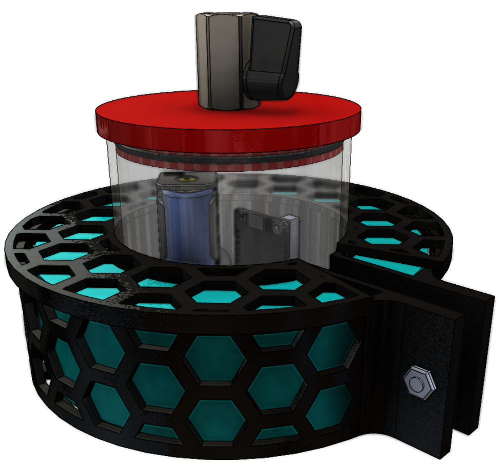
*Cornell University Autonomous Underwater Vehicle Team*

Spring 2025

# Transmit Buoy



*Technical Report*

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# 1 Abstract

This transmit buoy is a novel endeavor designed to facilitate the testing of hydro-acoustic communication systems in our submarines. This versatile tool functions as a self-contained unit, distinct from the submarine, and serves as a ’wireless tether’ to enable certain low-bandwidth communications with the submarine. It can also act as a pinger capable of emitting multiple frequencies and serves as a valuable instrument for assessing the acoustic properties of various aquatic environments. As this project is currently under development, this technical report remains a work in progress. It is scheduled for completion by the end of the next semester, coinciding with the anticipated completion of a functional prototype. This document not only records the processes undertaken thus far but also seeks to offer guidance for the advancement of future interdisciplinary projects.

# 2 Design Requirements

## 2.1 Constraints

- The communication range should be at least 50 meters above water (using 2.4GHz WiFi) and 25 meters below water (using hydroacoustic communication)
- The buoy must be waterproof enough to be easily thrown into the pool
- The design should include either a long-lasting battery or easily replaceable batteries for quick operations

## 2.2 Objectives

- Establish a ”wireless tether” to communicate with the submarine without a physical connection
- Enable one-way communication to the submarine for commands such as reset or return
- Achieve a transmission rate of up to 200 symbols per second (stretch goal) or at least 20 symbols per second (Minimum Viable Product)
- Act as an advanced pinger for troubleshooting purposes, emitting hydroacoustic pings ranging from 15 kilohertz to 100,000 kilohertz
- Ensure the user interface is straightforward and easy to operate

## 3 High Level Description

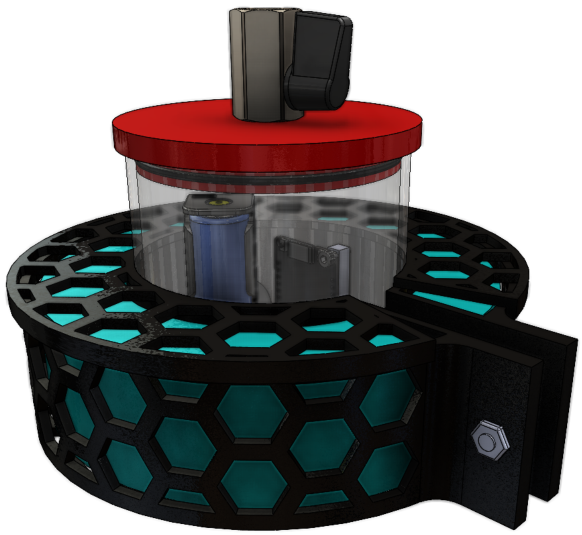


Figure 1: Foam Float Enclosure

The buoy is designed with an acrylic tube body, capped at both ends with machined aluminum end caps. One end features a cable penetrator for the piezoelectric transducer, which is encapsulated in urethane to emit hydroacoustic signals. At the top end cap, a valve is installed, identical to the one used in our UHPV, allowing for pressurization of the buoy. Additionally, for buoyancy, a foam float encased in a 3D-printed structure and reinforced with a pool noodle is attached externally, ensuring the buoy remains afloat and stable in aquatic environments. Internally, the buoy houses several key electronic components:

- A 18650 battery (3400 mAh, 8A Discharge) powers the entire electronic assembly.
- A charging board is included to maintain voltage levels and recharge the battery.
- An antenna is integrated to receive Wi-Fi signals.
- An ESP32 microcontroller processes all incoming 2.4 GHz Wi-Fi signals.
- A custom-designed transmit board, based on Karl's previous design, amplifies signals for transmission to the piezoelectric transducer.

### 3.1 Pressure Vessel

Figure 2: Pressure Vessel

The pressure vessel comprises a 3.75-inch outer diameter acrylic tube, coupled with two custom-machined aluminum end caps. The top end cap features a hole for a mini ball valve, while the bottom end cap contains a single hole designed to accommodate a 4.5-millimeter cable penetrator for a glue robotics system. This penetrator connects to a potted piezoelectric transducer, which emits hydroacoustic signals. This design closely resembles our existing battery pods, utilizing acrylic of the same size but cut to a shorter length. A notable distinction, however, lies in the sealing mechanism. Since my buoy does not require submersion in water, it can be secured using a single bore seal at each end, rather than custom fittings for screwing the top and bottom end caps together. The internal pressure created in this buoy by the same vacuum process used for sealing our UHPV is sufficient to maintain the end caps on the acrylic tube, thus preventing any leaks.

### 3.2 Internal Layout

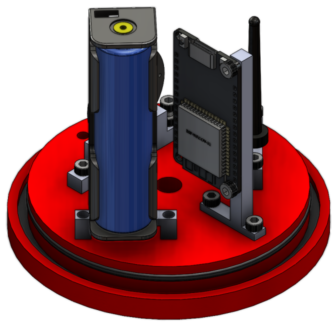


Figure 3: Internal Layout

The buoy's interior design is heavily focused on rapid prototyping, accommodating various potential electronic configurations. To facilitate this flexibility, the base plate, made of aluminum, is outfitted with multiple 4-40 tap holes. These holes allow for the attachment of diverse components through different 3D-printed mounts, catering to varying sizes and structural requirements.

The layout of these tap holes is methodically standardized, with a grid-like spacing of 0.5 inches between each point. This dimension is carefully chosen, considering the overall scale of the design. This standardized grid enables the secure and organized placement of a wide range of components, including antennas, batteries, PCBs, and interfacing hardware such as screws. The design ensures that modifications and upgrades can be easily implemented, reflecting the dynamic nature of the project's development.

### 3.3 Foam Float Enclosure

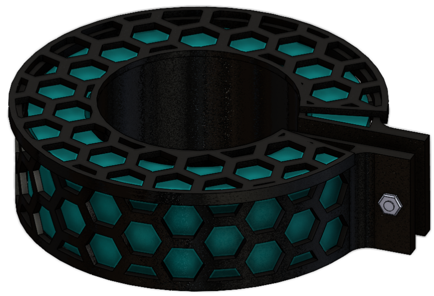


Figure 4: Foam Float Enclosure

The implementation of the foam float in the final design of the transit buoy is contingent on the buoyancy provided by the final components. While the buoy may inherently possess sufficient buoyancy, the design of the foam float is still interesting enough to be noted upon.

This float features a unique design with hexagonal holes in its 3D-printed structure, allowing it to securely clamp around the buoy. It is tailored to accommodate a standard pool noodle, which fits snugly when one of its edges is cut and scores are made along its inner side to adjust for the buoy's increased external diameter. The foam float is attached to the buoy's exterior through friction, which is facilitated by the normal force exerted by a screw and nut on either side of the two flanges that protrude from its cylindrical shape. This design ensures that the foam float, if required, can be easily and securely attached to enhance the buoy's buoyancy.

### 3.4 Internal Electronics

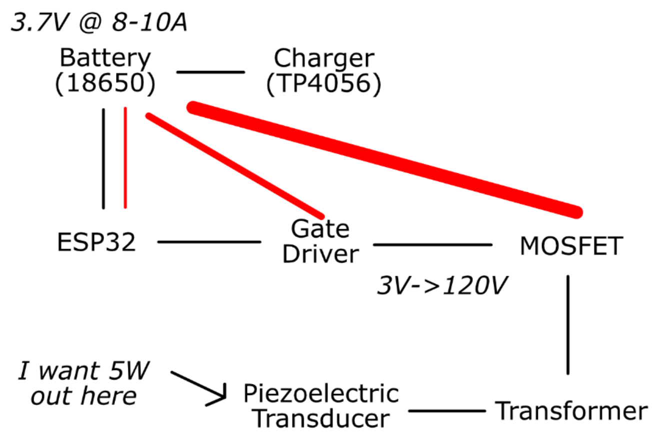



Figure 5: Internal Electronics

A full selection of components and circuitry are done for this board, but the PCB layout still has to be done. This design draws inspiration from the transmit board used in our previous submarine, Polaris, but incorporates two significant modifications.

Firstly, the information transmission source has shifted from the submarine itself to a Wi-Fi signal. To accommodate this, the microcontroller within the system has been replaced with an ESP32 board, known for its capability to receive wireless signals. This change necessitates adjustments in the communication protocol and specifications.

Secondly, the power source has been altered to a single 18650 battery, which presents a challenge in achieving high voltages. Unlike our previous setup in Polaris, where the transmit board received both a 3.3-volt line for data and a 12-volt line for power, the 18650 battery typically outputs 3.7 volts under normal conditions. Amplifying this to the required 120 volts will be a complex task, requiring a more intensive design and likely the incorporation of a voltage multiplier. Despite these challenges, the current design anticipates that the battery will provide sufficient power to operate the entire buoy system.

# 4 Current Status

## 4.1 End of FA23 Semester

To date, this semester's work on the Transmit Buoy project has been thoroughly documented in this technical report. It encompasses a detailed understanding of the buoy's functionality, the development of a 3D model, and an in-depth examination of the three interdisciplinary components (mechanical, electrical, and software) necessary for the buoy's construction. The buoy will be machined and assembled next semester, as well as populated with electronics, and flashed with its software.

## 4.2 End of SP24 Semester

As of the end of this school year, the enclosure has been fully machined, and when the cable penetrator and the ball valve is installed, is not fully leak proof due to the o-ring groove on the bottom being too shallow to fully fit a 2XX sized o-ring. However the top endcap has been completed to an acceptable leak-proof standard. The schematic for the internal electronics has also been made, integrating the esp32 and the rest of the DAC circuitry into a single board, while basic PCB routing has also been completed.

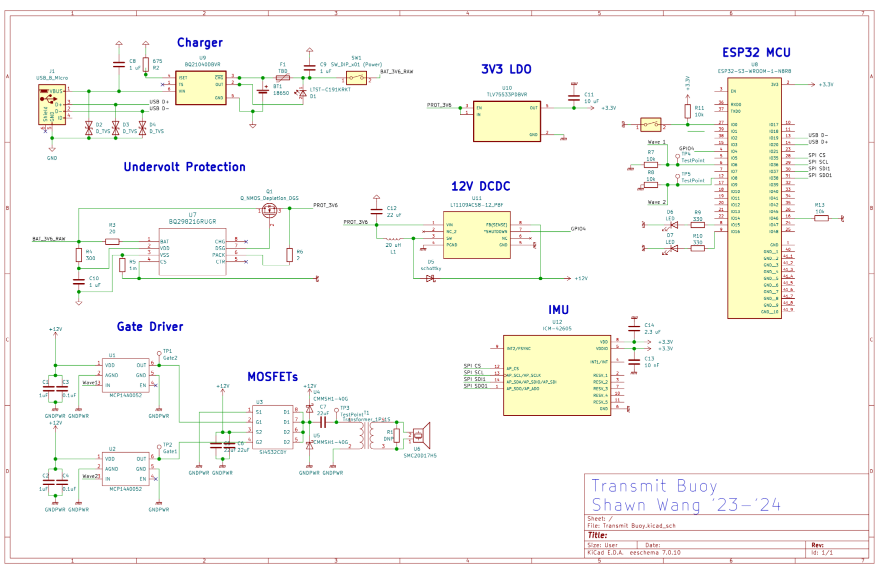



Figure 6: Full Schematic

# 5 Future Improvements

## 5.1 End of FA23 Semester

Looking ahead to the next semester, as I will be engaged with this project for the entire year, significant progress is anticipated. The immediate next steps involve advancing the electronic aspect of the project. This includes finalizing the selection of components and designing the layout of the PCBs. The goal is to complete this phase by mid-February, followed by placing orders for the PCBs, assembling, and testing them.

Subsequent efforts will focus on integrating these components into the buoy, ensuring everything is correctly set up internally, and testing the basic functionality of the pinger and other features. I aim to resolve all physical aspects of the project by late March.

In the remaining time, the focus will shift to developing a fundamental version of the software, albeit basic, which aligns with the project's scope and the one-year timeline. This software development will require closer collaboration with the software team to incorporate their desired functionalities into the buoy. Despite the ambitious nature of this project, the workload and goals set for the year seem achievable.

## 5.2 End of SP24 Semester

At this point, I personally have reached as far as I am willing to work on this project, and will no longer be further pursuing improvements towards it, both given a lack of will and also a lack of knowledge. The bottom endcap needs some clever machining to be done to get completely fixed, as there no longer exists enough clearance for the lathe to grab on to in order to deepen the O-ring groove using traditional machining practices. The PCB layout has also been attempted, but has enough errors inside of it that it may be worth it to start over. Prelimiary software has also been attempted, but no testing has been done. Otherwise, if any future member of the team is interested in picking up the project, I would be more than willing to share all files that I have made so far, and the general vision of the project, but I am also willing to shelve the project.

# 6 Interdisciplinary Difficulties and Reflections

## 6.1 End of FA23 Semester

As this is the first interdisciplinary project undertaken by an individual on our team in quite some time, several unforeseen challenges emerged. While some of these challenges may stem from my personal limitations as an engineer, they offer valuable insights for others who might undertake similar projects in the future and serve as a point of reflection for me.

Firstly, I realized that while I had not underestimated the amount of work required, I did underestimate my long-term motivation. This was partly due to a mindset that, since this project was not critical to the submarine's functionality, lagging behind in design progress was acceptable. However, this attitude proved counterproductive to meeting the one-year project deadline, underscoring the importance of acknowledging one's commitment at the outset of such endeavors.

The second major issue I encountered was a tendency to focus primarily on the aspects I was most familiar with, in my case, the mechanical system. This approach was somewhat narrow and could have led to significant setbacks. For instance, only recently did I confirm that the power consumption requirements for the project were feasible within the confines of the submarine. Had this not been the case, a complete redesign would have been necessary, wasting many hours of work. Additionally, the initial layout of the parts inside the buoy was based on approximations rather than a thorough understanding of the internal components, which could have led to inefficient design choices.

Despite these challenges, I am confident about completing the project by the end of the year. My motivation has been renewed, and I have overcome some of the more daunting aspects of the engineering process. A more comprehensive reflection and advice will be provided in the revised version of this technical documentation.

### 6.2 End of SP24 Semester

Looking back on my reflection from FA23, I unfortunately have fallen into the worst possible resulting case, and ultimately did not finish the project. Looking back on this whole process, I now definitely better understand my limitations as an engineer, and what scope of projects would better suit my skill set in the future. Overall, I believe the worst part of my mindset while creating this project boiled down to believing that my project did not provide any benefit to the team even if completed, and also not doing enough preliminary learning on what skills would be necessary before tackling the project.

As a whole, I can quite confidently say that I don't really regret taking on this project, as I did learn quite a lot both technically but also about myself through the whole process. The most controversial statement would be that I don't really regret my actions as well? I am definitely disappointed in myself for letting down the people around me and once again over-promising and under-delivering, but I think the word regret would entail that if I had a time-machine and could re-live the whole process, that I would trust in my ability to make things better this time compared to the last, which I really don't think I would be able to. I think this process has made me recognize that there are a lot more fundamental problems I need to solve with my engineering abilities before I tackle projects like this again.

# Appendices

## A Components To be Purchased

| **Component** | Qty. |
|---|---|
| 3.75” OD - 3.5” ID Acrylic Tube | 1 |
| 4.25” Diameter 1” Height 6061 Aluminum Stock | 2 |
| Piezo-electric cylinder | 1 |
| Blue Robotics 4.5 mm cable penetrator | 1 |
| TP4056 Charging Board | 1 |
| 2.4 GHz Antenna | 1 |
| ESP32 Micro-controller | 1 |
| 1/8” NPT Ball Valve | 1 |

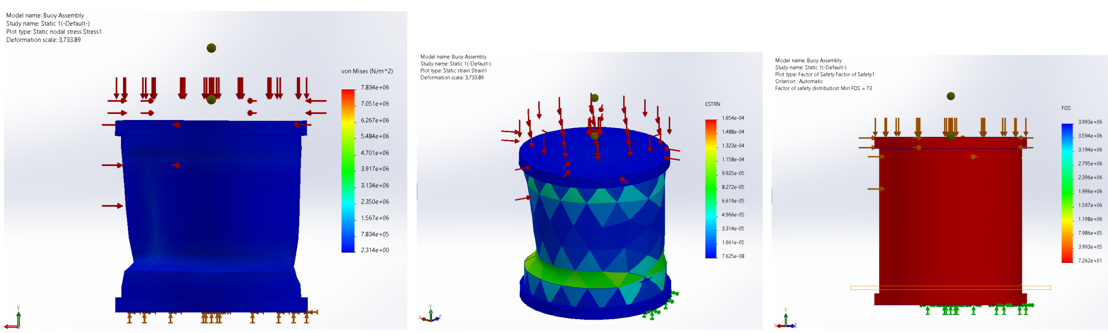
# B Finite Element Analysis

## B.1 Pressure Vessel Simulations

The outer hull of the transmit buoy consisting of acrylic and aluminum isn't subjected to any high forces in everyday operations, as the buoy floats. However, there is a possibility that we may want to fully submerge the buoy in order to test hydroaccoustic properties at the bottom of the pool. Therefore, I have run simulations to ensure that such functionality is still feasible within my design. I have run the simulation at 6 psi, simulating the buoy under 14 ft of water pressure.

Table 1: 14ft Analysis Data

| | |
|---|---|
| Max Stress (Aluminum) | 1.56e5 N/m$^2$ |
| Max Stress (Acrylic) | 4.23e4 N/m$^2$ |
| Factor of Safety | 7.26x |
| Max Deformation | 1.65e-4 in |




(a) Von-Mises Stress (b) Deformation (c) Factor of Safety

Figure 1: Transmit Buoy Pressure SolidWorks Simulation Results