Section 2 of this Agreement regarding the permitted scope of use of the Materials, which modifies paragraph 2 of the web site Terms and Conditions.

DIGI-KEY ELECTRONICS	PERMITTED USER
By Cory Helm (Signature)	By Neysha Irizarry C (Signature)
Name Cory Helm (Printed)	Name Neysha Irizarry Cardoza (Printed)
Its Team Lead, MKTG Production (Title)	Address: 609 Wren Avenue Longwood FL 32750 (Address)

Figure 46: Piezo Buzzer Permission

Deployment Rights for User Files

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Figure 47: Image Processing Data Exhibition User Rights

Copyright Permission Inbox ×

Neysha Irizarry Nov 20, 2018, 8:55 PM (6 days ago)

Hello, I am a student at the University of Central Florida. I am currently working with a group on our Sr. Design Class to create a pool alarm. I am requesting

IPC Marketing 10:08 AM (14 minutes ago)

to me

Hi Neysha
Please use the attached as it is the most recent image.
Also, please indicate in your paper "used by permission of IPC 2018"

Michael D. Milostan (Mike)
Marketing Director, Standards, Technology and Certification
IPC
3000 Lakeside Drive
Suite 105 N
Bannockburn, IL 60015
Direct: 847-597-2812

From: Neysha Irizarry <irizarry.neysha@gmail.com>
Sent: Tuesday, November 20, 2018 7:56 PM
To: IPC Marketing <IPCMarketing@ipc.org>
Subject: Copyright Permission

•••

Figure 48: IPC Standards Permission

Copyright Permission

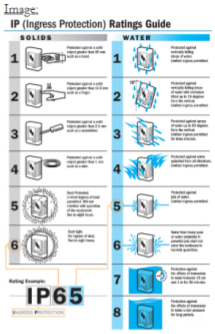
Neysha Irizarry <irizarry.neysha@gmail.com>
to conductor

Tue, Nov 20, 8:59 PM (13 hours ago)

Hello, I am a student at the University of Central Florida. I am currently working with a group on our Sr. Design Class to create a pool alarm. I am requesting permission to use your image from the following URL on my research paper for illustration purposes:

https://www.bluesea.com/resources/117

Image:



Thank You,
Regards,

Figure 49: IP Rating Chart Permission

Adafruit Industries

to me

8:44 PM (0 minutes ago)

yep, totally OK please do.

On Tue, Nov 20, 2018 at 8:44 PM Neysha Irizarry <support@adafruit.com> wrote:

> contactname : Neysha Irizarry
> email address : irizarry.neysha@gmail.com
> message text : Hello,
>
> I am a student at the University of Central Florida. I am currently working with a group on our Sr. Design Class to create a pool alarm. I am requesting permission to use your image from the following URL on my research paper for illustration purposes:
>
> https://www.adafruit.com/product/1578
> https://www.adafruit.com/product/761
>
> Thank You,
> Regards,
> Neysha Irizarry C.
> Client IP: 68.204.28.230

Figure 50: Cable Gland, 5000mAh 3.7V Li-Po battery used Permission