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S.A.V.E. M.E.

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S.A.V.E. M.E.
(Submerged Automated Vehicular Elevation Minor Extraction)

Alternatively:
Home Swimming Pool Rescue Device

Final Senior Design Report

Team Number: DT10

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Date Submitted: April 26, 2019

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Abstract

Ten deaths per day occur in the United States due to unintentional drownings. The majority of victims are children between the ages of 1-4 years old and occur typically in home swimming pools. A system is needed for home swimming pools that can not only detect a potential drowning child, but also attempt to save them. The objective of this project is to design a prototype robotic system that, when armed, detects a child's fall into a pool. A rechargeable robot placed at the bottom of a pool will maneuver to the location where the child entered the pool, defined as the splash location, and deploy a rescue device to save the child while using an alarm to alert others in the area. To accomplish this, acoustic devices will be used to triangulate the child's splash location and an inductive charging system will be incorporated at a specific portion of the track, defined as the home station, to charge the robot without user dependence. All components are designed for a 3m by 3m pool.

Problem Statement

Need Statement [PB, TD, AD, KO]:

According to the Center for Disease Control and Prevention, there are approximately ten deaths per day due to unintentional drowning, which results in an average of 3,536 deaths per year. The highest drowning rates are found among children ages 1 to 4 years old and occur mostly in home swimming pools. Some of the factors that influence the risk of drowning include lack of barriers and lack of close supervision. Unattended swimming pools can pose a serious risk to unsupervised children, inexperienced swimmer, and even pets. A system is needed that can not only detect a potential drowning victim, but also attempt to save them. [1]

Objective Statement [PB, TD, AD, KO]:

The objective of this project is to design and prototype a system that will make unattended swimming pools through detecting a victim’s presence, deploying a means to save the victim, and alerting others nearby of the situation. This system emcompasses sensors and devices within the pool and an alarm system outside of the pool. Upon detection of a sufficiently sized object entering the pool when the system is armed, a device will maneuver to the victim and deploy a flotation device that could assist or raise the drowning victim. [1]

Research Survey [PB, TD, AD, KO]:

According to the CDC, over the past decade, there has been an average of 3,500 accidental drowning deaths per year in the United States. [1] Currently, drowning is the leading cause of accidental death for children among the ages of 1-4 and the second leading cause of accidental death for children ages 1-14. [2,3] For young children the most common location of these drownings are in home swimming pools. This research has triggered the following question: ‘What can people do to prevent this tragedy from happening?’ Currently there are a variety of swimming pool alarms available on the market for consumers to install in, or around, their pools. These alarms range anywhere from as cheap as twenty dollars on Amazon up to almost one thousand dollars for a high-end system. No matter how complex or simple, the majority of these alarms all have one thing in common: they trigger an audible alarm, but do not provide a solution to try to save the person from drowning.

These horrible tragedies have been occuring ever since the invention of the swimming pool, yet there is still no true proactive solution to save a drowning victim. Unlike the other alerting and sensing methods that have been researched, this design project would use sonar to detect the presence of a child in an unsupervised pool. Once detected, the sensor would trigger an alarm to alert nearby person(s) and dispatch a device that would maneuver underneath the body, then deploy an inflatable (pneumatic) rubber tube that would simultaneously surround and lift the body to the surface of the pool in order to save the drowning child.

Lidar, radar, and sonar are different ways that can be used for object detection. Sonar, abbreviated for sound navigation and ranging is typically used for underwater detection of objects and measuring the depth of water. The detection works by “emitting sound pulses and measuring how long it takes the echoes to return.” [4]

A type of system that can be utilized to locate the position and identify an object is digital sonar. Digital sonar “uses digital signal processing theory and techniques” and “compared with the analogue processing of signal, digital processing has many advantages, as digital data is easy to store, transmit, and process.” [5] The purpose for utilizing sonar is because sound waves are the only physical medium which has the ability to propagate through water over a long distance.

Incorporated in a sonar system is the “wet end”, which contains the components such as the transmitter and receiver array, cables and connectors which are underwater. In addition, there is a “dry end” which is installed above ground and contains the signal processing console and/or controller. [5]

The article titled, *Acoustic beam profile-based rapid underwater object detection for an imaging sonar*, published in the Journal of Marine Science and Technology looked into a method of high-speed imaging sonar to detect underwater objects. When suspected objects were found an alarm signal would alert underwater vehicles or human operators. This idea of alerting corresponds with the project’s idea of having an alarm if the sonar picked up an object the size of a small child that had fallen into the pool. For their high-speed imaging they use three stages of detection. An initial scan is performed that any object that is seen is considered an object. If an object is detected a second scan is performed as an AUV (autonomous underwater vehicle) approaches the object. Finally, once the AUV is close enough to the object the third scan is performed to the object to see if the object is the ‘target’ object. [6] This idea applies into the project as the idea of having the lifesaving component would need to also detect the object that falls in the pool in order to save the person or pet.

Another example of sonar systems being implemented for data acquisition of objects or surfaces at large underwater distances is underwater object location identification being performed in the process of constructing ports when laying new cables and pipelines. For detecting objects such as large submerged vessels, a multibeam sonar system, which uses an interferometric acoustic detection method, to collect acoustic backscatter information is used to detect sea floor objects, then uses GPS to determine position and 3D orientation. [7] As the proposed application implements sonar on a smaller scale the application will utilize similar real-time data collection, real-time data processing concepts, plotting, and volume computations of the swimming pool area to determine location of the victim.

As mentioned, there are various pool alarm ideas and products in existence that use a variety of detecting approaches. One of the more inaccurate solutions found incorporates a system in which two conductors are attached to the pool wall, one below the water and one above. Upon armed, an alarm is held in an energized state by electronic switching until a splash of water, occurring when someone falls into the pool, ‘closes’ the conductor sounding the alarm. [8] This system does not locate or differentiate between objects that enter the pool. So whether a branch or person enters, no differentiation is made. Using a sonar system, the design project system will be able to distinguish between objects to ensure the floatation device deployment and alarm are enacted appropriately.

Another system solution that exists that can detect falls into a swimming pool will respond by sounding an alarm or calling numbers on an emergency call list. This system involves the use of one or multiple wireless water wave detector devices where each is a “low power, wireless, dome-shaped floatation device that would float freely in the to-be-monitored swimming pool”. [9] This specific system also incorporated a camera identification system that could be mounted to the pool fence.

The wave detector of this systems measures three dimensional water wave acceleration motion vectors in real-time using a three axis accelerometer. The acceleration data is transmitted over a radio frequency link to an embedded collector analyzer server which also contains the alarm generator. The software driving this system uses “a unique differential acceleration time derivative algorithm” [9] and motion analysis software to differentiate between normal wind driven waves versus waves induced by a fall or if the detector is removed from the pool and is sitting on stable ground.

A drawback of this technology is that if the wave detectors drift too close to one another, the user once alerted by the system must physically come to the pool to spread them out on the water's surface to become an effective detection system again. [9] The design project system will, as described, not only alert but perform a means of rescue. The project components will be such that the system, once placed or mounted, will not experience any kind of interference or physical hindrance that would require human assistance to once again perform its specific task.

A system similar to the proposal uses sonar to detect motionless bodies in a swimming pool. [10] While most pool alarms are designed to work with no one in the pool, this system is designed to work even with people swimming in the water. The primary idea behind this system is that if someone is motionless at the bottom of the pool, it is harder to detect with many others in the pool. Therefore, the sonar system used here is designed so that large unmoving objects can be detected even with other disturbances like pool-goers.

The system uses multiple sonar systems to scan the top of the pool and the bottom of the pool during its use. This allows them to detect objects on the top and bottom of the pool. Here, the sonar system works by sending successive frames of image data containing contours of objects in the pool. These contours of image data are only sent if the object is within a certain size threshold. If the contours in the frames of the data consistently have a displacement that is less than a predetermined threshold, then the system will identify it as a motionless body. Afterwards, the alarm will be activated. [10]

One of the limitations of this is that if a very large object is detected motionless in the pool, the alarm will still sound anyway. Namely, any object larger than a human can cause this.

Another drawback is, like with many other designs, this system is designed around the idea that someone will be near in the event of a motionless body in the pool. There is no contingency plan in a scenario where no one is around. [10]

After extensive research, there was only one patent that seemed in principle similar to what the project plans to accomplish in regards to attempting a rescue; however, the pending patent, as outlined, was purely conceptual involving the use of raising platforms from beneath the water as a means of victim rescuing [9]. However there were no detailed engineering specifications. Whereas, we are proposing to use a sonar-guided device that would move along the bottom of a pool in order to locate the victim. The patent pending "concept" only refers to the use of sensors in a general term and no specific technology is referenced. [11]

Marketing Requirements [PB, TD, AD, KO]:

1. The system should be used for a home swimming pool when no one is using it.

2.The system should be able to be armed.

3.The system should be waterproof.

4.The system should perform autonomously.

5.The system should contain an alarm, a detection device, and a rescue device.

6.The alarm should be able to be able to be heard from a fair distance away.

7.The detection device should detect for person presence.

8. The system should perform real-time tracking.

9. The detection device should communicate to the rescue device and the alarm.

10.The rescue device should be able to maneuver to the location of the person.

11.The rescue device should deploy a means to raise the person to the surface of the water.

Objective Tree [PB, TD, AD, KO]:

The objective tree outlines the four main areas of S.A.V.E. M.E. and the requirements for each section.

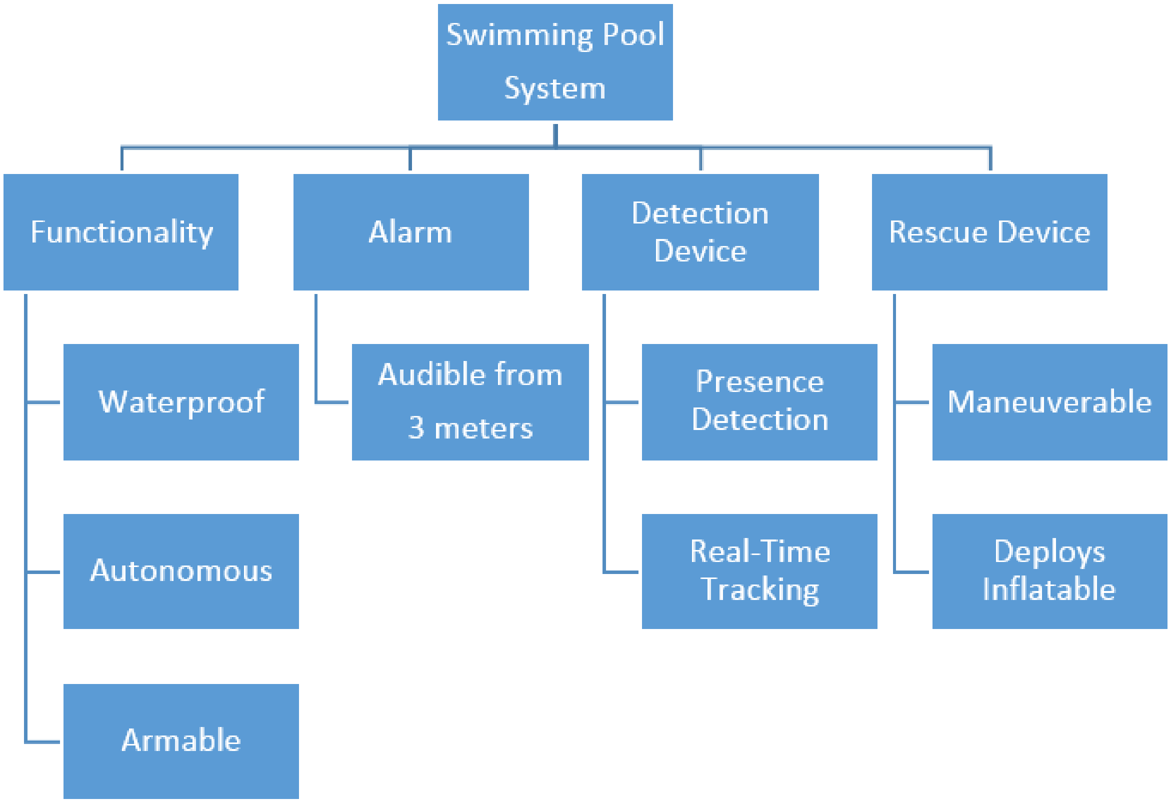

Figure 1: Objective Tree

Design Requirements Specification:

Marketing Requirements [PB, TD, AD, KO]:

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Design Requirements

Marketing Requirements	**Engineering Requirements**	**Justification**
1,2	The system should only be armed/on by a mechanical switch when no one is using the swimming pool.	Majority of at home swimming pool drownings occur when the pool is unattended.
3	The system should be waterproof.	Electrical components must be sealed in a container that does not interfere with daily use of the pool.
6	The alarm should operate at 100 decibels.	Typical swimming pool alarms on the market are set around 100 dB. Other emergency alarms, like the household smoke alarm, operate at around 85 dB.
2,4,7,8,9,10, 11	The inductive charger should be powered by 12 VAC and set to a desired resonant frequency to be fully charged in less than 8 hours.	The system should be staying inside the pool at all times. The robot needs to be ready to deploy at any time of day.
7,8	The robot should be able to identify the splash location of the child.	Triangulating the location of the victim is the necessary initial step in order to deploy the robot.
10	The robot should not weigh more than 45 kg (100 lbs).	The robot should be small enough that it does not interfere with the use of the pool.
5, 11	The rescue raft should be have a minimum surface area of $1m^2$.	The average height range of an American toddler goes from 0.855 m to 1 m.
9,10	The detection process should take no longer than 5 seconds.	A drowning victim becomes unconscious within two minutes.
10	The robot should move no slower than 0.1524 m/sec (0.5ft/sec).	A drowning victim becomes unconscious within two minutes.
10	The deployment of the rescue should move no slower than 0.3048m/sec (1 ft/sec).	A drowning victim becomes unconscious within two minutes.

Accepted Technical Design

Block Diagram Level 0 [PB, TD, AD, KO]:

The level 0 block diagram is a basic layout of how S.A.V.E. M.E. will work. First the system needs to be armed by the user so the device will only then detect for children falling in the pool. Once a child is detected in the pool, simultaneously the alarm will be activated and the device will begin to travel to the splash location.

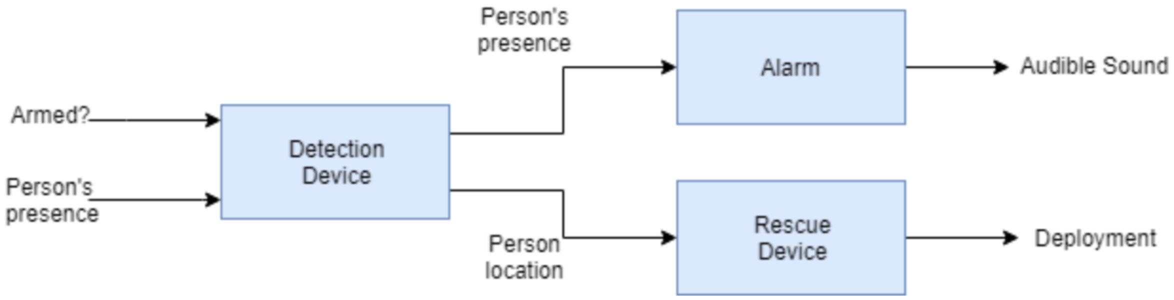


Figure 2: Level 0 Block Diagram

Block Diagram Level 1 w/Functional Requirements [PB, TD, AD, KO]:

The level 1 block diagram again shows how the system will work, but now with more detail compared to level 0. In this diagram the project is broken up into 5 main sections: the user interface, power supply, home station, robot, and the rescue device.

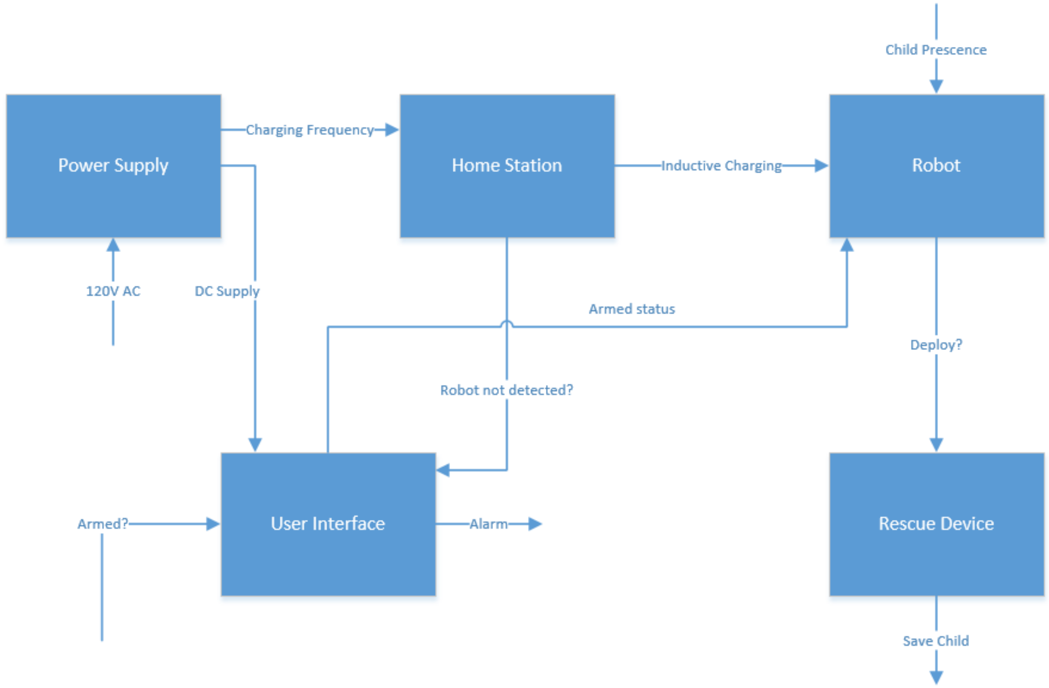


Figure 3: Level 1 Block Diagram

Tables 1-5 outline each section of the Level 1 block diagram including: the power supply, home station, user interface, robot, and the rescue device.

Module	**Power Supply**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	120 VAC
Outputs	Charging Frequency DC Supply
Functionality	Convert 120VAC wall power to two forms: ● Lower Voltage, specific frequency AC Supply ● 5-12V DC Supply

Table 1

Module	**User Interface**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	Armed? Robot Not detected?
Outputs	Armed Status Alarm
Functionality	Read in Armed Switch status and if armed send status to Robot Read in whether Robot has left the home station, and if so sound alarm.

Table 2

Module	**Home Station**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Charging Frequency
Outputs	Inductive Charging Robot Not Detected?
Functionality	Apply AC one coil of inductive charging system

Table 3

Module	**Robot**
Designer	Taylor Davis, Adrianna Dunlap, Parsa E. Bayat, and Kelly O’Neill
Inputs	Inductive Charging Armed Status Child Presence
Outputs	Deploy?
Functionality	When Armed: ● Use Hydrophone to detect child presence ● When detected, maneuver along track to location of child entry ● Initiate rescue device inflation

Table 4

Module	**Rescue Device**
Designer	Taylor Davis, Adrianna Dunlap, Parsa E. Bayat, and Kelly O’Neill
Inputs	Deploy?
Outputs	Save Child
Functionality	Catches child.Rises to surface.

Table 5

Level 2 Hardware Block Diagram with Functional Requirements

The level 2 hardware block diagram is an in-depth figure on the functionality of S.A.V.E. M.E. The project is first broken down into three sections: above water, the home station, and underwater. The above water section outlines how the system needs to be armed and how the user interface and alarm will be powered. Next, the figure transitions into the home station section which is where the robot will dock underwater as well as charge inductively. Lastly, the elements of the project that will be located underwater are explained. This section mainly focuses on the tracking and movement process of the robot.

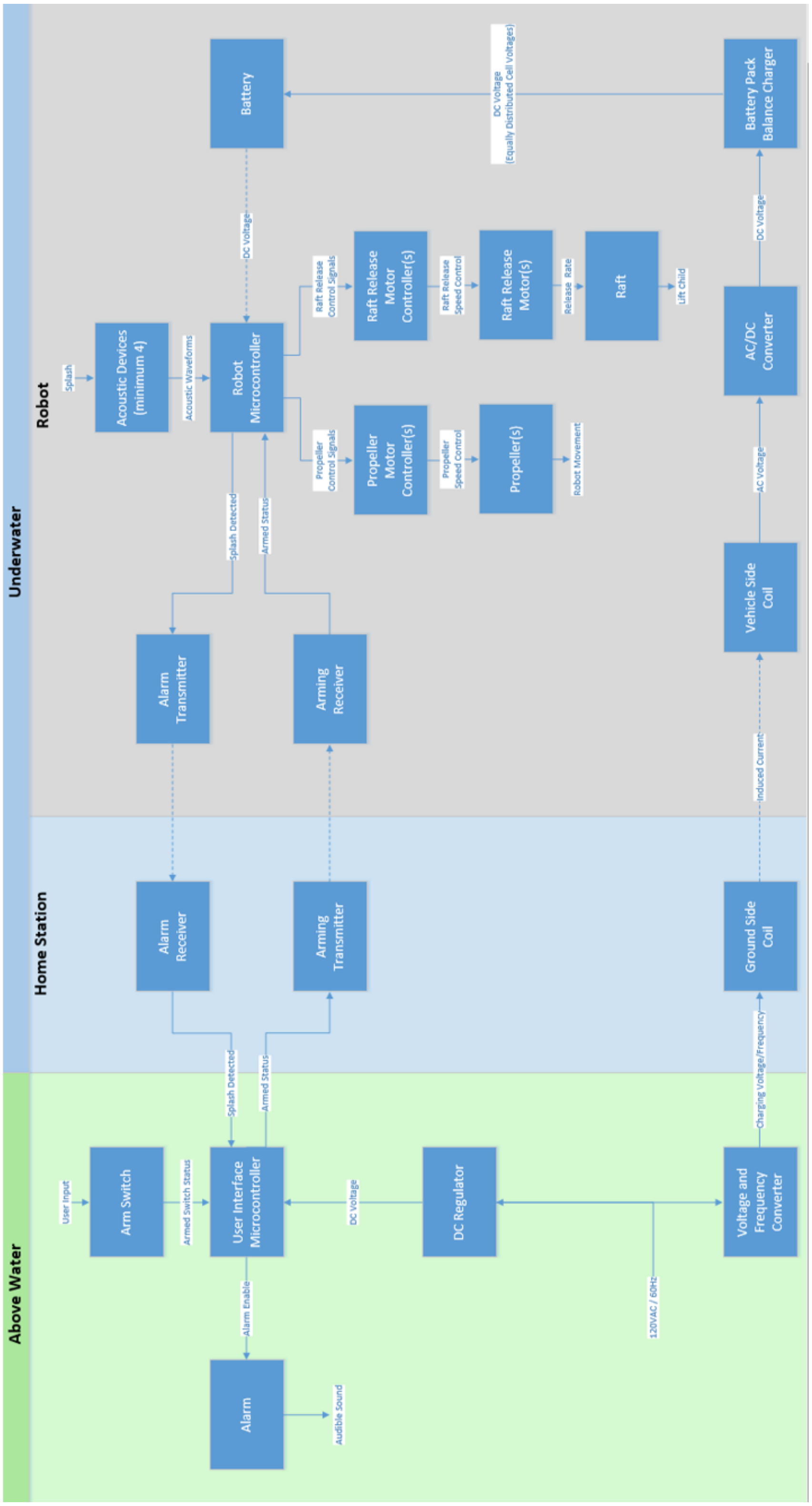


Figure 4: Level 2 Hardware Block Diagram

Tables 6 through 26 elaborate on the components of the Level 2 Hardware Block Diagram. The components comprising the Inductive charging portion of the system are covered in Tables 6 through 9. The battery pack is included in Tables 10 and 11, while the detection of the splash location for the robot is covered in Tables 12 and 13. The breakdown of deployment for the rescue device is outlined in Tables 14-16. In Tables 17 and 18 the movement of the robot itself is depicted, while in Tables 19, 20, and 26 the arming of the robot to be used while the pool is not in use is defined. Table 21 outlines the user interface that will be used outside the swimming pool, and the alarm that will be used is broken down among Tables 22, 23, and 25. In addition the DC Regulator that will be used to provide power to the electronics outside of the swimming pool such as the user interface and alarm is detailed in Table 24.

Module	**Voltage and Frequency Converter**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	120 VAC, 60Hz
Outputs	Charging Frequency Lowered AC Voltage
Functionality	Convert 120VAC wall power for inductive charger: ● Lower Voltage, specific frequency AC Supply

Table 6

Module	**Ground Side Coil**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Charging Voltage and Frequency
Outputs	Electromagnetic Field
Functionality	Apply AC voltage to one coil of inductive charging system to induce current in the robot side coils

Table 7

Module	**Vehicle Side Coils**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Electromagnetic Field
Outputs	AC Current
Functionality	Takes the electromagnetic field produced by the home and converts it into AC to be converted for charging

Table 8

Module	**AC/DC Converter**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	AC Voltage
Outputs	DC Voltage
Functionality	Converts AC voltage to DC voltage to supply the robot’s batteries.

Table 9

Module	**Battery Pack Balance Charger**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	DC Voltage
Outputs	DC Voltage
Functionality	Equally distributes the DC voltage to each battery cell.

Table 10

Module	**Battery Pack**
Designer	Taylor Davis, Adrianna Dunlap, and Kelly O’Neill
Inputs	DC Voltage
Outputs	DC Voltage
Functionality	Provides DC Voltage to the microcontroller, sensors, motors, and motor controllers.

Table 11

Module	**Robot Microcontroller**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	DC Voltage, Arming Signal, Acoustic Waveforms
Outputs	Propeller Control Signals, Raft Release Control Signals, Splash Detected
Functionality	Uses the sound waveforms from the acoustic device to determine the location of whatever falls into the pool. The control signals will activate the motors until they reach the intended location and release the raft. Receives armed status and sends initial alarm signal.

Table 12

Module	**Acoustic Devices**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	Splash (sound from entity falling into the pool)
Outputs	Acoustic Waveforms
Functionality	At least four devices will collect data. Acoustic waveforms will be sent to the microcontroller to calculate the splash location.

Table 13

Module	**Raft Release Motor Controller(s)**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Raft Release Control Signals
Outputs	Raft Release Speed Control
Functionality	Converts serial data from microcontroller to an interpretable release speed for raft motors

Table 14

Module	**Raft Release Motor(s)**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Raft Release Speed Control
Outputs	Release Rate
Functionality	Controls the speed of deployment of the raft.

Table 15

Module	**Raft**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Motor Controlled Signal
Outputs	Floatation underneath child
Functionality	Lifts child above the water's surface.

Table 16

Module	**Propeller Motor Controller(s)**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Propeller Control Signals
Outputs	Propeller Speed Control
Functionality	Controls the speed of propellers.

Table 17

Module	**Propellers**
Designer	Taylor Davis and Adrianna Dunlap
Inputs	Propeller Speed Control
Outputs	Robot Movement
Functionality	Moves the robot in a bidirectional motion

Table 18

Module	**Arming Transmitter**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	Armed Status
Outputs	Signal
Functionality	On Home Station: - Provides transmission of armed switch status to be received by on-robot sensor

Table 19

Module	**Arming Receiver**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	Signal
Outputs	Armed Status
Functionality	On Robot - Receives armed switch signal to be send to robot microcontroller

Table 20

Module	**User Interface Microcontroller**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	DC Voltage, Splash Detected, Arm Switch Status
Outputs	Armed Status, Alarm Enable
Functionality	Interprets armed switch status and sends status to robot. Receives a signal to sound an alarm when the robot detects a splash and leaves the home station.

Table 21

Module	**Alarm Transmitter**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	Splash Detected
Outputs	Signal
Functionality	On Robot: - Provides transmission for sounding alarm to be received by home station sensor

Table 22

Module	**Alarm Receiver**
Designer	Kelly O’Neill and Parsa E. Bayat
Inputs	Signal
Outputs	Splash Detected
Functionality	On Home Station - Receives signal representing sound alarm status to be interpreted by user interface microcontroller

Table 23

Module	**DC Regulator**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	120VAC
Outputs	DC Voltage
Functionality	Rectifies and converts VAC to low DC voltage to power User Interface Microcontroller, amplifier, speaker

Table 24

Module	**Alarm**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Alarm Enable
Outputs	Audible Sound
Functionality	Initiates a 100dB alarm

Table 25

Module	**Arm Switch**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	User Input
Outputs	Armed Switch Status
Functionality	Provides user control to arm the system.

Table 26

Level 2 Software Block Diagram with Functional Requirements

At the start of the diagram, we will be waiting for input from the microphone. When a proper microphone input is received, a signal will be sent to sound the alarm. From there, the data from the microphone is sent to the processor. The processor will interpret the data and use it to determine the location of the splash. The determined location will correspond to a 1 meter by 1 meter square in the pool. Next, the motor must be turned on for a certain period of time. The duration that the motor is turned on will be set based on the square chosen in the previous block. After that, the motor will be turned on. The motor will be kept on until the duration of time has ended. When time is up, the motor will be turned off and the raft will be deployed.

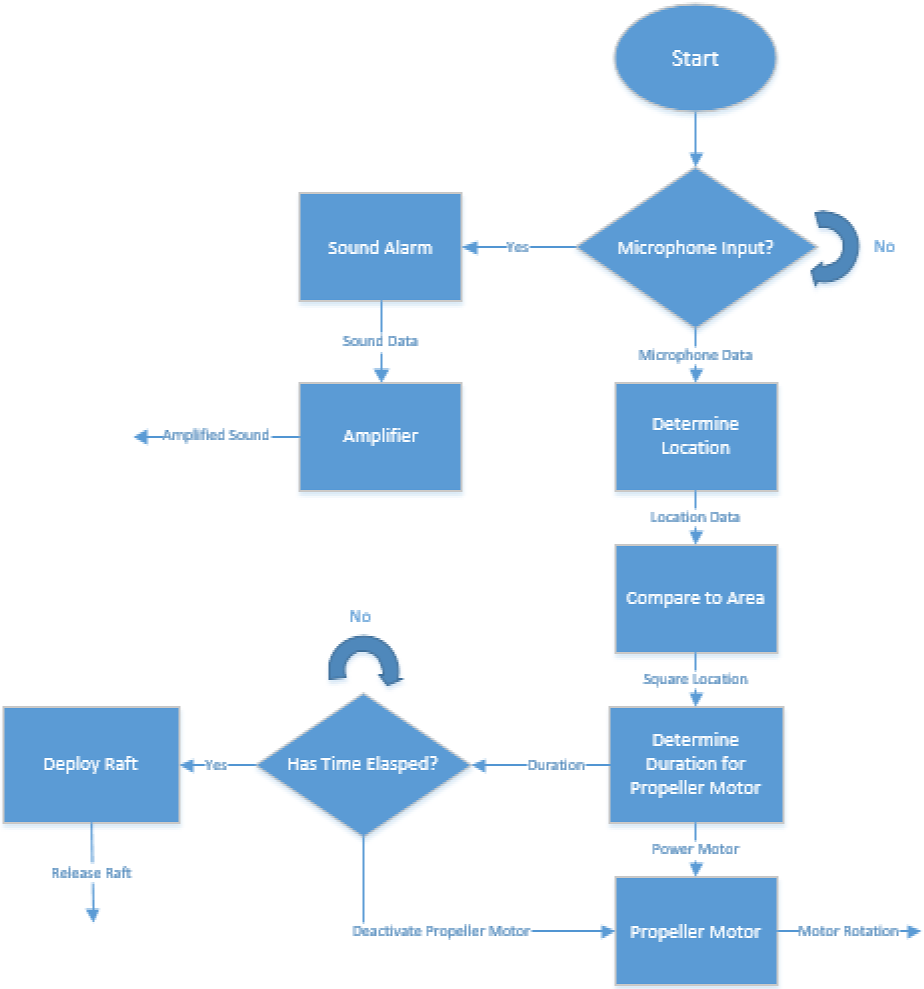


Figure 5: Level 2 Software Block Diagram

Tables 27-36 outline each section of the Level 2 Software Block Diagram. Beginning with the first step of arming the system to the last step of deploying the rescue device, this set of tables details all of the steps taken for tracking the splash location and moving the robot there. Tables 27-32 focus on the tracking of the splash location once a child has fallen into the pool. Lastly, Tables 33-36 focus on the movement of the robot and deployment of the rescue device.

Module	**System Armed?**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	External Switch Signal (High or Low)
Outputs	Yes, No
Functionality	If Yes (armed switch activated), signal sent to arm/prepare robot.

Table 27

Module	**Microphone Input?**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Analog waveform
Outputs	Yes, Microphone Data, No
Functionality	If yes, alarm will be activated and microphone data will be sent. If no, stay in loop.

Table 28

Module	**Sound Alarm**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Yes
Outputs	Sound Data
Functionality	If yes, sound data for alarm is sent to amplifier.

Table 29

Module	**Amplifier**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Sound Data
Outputs	Amplified Sound
Functionality	Increases gain to amplify sound data

Table 30

Module	**Determine Location**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Microphone Data
Outputs	Location Data
Functionality	Function that uses the microphone data to determine the location of of the object in the pool

Table 31

Module	**Compare to Area**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Location Data
Outputs	Square Location
Functionality	Compares the location data to predetermined areas and picks the “square” that the location data resides in.

Table 32

Module	**Determine Duration for Propeller Motor**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Square Location
Outputs	Power Motor, Duration
Functionality	Determines how long the motor should be powered on based on the square determined in the previous function

Table 33

Module	**Propeller Motor**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Power Motor, Deactivate Propeller Motor
Outputs	Motor Rotation
Functionality	Turns on or off motor based on desired duration

Table 34

Module	**Has Time Expired?**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Duration
Outputs	No, Yes, Deactivate Propeller Motor
Functionality	Constantly checks if the time has expired. Sends Deactivate Motor Signal and Deploy Raft Signal when the time has expired

Table 35

Module	**Deploy Raft**
Designer	Kelly O’Neill and Parsa Bayat
Inputs	Yes
Outputs	Deploy Raft
Functionality	Sends a signal to the hardware to deploy the raft

Table 36

Mechanical Sketch of System [TD]

S.A.V.E. M.E. is being designed for a 3 meter by 3 meter pool. On the bottom of the pool, there will be a 2 meter by 2 meter track. The size of the track was chosen based off of several factors including research shows that children that fall in the pool stay near the sides and the rescue device having a minimum surface area of 1m^2 The underwater robot will be guided along the bottom of the track by a wheel or roller. The robot will move forwards and backwards via underwater propellers. Lastly, the rescue device will be tethered to the robot and released when the robot arrives at the splash location. A simple mechanical design of the system can be seen in Figures 6 and Figure 7.

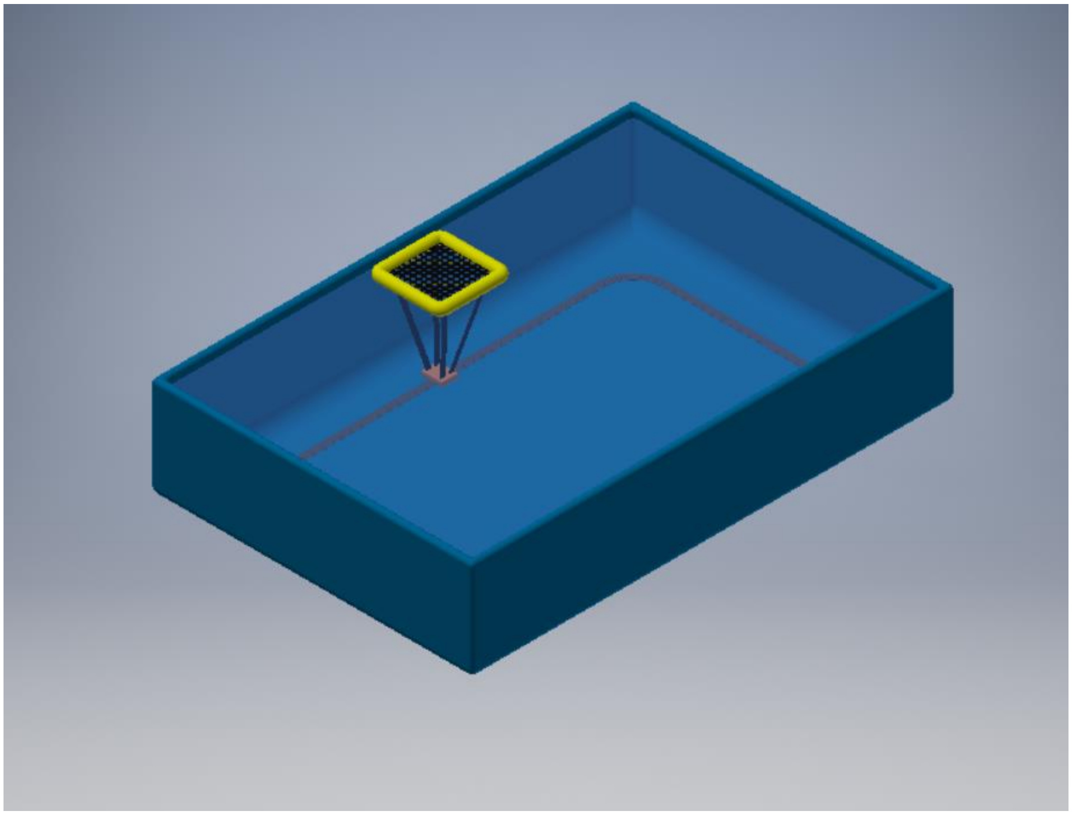


Figure 6: Isometric View

Figure 7: Side View

Engineering Analysis

Mechanical Design of the Track [TD]:

The track will be either built in the University of Akron machine shop or purchased from an industrial curtain supplier. For the design of the track, an “I” beam configuration was chosen. As specified in the design requirements, the pool is to be 3 meters by 3 meters and the track is to be 2 meters by 2 meters. This size was chosen due to research showing that when children fall in the pool they stay relatively close to the edge. The track will be comprised of 4 sections of straight pieces of track and 4 rounded corners so that the robot can easily make turns underwater. The corner pieces were designed to be 0.6096 meter (2 feet) radius at a 90° angle. The 4 straight pieces were designed to be 1.3 m in length. With this sizing design for the corner and straight pieces, each side will be in total 2 meters (6.5 feet) which can be seen in the figures below.

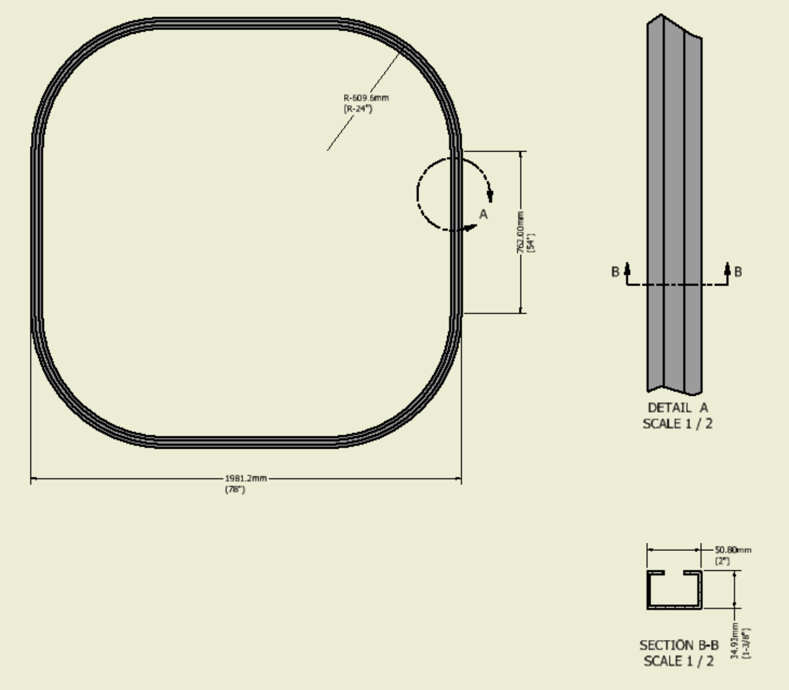


Figure 8: Top View of the Track

To guide the robot along the track a wheel carrier will be attached to the bottom of the robot. The “I” beam configuration that the wheel carrier will move through was designed to be 50.88 mm in width and 35 mm in height. These sizes were chosen based off standard industrial “I” beam designs that are able to be purchased if needed.

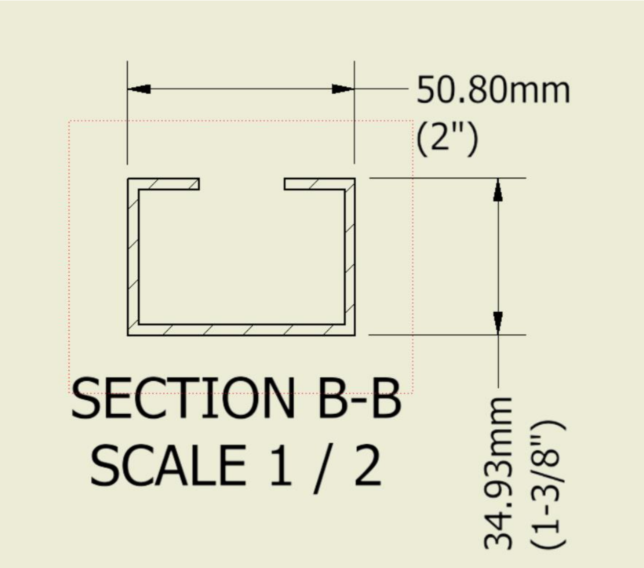


Figure 9: Cross Sectional View of the Track

Shown below in Figure 10, is a drawing of the robot attached to the wheel carrier inside the track.

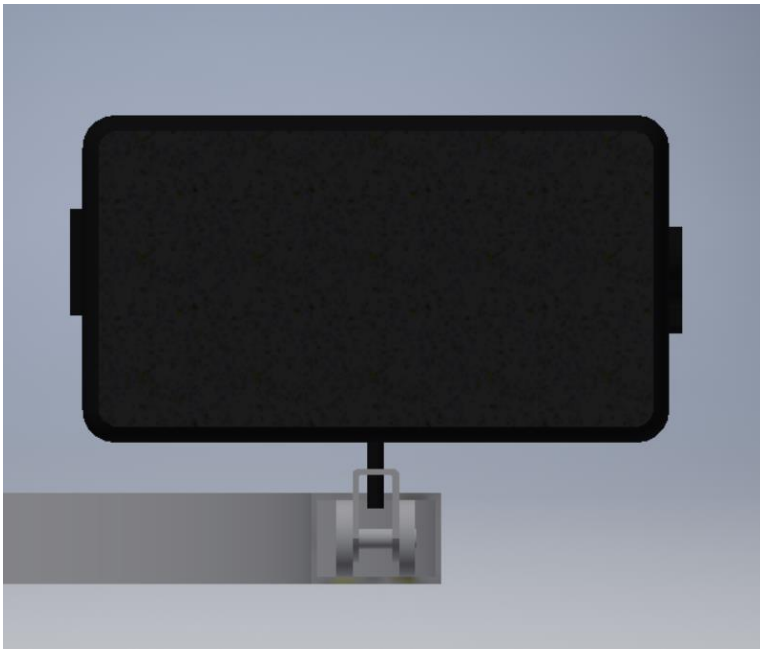


Figure 10: Robot & Wheel Carrier Cross Sectional View

Lastly, the track will be made out of metal, ideally steal. The robot moving along the track can be seen below in Figure 11.

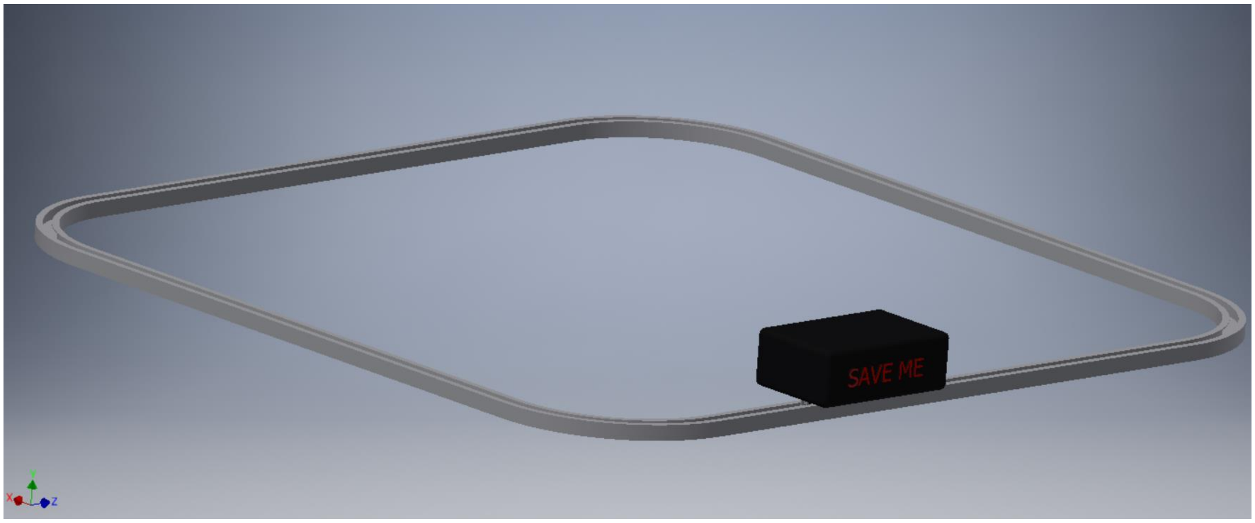


Figure 11: Robot Along the Track

Underwater Movement [TD]:

The robot will be guided by a roller along the track, but it will be propelled forwards and backwards by an underwater thruster. The thruster will be powered by 12V DC by the robot side battery pack. The max current draw of the thrusters is 25A and at max current it can push 7.8lbs of force. The thrusters were donated from Blue Robotics.

Robot Enclosure [TD]:

Per the design requirements, the system needs to be waterproof. For this an underwater enclosure was chosen based off of the required dimensions needed to hold the robot battery and PCB boards.

Raft Design [AD]:

To design the size of the raft that will lift the drowning child above the surface of the water, research needed to be done on the intended user of the device. The system is designed to save young children in the age range of 1-4 years old. The height of an average American toddler can range anywhere from 0.7 meters to right under 1 meter. Based on this information, the raft is designed to have a minimum surface area of 1m^2 so that it can be large enough to hold and lift up a child this size. The raft needs to be able to be submerged underwater while the robot is moving along the track to the splash location and easily rise and float above the surface of the water when performing a rescue. To meet this criteria, the raft will be made of the material polyethylene or styrofoam, which has a density less than water.

The buoyancy force of the raft needed to be calculated by using $F_b = \rho g V$where $\rho$is the density of the liquid, which is $1000\frac{kg}{m^3}$, $g = 9.81\frac{m}{s^2}$and V is the volume displaced is

For a $1m * 1m * .0508m$, $V = .0508m^3$and therefore $F_b = \left(\frac{1000kg}{m^3}\right)\left(\frac{9.81m}{s^2}\right)(.0508m^3) = 498.348N \sim 112lb - f$

Recognizing the need to take away some of the force, 36, 4in holes will be cut in the raft material, reducing the buoyancy force significantly.

The volume of each cylindrical cutout will be $V = \pi r^2 h = \pi(.0508)^2(.0508) = 4.11851839 * 10^{-4} m^3$. For 36 holes, the volume taken out would be $V_{holes} = .0148266662m^3$resulting in $V_{displaced,new} = .0508m^3 - .0148266662m^3 = .0359733338m^3$

The new buoyancy force would be $F_b = \left(\frac{1000kg}{m^3}\right)\left(\frac{9.81m}{s^2}\right)(.0359733338m^3) = 352.898N \sim 80lb - f$

Therefore, the single cable attached to the robot must have a greater force pull down of 353N.

Raft Release [TD]:

The raft is going to be tethered to the robot via four cables. To release the cables and elevate the rescue device a pinch solenoid will be used. The solenoid will be powered by the 12V DC battery pack inside the robot. An explanation of the drive circuitry is explained in further detail in the alarm and solenoid engineering analysis and in figure 26.

Tracking [PB]:

One of the requirements for the device is to be able to determine the location of a person falling into the pool. In order to do this, a microphone array will be mounted to the robot. When someone falls into the pool, the sound of the splash will travel to the array. Using the known value of sound propagation, the location of the splash can be determined. In order to calculate the location, the pool will first be converted to a coordinate system. For our purposes, the coordinate grid will be created based off of a 3 meter by 3 meter pool with a depth of 5 meters. Each unit on the grid will represent 1 centimeter on the actual pool. One of the microphones on the robot will be positioned at the origin of the pool to make the calculations simpler. The default position of the robot will be 500 centimeters south from the middle of the pool. This creates a coordinate grid with an x-axis range of -1500 to 1500, a y-axis of -500 to 2500, and a z-axis of 0 to 3000.

The time it takes for an object to reach one point to another can be represented by the equation $t = \frac{1}{v}\sqrt{(x-x_0)^2+(y-y_0)^2}$ where v is the velocity of the object, x and y are the starting position of the object, and x_0 and y_0 are the ending position. For the calculations, v will represent the speed of sound in water (0.1498 cm/us), x_0, y_0, x_1, y_1, x_2, y_2, x_3 and y_3 will represent the locations of the microphones, and x and y will represent the location of the splash.

$$t_0 = \frac{1}{v}\sqrt{(x-x_0)^2+(y-y_0)^2} \rightarrow \frac{1}{v}\sqrt{x^2+y^2}$$

$$t_1 = \frac{1}{v}\sqrt{(x-x_1)^2+(y-y_1)^2}$$

$$t_2 = \frac{1}{v}\sqrt{(x-x_2)^2+(y-y_2)^2}$$

$$t_3 = \frac{1}{v}\sqrt{(x-x_3)^2+(y-y_3)^2}$$

- Note that in the equation for t_0, the values of x_0 and y_0 can be removed because the first microphone resides at the origin.

Using the above equations, a system of equations can be created by subtracting the values of t by each other. For simplicity, all of the equations will be subtracted by the first equation. From this the following equations are derived:

$$\Delta t_1 = t_1 - t_0 = \frac{1}{v}\sqrt{(x-x_1)^2 + (y-y_1)^2} - \sqrt{x^2+y^2}$$

$$\Delta t_2 = t_2 - t_0 = \frac{1}{v}\sqrt{(x-x_2)^2 + (y-y_2)^2} - \sqrt{x^2+y^2}$$

$$\Delta t_3 = t_3 - t_0 = \frac{1}{v}\sqrt{(x-x_3)^2 + (y-y_3)^2} - \sqrt{x^2+y^2}$$

The Δt values will be the “real world” values that are obtained by the microphones. When a microphone hears the splash, a timer will be stopped. The timers will all be subtracted by each other to get their respective Δt values. Substituting in the Δt values, the value of the speed of sound in water, and the location of the microphones on the axis, the above system of equations can be solved for x and y. These values will represent the position of the splash on the coordinate grid.

Pseudocode [PB]:

Pseudocode for robot in pool:

```
Start

Set variable IR_arm_signal_from_microcontroller to false //This variable will be set to true when
//a signal is received


While IR_arm_signal_from_microcontroller is false
{
                Nop;  //Nothing is done while no arming signal is sent to the robot
}

Run timer0 counter in background to count in nanoseconds
Run timer1 counter in background to count in nanoseconds
Run timer2 counter in background to count in nanoseconds
Run timer3 counter in background to count in nanoseconds

Set mic0 to false
Set mic1 to false
```

```
Set mic2 to false
Set mic3 to false
Set mic input to false

While (mic0 mic1 mic2 mic3 are all false) {
            Get mic0 value from input          //interrupt routine
      If mic0 value is over the threshold, set mic0 to true, stop timer0

            Get mic1value from input           //interrupt routine
      If mic1value is over the threshold, set mic1 to true, stop timer1

            Get mic2value from input           //interrupt routine
      If mic2value is over the threshold, set mic2 to true, stop timer2

      Get mic3value from input           //interrupt routine
      If mic3value is over the threshold, set mic3 to true, stop timer3
}

Set alarm to true             //sound the alarm

Set T1 equal to timer1 minus timer0
Set T2 equal to timer2 minus timer0
Set T3 equal to timer3 minus timer0

Solve system of equations
v = 1/0.1498;                 //speed of sound underwater

x1 = -18;   //location of mic1
y1 = 22;
z1 = 0;

x2 = 18;       //location of mic2
y2 = 22;
z2 = 0;

x3 = -18;   //location of mic3
y3 = 0;
z3 = 0;

//equation 1
```

```
eq1 = (v)*((sqrt(((x-(x1))^2)+((y-(y1))^2 +((z-z1)^2)))-(sqrt((x^2)+(y^2)+(z^2)))))==T1;

//equation 2
eq2 = (v)*((sqrt(((x-(x2))^2)+((y-(y2))^2)+((z-z2)^2)))-(sqrt((x^2)+(y^2)+(z^2))))==T2;

//equation 3
eq3 = (v)*((sqrt(((x-(x3))^2)+((y-(y3))^2)+((z-z3)^2)))-(sqrt((x^2)+(y^2)+(z^2))))==T3;

sol = solve([eq1,eq2,eq3],[x,y,z]);

//set the solutions
X = sol.x;          //set X's value
Y = sol.y;          //set Y's value
Z = xol.z;          //set Z's value

//Square0-7 all correspond to a specific section of the pool


//Disregard Z value
if ( X < -50){
        if (Y < 50)
Square_Location = 7;
        if (50 < Y < 150)
            Square_Location = 6;
        if (150 < Y)
            Square_Location = 5;
}
else if ( -50 <  X < 50){
        if (Y < 50)
Square_Location = 0;
        if (50 < Y < 75)
//This is the middle of the pool. The robot cannot physically move to this location.
Square_Location = 0;
        If (75 < Y < 150)
If(X < 0)
        Square_Location = 6;
else if (X > 0)
        Square_Location = 2;

        if (150 < Y)
```

```
Square_Location = 4;
}
else if ( X > 50){
            if (Y < 50)
Square_Location = 1;
            if (50 < Y < 150)
Square_Location = 2;
            if (150 < Y)
Square_Location = 3;
}

//Switch statement used to choose location
Switch(Square_Location)
{
            Case 0: Set propeller duration to get to square 0
            Case 1: Set propeller duration to get to square 1
            Case 2: Set propeller duration to get to square 2
            Case 3: Set propeller duration to get to square 3
            Case 4: Set propeller duration to get to square 4
            Case 5: Set propeller duration to get to square 5
            Case 6: Set propeller duration to get to square 6
            Case 7: Set propeller duration to get to square 7
}

While(propeller duration != 0)
{
            Turn on propeller motor
}

Turn off propeller motor
Deploy raft

Stop
```

<u>Pseudocode for microcontroller outside pool:</u>

```
Start

Declare variable Arming_Switch                //represents a physical switch
```

```
While Arming_Switch is false
{
            Nop;  //Nothing is done while no arming signal is sent to the microcontroller
}

//loop will exit when an arming signal is received

Send IR Signal to the Robot   //This signal will let the robot know that the system is armed
                              //and to start listening

Set Alarm_Signal to false          //Alarm_Signal represents the signal that the robot will
                                   //send to the microcontroller to activate the alarm

While Alarm_Signal is false
{
            Nop;    //wait for Alarm_Signal from the robot
}

Sound alarm

Stop
```

User Interface Rectifier and Regulator Circuit [TD]:

To power the alarm and microcontroller used for arming the system once a child has fallen into the pool, a 12V DC source is needed. To do this a rectifier and 12V DC regulator circuit was designed which can be seen below in Figure 12. A transformer of 120 VAC to 20 VAC was chosen to accommodate both the alarm circuit outside of the pool as well as the inductive charging unit and robot inside of the pool. Once the transformer was chosen, the rectifier and regulator circuit were able to be designed with the following calculations:

First the peak voltage was calculated:

1. 20 V rms = $\sqrt{2} * 20\ Vrms =\ 28.28\ V_{peak}$

Next the voltage drop due to 2 of the diodes was subtracted from Vpeak:

2. 28.29 Vpeak - 0.7 V - 0.7 V = 26.89 V

Then the DC voltage converted by the bridge rectifier circuit was calculated by:

3. DC Voltage = $\frac{2*V}{\pi}$= $\frac{2*26\ V}{\pi}$= 16.55 V DC
4. Current rating of Alarm + microcontroller = 1 amp
5. Max Current Rating = 1 amp * 2 (factor of safety) = 2 amps
6. R_2 (Alarm) =$\frac{12\ VDC}{2amps}$= 6 ohms

Next a capacitor is needed that appears as a short to the AC ripple, to achieve that, the impedance of the capacitor must be smaller than or equal to one hundredth of the load:

7. $X_C = \frac{6ohms}{100}$= 0.06 ohms
8. Frequency of a full wave rectifier, f = 120 Hz

9. $X_C = \frac{1}{2*\pi*f*C}$ resolving for $C = \frac{1}{2*\pi*120\ Hz*\ 0.06\Omega}$= 22,104 uF

10. The zener diode was chosen off of the desired breakdown voltage of 13V DC and a of $I_z = 80\ mA$ based off of the following calculations:

$V_Z = V_{LOAD} + V_{BE} = 12V + 0.7V = 12.7$ V
$P_{Dmax} = 1W$
$I_z = \frac{P_{Dmax}}{V_z} = \frac{1\ W}{13\ V}$ = 76.9 mA

11. The resistor, R1, is then calculated using the I_z found in the step above:
R1 = $\frac{V_{R1}}{I_z} = \frac{(25\ V - 13\ V)}{76.9\ mA}$ = 156 Ω

Chose a standard resistor value of 150 Ω.

12. The transistor, Q1, was chosen based on the following specifications:

$I_c = 2$ A = Max Current Rating
$V_{ceo} \geq$ 28.29 Vpeak - 0.7 V - 0.7 V = 26.89 V
P = $(V_C - V_E) * I_c$ = (25 -12 V)*2 $\geq$ 26 W

13. To chose the diodes for the bridge rectifier:

V = 2* $V_{peak} = 2 * 28.28 \geq 56.56\ V$

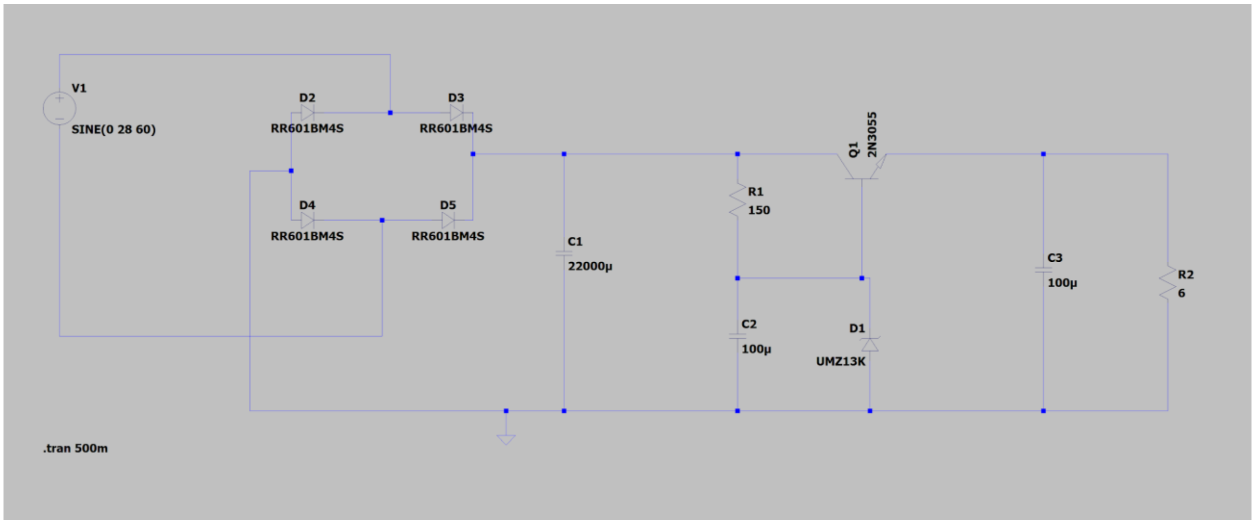


Figure 12: User Interface Rectifier and Regulator Circuit

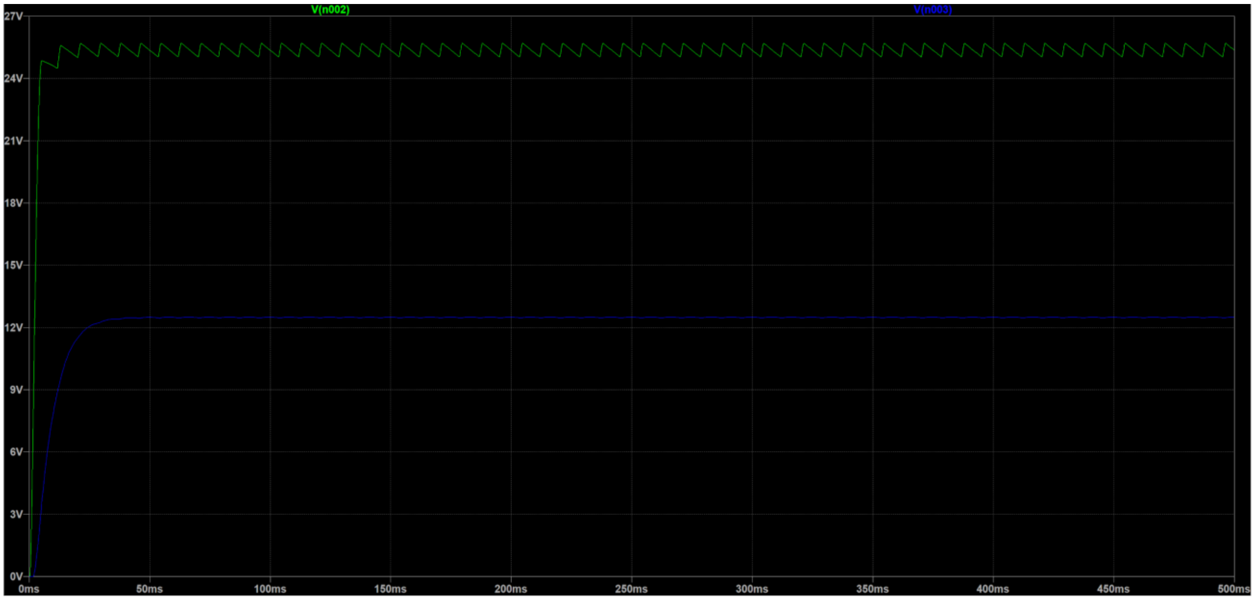


Figure 13: Output Voltage Waveforms of Figure 12

The top waveform is the output voltage waveform with respect to time of the rectifier circuit. The input voltage of the schematic is 20 VAC RMS which will be stepped down from a 120V AC transformer. The input AC voltage is then converted to DC voltage via a bridge rectifier circuit. The capacitor, C1, then smooths out the full wave rectifier waveform and has an average DC value around 25 volts.

The bottom waveform is the output voltage waveform with respect to time of the regulator circuit. The regulator circuit takes the 20V DC and drops it down to the desired DC voltage, which for the alarm and user interface is 12 V DC. For the regulator circuit, an integrated circuit 12V DC voltage regulator will be used.

Microphone Testing [KO]:

To obtain necessary splash data for triangulation, microphones were needed to hear the splash. Based on the quality of microphone data obtained from a bench test, a microphone and the corresponding, appropriate filtering and sampling hardware was chosen.

With the goal of testing this project eventually in either the University of Akron's ONAT or leisure pool, a bench test environment was initially constructed using a ten gallon fish tank with a filter pump. The filter pump was used to represent a large pool pump and a splash in addition to keeping the water from becoming stagnant in the lab.

In the bench test environment, three options for microphones were tested: an Andoer piezo contact microphone, a lapel microphone, and a Microseven M7WP-MIC waterproof outdoor microphone. Waveform data using each microphone was observed using an oscilloscope. From that data, a microphone was chosen for testing in the actual large pool environment.

The Andoer piezo contact microphone performed very insufficiently as it senses audio vibrations through contact with solid objects. When simply placing the microphone suspended in the water, no splash could be detected. Even after placing the microphone up against the side of the fish tank, very little difference in the waveform due to the splash was detected. If this microphone would be chosen, an amplifier would be a necessity, and the microphone would need to be mounted firmly to the body of the robot to sense the splash. However, with this option, there is concern as to whether a delay would be noticeable as the entire body of the robot would ‘feel’ the splash vibration.

The lapel microphone performed poorly. As this microphone is not waterproof, a balloon was secured around the head of the microphone before being placed in the tank for testing. No waveform difference was detected when testing this microphone.

The best results came from the Microseven M7WP-MIC waterproof outdoor microphone. Initially the microphone was placed directly in the tank with the filter running. A waveform with positive amplitude in the 0.5 to 4V range was observed at the output. A splash was created by slapping the surface of the water and the waveform in Figure 14 was recorded on the oscilloscope. It can be seen that during the splash, there is saturation of the signal. While the splash is noticeable on an oscilloscope during a certain time frame, analysis of the amplitudes during the splash and calm time periods show the waveforms reach similar amplitudes. Because a distinct difference in amplitude is desired for the microcontroller to identify a splash, this was a large concern.

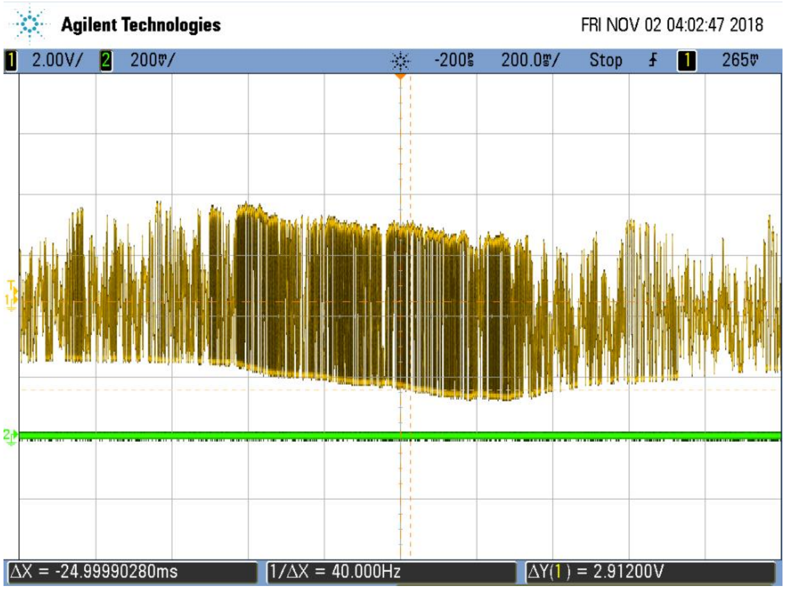


Figure 14: Non-encased Microseven M7WP-MIC Microphone in Bench Test with Splash

Some of the concerns identified prior to transitioning from the bench test to ONAT pool environment include the noise generated from the university pool pumps and the saturation of the waveform when the microphone is placed directly in the water. To address these concerns, the Microseven M7WP-MIC waterproof outdoor microphone was tested in the ONAT pool at the University of Akron both with the microphone encased in a waterproof container and placed directly in the water.

The test was extremely successful. In both encasement situations, a splash was able to be heard on the surface from a minimum distance of 3m away when the microphone was submerged to the ONAT pool's 5 ft depth. However, when encased, the microphone did pick up less extraneous noise from the pool pump, resulting in a more defined pulse.

Figure 15 depicts a surface splash created within 1m of the encased microphone. The peak amplitude of the pulse is approximately 7V which differs significantly from the sound heard from the pool pump which is less than 1V.

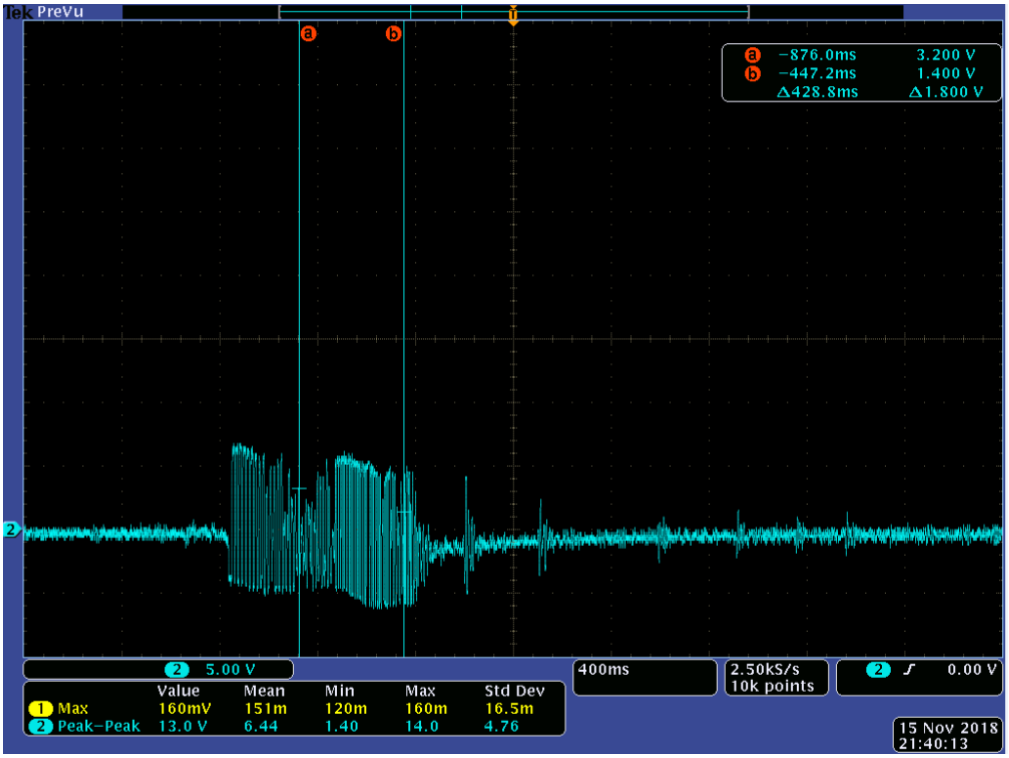
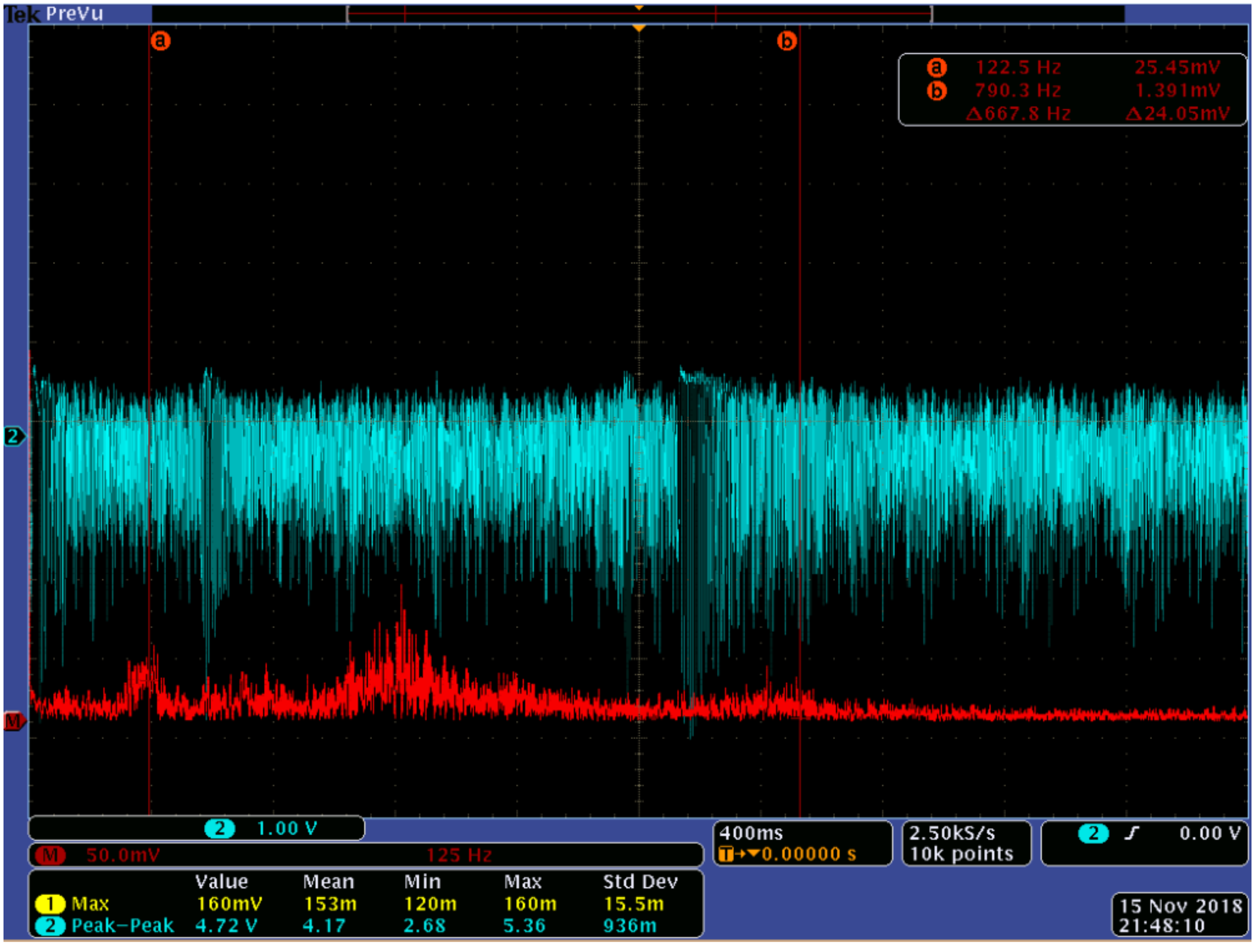


Figure 15: Encased Microseven M7WP-MIC Microphone - Splash less than 1m away

Figure 16 depicts a splash created within 1m of the microphone when placed directly in the water. The peak amplitude of the splash is approximately 4V but as the pump noise has an amplitude of 2-3V it is much more difficult to distinguish the splash, specifically the initial instant the splash was heard.



	Value	Mean	Min	Max	Std Dev
1 Max	160mV	153m	120m	160m	15.5m
2 Peak–Peak	4.72 V	4.17	2.68	5.36	936m

Figure 16: Non-encased Microseven M7WP-MIC Microphone - Splash less than 1m away

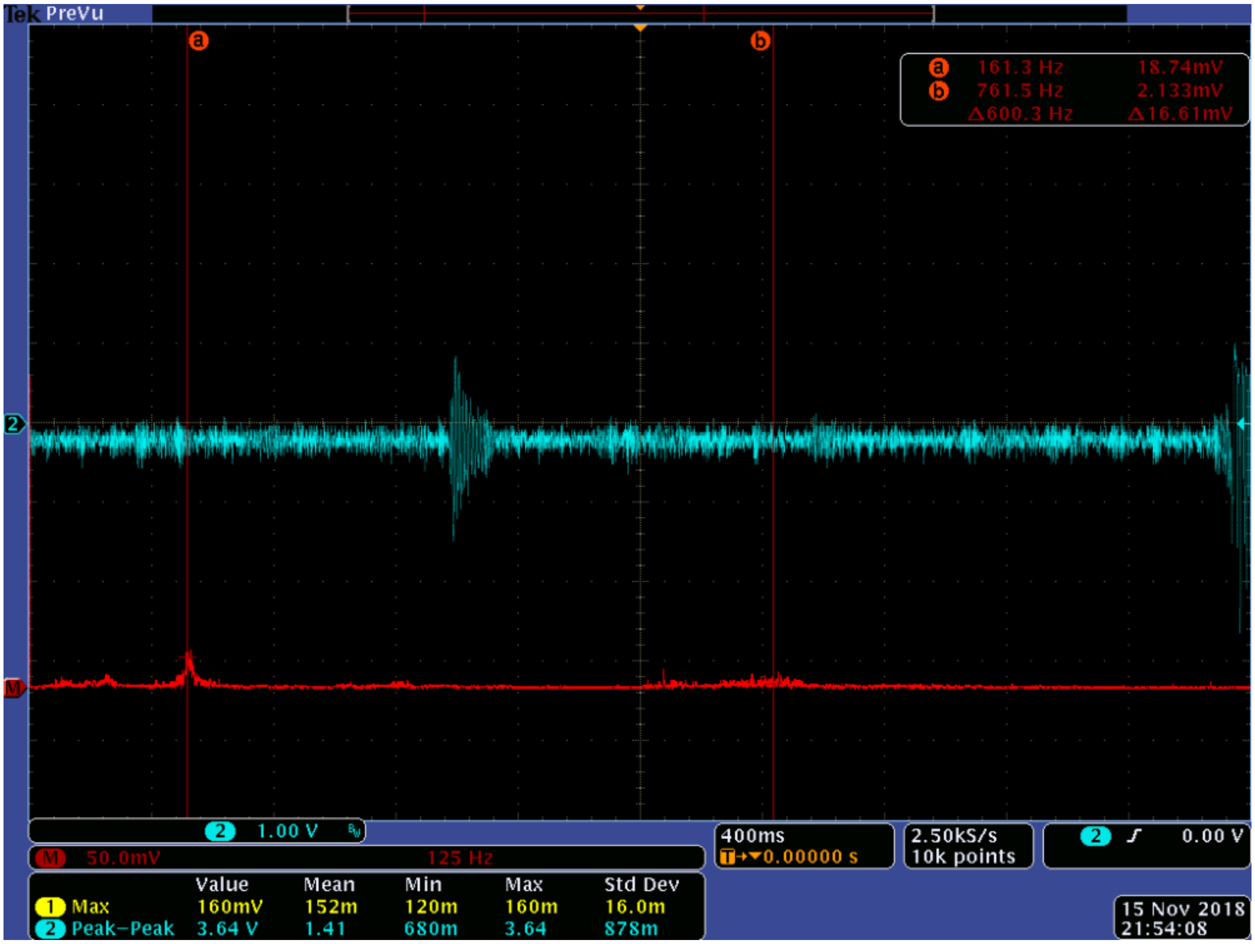
This initial rise, or change in amplitude, is what will be examined for timing and triangulation analysis. Through this testing, it was decided that the Microseven M7WP-MIC waterproof outdoor microphone, when submerged at 5ft and encased in a waterproof container, is a useable choice to hear a splash at the necessary distance for the defined 3m by 3m pool. The remainder of testing and analysis will be performed for an encased Microseven M7WP-MIC waterproof outdoor microphone.

The testing in the ONAT was additionally conducted to obtain the frequency of the noise created by the pool pump so it can be filtered out. The waveforms in Figure 17 and Figure 18 below were utilized to see which frequencies need to be filtered out. Figure 17 depicts the sound heard by the microphone when no splash is occurring. An FFT, or a Fast Fourier Transform, analysis was conducted for the waveform. As the cursors do not show at what frequency the spike occurs, it is compared with Figure 18 which has identically 400 ms per division to determine that the frequency spike in Figure 17 occurs at 160Hz. Figure 18 shows the FFT analysis of a splash. A 160 Hz spike is clearly visible. It is difficult to identify the frequency of the splash from the waveforms as the amplitude compared to the frequency is minimal.

a −1.324 s −218.0mV
b 408.8ms −122.0mV
Δ1.733 s Δ96.00mV

	Value	Mean	Min	Max	Std Dev
1 Max	160mV	150m	120m	160m	17.7m
2 Peak−Peak	>700mV	⚠ Clipping negative			

Figure 17: FFT Analysis of ONAT Pool Pump Noise



	Value	Mean	Min	Max	Std Dev
1 Max	160mV	152m	120m	160m	16.0m
2 Peak–Peak	3.64 V	1.41	680m	3.64	878m

Figure 18: FFT Analysis of ONAT Pool Pump Noise and Splash

Therefore, by implementing a low pass filter that will filter out frequencies in the 150Hz to 170 Hz range, only the splash waveform data will be obtained and analyzed. In the next test of the microphones in the ONAT, this choice of filter will be tested and verified.

Band Stop Filter and Envelope Detector [KO]:

From testing in the ONAT, it was determined that the 160Hz noise created by the pool pump needs filtered out. As this single frequency needs filtered out, a band pass filter, specifically a Twin-T Notch filter is chosen to be used as this type of filter is typically used to reject a specific frequency that is generating electrical noise. It provides a narrow, deep stop band around a specific notch frequency. With a desired cutoff off, or notch frequency of 160Hz, the below equation is utilized to determine values for R and C.

$$f_N = \frac{1}{4\pi RC}$$
$$160Hz = \frac{1}{4\pi RC}$$
$$RC = \frac{1}{4\pi(160)} \approx 0.000497$$

Choose R = 1.8kΩ, C = 0.27uF, 2R = 3.6kΩ, and 2C = 0.56uF

This resistor and capacitor value is utilized for each of the four microphone input band stop filter circuits.

To obtain the positive envelope of the band pass filtered analog waveform, a Schottky diode and RC delay are utilized. A Schottky diode is chosen as it has a low forward voltage drop which will allow for nearly the full range of analog voltage values to be sampled. Specifically for the CUS520,H3F Schottky diode chosen, the forward voltage drop is merely 280mV. The RC delay is utilized to minimize ripple and negative peak clipping. As the microcontroller will only be looking for the initial voltage amplitude increase of each microphone due to a splash, a greater emphasis is placed on minimizing ripple and very minimal emphasis on negative peak clipping. Thus, the time constant, τ, is chosen to be a large value, 10ms, and the resistor and capacitor is chosen accordingly.

$$\tau = RC$$
$$0.01 = RC$$

Choose R = 10kΩ and C = 1uF

This resistor and capacitor value is utilized for each of the four microphone input envelope detector circuits. Figure 19 depicts the filtering and envelope detecting circuit for all four microphones.

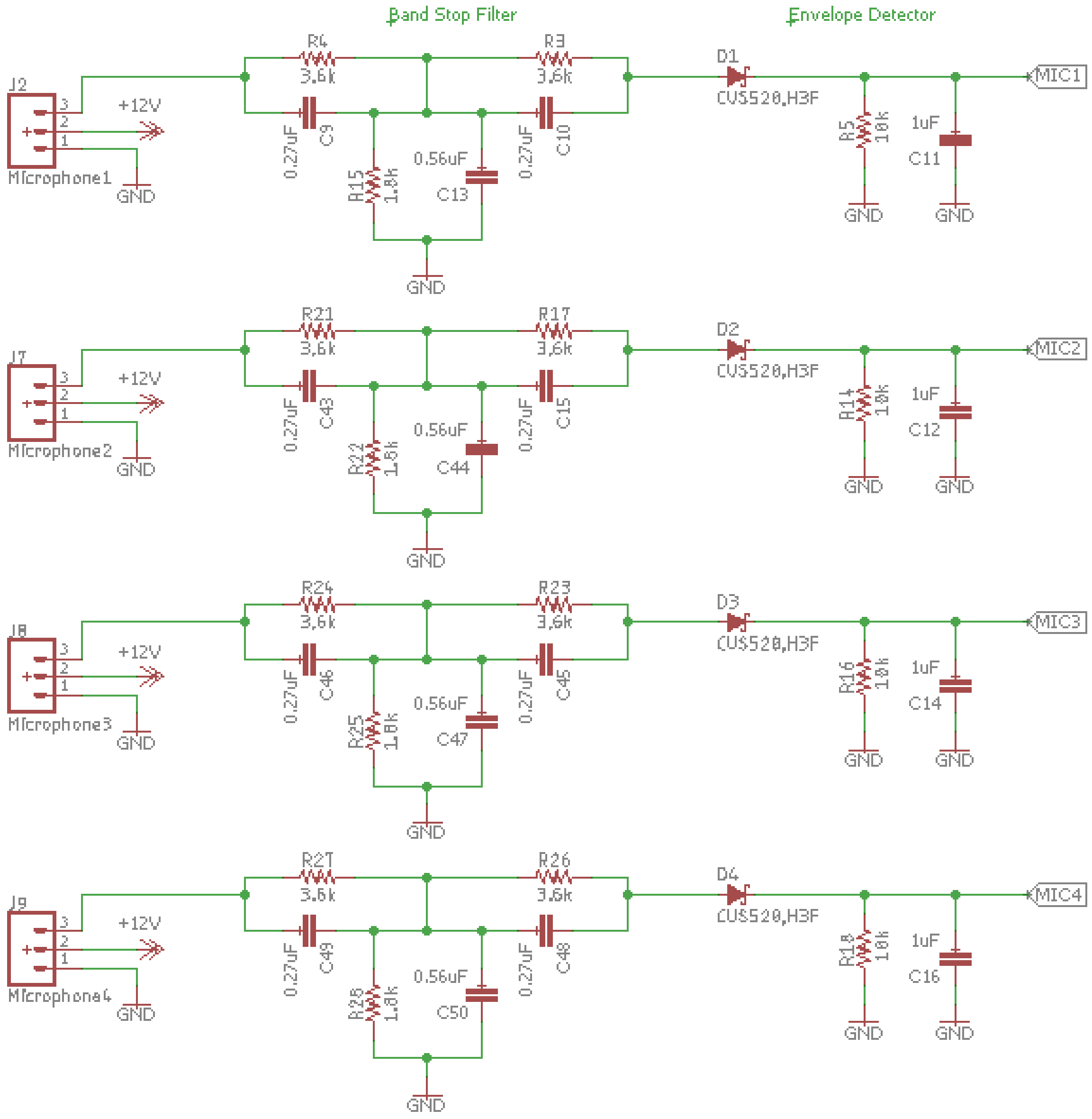


Figure 19: Band Stop Filter and Envelope Detection Circuit Schematic

Analog to Digital Converter (ADC) [KO]:

After passing each microphone waveforms through the low pass filter and envelope detector respectively, the waveforms are each sampled using an analog to digital converter (ADC) so data can be passed to the microcontroller for analysis.

From the experimental tests conducted in the ONAT, the maximum amplitude of the splash waveform was observed to be around 7V, seen in Figure 15. As most ADCs are designed for 3.3V or 5V analog signals, an ADC needed to be found that could handle larger analog inputs. Additionally, as the converted digital data, typically in the range of 8-16 bits, from each of four microphones needs to be sent from the microcontroller for analysis a choice of whether the data should be sent in parallel, sending each bit to a pin individually, or using a communication protocol. As sending the data from four ADCs in parallel would require 32-64 GPIO pins depending on the chosen ADC, it was decided that choosing an ADC that communicates with a specific protocol would significantly simplify PCB layout construction and speed up the microcontroller program analysis of the data.

Texas Instruments' ADS8664 analog to digital converter satisfies both of these determined component requirements. This ADC is rated for an absolute maximum of -20V to 20V on the negative and positive analog signal input pins respectively. However, the input range is configurable as well based on a reference voltage. The internal reference voltage will be utilized and because the envelope detector will make the negative analog signal input be ground, the analog input range will be configured to 0 to 10.24V, or 0 to 2.5×Vref, where for the internal reference Vref = 4.096.

This ADC additionally uses SPI, Serial Peripheral Interface, to communicate. A unique configuration with this ADC is available for SPI that allows for daisy chaining of the serial data out (SDO) pins. This allows for the same synchronous clock to drive each ADC, resulting in synchronous data sampling of the four microphones and a collective data pulse stream being sent to the microcontroller. A single SPI channel is required for this configuration as the same clock (SCLK), serial data in (SDI), and chip select (CS) pin from the microcontroller drives and configures all four ADCs. The four converters are depicted in Figure 20 where labels are utilized to daisy chain the data outputs of each ADC.

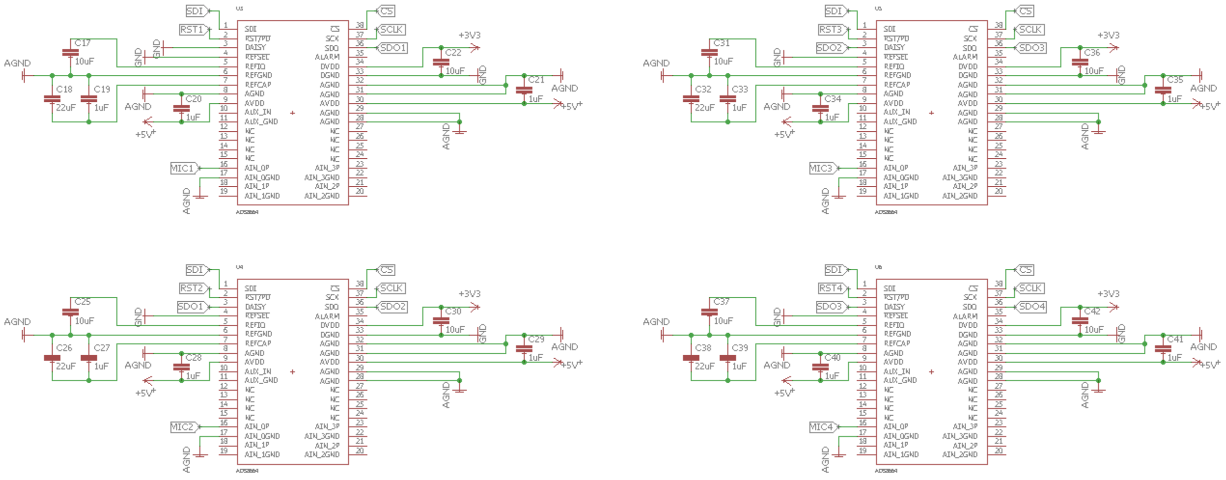


Figure 20: Analog to Digital Converter Circuit Schematic for all Sampling

The recommended decoupling capacitors are added identically for each converter according to the datasheet. The ADC circuit to sample the analog waveform originating from Microphone 1 is shown in Figure 21 using the Texas Instruments part ADS8664. This ADC is the beginning of the daisy chain with the DAISY pin grounded and the SDO pin single labeled SDO1 being fed into the DAISY pin of the ADC for the Microphone 2 data.

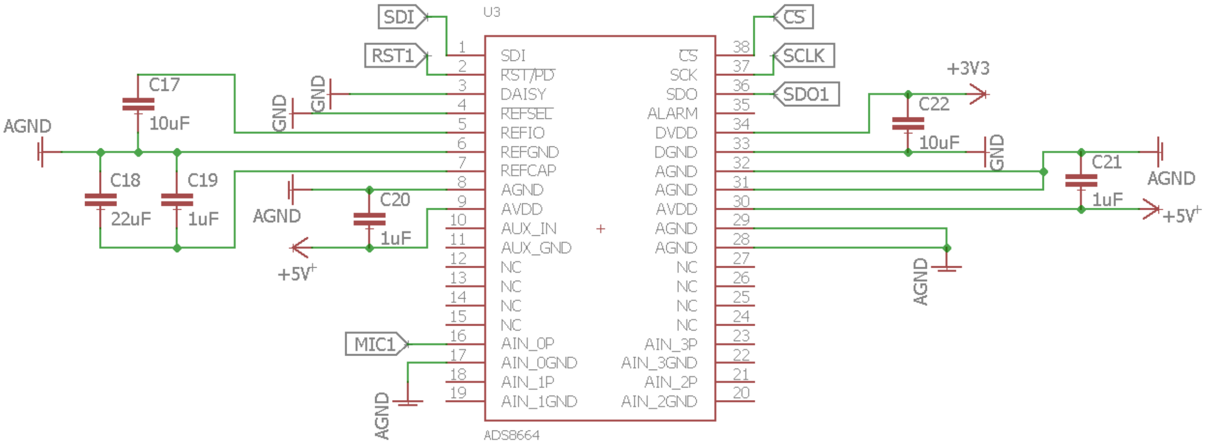


Figure 21: Analog to Digital Converter Circuit Schematic for Microphone 1

<u>IR Communication [KO]:</u>

To communicate the arm robot signal and activate alarm signal between the user interface and robot, IR LEDs are chosen to communicate these status signals. On the user interface, the armed switch status will be read by the microcontroller and will drive an IR LED to be read by the robot. On the robot microcontroller an IR receiver will be wired to receive the armed status. Mirroring this communication, an IR LED will be 'ON' continuously on the robot once armed. Upon hearing a splash, the robot moves away from the home station, the IR receiver wired to the user interface microcontroller will no longer read the IR LED. This change in status will activate the alarm outside the pool. Connectors for the IR LED and IR Receiver are connected to GPIO pins on each microcontroller as the transmitter and receiver will need to be in specific locations away from the mounted PCB respectively.

A TSOP38238 IR receiver is chosen to interpret this signal. This package is a combined pin diode and sensor IC that amplifies, filters, and demodulates the input to bias a transistor that triggers an output pin accordingly. This output value will be read by a GPIO pin of the microcontroller. The IR LED chosen is a 940nm LED, as the receiver has peak sensitivity at that wavelength. A three-pin connector is utilized for the receiver and a two pin connector is utilized for the IR LED.

To limit the current draw from the IR LEDs, setting the desired continuous current to 20mA results in the forward voltage drop across the LED to be 1.2V. A 200Ω resistor to limit the current to approximately 20 mA is chosen based on the below calculation

$$V_{S,micro} = V_{LED} + V_R$$
$$3.3V \;=\; 1.2V \;+ (20mA)R$$
$$R \;=\; 105\Omega$$

Choose R = 120Ω

The circuits for the IR Communication elements are shown in the Figure 22 and Figure 23 circuit schematics for the user interface and robot respectively. The ALARM_OUT signal and ARMED_OUT signal connect to the user interface microcontroller and robot user interface respectively.

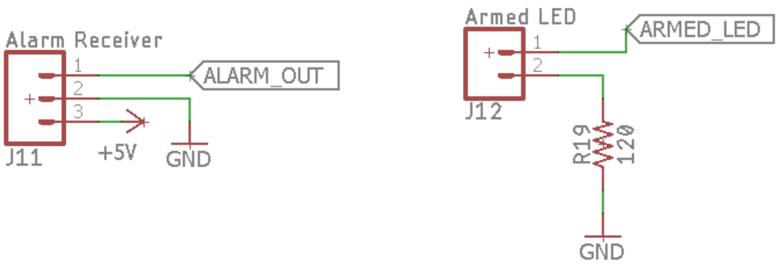


Figure 22: IR Communication Circuit Schematic on User Interface

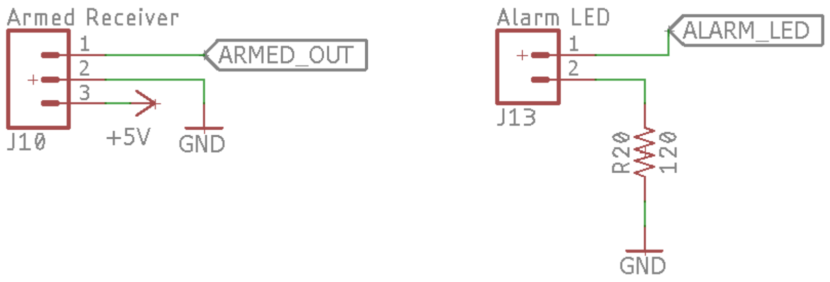


Figure 23: IR Communication Circuit Schematic on Robot

Robot Microcontroller [KO]:

The microcontroller for the robot was chosen based on several factors: necessary processing speed, necessary memory, number of SPI channels, and available peripheral for driving the propellers. From the constructed software model of a splash heard in a 3m by 3m swimming pool and using the tracking equations, it was determined that each tenth of a microsecond a timer value needs incremented to analyze the microphone data. This corresponds with a processor speed of 10 Mhz. Therefore, as initial component selection requirement, the processor has to run at a minimum of 10 Mhz. The software library containing the tracking and triangulation equations is very large so a processor with a large memory is required. As initially four ADC converters were to be utilized, each requiring its own channel, a processor with at least four SPI peripheral channels is chosen. With a preference to utilize a Microchip PIC processor, the PIC32MK1024MCF064-I/PT was chosen. At the time the microcontroller was chosen, it was unclear which propeller would be utilized and which could possibly be donated. With that in mind this processor was additionally chosen for the Motor Control PWM Driver peripherals.

From the datasheet, the appropriate decoupling capacitors, programming pins, and reset circuitry was determined and chosen. With the daisy chaining of the ADCs, a single SPI channel is utilized and the clock, slave select, serial data in, and serial data out are connected to the appropriate peripheral pins of the processor.

The IR LED is driven from a GPIO pin and the IR receiver feedback is read by another GPIO pin. The PWM signal required by the propeller ESCs are driven from GPIO pins as well. For testing, the eight pins of Port A are broken out to a debug header and eight pins of Port B are broken out to eight debug LEDS.

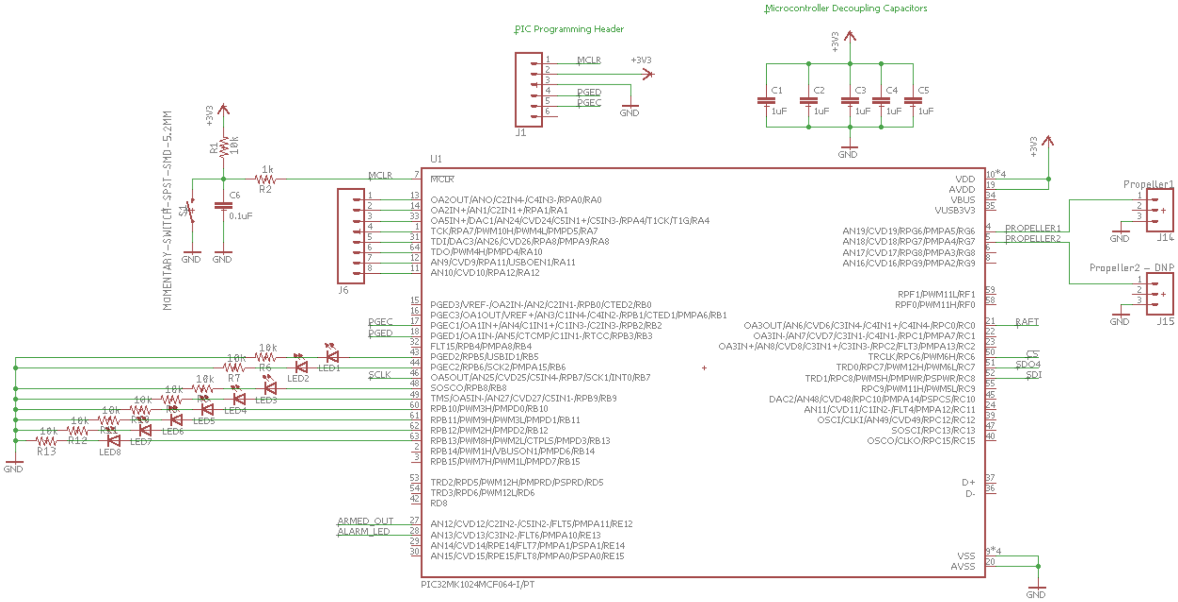


Figure 24: Robot Microcontroller Circuit Schematic

User Interface Microcontroller [KO]:

For simplicity, the same microcontroller is chosen to be utilized for the user interface. The same decoupling capacitors, programming pins, debug header and LEDs, and reset circuitry is present. A connector for the arming switch and supporting circuitry similar to the reset switch of the microcontroller is used. Figure 25 depicts the circuit schematic constructed for the user interface.

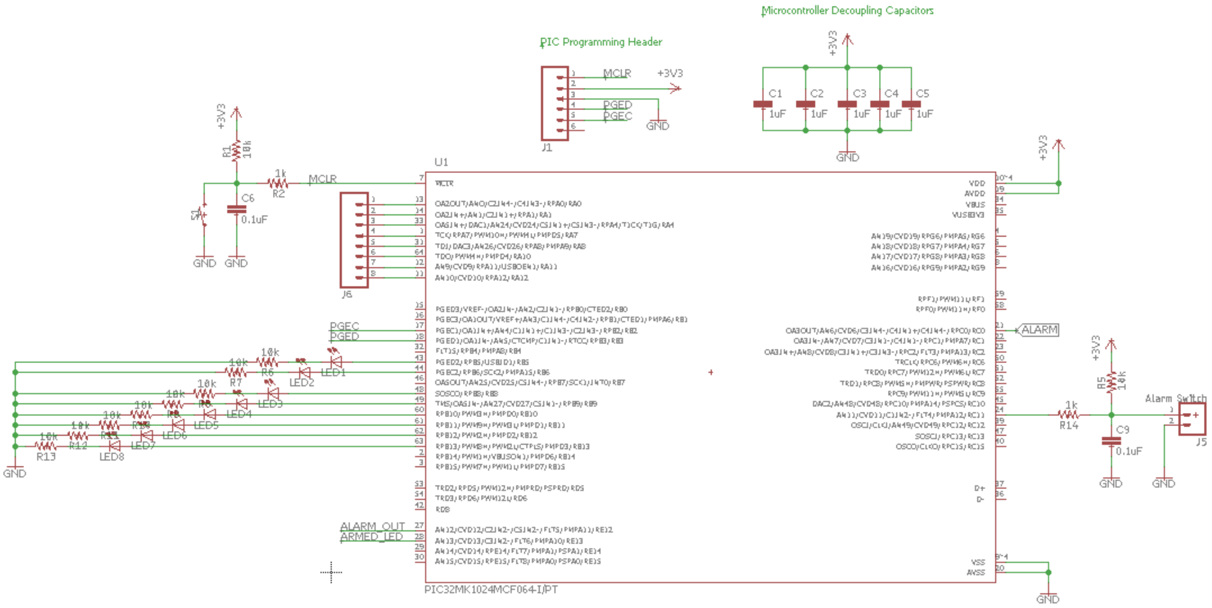


Figure 25: User Interface Microcontroller Circuit Schematic

Alarm and Solenoid Drive Circuitry [KO]:

To drive the alarm on the user interface and the solenoid on the robot, a low side switch using an N-Channel MOSFET is implemented. A low side switch was chosen to be utilized rather than a high side switch so that it can be activated using the voltage output from one of the microcontroller’s GPIO pins. When not driven from the GPIO, a resistor from the gate to ground pulls the MOSFET gate low so that it is not floating. Two resistors create a voltage divider that will provide the gate of the MOSFET 1.8V. These resistor values were chosen to provide a voltage greater than the gate threshold of the chosen MOSFET which is 1.5V. Figure 26 depicts the drive circuitry specifically for the user interface alarm, but the identical schematic and part numbers are implemented on the robot schematic for driving the solenoid.

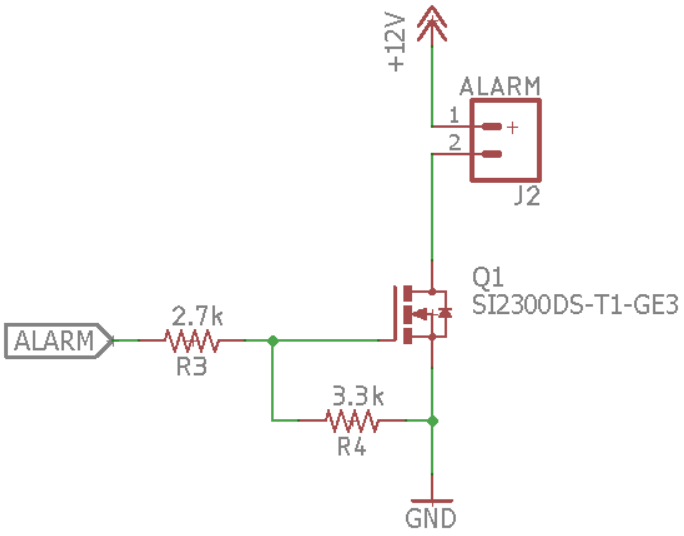


Figure 26: Alarm Drive Circuitry Schematic

Power Supply (5V and 3.3V) [KO]:

As the analog supply of the ADC and IR communication utilizes a 5V input and the microcontroller and digital supply of the ADC utilize a 3.3V input, two voltage regulators are required to step down the 12V DC input on for both the robot and user interface. A switching regulator is chosen to step down the 12V to 5V, and a linear regulator is chosen to step down 5V to 3.3V. Based on the total current draw by the various component as can be seen explicitly in Table #, the 3.3V linear regulator would need to be rated for at least 202mA. Adding a factor of safely, a 3.3V 1A rated linear regulator, AP2114HA-3.3TR was chosen to be utilized. The schematic shown in Figure # below depicts this component and the two 1uF decoupling capacitors required on the input and output as identified by the datasheet.

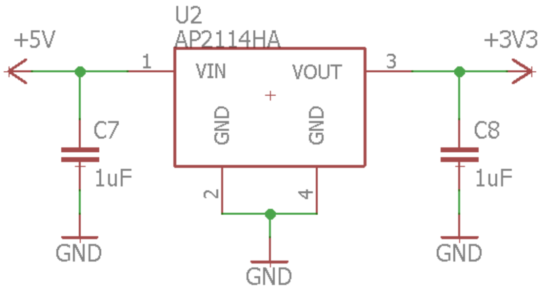


Figure 27: 3.3V Linear Regulator Circuit Schematic

Based on the maximum current draw as described in Table 38 below, a 5V switching regulator would need to be rated for at least 300mA and be able to take 12V as an input. The LM2575 buck converter is chosen. For design purposes and adding a factor of safety, a input voltage of 13V and current of 500mA is chosen to design the four additional components necessary. To prevent large voltage transients at the input, a 100uF aluminum electrolytic bypass capacitor is chosen to protect the input. A 3A Schottky diode is chosen as the catch diode, which is sufficient to handle the 1A maximum output of the regulator. Using the inductor selection guide in the LM2575 datasheet and the maximum input voltage and load current values, a 470uH inductor value is chosen. Using this inductor value, the maximum peak inductor current is calculated,

$$I_{Pmax} = I_{Load,max} + \frac{(VinVout)ton}{2L}$$

$$\text{where} \quad ton = \frac{Vout}{Vin\ (fosc)} = \frac{5}{13\ (52kHz)} = 7.4\ us$$

$$I_{Pmax} = (500mA) + \frac{(13)(5)(7.4us)}{2(470uH)}$$

$$I_{Pmax} = 1.01\ A$$

From this, the SRR1210A-471M inductor which is rated for 1.2A is chosen for the application. To minimize output ripple voltage, the below equation is utilized to calculate the minimum output capacitance value required.

$$Cout \geq 7.785 \frac{Vin}{Vout\ (L\ [uH])}$$

$$Cout \geq 7.785 \frac{13}{5\ (470)}$$

$$Cout \geq 43uF$$

A 100uF aluminum electrolytic capacitor is chosen for the design. The 5V switching regulator circuit used for both the robot and user interface is shown in Figure 28.

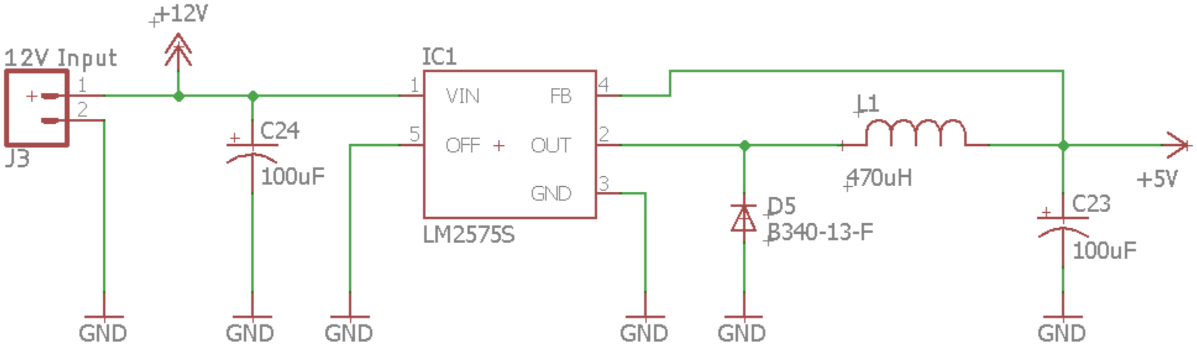


Figure 28: 5V Switching Regulator Circuit Schematic

System Power Consumption Analysis

Power consumption for the various components and subsystems totals for the robot and the user interface were calculated and recorded in Table 37 and 38 respectively.

Robot Power Consumption				
Component	Max Current Draw	Voltage (V)	Multiplier	Power (W)
Propeller	25A	12	1	300
Raft Release	216mA	12	1	2.6
Microphone	1mA	12	4	0.048
IR LED	20mA	5	1	0.1
IR Receiver	3mA	5	1	0.015
ADC Analog	11.5mA	5	4	0.23
ADC Digital	0.5mA	3.3	4	0.0066
Microcontroller	200mA	3.3	1	0.66
			Total	303.66 W

Table 37: Robot Power Consumption

User Interface Power Consumption				
Component	Max Current Draw	Voltage (V)	Multiplier	Power (W)
Alarm	1A	12	1	12
IR LED	20mA	5	1	0.1
IR Receiver	3mA	5	1	0.015
Microcontroller	200mA	3.3	1	0.66
			Total	12.775 W

Table 38: User Interface Power Consumption

Inductive Charging Design [AD]:

First, picking out a battery to be able to provide the durability and high current required for the BlueRobotics propellers, a 12V, 10Ah sealed lead acid battery was chosen. In order to charge the battery pack in the robot while avoiding cables connecting to the robot underwater, the battery pack will be charged using inductive charging. An inductive charger is comprised of two coils with the ground side coil taking the AC wall voltage of 120V/60Hz which will be fed to a transformer to drop down the voltage to a desired voltage. It is then fed to the primary coil where an electromagnetic field induces a current in the secondary coil. The current is then fed through a rectifier circuit to convert the current to DC to charge the 12V battery pack. An AC to DC rectifier will be used to take the voltage of the secondary coil and convert it to approximately 12-14V DC. As batteries have a normally fully charged voltage of 14V, there is a need to keep the voltage level higher than the nominal 12V. Therefore, for simulation purposes the schematics included the components to provide a regulated 12V to the battery, however, when moving forward with the PCB board design, a 15V regulator IC will be used.

For this application the system requires a 120VAC to 24VAC transformer to come from the wall and go to the ground side coil. The ground side coil will induce a current in the vehicle side coil where it will be rectified to DC and regulated to slightly above 12V to be supplied to the battery pack. The AC/DC rectifier and 12V DC regulator circuit that is needed is shown in Figure 29. Working backwards, the sealed lead acid battery was going to be estimated for 12V and 10A capability, and the AC voltage needed on the vehicle side coil was needed to be calculated. To determine the peak voltage that must be present to charge the battery, the uncontrolled full wave rectifier equation was used of $V_{DC} = \frac{2*V_m}{\pi}$. Solving for the peak voltage with $V_m = \frac{12*\pi}{2}$ yielded ~18.85V. Including a factor of safety, the 18.85V was rounded to 24V to accommodate for the losses across the diodes and other components. The components to make up the regulator circuit were modified from the DC Regulator for the User Interface in order to suit the needs of the battery pack.

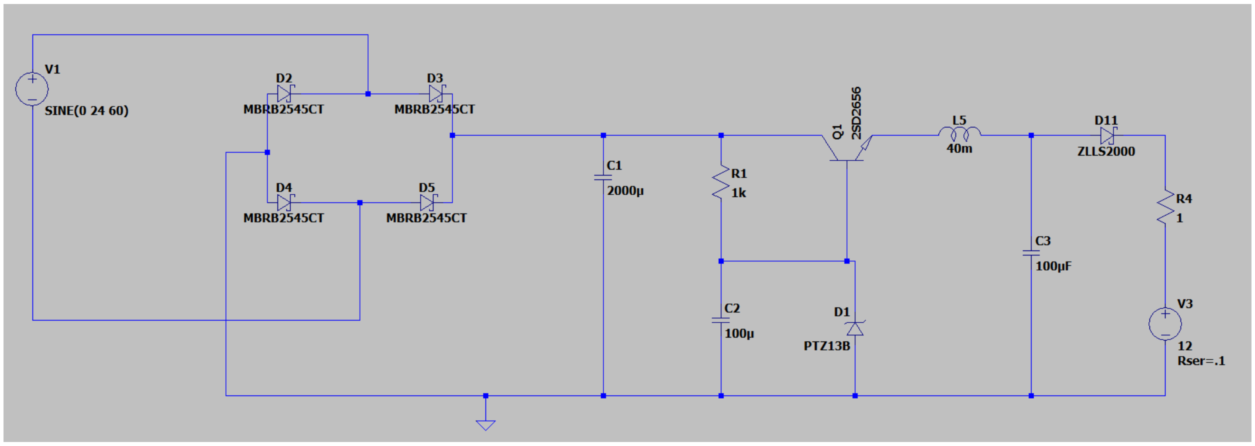


Figure 29: AC/DC Rectifier and Regulator Inductive Charging

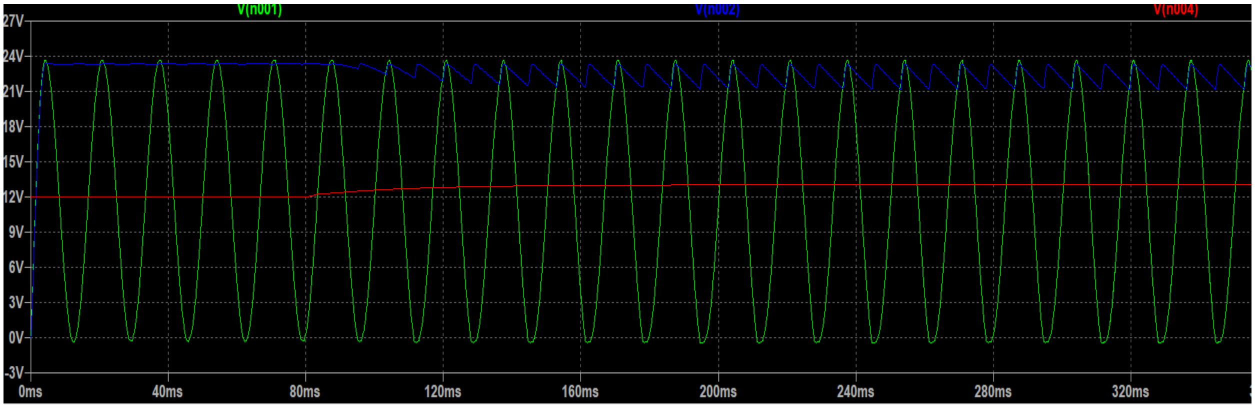


Figure 30: Waveforms of Rectifier and Regulator Inductive Charging

In Figure 30, the green waveform is the 24V sinusoidal input expected from the secondary coil, the blue waveform is the output of the diode bridge at the node with the capacitor, C1, and the red waveform is the voltage seen at the node of C3 after it has passed through the 12V voltage limiting circuit.

Expanding the schematic to include the vehicle and ground side coils, it was determined that with 24V coming out of the wall transformer, a 1:1 turn ratio was needed to keep roughly

24V on the vehicle side, accounting for losses along the circuit. Turns ratio was simply $Turns\ Ratio = \frac{V_p}{V_s} = \frac{20V}{20V} = 1$. Choosing a receiving coil inductance of 10uH, the transmitting coil would also have to be 10uH. The length of wire that would run from the ground side coil to the transformer that was plugged into the wall was estimated to need to be 15ft with a factor of safety thrown in. For design purposes the resistance of the wire needed to be factored in. $R = \rho \frac{l}{a}$ where ρ is the resistivity of the material, l is the length of the wire in meters, and a is the cross-sectional area in mm^2. The resistivity of copper is $1.6*10^{-8}\Omega$m, using 12 gauge wire due to the current that it can handle is 20 amps, the cross sectional area of the wire is ~3.31mm^2. Therefore, $R = (1.6 * 10^{-8}\Omega m) * \frac{4.572m}{3.31mm^2} = .0221\Omega.$

Currently after the step-down transformer and the AC/DC rectifier, seen in Figure 31 produces the waveform of a constant 23V DC that is seen in Figure 32, which will then be fed through the inverter or a power oscillator in order to feed the ground side coil an AC signal.

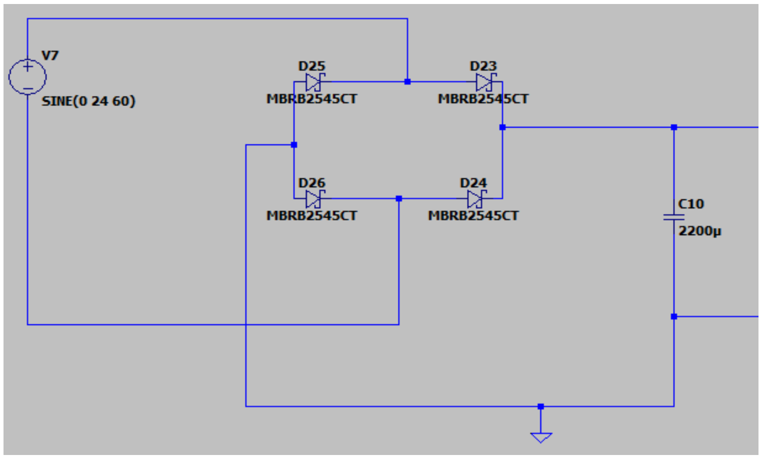


Figure 31:AC/DC Rectifier

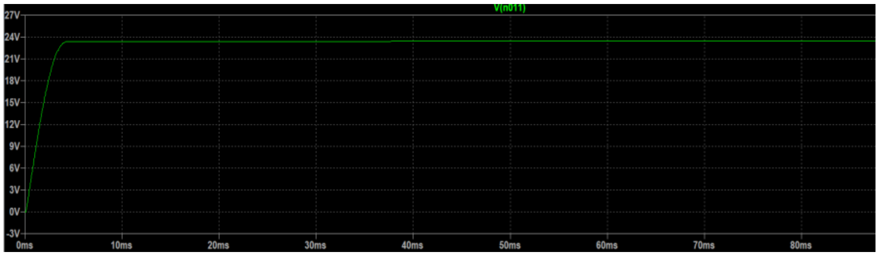


Figure 32: Output of the AC/DC Rectifier

Due to the high current on the primary side coil, the 24V from the stepped down transformer was sent through a AC/DC rectifier and then fed through a high frequency switch to get the waveform back to AC for the primary side coil. Limiting the current to be about 5A and with 20V, the impedance on the primary side must be equal to 4Ω. Using $Z_p = R5 + j(2\pi f)L8$, $4 = .0221 + j * 2\pi * 10\mu H \Rightarrow f = 63661Hz$Therefore the period parameter for switching would be $T = 15.708\mu s \sim 16\mu s$and $T_{on} =\sim 8\mu s$for a duty ratio of 0.5.Another possibility for charging that is being pursued is Inductive Resonance Charging that would utilize the idea of trickle charging as it does not provide much power to the battery, which would keep the battery constantly at its voltage. Resonant frequency can be calculated using the equation $f = \frac{1}{2\pi * \sqrt{LC}}$where the inductance will be the 10uH from the ground side coil. A 24V center tapped transformer and power oscillator could be used in the circuit, a low power DC/AC inverter, or DC/AC Sinusoidal H bridge inverter. The inverter would output a square wave that could be filtered and smoothed to resemble a sinusoidal wave. For now the current schematic after the 120VAC to 24VAC step down transformer is seen in Figure ##.

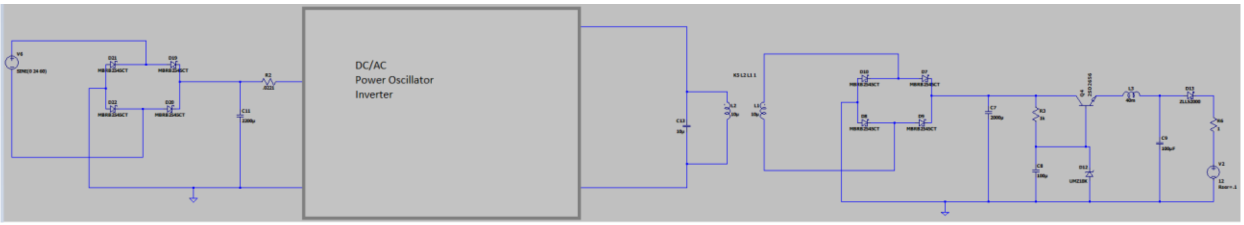


Figure 33: Charging Schematic After Step Down Transformer

Parts Lists

Parts List [PB, TD, AD, KO]]

Parts List- Track			
Quantity	**Part Number**	**Reference Designator**	**Description**
4	N/A	N/A	Industrial Curtain Track
4	N/A	N/A	Curved Roller Tracks with 90 Degree 24" Radius
1	N/A	N/A	Nylon Roller Wheel Trolley

Table 39: Track Parts List

Parts List- Underwater Movement			
Quantity	**Part Number**	**Reference Designator**	**Description**
2	T200-ESC	N/A	Thruster Operating Voltage: 6-24 V DC Max Current: 25 A Max Power: 350 W With Electronic Speed Controller

Table 40: Underwater Movement Parts List

Parts List- Underwater Robot Enclosure			
Quantity	**Part Number**	**Reference Designator**	**Description**
1	Underwater Container	N/A	Underwater Container Cabela’s Length: 0.3556 m (14 inches) Width: 0.2286 m (9 inches) Height: 0.127 m (5 inches)

Table 41: Underwater Robot Enclosure Parts List

Parts List- Rescue Raft			
Quantity	**Part Number**	**Reference Designators**	**Description**
1	Joann’s ITEM # 5762182	N/A	Length:18” Width:12” Height: 2”

Table 42: Rescue Raft Parts List

Parts List- Raft Release			
Quantity	**Part Number**	**Reference Designators**	**Description**
1	EW-98302-02	N/A	Pinch Solenoid Cole-Parmer Two-way normally closed solenoid pinch valve; 12 VDC, 1/16" ID x 1/8" OD tubing

Table 43: Raft Release Parts List

Parts List- User Interface Rectifier & Regulator Circuit			
Quantity	**Part Number**	**Reference Designators**	**Description**
1	F-259U XFMR	V1	Power Transformer Primary: 120 VAC Secondary: 20 V AC RMS
4	RR601BM4S	D2,D3,D4,D5	Rectifier Diode Breakdown Voltage: 400 V I = 6 A
1	1189-2885-ND	C1	22,000uF Capacitor Voltage Rating: 35 V
2	ECA-1HM101B	C2, C3	100uF Capacitor Voltage Rating: 50 V
1	ALSR5F-150-ND	R1	150Ω Resistor Power: 5 W
1	2N3055	Q1	NPN Transistor $V_{CEO} = 60 V$ $I_C = 10 A$
1	UMZ13K	D1	Zener Diode Breakdown Voltage: 13 V
1	MP502W-BPMS-ND	D2,D3,D4,D5	Bridge Rectifier Forward bias Voltage: 1.2 V @ 20 A I average = 2 A Reverse Bias Voltage: 200 V
1	MC7812BDTRKGOSCT-ND	R1, C2, D1, Q1	Regulator IC REG LINEAR 12V 1A DPAK

Table 44: User Interface Rectifier & Regulator Circuit Parts List

Parts List - Robot Microcontroller and Microphone Circuitry			
Qty.	**Part Num.**	**Refdes**	**Description**
4	M7WP-MIC	N/A	Microseven M7WP-MIC waterproof outdoor Microphone for M7B77-POE
1	PIC32MK1024MCF064T-I/PT	U1	IC MCU 32BIT 1MB FLASH 64TQFP
1	RS-187R05A2-DS MT RT	S1	SWITCH TACTILE SPST-NO 0.05A 12V
1	SI2300DS-T1-GE3	Q1	MOSFET N-CH 30V 3.6A SOT-23
4	ADS8664IDBT	U3, U4, U5, U6	IC ADC 12BIT 500KSPS 4CH 38TSSOP
4	CUS520H3FCT-ND	D1, D2, D3, D4	DIODE SCHOTTKY 30V 200MA
1	AP2114HA-3.3TRG1	U2	IC REG LINEAR 3.3V 1A SOT223
1	LM2575-5.0WU	IC1	IC REG BUCK 5V 1A TO263-5
1	SRR1210A-471M	L1	FIXED IND 470UH 1.2A 820 MOHM
2	UWT1V101MCL1GS	C23, C24	CAP ALUM 100UF 20% 35V SMD
1	B340-13-F	D5	DIODE SCHOTTKY 40V 3A SMC
1	TSOP38238	N/A	IC IR RCVR MOD 38KHZ DOME RADIAL
1	IR333-A	N/A	EMITTER IR 940NM 100MA RADIAL
22	CL21B105KAFNFNE	C1, C2, C3, C4, C5, C7, C8, C11, C12, C14, C16, C19, C20, C21, C27, C28, C29, C33, C34, C35, C39, C40, C41	CAP CER 1UF 25V X7R 0805
8	C2012X7R1A106K125AC	C17,C22, C25, C30, C31, C36, C37, C42	CAP CER 10UF 10V X7R 0805
4	CL21A226KPCLRNC	C18, C26, C32, C38	CAP CER 22UF 10V X5R 0805
4	C0805C564K4RACTU	C13, C44, C47, C50	CAP CER 0.56UF 16V X7R 0805

8	CC0805KRX7R7BB274	C9, C10, C15, C43, C45, C46, C48, C49	CAP CER 0.27UF 16V X7R 0805
1	885012207045	C6	CAP CER 0.1UF 16V X7R 0805
1	RC0805FR-071KL	R2	RES SMD 1K OHM 1% 1/8W 0805
13	RC0805FR-0710KL	R1, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R16, R18	RES SMD 10K OHM 1% 1/8W 0805
1	RC2012F121CS	R20	RES SMD 120 OHM 1% 1/8W 0805
1	RC2012F272CS	R3	RES SMD 2.7K OHM 1% 1/8W 0805
1	KTR10EZPF3301	R4	RES SMD 3.3K OHM 1% 1/8W 0805
8	RC0805FR-073K6L	R17, R21, R23, R24, R26, R27, R31, R32	RES SMD 3.6K OHM 1% 1/8W 0805
4	RC0805JR-071K8L	R15, R22, R25, R28	RES SMD 1.8K OHM 5% 1/8W 0805
8	150080GS75000	LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8	LED GREEN CLEAR 0805 SMD
1	4-103747-0	J1	6pos 0.1in header
6	22-23-2031	J7, J8, J9, J10, J14, J15, J16	3pos 0.1in locking header
3	22-23-2021	J2, J3, J13	2pos 0.1in locking header
1	4-103747-0	J8	8pos 0.1in header
6	22-01-2037	N/A	3pos 0.1in locking housing
3	22-01-2027	N/A	2pos 0.1in locking housing
24	08-50-0114	N/A	0.1in locking housing crimp

Table 45: Robot Microcontroller and Microphone Circuitry Parts List

Parts List - User Interface Microcontroller and Alarm Circuitry			
Qty.	**Part Num.**	**Refdes**	**Description**
1	a12092100ux0067	N/A	Continuous Sound Alarm Buzzer 6-24VDC 100dB
1	PIC32MK1024MCF064T-I/PT	U1	IC MCU 32BIT 1MB FLASH 64TQFP
1	RS-187R05A2-DS MT RT	S1	SWITCH TACTILE SPST-NO 0.05A 12V
1	SI2300DS-T1-GE3	Q1	MOSFET N-CH 30V 3.6A SOT-23
1	AP2114HA-3.3TRG1	U2	IC REG LINEAR 3.3V 1A SOT223
1	LM2575-5.0WU	IC1	IC REG BUCK 5V 1A TO263-5
1	SRR1210A-471M	L1	FIXED IND 470UH 1.2A 820 MOHM
2	UWT1V101MCL1GS	C23, C24	CAP ALUM 100UF 20% 35V SMD
1	B340-13-F	D5	DIODE SCHOTTKY 40V 3A SMC
1	TSOP38238	N/A	IC IR RCVR MOD 38KHZ DOME RADIAL
1	IR333-A	N/A	EMITTER IR 940NM 100MA RADIAL
7	CL21B105KAFNFNE	C1, C2, C3, C4, C5, C7, C8	CAP CER 1UF 25V X7R 0805
2	885012207045	C6, C9	CAP CER 0.1UF 16V X7R 0805
2	RC0805FR-071KL	R2, R14	RES SMD 1K OHM 1% 1/8W 0805
10	RC0805FR-0710KL	R1, R5, R6, R7, R8, R9, R10, R11, R12, R13	RES SMD 10K OHM 1% 1/8W 0805
1	RC2012F121CS	R19	RES SMD 120 OHM 1% 1/8W 0805
1	RC2012F272CS	R3	RES SMD 2.7K OHM 1% 1/8W 0805
1	KTR10EZPF3301	R4	RES SMD 3.3K OHM 1% 1/8W 0805
8	150080GS75000	LED1, LED2, LED3, LED4, LED5, LED6,	LED GREEN CLEAR 0805 SMD

		LED7, LED8	
1	4-103747-0	J1	6pos 0.1in header
1	22-23-2031	J11	3pos 0.1in locking header
4	22-23-2021	J2, J3, J5, J12	2pos 0.1in locking header
1	4-103747-0	J8	8pos 0.1in header
4	22-01-2037	N/A	3pos 0.1in locking housing
1	22-01-2027	N/A	2pos 0.1in locking housing
11	08-50-0114	N/A	0.1in locking housing crimp

Table 46: User Interface Microcontroller and Alarm Circuitry Parts List

Parts List- Inductive Charging			
Qty	**Part Number**	**Reference Designators**	**Description**
1	SLAA12-10F2	V5	Duracell Ultra 12V 10AH AGM SLA Battery with F2 Terminals
2	KTJ250B107M76BFT00	C5, C6	100µF ±20% 25V Ceramic Capacitor X7R Stacked SMD, 2 J-Lead
1	EEU-TP1V202SB	C4	CAP ALUM 2000UF 20% 35V RADIAL
1	22R476MC	L9	FIXED IND 47MH 33MA 154 OHM SMD
1	ZLLS2000TA	D18	DIODE SCHOTTKY 40V 2.2A SOT23-6
1	2SD2656T106	Q2	TRANS NPN 30V 1A SOT-323
1	ESR10EZPF1001	R8	RES SMD 1K OHM 1% 0.4W 0805

1	UMZ18NT106	D17	DIODE ZENER ARRAY 18V 200MW UMD3
8	MBRB2545CTT4G	D6, D16, D14, D15, D23, D25, D26, D24	DIODE ARRAY SCHOTTKY 45V D2PAK
1	760308201	L7	RX 1 COIL 1 LAYER 10UH 4.5A
1	760308141	L8	TX 1 COIL 1 LAYER 10UH 9A
1	860010781028	C10	CAP 2200 UF 20% 63 V
1	TCT40-01E07K	V7	XFRMR LAMINATED 40VA CHAS MOUNT
1	IPT004N03LATMA1	M1	MOSFET N-CH 30V 300A 8HSOF
1	LM7815CT/NOPB	Replacing Circuitry	IC REG LINEAR 15V 1A TO220-3
2	GMK212BJ104KGHT	Replacing Circuitry	CAP CER 0.1UF 35V X5R 0805

Table 47: Inductive Charging Parts List

Materials Budget

Quantity	Part Number	Description	Unit Cost	Total Cost	Donation Status
User Interface Regulator and Rectifier Circuit					
1	F-259U XFMR 20V 10A 4X3X3	Power Transformers Primary: 120 VAC Secondary: 20 V AC RMS	$37.86	$ 37.86	
1	MP502W-BPMS-ND	Bridge Rectifier Forward bias Voltage: 1.2 V @ 20 A I average = 2 A Reverse Bias Voltage: 200 V	$4.88	$ 4.88	
1	MC7812BDTRKGOSTR-ND	Regulator IC REG LINEAR 12V 1A DPAK	$0.71	$ 0.71	
1	1189-2885-ND	22,000uF Capacitor Voltage Rating: 35 V	$5.10	$ 5.10	
1	ECA-1HM101B	100uF Capacitor Voltage Rating: 50 V	$0.39	$ 0.39	
Track					
4	N/A	Industrial Curtain Track	$14.50	$ 58.00	Donation Requested
4	N/A	Curved Roller Tracks with 90 Degree 24" Radius	$67.75	$ 271.00	Donation Requested
1	N/A	Nylon Roller Wheel Trolley	$2.50	$ 2.50	Donation Requested
Underwater Movement					

2	T200-ESC	Thruster Operating Voltage: 6-24 V DC Max Current: 25 A Max Power: 350 W With Electronic Speed Controller	$194	$ 388.00	Donated
Robot Enclosure					
1	Underwater Container	Underwater Container Cabelas Length: 0.3556 m (14 inches) Width: 0.2286 m (9 inches) Height: 0.127 m (5 inches)	$50.00	$ 50.00	
Rescue Raft					
4	Joann’s ITEM # 5762182	2"x12"x18" Styrofoam Block-1PK/White	$10.99	$ 43.96	
Raft Release					
1	EW-98302-02	Pinch Solenoid Cole-Parmer Two-way normally closed solenoid pinch valve; 12 VDC, 1/16" ID x 1/8" OD tubing	$87.50	$ 87.50	Permission to request donation pending.
User Interface and Robot Microcontroller with Alarm and Microphone Circuitry					

1	a12092100ux0067	Continuous Sound Alarm Buzzer 6-24VDC 100dB	$7.67	$ 7.67	
4	M7WP-MIC	Microseven M7WP-MIC waterproof outdoor Microphone for M7B77-POE	21.99	$ 87.96	Donation Requested
2	PIC32MK1024MCF064T-I/PT	IC MCU 32BIT 1MB FLASH 64TQFP	7.54	$ 15.08	
2	RS-187R05A2-DS MT RT	SWITCH TACTILE SPST-NO 0.05A 12V	0.53	$ 1.06	
2	SI2300DS-T1-GE3	MOSFET N-CH 30V 3.6A SOT-23	0.48	$ 0.96	
4	ADS8664IDBT	IC ADC 12BIT 500KSPS 4CH 38TSSOP	6.74	$ 26.96	
4	CUS520H3FCT-ND	DIODE SCHOTTKY 30V 200MA	0.22	$ 0.88	
2	AP2114HA-3.3TRG1	IC REG LINEAR 3.3V 1A SOT223	0.37	$ 0.74	
2	LM2575-5.0WU	IC REG BUCK 5V 1A TO263-5	2.34	$ 4.68	
2	SRR1210A-471M	FIXED IND 470UH 1.2A 820 MOHM	1.57	$ 3.14	
4	UWT1V101MCL1GS	CAP ALUM 100UF 20% 35V SMD	0.43	$ 1.72	
2	B340-13-F	DIODE SCHOTTKY 40V 3A SMC	0.39	$ 0.78	
2	TSOP38238	IC IR RCVR MOD 38KHZ DOME RADIAL	1.12	$ 2.24	
2	IR333-A	EMITTER IR 940NM 100MA RADIAL	0.44	$ 0.88	
29	CL21B105KAFNFNE	CAP CER 1UF 25V X7R 0805	0.11	$ 3.19	
8	C2012X7R1A106K125AC	CAP CER 10UF 10V X7R 0805	0.52	$ 4.16	

4	CL21A226KPCLRNC	CAP CER 22UF 10V X5R 0805	0.39	$ 1.56	
4	C0805C564K4RACTU	CAP CER 0.56UF 16V X7R 0805	0.81	$ 3.24	
8	CC0805KRX7R7BB274	CAP CER 0.27UF 16V X7R 0805	0.35	$ 2.80	
3	885012207045	CAP CER 0.1UF 16V X7R 0805	0.1	$ 0.30	
3	RC0805FR-071KL	RES SMD 1K OHM 1% 1/8W 0805	0.1	$ 0.30	
23	RC0805FR-0710KL	RES SMD 10K OHM 1% 1/8W 0805	0.1	$ 2.30	
2	RC2012F121CS	RES SMD 120 OHM 1% 1/8W 0805	0.1	$ 0.20	
2	RC2012F272CS	RES SMD 2.7K OHM 1% 1/8W 0805	0.1	$ 0.20	
2	KTR10EZPF3301	RES SMD 3.3K OHM 1% 1/8W 0805	0.1	$ 0.20	
8	RC0805FR-073K6L	RES SMD 3.6K OHM 1% 1/8W 0805	0.1	$ 0.80	
4	RC0805JR-071K8L	RES SMD 1.8K OHM 5% 1/8W 0805	0.1	$ 0.40	
16	150080GS75000	LED GREEN CLEAR 0805 SMD	0.18	$ 2.88	
2	4-103747-0	6pos 0.1in header	0	$ -	ECE Shop
7	22-23-2031	3pos 0.1in locking header	0	$ -	ECE Shop
7	22-23-2021	2pos 0.1in locking header	0	$ -	ECE Shop
2	4-103747-0	8pos 0.1in header	0	$ -	ECE Shop
7	22-01-2037	3pos 0.1in locking housing	0	$ -	ECE Shop
7	22-01-2027	2pos 0.1in locking housing	0	$ -	ECE Shop
35	08-50-0114	0.1in locking housing crimp	0	$ -	ECE Shop

Inductive Charging					
1	SLAA12-10F2	Duracell Ultra 12V 10AH AGM SLA Battery with F2 Terminals	$49.99	$ 49.99	
2	KTJ250B107M76BFT00	100µF ±20% 25V Ceramic Capacitor X7R Stacked SMD, 2 J-Lead	$7.29	$ 14.58	
1	EEU-TP1V202SB	CAP ALUM 2000UF 20% 35V RADIAL	$3.94	$ 3.94	
1	22R476MC	FIXED IND 47MH 33MA 154 OHM SMD	$0.89	$ 0.89	
1	ZLLS2000TA	DIODE SCHOTTKY 40V 2.2A SOT23-6	$0.92	$ 0.92	
1	2SD2656T106	TRANS NPN 30V 1A SOT-323	$0.54	$ 0.54	
1	ESR10EZPF1001	RES SMD 1K OHM 1% 0.4W 0805	$0.17	$ 0.17	
1	UMZ18NT106	DIODE ZENER ARRAY 18V 200MW UMD3	$0.54	$ 0.54	
8	MBRB2545CTT4G	DIODE ARRAY SCHOTTKY 45V D2PAK	$1.40	$ 11.20	
1	760308201	RX 1 COIL 1 LAYER 10UH 4.5A	$8.58	$ 8.58	
1	760308141	TX 1 COIL 1 LAYER 10UH 9A	$22.55	$ 22.55	
1	860010781028	CAP 2200 UF 20% 63 V	$4.77	$ 4.77	
1	TCT40-01E07K	XFRMR LAMINATED 40VA CHAS MOUNT	$15.78	$ 15.78	
1	IPT004N03LATMA1	MOSFET N-CH 30V 300A 8HSOF	$5.55	$ 5.55	
1	LM7815CT/NOPB	IC REG LINEAR 15V 1A TO220-3	$1.54	$ 1.54	
2	GMK212BJ104KGHT	CAP CER 0.1UF 35V X5R 0805	$0.20	$ 0.40	
		Total		**$ 1,269.12**	

System Updates from Implementation and Testing

Updated Microphone Circuitry [KO, PB]

During testing of the microphone signal analysis circuitry using the small test circuit board shown in Figure 34, it was found that the envelope detector loaded down the microphone signal too much. In order to remedy this, the design was changed to implement a buffer at the output of the microphone itself. Because the buffer was biased with the 0-12V source of the system, the reference of the microphone signal at the output was shifted to be in an entirely positive range. This resulted in the envelope detector being obsolete for the design.

Figure 34: Microphone Signal Analysis Test PCB

Additionally, using this test board, an unsuccessful attempt was made to communicate with the chosen ADC IC over SPI. The 32bit packets were not able to be appropriately received and no data was seen transmitted back. After extensive troubleshooting, the sampling of the microphone signal was chosen to be moved from occurring on a separate ADC IC to occurring inside the microprocessor. The signal from each microphone is now fed to four independent ADC channels on the microprocessor. This implementation also allows for faster data acquisition. Using EagleCAD, the revised schematic shown in Figure 35 was used to create the PCB layout for both the user interface and robot microcontroller circuits, shown in Figure 36. As printed circuit boards of the same design are typically manufactured in batches of five or more boards regardless of how many the buyer actually needs, making the schematic useable for both aspects of the system when certain components are populated was the most cost-effective solution. It also significantly simplified programming the microcontroller as the pinouts are identical. The resultant populated board is shown in Figure 37:

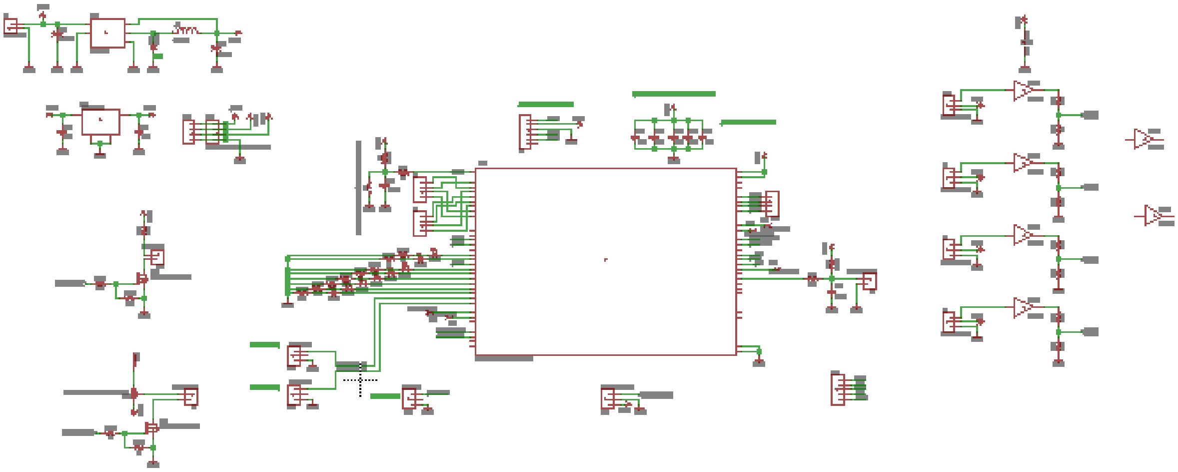


Figure 35: User Interface and Robot Microcontroller Circuit Schematic

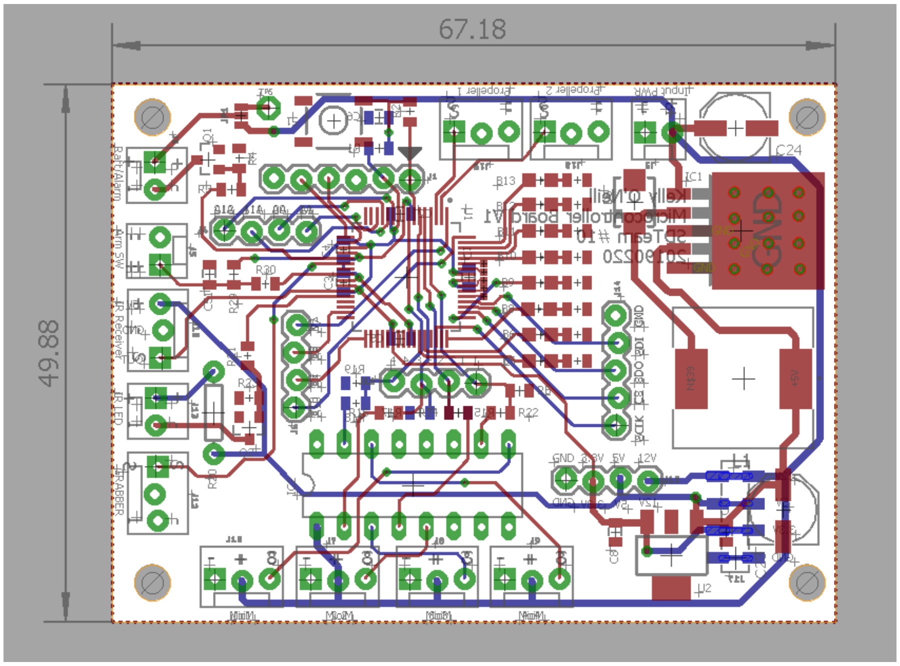


Figure 36: User Interface and Robot Microcontroller PCB Layout

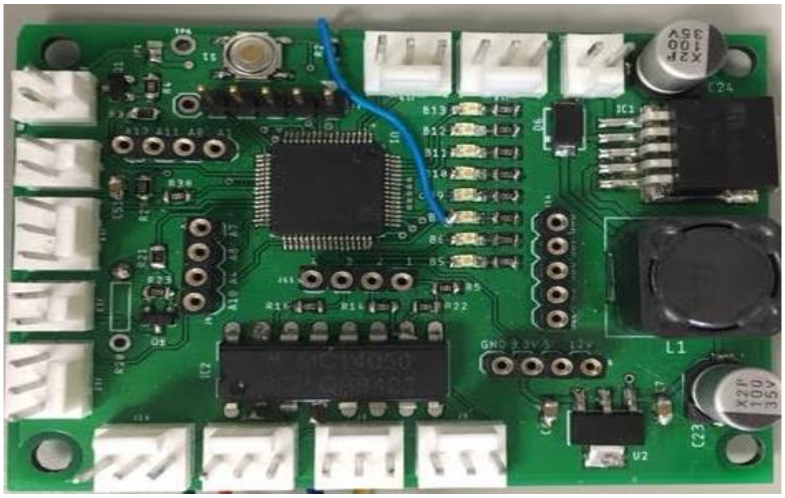


Figure 37: User Interface and Microcontroller PCB Top View

Upon receiving the Microcontroller PCB and conducting further testing, it was found that for the microphone signal analysis a cascade of an operational amplifier buffer and a CMOS buffer obtained pulses with a very clear transition when a splash occurs. Additionally, in testing it was seen that the biasing of the microphone would change based on the environment, so a 0.1uF capacitor was put in line before the signal was passed through the buffers to eliminate the AC small signal of the input. The new microphone circuit design is shown below in Figure 38 for a single microphone, with an identical circuit implementation for each microphone. A HEX Buffer IC package was chosen for each the operational amplifier and CMOS buffer so all four signals could be passed to a single chip.

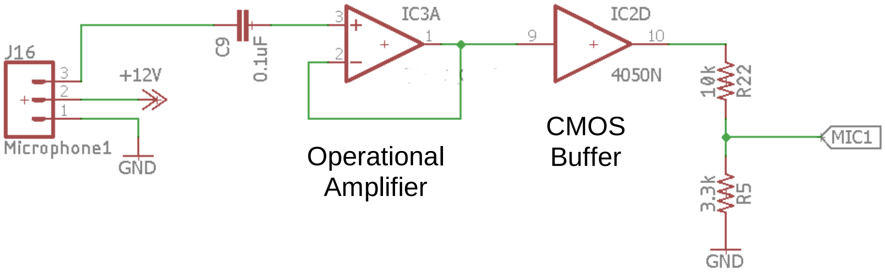


Figure 38: Updated Microphone Circuitry

The circuit revision is seen implemented in Figure 39 below where the needed components were soldered to a protoboard and then connected to the microcontroller circuit appropriately.

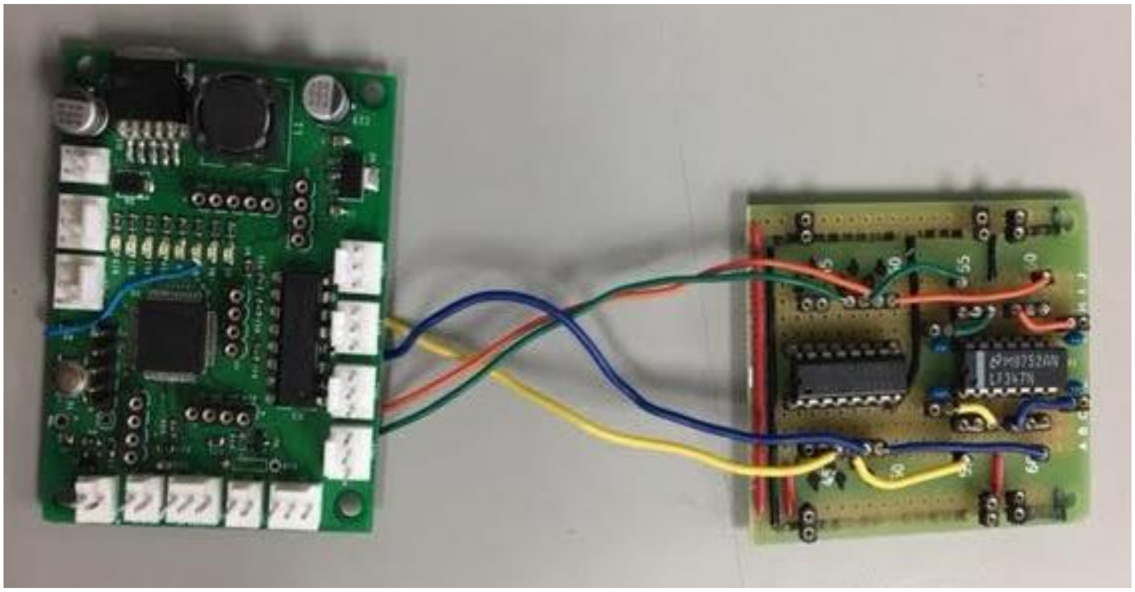


Figure 39: Microcontroller PCB with Updated Microphone Circuitry

The microphone signal when a splash is heard is shown below in Figure 40. Channel 1 (yellow) shows the signal directly produced by the microphone. Channel 2 (blue) depicts the signal after the operational amplifier buffer where the signal is seen to be rebiased between 12V and ground. Channel 3 (pink) shows the signal once passed through the CMOS buffer. A very distinct change in state is seen at each splash pulse. Channel 4 (green) depicts the signal when stepped down to approximately 3V to be fed to the ADC of the microcontroller.

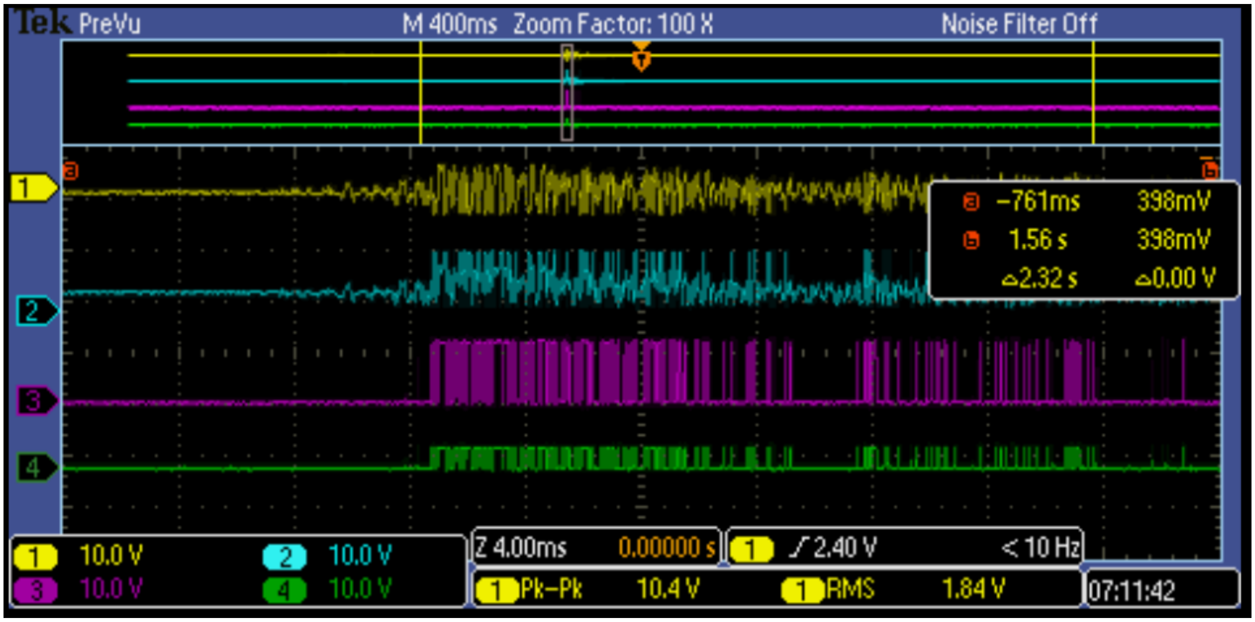


Figure 40: Microphone Signal Progression using Microphone Circuitry

An example of the difference in time between all four microphoned utilized to determine the splash location is seen below in Figure 41.

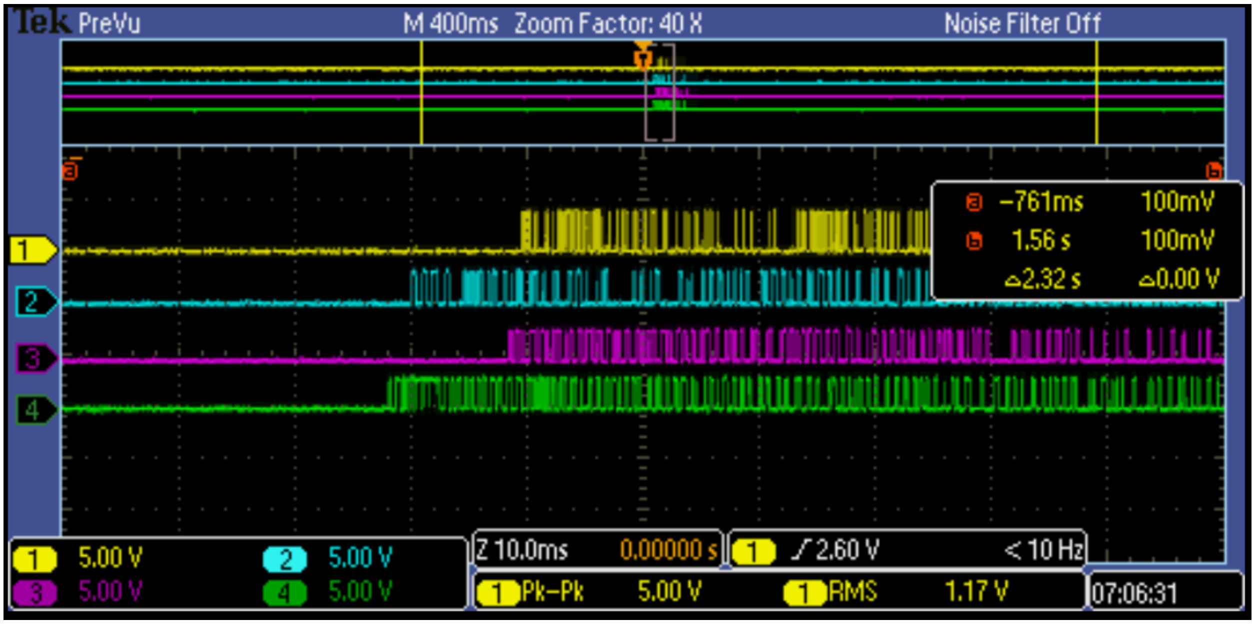
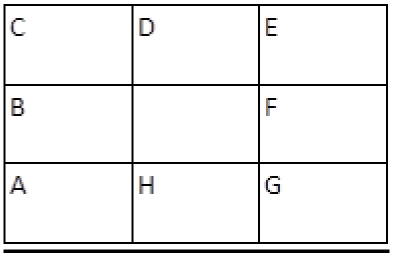


Figure 41: Four Microphones Hearing a Splash

Updated Microphone Implementation [KO, PB]

While working on underwater tracking for the robot, there was an issue that arose during testing. It so happens that the 1 meter by 1 meter square that the microphones had been placed in was not sufficient for the project's purposes. The time differences that were acquired from this distance were inconsistent and not distinct enough to use the original tracking equations. To rectify this, the microphones were moved to be in a 5.5 meter by 5.5 meter square centered around the track above the water. After doing this, multiple time differences between microphones in each section of the grid were recorded and placed into a table. Using this table, we were able to determine the time difference ranges that each of the grid squares fall into. This time, the time differences were very distinct and consistent. Using the microphones, the locations were able to be determined the majority of the time using the larger square.

Bringing the microphones above water meant that the microphones could no longer be attached to the robot underwater. Doing so would cause the microphones to be dragged along while the robot moved to the calculated location. The microphones would now be attached to the user interface above the water. All the calculations to determine location would also be done on the user interface as well. After the location was determined on the user interface, the location would have to be communicated to the underwater robot. To do this, the IR LED would be flashed by the home station to communicate findings to the underwater robot. The number of times the LED flashes corresponds to one of the locations in the pool. Looking at the below diagram in Figure 42, one flash would correspond to position A, two flashes for position B, three flashes for position C, etc. For example, flashing the IR LED eight times would indicate that the location was calculated to be directly above the underwater robot, so the robot would not move. The raft would be released immediately.



C	D	E
B		F
A	H	G

Figure 42: Locations in Pool

Updated Rectifier & Regulator Circuit [TD]:

To power the alarm and microcontroller used for arming the system once a child has fallen into the pool, a 12V DC source is needed. To do this a rectifier and 12V DC regulator circuit was designed which can be seen below in Figure 43. After a successful simulation, the circuit was first built and tested on a breadboard. Next, the circuit schematic was drawn using Eagle and the PCB layout was completed in Figure 44. The circuit successfully outputs 12 V DC and interfaces with the user interface circuit as can be seen in Figure 45.

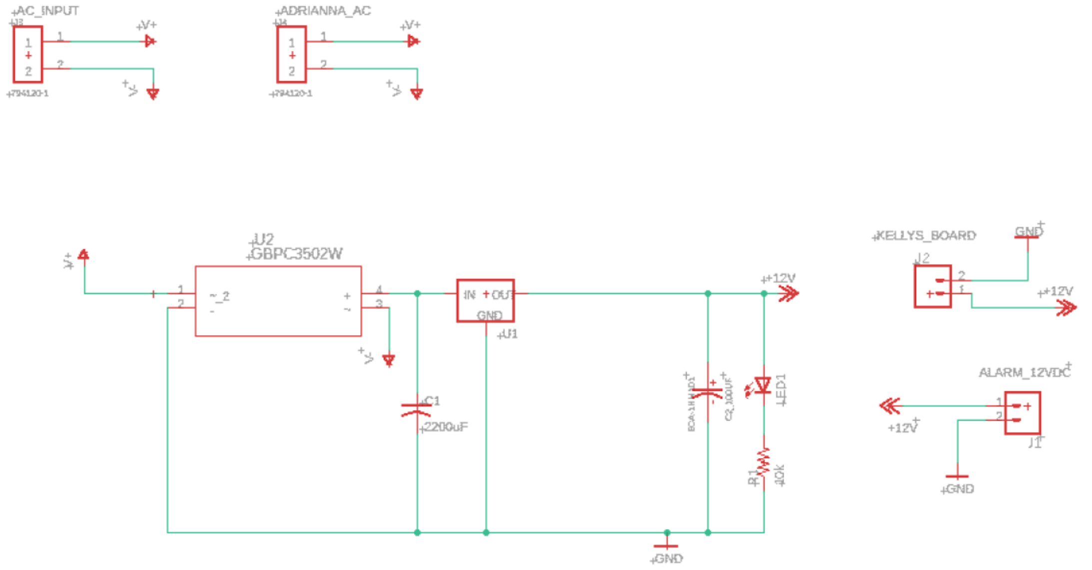


Figure 43: 12V DC Regulator Eagle Schematic

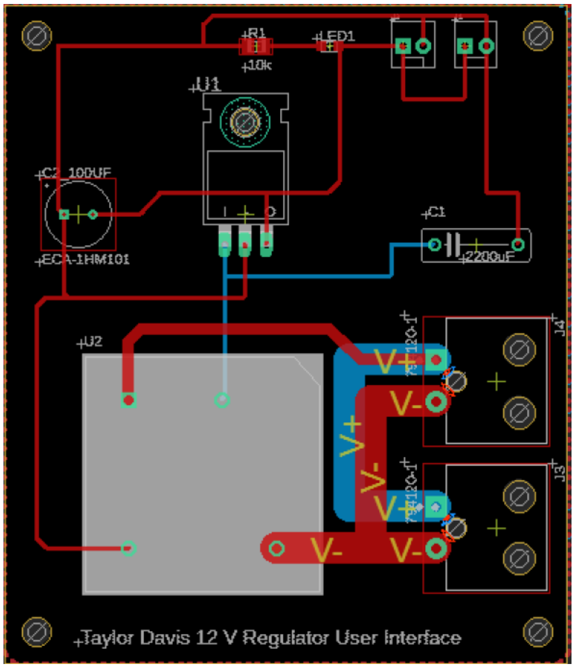


Figure 44: 12V DC Regulator PCB Layout

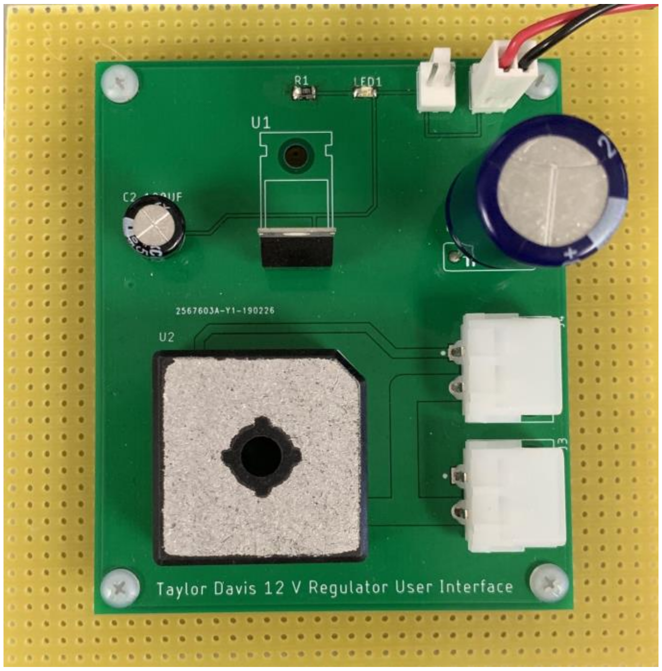


Figure 45: 12V DC Rectifier & Regulator PCB Top View

Updated Robot [TD]:

To ensure the robot would move smoothly underwater, an aerodynamic sub was designed using SolidWorks. The sub was designed and 3D printed in six separate pieces: the nose, lid, box, side shields, thruster mounting bracket, and the roller retaining brackets. The shape of the nose was chosen to lower the drag during propulsion of the robot. The box and the lid needed to be designed to enclose the underwater container that held all of the electronics. The external dimensions of the underwater container are 9.10’’x5.90’’x4.30’’ so the box was designed to be 11’’x6.90’’x4.8’’ and the lid’s dimensions are 11.00’’x6.90’’x1.50’’. Next, the thruster bracket was designed so that the thrusters could be mounted on the back of the sub and propel the robot forward along the track. Three cut outs were designed into the side shields to allow more water to flow through the thrusters. Lastly, two roller retaining brackets were designed with a quarter inch diameter so that the rollers could be hooked onto the sub and guide it along the track. The sub was 3D printed at the MakerStudio in Bierce Library and on the EE department printer.

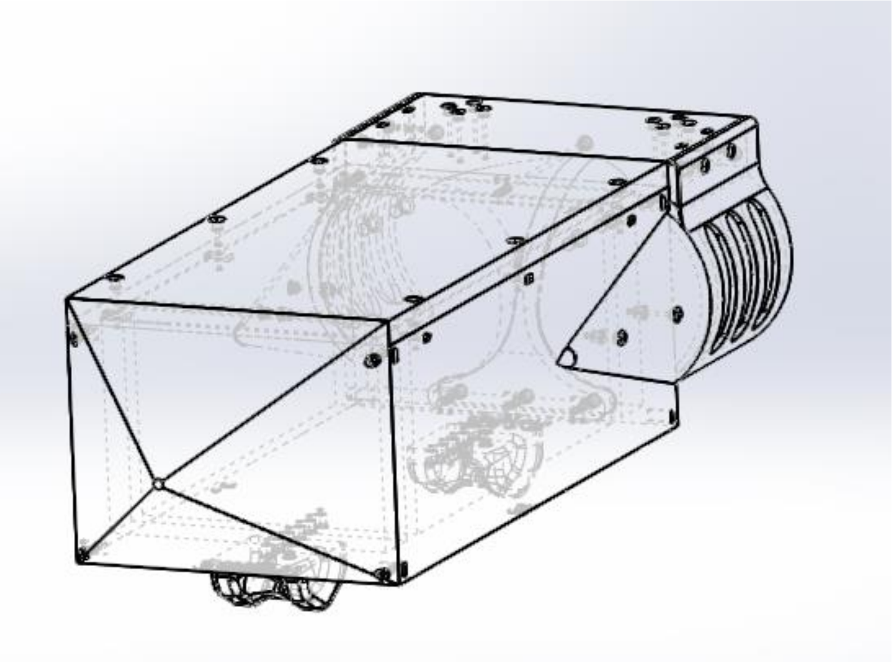


Figure 46: Front View of Sub

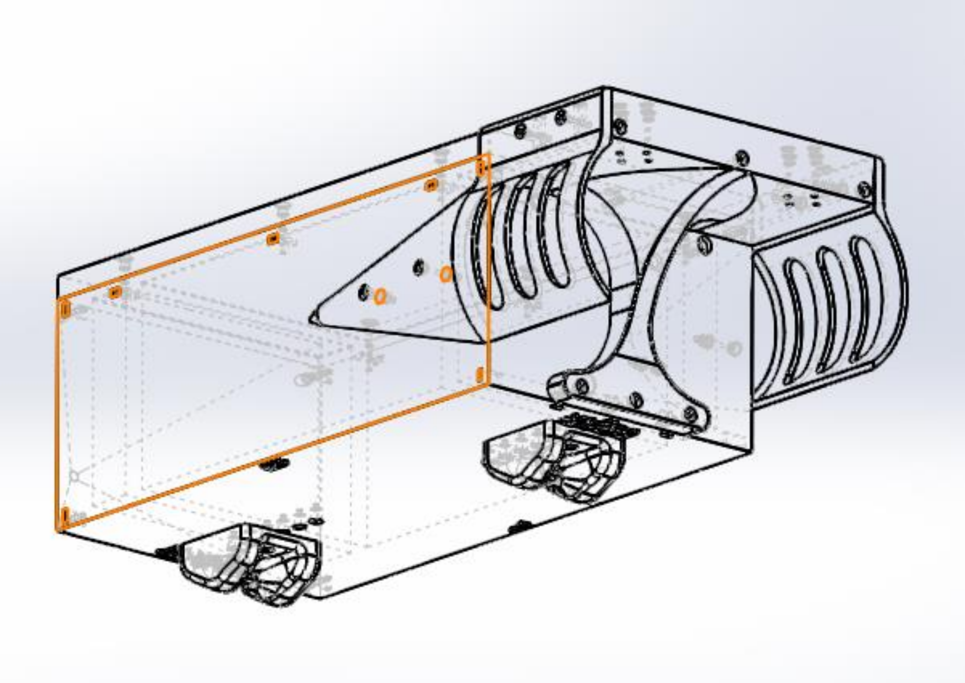


Figure 47: Side View of Sub

Figure 48: Side View of Sub

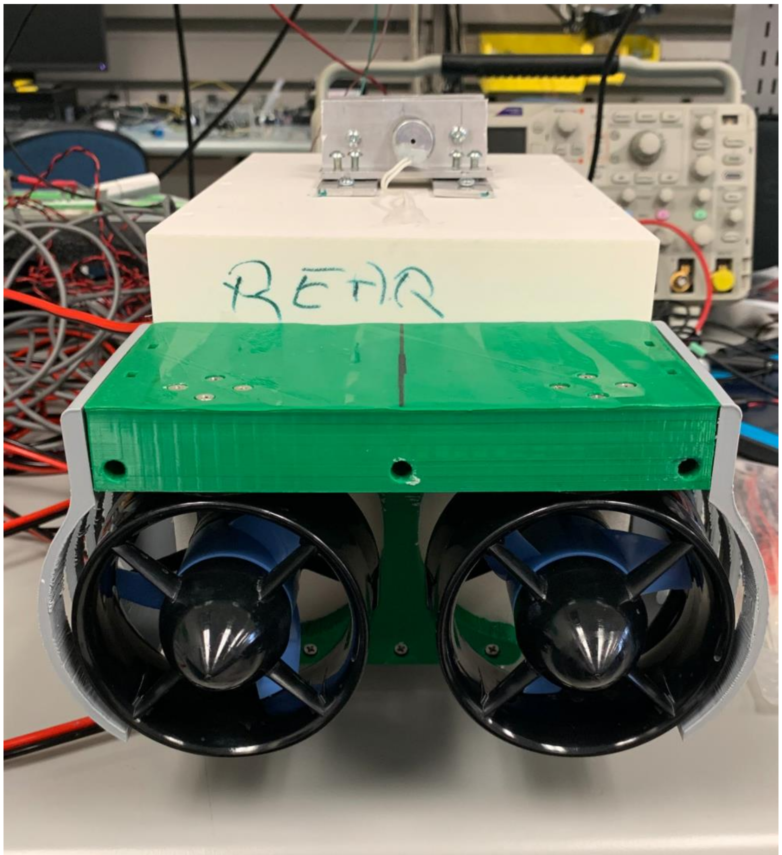


Figure 49: Rear View of Sub

Updated Raft [AD]:

Initially, the intention was to solely modify a 1” piece of foam supplied by Grainger Industrial to support the victim when released. Further into the construction, the foam was to be incorporated in a solid structured frame to ensure that the child did not easily roll off of the raft. A 9-square grid was constructed where each side component is made of 1ft long piece of ¾” PVC, as well as four elbows, four crosses and eight tees all in ¾” size. The foam pieces were cut to fit inside the squares and holes were cut to reduce the buoyancy force and allow for attachment to the frame. Due to the limited amount of force that the solenoid is able to take on, the raft could not have a buoyancy force greater than approximately fifty pounds. With that in mind the rope to tether the raft to the solenoid was spec'd out to be no greater than sixty pounds and was attached to the four corners of the raft, and tied at the middle of the grid. All four pieces were threaded through the plunger of the solenoid and then tied around itself resulting in an even dispersion of pull down force, and equality in rise time when the solenoid was retracted. The distance between the raft and the solenoid was kept short in order to ensure that when the robot reached it’s stopping position, the raft did not move out of the area it was intended to be released in. Upon testing for submersion of the completed structure which included the PVC frame and foam mats, the raft could not be submerged even with 165 pounds, resulting in the removal of foam pieces until the mark of approximately 30 pounds was attained. To obtain the ability to submerge the raft, all nine pieces of foam were taken out, resulting in the buoyant PVC frame to be all that is remaining. When released the raft rises to the surface uniformly and within the 1ft/sec design requirement as well as the size meeting the design requirement of a surface area of 1m^2. Finally, a netting was placed over the PVC construction in order to not allow the victim to slip in between the empty squares. The full construction can be seen in Figure 50.

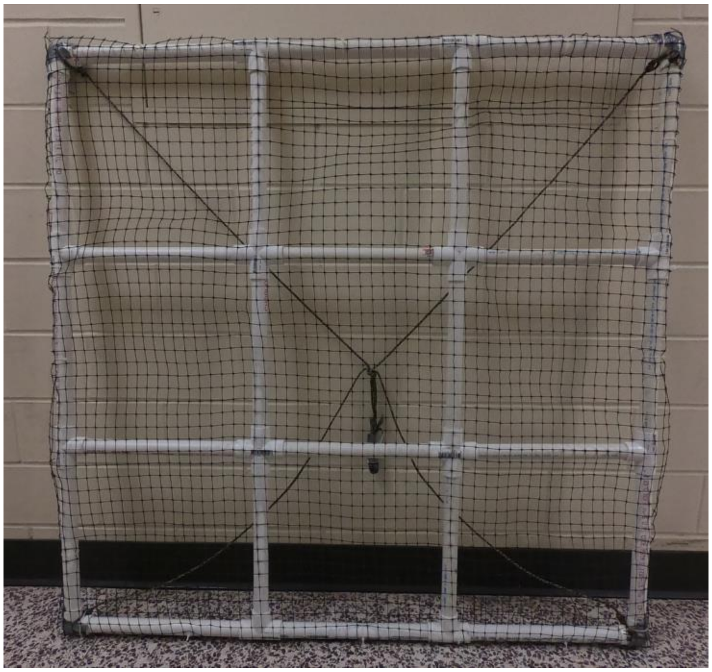


Figure 50: Raft Construction

Updated Raft Release [TD]:

Originally the raft was designed to be released by a 12 V DC pinch valve. Upon further research, it was found that the pinch valve was not waterproof nor submersible in water. The final raft release design was chosen to be a 12V DC enclosed solenoid with a retracting plunger. The raft is tied around a ring on the plunger and once the sub reaches the splash location, a HI pulse is sent from the PIC32 microcontroller and the plunger is retracted releasing the raft. To interface with the microcontroller and amplify the current to the 2 A DC needed by the solenoid, an interfacing circuit was designed which can be seen in Figure 51. In the preceding circuit, when +3.3 volts is applied from the PIC to the solenoid control circuit, it causes Q3 to go into saturation (short) which causes the optoisolator, U2, to go into saturation, which causes Q1 to go into cutoff (open), which causes Q2 to go into saturation turning on the solenoid. When 0 volt comes from the PIC, Q3 goes into cutoff, causing the optoisolator, U2, to go into cutoff, putting Q1 into saturation, causing Q2 to go into cutoff turning off the solenoid.

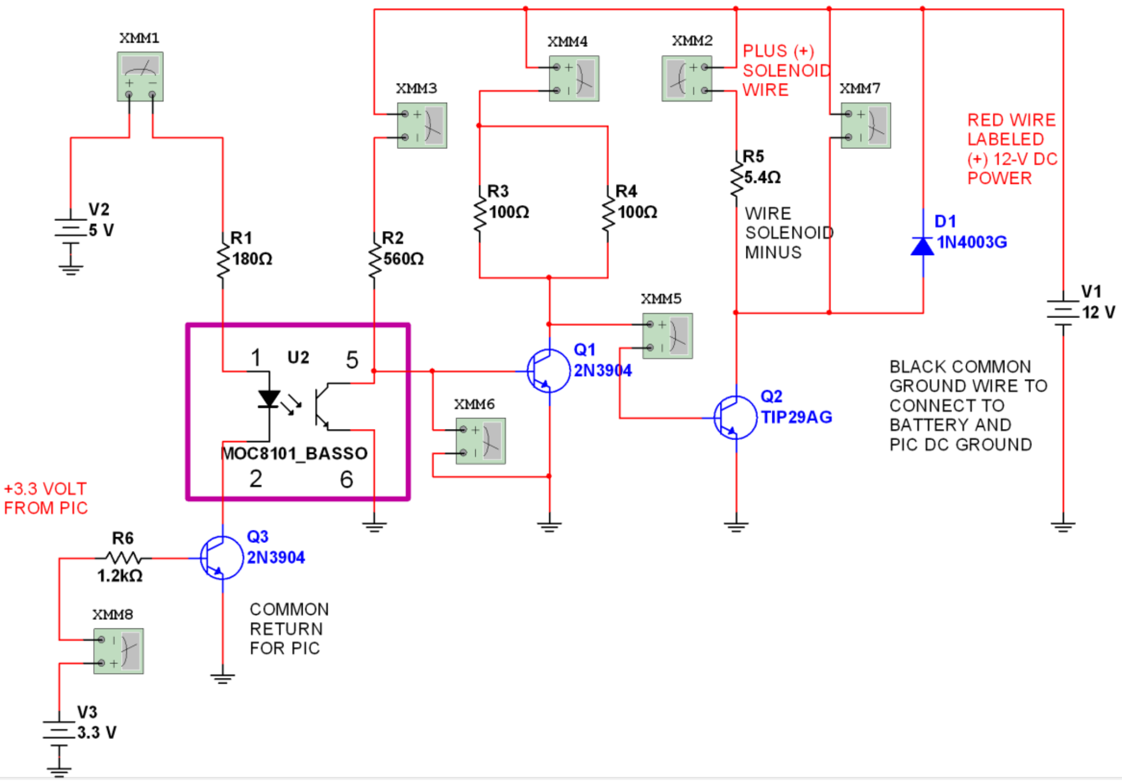


Figure 51: Solenoid to PIC32 Interfacing & Amplifying Circuit

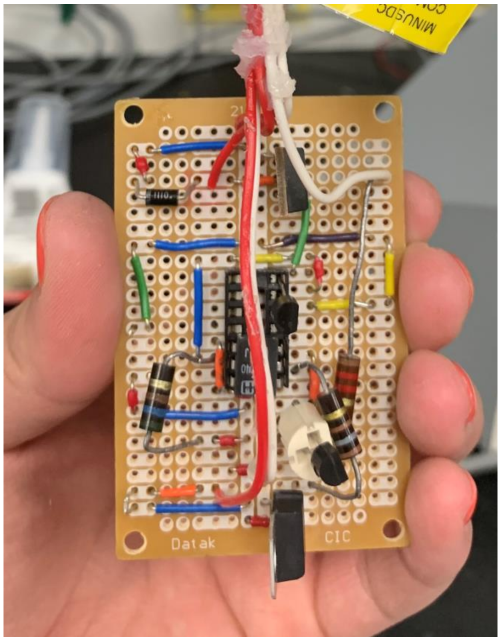


Figure 52: Solenoid Circuit Soldered on Prototyping Board

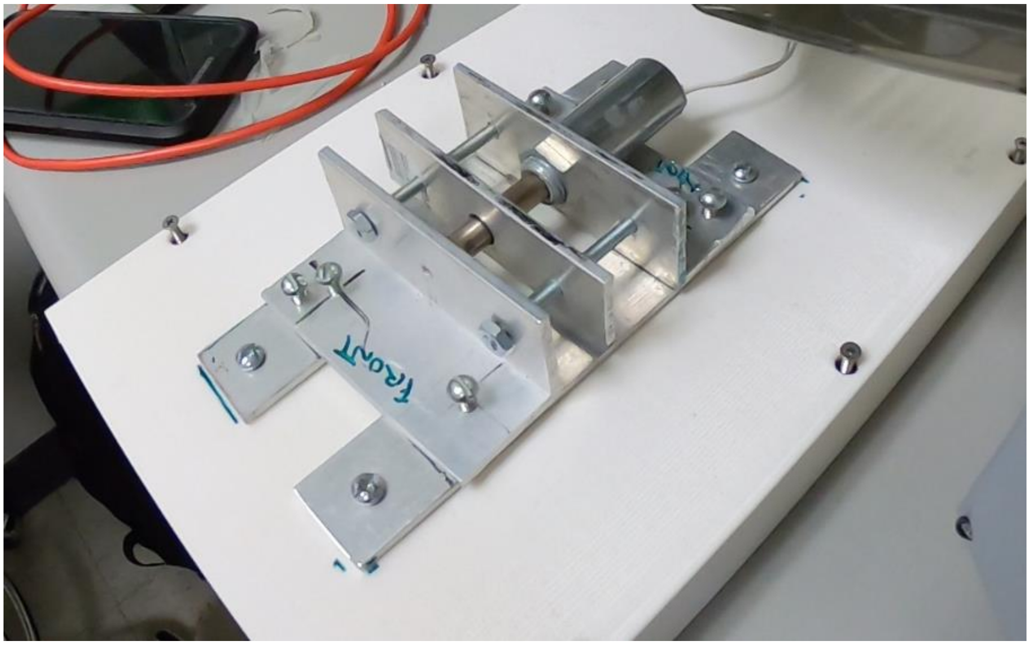


Figure 53: Solenoid & Plunger Mounted to Lid of Sub

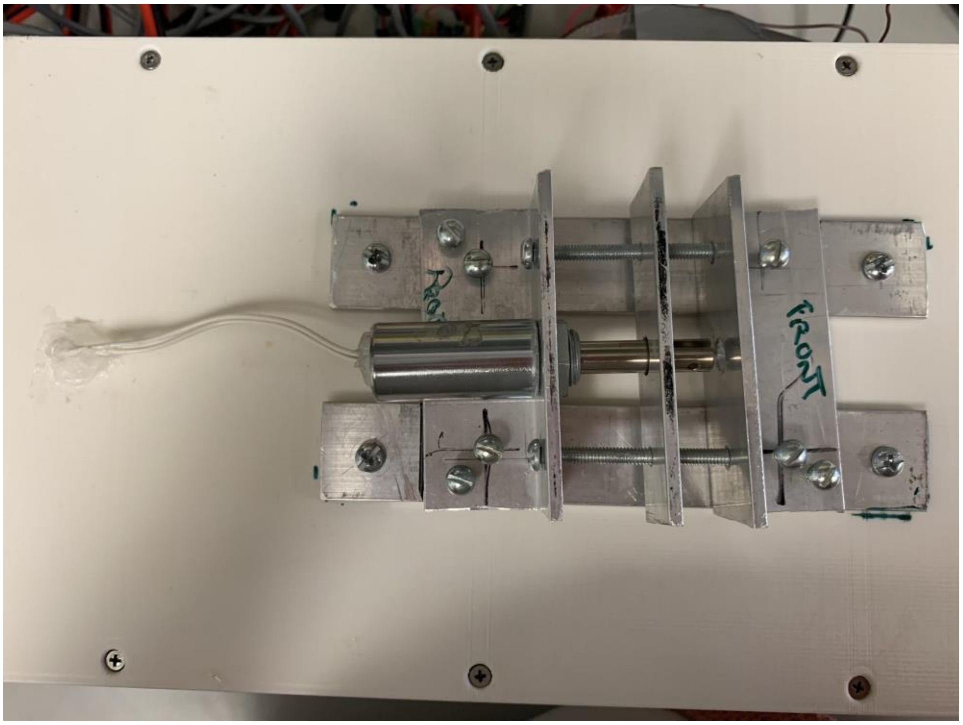


Figure 54: Solenoid & Plunger Top View

Updated Inductive Charging [AD]:

Overall, the inductive charger's purpose is to supply the battery of the robot in the pool with the ability to charge wirelessly. This is done through the schematic shown in Figure 55.

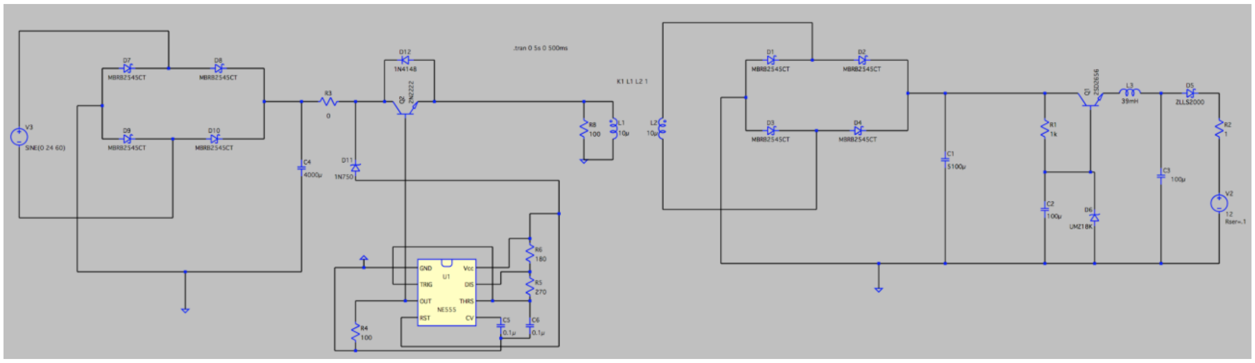


Figure 55: Complete Inductive Charging Circuit

In order to charge wirelessly the charger is broken up into the GSU and the VSU circuits which are coupled together through two Wurth Electronics coils. The schematic of the GSU is shown in Figure 56 and the VSU schematic is displayed in Figure 57.

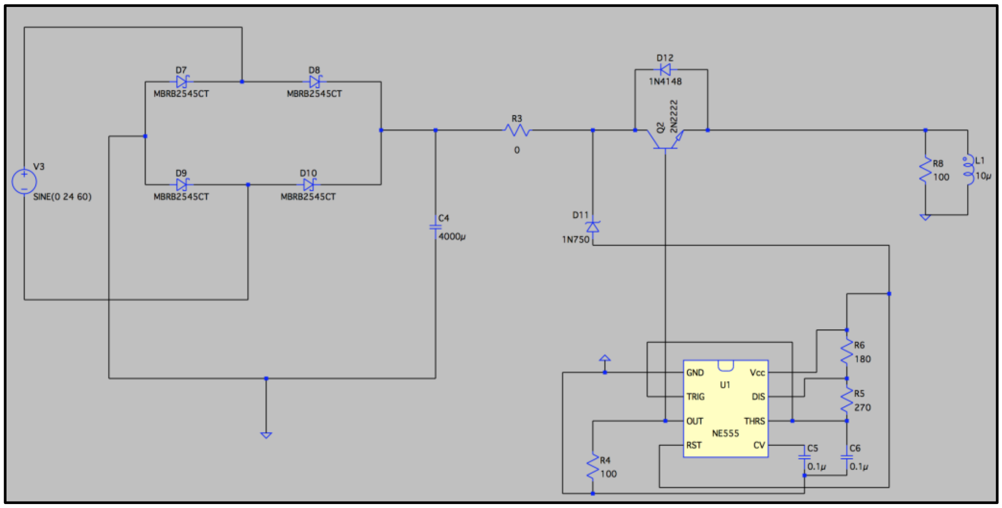


Figure 56: GSU Schematic

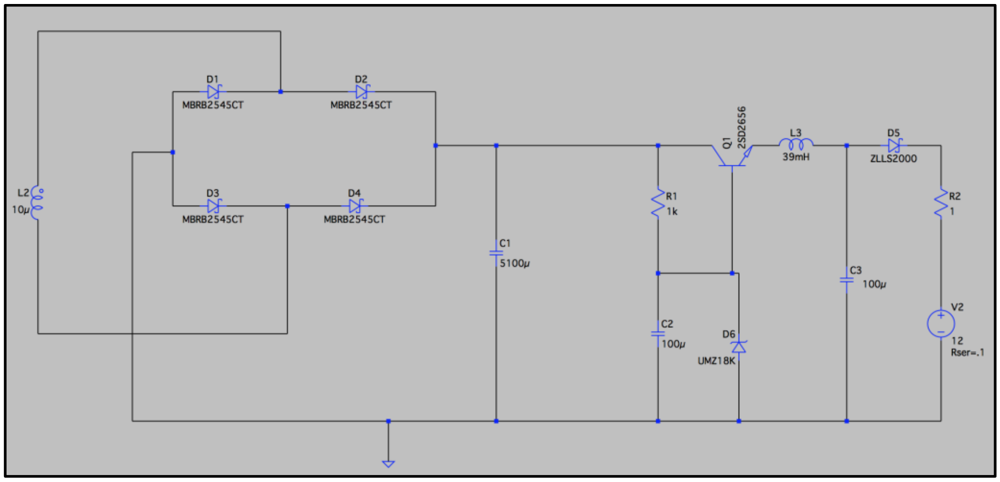


Figure 57: VSU Schematic

The AC/DC converter takes in the 24VAC from the transformer through the 12V Regulator Board that is also in the home station. In between both boards is a mechanical toggle switch that allows controllability for when the battery should be charging.

Even though a large capacitance value was placed to produce a 24V DC there is a significant ripple which is shown below in Figure 58.

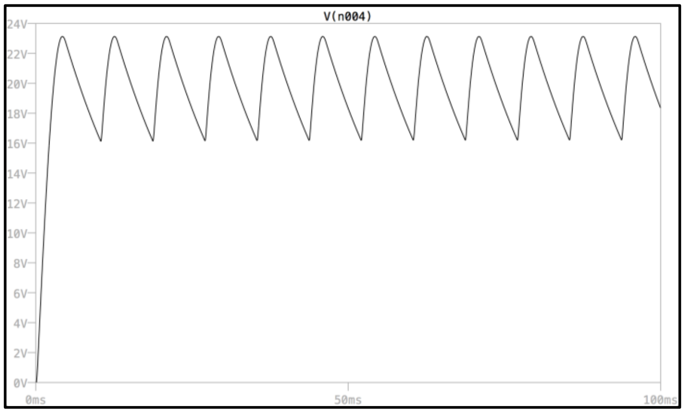


Figure 58: Output of the GSU AC/DC Converter

In order to provide an AC input to the 10uH coil a 20kHz switching circuit was implemented and in order to diminish the amount of voltage and current going to the 9A rated coil, a large power rated zener diode was used to drop down some of the voltage, and the second purpose was to provide Vcc to the 555 timer. The diode also acts as a safety feature, being if the diode was to blow, there would be no voltage on the coil because the switching circuit is disconnected. The voltage output of the first coil can be shown in Figure 59.

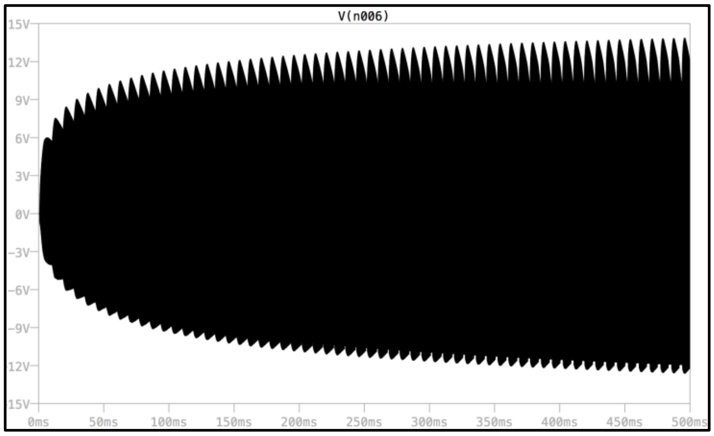


Figure 59: Voltage Output of the GSU Coil

The induced voltage that is seen on the VSU coil is seen in Figure 60 and the final output voltage to the battery is seen in Figure 61.

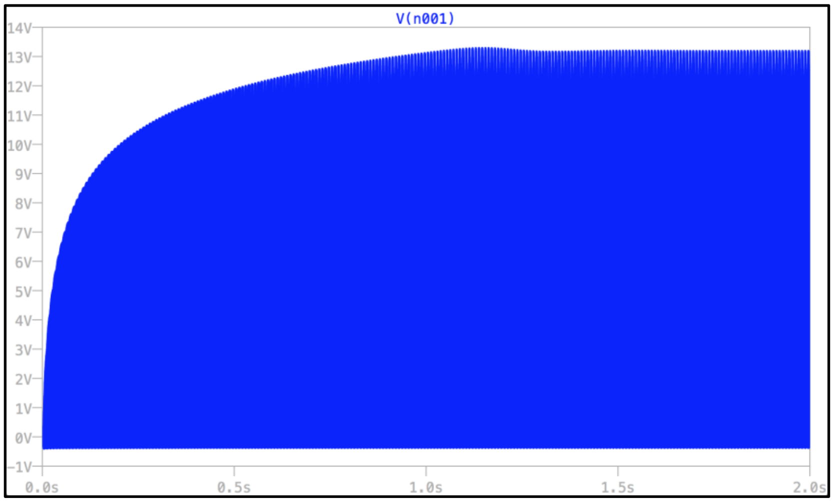


Figure 60: Induced Voltage on the VSU Coil

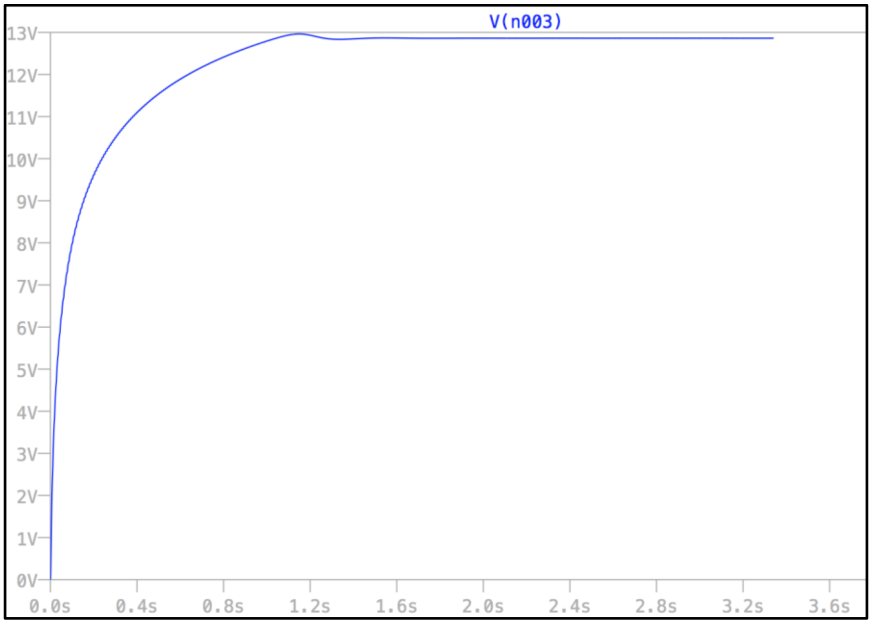


Figure 61: Output Voltage to the Battery

Once the schematics were completed, the circuits were designed in Eagle, a PCB layout program. The GSU layout can be seen in Figure 62, while the PCB layout board of the VSU is shown in Figure 63.

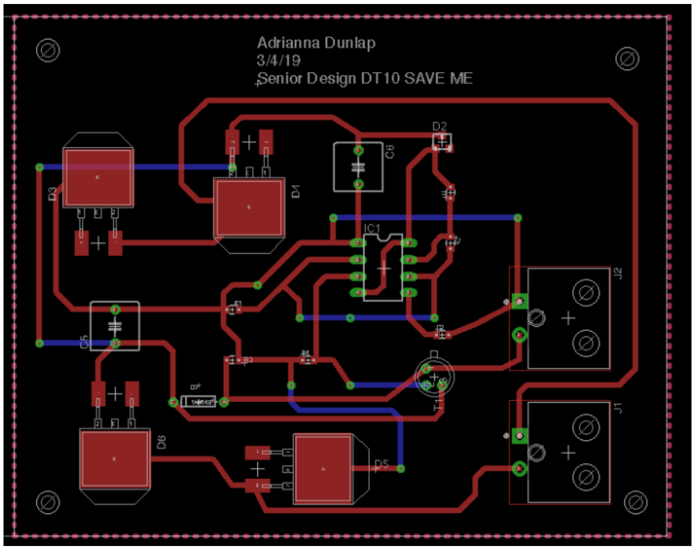


Figure 62: PCB Layout of the GSU

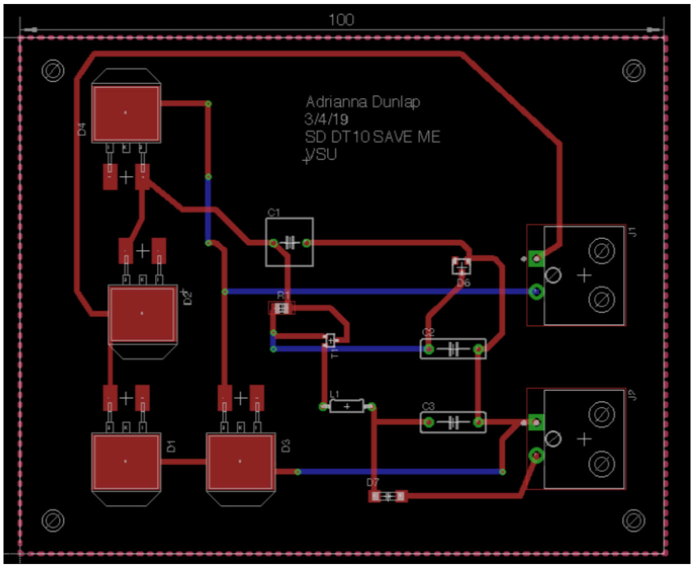


Figure 63: PCB Layout of the VSU

The GSU PCB construct can be seen in Figure 64 and the VSU in Figure 65 The intended interaction of the coils is found in Figure 66

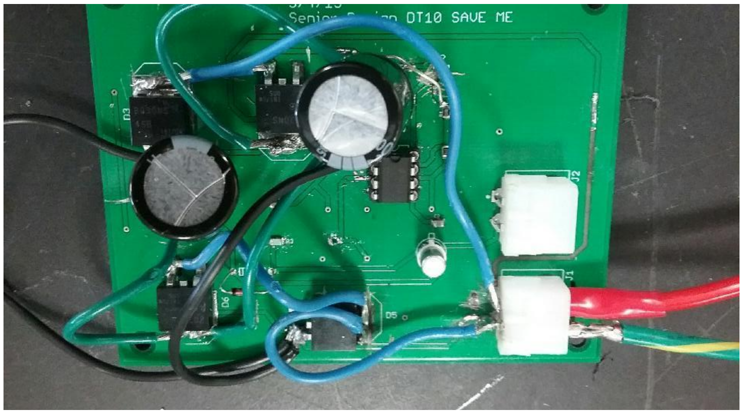


Figure 64: GSU Construction

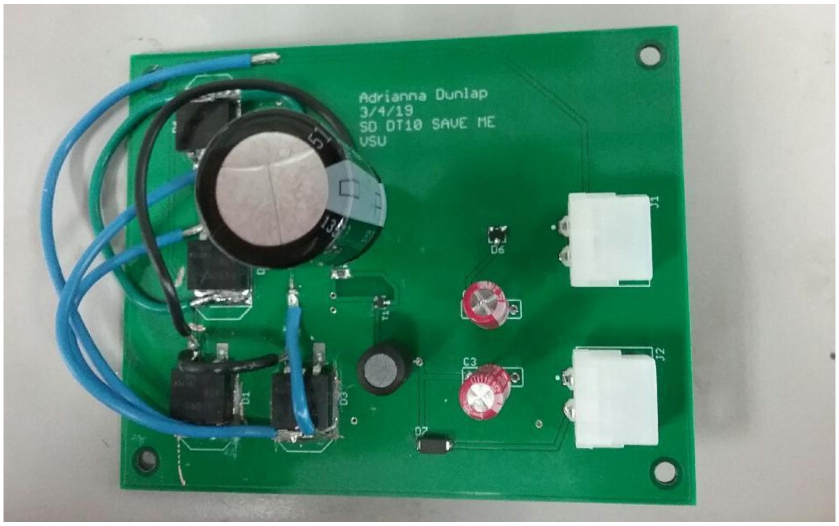


Figure 65: VSU Construction

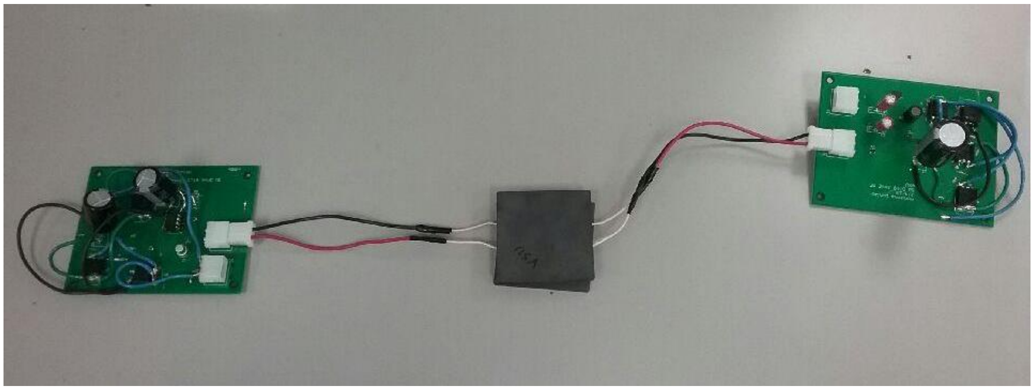
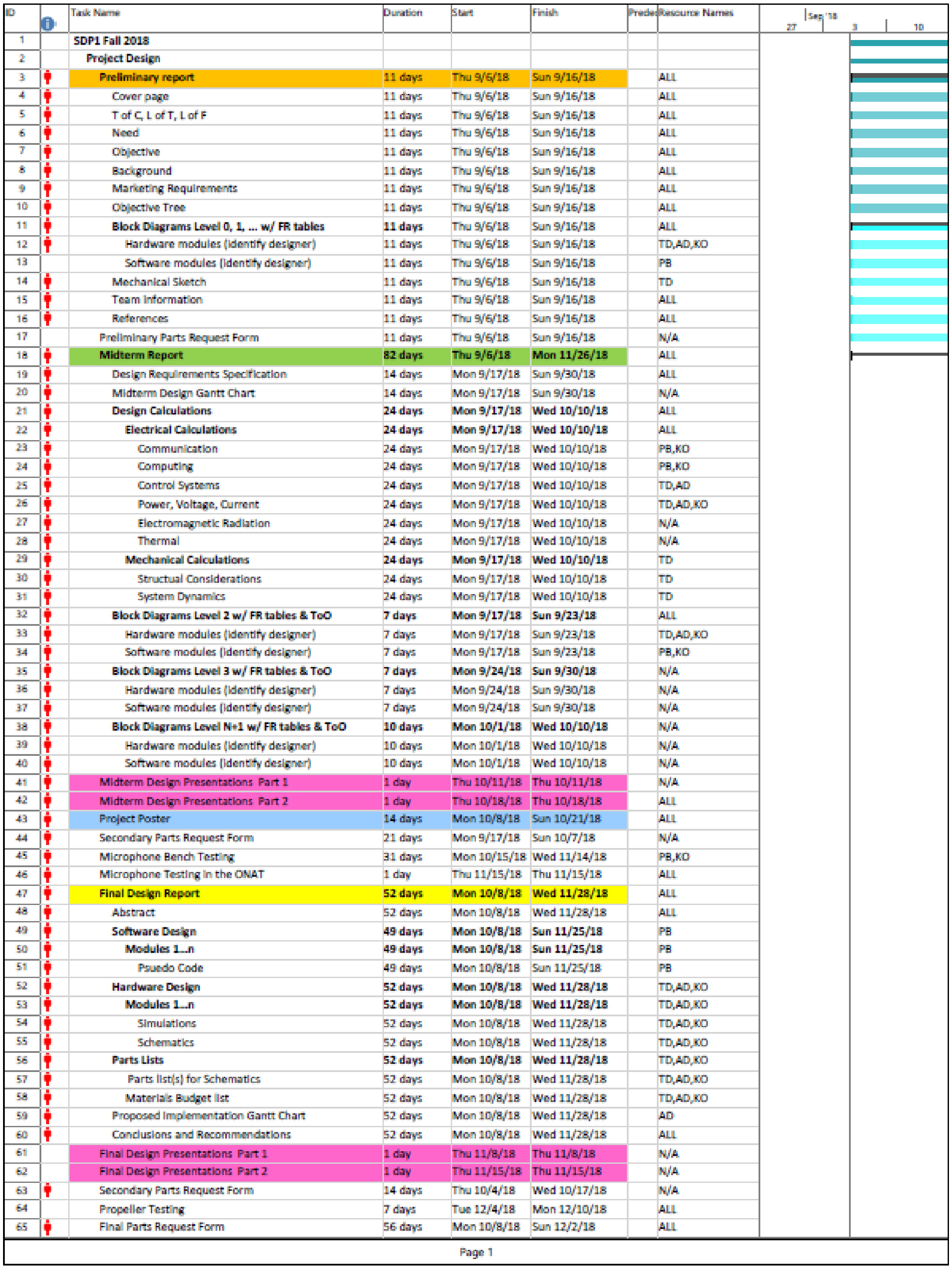


Figure 66: Intended Interaction of Coils

Project Schedules

Midterm Design Gantt Chart

Gantt Chart Fall 2018:



ID		Task Name	Duration	Start	Finish	Predec	Resource Names
1		**SDP1 Fall 2018**					
2		**Project Design**					
3		**Preliminary report**	11 days	Thu 9/6/18	Sun 9/16/18		ALL
4		Cover page	11 days	Thu 9/6/18	Sun 9/16/18		ALL
5		T of C, L of T, L of F	11 days	Thu 9/6/18	Sun 9/16/18		ALL
6		Need	11 days	Thu 9/6/18	Sun 9/16/18		ALL
7		Objective	11 days	Thu 9/6/18	Sun 9/16/18		ALL
8		Background	11 days	Thu 9/6/18	Sun 9/16/18		ALL
9		Marketing Requirements	11 days	Thu 9/6/18	Sun 9/16/18		ALL
10		Objective Tree	11 days	Thu 9/6/18	Sun 9/16/18		ALL
11		**Block Diagrams Level 0, 1, … w/ FR tables**	**11 days**	Thu 9/6/18	Sun 9/16/18		ALL
12		Hardware modules (identify designer)	11 days	Thu 9/6/18	Sun 9/16/18		TD,AD,KO
13		Software modules (identify designer)	11 days	Thu 9/6/18	Sun 9/16/18		PB
14		Mechanical Sketch	11 days	Thu 9/6/18	Sun 9/16/18		TD
15		Team Information	11 days	Thu 9/6/18	Sun 9/16/18		ALL
16		References	11 days	Thu 9/6/18	Sun 9/16/18		ALL
17		Preliminary Parts Request Form	11 days	Thu 9/6/18	Sun 9/16/18		N/A
18		**Midterm Report**	**82 days**	**Thu 9/6/18**	**Mon 11/26/18**		ALL
19		Design Requirements Specification	14 days	Mon 9/17/18	Sun 9/30/18		ALL
20		Midterm Design Gantt Chart	14 days	Mon 9/17/18	Sun 9/30/18		N/A
21		**Design Calculations**	**24 days**	**Mon 9/17/18**	**Wed 10/10/18**		ALL
22		**Electrical Calculations**	**24 days**	**Mon 9/17/18**	**Wed 10/10/18**		ALL
23		Communication	24 days	Mon 9/17/18	Wed 10/10/18		PB,KO
24		Computing	24 days	Mon 9/17/18	Wed 10/10/18		PB,KO
25		Control Systems	24 days	Mon 9/17/18	Wed 10/10/18		TD,AD
26		Power, Voltage, Current	24 days	Mon 9/17/18	Wed 10/10/18		TD,AD,KO
27		Electromagnetic Radiation	24 days	Mon 9/17/18	Wed 10/10/18		N/A
28		Thermal	24 days	Mon 9/17/18	Wed 10/10/18		N/A
29		**Mechanical Calculations**	**24 days**	**Mon 9/17/18**	**Wed 10/10/18**		TD
30		Structual Considerations	24 days	Mon 9/17/18	Wed 10/10/18		TD
31		System Dynamics	24 days	Mon 9/17/18	Wed 10/10/18		TD
32		**Block Diagrams Level 2 w/ FR tables & ToO**	**7 days**	**Mon 9/17/18**	**Sun 9/23/18**		ALL
33		Hardware modules (identify designer)	7 days	Mon 9/17/18	Sun 9/23/18		TD,AD,KO
34		Software modules (identify designer)	7 days	Mon 9/17/18	Sun 9/23/18		PB,KO
35		**Block Diagrams Level 3 w/ FR tables & ToO**	**7 days**	**Mon 9/24/18**	**Sun 9/30/18**		N/A
36		Hardware modules (identify designer)	7 days	Mon 9/24/18	Sun 9/30/18		N/A
37		Software modules (identify designer)	7 days	Mon 9/24/18	Sun 9/30/18		N/A
38		**Block Diagrams Level N+1 w/ FR tables & ToO**	**10 days**	**Mon 10/1/18**	**Wed 10/10/18**		N/A
39		Hardware modules (identify designer)	10 days	Mon 10/1/18	Wed 10/10/18		N/A
40		Software modules (identify designer)	10 days	Mon 10/1/18	Wed 10/10/18		N/A
41		Midterm Design Presentations Part 1	1 day	Thu 10/11/18	Thu 10/11/18		N/A
42		Midterm Design Presentations Part 2	1 day	Thu 10/18/18	Thu 10/18/18		ALL
43		Project Poster	14 days	Mon 10/8/18	Sun 10/21/18		ALL
44		Secondary Parts Request Form	21 days	Mon 9/17/18	Sun 10/7/18		N/A
45		Microphone Bench Testing	31 days	Mon 10/15/18	Wed 11/14/18		PB,KO
46		Microphone Testing in the ONAT	1 day	Thu 11/15/18	Thu 11/15/18		ALL
47		**Final Design Report**	**52 days**	**Mon 10/8/18**	**Wed 11/28/18**		ALL
48		Abstract	52 days	Mon 10/8/18	Wed 11/28/18		ALL
49		**Software Design**	**49 days**	**Mon 10/8/18**	**Sun 11/25/18**		PB
50		**Modules 1…n**	**49 days**	**Mon 10/8/18**	**Sun 11/25/18**		PB
51		Psuedo Code	49 days	Mon 10/8/18	Sun 11/25/18		PB
52		**Hardware Design**	**52 days**	**Mon 10/8/18**	**Wed 11/28/18**		TD,AD,KO
53		**Modules 1…n**	**52 days**	**Mon 10/8/18**	**Wed 11/28/18**		TD,AD,KO
54		Simulations	52 days	Mon 10/8/18	Wed 11/28/18		TD,AD,KO
55		Schematics	52 days	Mon 10/8/18	Wed 11/28/18		TD,AD,KO
56		**Parts Lists**	**52 days**	**Mon 10/8/18**	**Wed 11/28/18**		TD,AD,KO
57		Parts list(s) for Schematics	52 days	Mon 10/8/18	Wed 11/28/18		TD,AD,KO
58		Materials Budget list	52 days	Mon 10/8/18	Wed 11/28/18		TD,AD,KO
59		Proposed Implementation Gantt Chart	52 days	Mon 10/8/18	Wed 11/28/18		AD
60		Conclusions and Recommendations	52 days	Mon 10/8/18	Wed 11/28/18		ALL
61		Final Design Presentations Part 1	1 day	Thu 11/8/18	Thu 11/8/18		N/A
62		Final Design Presentations Part 2	1 day	Thu 11/15/18	Thu 11/15/18		N/A
63		Secondary Parts Request Form	14 days	Thu 10/4/18	Wed 10/17/18		N/A
64		Propeller Testing	7 days	Tue 12/4/18	Mon 12/10/18		ALL
65		Final Parts Request Form	56 days	Mon 10/8/18	Sun 12/2/18		ALL

Page 1

Figure 67: Fall 2018 Gantt Chart

Proposed Implementation Gantt Chart

Gantt Chart Spring 2019:

ℹ	Task Mode	Task Name	Duration	Start	Finish		Resource Names	*Add New Column*
	📌	**◢ SDPII Implementation 2018**	**103 days**	**Mon 1/14/19**	**Fri 4/26/19**			
🔴	📌	Revise Gantt Chart	14 days	**Mon 1/14/19**	Sun 1/27/19		AD	
🔴	📌	**◢ Implement Project Design**	**96 days**	**Mon 1/14/19**	**Fri 4/19/19**		**ALL**	
🔴	📌	**◢ Hardware Implementation**	**56 days**	**Mon 1/14/19**	**Sun 3/10/19**		**TD,AD,KO**	
🔴	📌	Testing of Alarm	1 day	Fri 1/18/19	Fri 1/18/19		PB,TD,AD,KO	
🔴	📌	Microtest PCBs/SPI Test	8 days	Fri 1/18/19	Fri 1/25/19		PB,KO	
🔴	📌	Send out PCB	8 days	Fri 1/25/19	Fri 2/1/19		PB,KO	
🔴	📌	Microphone Array Testing	8 days	Fri 2/1/19	Fri 2/8/19		PB,KO	
🔴	📌	IR System, User Interface, Alarm, Arm Switch	8 days	Fri 2/8/19	Fri 2/15/19		PB,KO	
🔴	📌	Data Array	8 days	Fri 2/15/19	Fri 2/22/19		PB,KO	
🔴	📌	Robot, Sealed and Wired	8 days	Fri 2/22/19	Fri 3/1/19		PB,KO	
🔴	📌	Testing of Thrusters in Contained Area	1 day	Wed 1/23/19	Wed 1/23/19		TD,AD,KO	
🔴	📌	Testing of ESC Controllers	1 day	Wed 1/23/19	Wed 1/23/19		TD,AD,KO	
🔴	📌	DC Regulator Breadboarded	10 days	Tue 1/22/19	Thu 1/31/19		TD	
🔴	📌	PO sent for Battery, Raft Pieces	1 day	Fri 1/18/19	Fri 1/18/19		TD,AD	
🔴	📌	Breadboard Components	13 days	**Mon 1/14/19**	Sat 1/26/19		TD,AD,KO	
🔴	➡	Layout and Generate PCB(s)	14 days	Sun 1/27/19	Sat 2/9/19	16	TD,AD,KO	
🔴	➡	Assemble Hardware	7 days	Sun 2/10/19	Sat 2/16/19	17	TD,AD,KO	
🔴	➡	Test Hardware	14 days	Sun 2/17/19	Sat 3/2/19	18	TD,AD,KO	
🔴	➡	Revise Hardware	14 days	Sun 2/17/19	Sat 3/2/19	18	TD,AD,KO	
	➡	*MIDTERM: Demonstrate Hardware*	5 days	Sun 3/3/19	Thu 3/7/19	19		
	📌	SDC & FA Hardware Approval	0 days	Fri 3/8/19	Fri 3/8/19	21		
	📌	SDC & FA Hardware Approval	0 days	Fri 3/8/19	Fri 3/8/19	21		
🔴	📌	Track Delivered	29 days	Fri 1/18/19	Fri 2/15/19		TD	
🔴	📌	Enclosures Design Completed	11 days	Tue 1/22/19	Fri 2/1/19		TD,AD	
🔴	📌	Enclosure Fabrication Completed	15 days	Fri 2/1/19	Fri 2/15/19		TD,AD	
🔴	📌	Testing of Movement Along the Track (Wired)	5 days	Mon 2/18/19	Fri 2/22/19		TD,AD	
🔴	📌	Electrical and Mechanical Completion	43 days	Fri 1/18/19	Fri 3/1/19		TD,AD	
🔴	📌	**◢ Software Implementation**	**56 days**	**Mon 1/14/19**	**Sun 3/10/19**	**22**	**PB**	
🔴	📌	Pinpoint Location in Lab	5 days	Mon 3/11/19	Fri 3/15/19		PB,KO	
🔴	📌	Pinpoint Location in ONAT	5 days	Mon 3/18/19	Fri 3/22/19		PB,KO	
🔴	📌	Develop Software	27 days	**Mon 1/14/19**	Sat 2/9/19		PB	
🔴	➡	Test Software	21 days	Sun 2/10/19	Sat 3/2/19	31	PB	
🔴	➡	Revise Software	21 days	Sun 2/10/19	Sat 3/2/19	31	PB	
🔴	➡	*MIDTERM: Demonstrate Software*	5 days	Sun 3/3/19	Thu 3/7/19	33	PB	
	📌	SDC & FA Software Approval	0 days	Fri 3/8/19	Fri 3/8/19	34		
🔴	📌	**◢ System Integration**	**42 days**	**Sat 3/9/19**	**Fri 4/19/19**		**ALL**	
🔴	📌	Assemble Complete System	14 days	**Sat 3/9/19**	Fri 3/22/19		ALL	
🔴	📌	Electrical and Mechanical Mounting	15 days	Sat 3/9/19	Sat 3/23/19	37	TD,AD,KO	
🔴	📌	User Interface	15 days	Sat 3/9/19	Sat 3/23/19	38	PB,KO	
🔴	📌	Home Station	15 days	Sat 3/9/19	Sat 3/23/19	39	KO,AD	
🔴	📌	Underwater Robot	15 days	Sat 3/9/19	Sat 3/23/19	40	ALL	
	📌	Raft Construction	15 days	Sun 3/24/19	Sun 4/7/19	41	TD,AD	
🔴	📌	Motor, Timing Testing, Autonomy, Wireless	12 days	Mon 4/1/19	Fri 4/12/19	42	ALL	
🔴	📌	Assemble Complete System	14 days	**Sat 3/9/19**	Fri 3/22/19		ALL	
🔴	📌	Electrical and Mechanical Mounting	15 days	Sat 3/9/19	Sat 3/23/19	37	TD,AD,KO	
🔴	📌	User Interface	15 days	Sat 3/9/19	Sat 3/23/19	38	PB,KO	
🔴	📌	Home Station	15 days	Sat 3/9/19	Sat 3/23/19	39	KO,AD	
🔴	📌	Underwater Robot	15 days	Sat 3/9/19	Sat 3/23/19	40	ALL	
	📌	Raft Construction	15 days	Sun 3/24/19	Sun 4/7/19	41	TD,AD	
🔴	📌	Motor, Timing Testing, Autonomy, Wireless	12 days	Mon 4/1/19	Fri 4/12/19	42	ALL	
🔴	📌	Test Complete System	21 days	Tue 4/9/19	Mon 4/29/19	43	ALL	
🔴	📌	Revise Complete System	21 days	Sat 3/23/19	Fri 4/12/19	37	ALL	
🔴	➡	*Demonstration of Complete System*	7 days	Sat 4/13/19	Fri 4/19/19	45	ALL	
🔴	📌	**◢ Develop Final Report**	**99 days**	**Mon 1/14/19**	**Mon 4/22/19**		**ALL**	
🔴	📌	Write Final Report	99 days	Mon 1/14/19	Mon 4/22/19		ALL	
	➡	Submit Final Report	0 days	Mon 4/22/19	Mon 4/22/19	48	AD	
	📌	Spring Recess	7 days	Mon 3/25/19	Sun 3/31/19			
	📌	***Project Demonstration and Presentation***	0 days	Fri 4/26/19	Fri 4/26/19		ALL	

Figure 68: Spring 2019 Gantt Chart

Design Team Information *Name, major. ESI (Y/N)*

Parsa Esshaghi Bayat,	Computer Engineering,	ESI (Y)
Taylor Davis,	Electrical Engineering,	ESI (Y)
Adrianna Dunlap,	Electrical Engineering,	ESI (Y)
Kelly O’Neill,	Electrical Engineering,	ESI (Y)

Conclusions and Recommendations

At this time the team is making progress towards completion of the design and the determination of components that comprise the system. The team realizes that building the entire system will be a challenge, however, there is hope that the deadlines will still be met.

From a time, management, and budget the team would recommend to others to not choose a project that is a system or utilizes electronics underwater.

References

Works Cited

[1] Cdc.gov. (2018). *Unintentional Drowning: Get the Facts | Home and Recreational Safety | CDC Injury Center*. [online] Available at: https://www.cdc.gov/homeandrecreationalsafety/water-safety/waterinjuries-factsheet.html [Accessed 28 Feb. 2018].

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[3] Childrenssafetynetwork.org. (2018). *Why Drownings Are a Leading Cause of Death among Children | Children's Safety Network*. [online] Available at: https://www.childrenssafetynetwork.org/webinar/why-drownings-are-leading-cause-death-among-children [Accessed 28 Feb. 2018].

[4] Bridges, A. (2018). *Explainer: What are lidar, radar and sonar?*. [online] Science News for Students. Available at: https://www.sciencenewsforstudents.org/article/explainer-what-are-lidar-radar-and-sonar [Accessed 28 Feb. 2018].

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[7] M. Valikhanov and A. Aleshechkin, "System for detecting and researching of underwater objects," in Proc. of the 2013 International Siberian Conference on Control and Communications (SIBCON, September 12-13 2013, Krasnoyarsk, Russia [Online]. IEEE, 2014. Available: IEEE Xplore, http://www.ieee.org. [Accessed: 27 February. 2018].

[8] N.Caprillo, J. Husko, and D. Snyder, “Swimming pool alarm system,” U.S. Patent 3,732,556, issued May 8, 1973.

[9] A. J. Kalpaxis, "Wireless Detection and Alarm System For Monitoring Human Fall and Entries into Swimming Pools by using Three Dimensional Acceleration and Wireless link Energy Data Method and Apparatus." U.S. Patent 20080258907A1, issued October 23, 2008.

[10] Rooz, Elkana, and Isaac Ben-Sira. "Method and system for detecting a motionless body in a pool." U.S. Patent No. 5,043,705. 27 Aug. 1991.

[11] Segal, Elazar. "Lifesaving system and method for swimming pool." U.S. Patent Application No. 14/964,576. Issued June 15, 2017.

Appendices

Datasheets:

User Interface Alarm Rectifier & Regulator Circuit Design

- Power Transformer s- http://catalog.triadmagnetics.com/Asset/F-259U.pdf
- Bridge Rectifier - http://www.mccsemi.com/up_pdf/MP5005W-MP5010W(MP-50W).pdf
- Regulator - https://www.onsemi.com/pub/Collateral/MC7800-D.PDF
- 22,000uF Capacitor - http://www.rubycon.co.jp/en/catalog/e_pdfs/aluminum/Radial_Lead_Alumi_Eng.pdf
- 100 uF Capacitor - https://media.digikey.com/pdf/Data%20Sheets/Panasonic%20Electronic%20Components/ECA-xxM%20Series,TypeA.pdf

Underwater Movement

- T200 Thruster - http://docs.bluerobotics.com/thrusters/t200/

User Interface and Robot Microcontroller with Alarm and Microphone Circuitry

- Continuous Sound Alarm Buzzer 6-24VDC 100dB - http://a.co/d/iQWESEv
- Microseven M7WP-MIC waterproof outdoor Microphone for M7B77-POE - http://a.co/d/aAhx03l
- MOSFET N-CH 30V 3.6A SOT-23 - http://www.vishay.com/docs/65701/si2300ds.pdf
- IC REG LINEAR 3.3V 1A SOT223 -https://www.mouser.com/datasheet/2/115/AP2114-271472.pdf
- DIODE SCHOTTKY 30V 200MA - https://toshiba.semicon-storage.com/info/docget.jsp?did=7041&prodName=CUS520
- IC MCU 32BIT 1MB FLASH 64TQFP - http://ww1.microchip.com/downloads/en/DeviceDoc/PIC32MK-General-Purpose-and-Motor-Control-%20(GPMC)-Family-Datasheet-60001402E.pdf
- IC REG BUCK 5V 1A TO263-5 - https://www.mouser.com/datasheet/2/268/lm2575-777962.pdf
- FIXED IND 470UH 1.2A 820 MOHM- https://www.mouser.com/datasheet/2/54/RR1210A-1391531.pdf
- CAP ALUM 100UF 20% 35V SMD- http://nichicon-us.com/english/products/pdfs/e-uwt.pdf
- DIODE SCHOTTKY 40V 3A SMC- https://www.diodes.com/assets/Datasheets/ds30923.pdf
- IC IR RCVR MOD 38KHZ DOME RADIAL- https://www.vishay.com/docs/82491/tsop382.pdf
- EMITTER IR 940NM 100MA RADIAL- http://www.everlight.com/file/ProductFile/201407061516067600.pdf
- IC ADC 12BIT 500KSPS 4CH 38TSSOP- http://www.ti.com/lit/ds/symlink/ads8664.pdf
- CAP CER 1UF 25V X7R 0805- https://media.digikey.com/pdf/Data%20Sheets/Samsung%20PDFs/CL_Series_MLCC_ds.pdf

- CONN HOUSING 2POS - https://www.molex.com/pdm_docs/sd/022012027_sd.pdf
- CONN HOUSING 3POS - https://www.molex.com/pdm_docs/sd/022012037_sd.pdf
- CONN HDR BRKWAY .100 40POS VERT - https://www.te.com/commerce/DocumentDelivery/DDEController?Action=srchrtrv&DocNm=103747&DocType=Customer+Drawing&DocLang=English
- CONN TERM FEMALE 22-30AWG - https://www.molex.com/pdm_docs/ps/PS-99020-0088.pdf
- CONN HEADER 2POS .100 R/A TIN - https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf
- CONN HEADER 3POS .100 R/A TIN - https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

Inductive Charging

- Battery - https://www.batteriesplus.com/productdetails/SLAA12=10F2?locationofinterest=9051924&locationphysical=9015403&gclid=EAIaIQobChMIorrn-Z_23gIVgjppCh3JGAraEAQYAiABEgLlj_D_BwE
- 100uF Capacitors- https://media.digikey.com/pdf/Data%20Sheets/United%20Chemi-Con%20PDFs/NTJ_Series_2016.pdf
- Capacitor-200uF- https://industrial.panasonic.com/ww/products/capacitors/aluminum-capacitors/aluminum-cap-lead/tp/EEUTP1V202SB
- 47mH Inductor- https://www.murata-ps.com/data/magnetics/kmp_2200rm.pdf
- Schottky Diodes- https://www.diodes.com/assets/Datasheets/ZLLS2000.pdf
- Q2 - http://rohmfs.rohm.com/en/products/databook/datasheet/discrete/transistor/bipolar/2sd2656t106-e.pdf
- Resistor-1k-https://www.rohm.com/datasheet/ESR01MZPF/esr-e
- Diodes in Diode Bridge- https://www.onsemi.com/pub/Collateral/MBRB2545CT-D.PDF
- RX Coil- https://katalog.we-online.de/pbs/datasheet/760308201.pdf
- TX Coil- https://katalog.we-online.de/pbs/datasheet/760308141.pdf
- 2200uF Capacitor- https://katalog.we-online.de/pbs/datasheet/860010781028.pdf
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