ENG 102: Sink or Swim
Project 3: Mini-Submarine

Dang Hung Duong[1], Dinh Viet Hoang[2],
Nguyen Hoang Minh[3], Nguyen Quoc Hieu[4]

[1]220218, [2]220019, [3]210093, [4]210210

December 17, 2024

1 Submarine Design and Engineering Decisions

1.1 Conversion Process

To convert our boat into a submarine, we integrated several new components: a LORA with an antenna, a water pump, and a cylinder. We also constructed a base circuit to enhance underwater control using the LORA system, which was assembled quickly as it was separate from the main box.

1.2 Component Fitting Challenges

Fitting all components into the existing box from our previous project proved challenging due to space constraints. The pump and cylinder were particularly problematic, as the box could only accommodate one at a time. We drilled two critical holes—one for the pump's tube and another for an external waterproof power switch. These hole positions were crucial for optimal internal arrangement.

1.3 Adjustments and Improvements

Our initial plan to drill both holes on one side was impractical. We sealed one hole with UV glue and relocated the switch hole to the back for better space management. Additionally, the 10ml cylinder was insufficient to submerge the submarine, necessitating an upgrade to a 60ml version. This larger cylinder, being waterproof, was mounted externally. We drilled a hole in the submarine's roof to connect the cylinder to the pump and secured all holes with UV glue.

1.4 Internal Configuration

Inside the box, we positioned the pump at the rear near the main motor hole, routing tubes to the left side and top. The battery was placed at the bottom, with the main circuit and LORA stacked on top. Despite the functioning pump, the submarine wouldn't sink due to insufficient weight. We finally achieved submersion by attaching a bag of weights to the bottom, enabling the submarine to submerge when the cylinder filled with water.

In summary, converting our boat into a mini-submarine involved strategic component placement and overcoming spatial constraints. By upgrading the cylinder and managing weight distribution, we successfully created a functional submarine capable of controlled submersion. Therefore, this project provides valuable insights for future underwater vehicle designs.

2 Circuit Diagram

2.1 Submarine Circuit

The components needed for the submarine's circuit are:

- LORA SX1278 with Antenna: Allows for long-range wireless communication, enabling remote control and data transmission for the submarine.
- Peristaltic Pump: Used for precise fluid movement, aiding in controlling the buoyancy of the submarine by pumping water in and out of the cylinder.
- Cylinder: Stores water to adjust the submarine's buoyancy. The pump and cylinder system allows the submarine to submerge and resurface by changing its volume and weight.
- ESP-WROOM-32: A powerful microcontroller with Wi-Fi and Bluetooth capabilities. It is the brain of the system, processing sensor data and controlling motors to maintain stability and achieve navigation goals.
- 2 DC Motors: Provide the boat's movement.
- Dual Channel H-Bridge (MX1508): Controls the direction and speed of the DC motors. By adjusting voltage, it makes motors move forward, backward, or stop.
- 2 DC Voltage Step Down Modules: A 5V module powers the MX1508, while a 3.3V module powers the ESP-WROOM-32 and BNO055 sensor. These ensure components operate within their required voltage range.

- BNO055: An absolute orientation sensor providing data (tilt, rotation, heading) to the ESP-WROOM-32. This data is essential for stable navigation, allowing the system to adjust motor speeds and directions to maintain balance and follow the desired path.
- Power Supply with 3 Batteries and 3S Protection Board (12.6V 20A): Provides energy to all components. The protection board ensures safe battery charging and discharging, preventing overcharging, over-discharging, and excessive current draw.

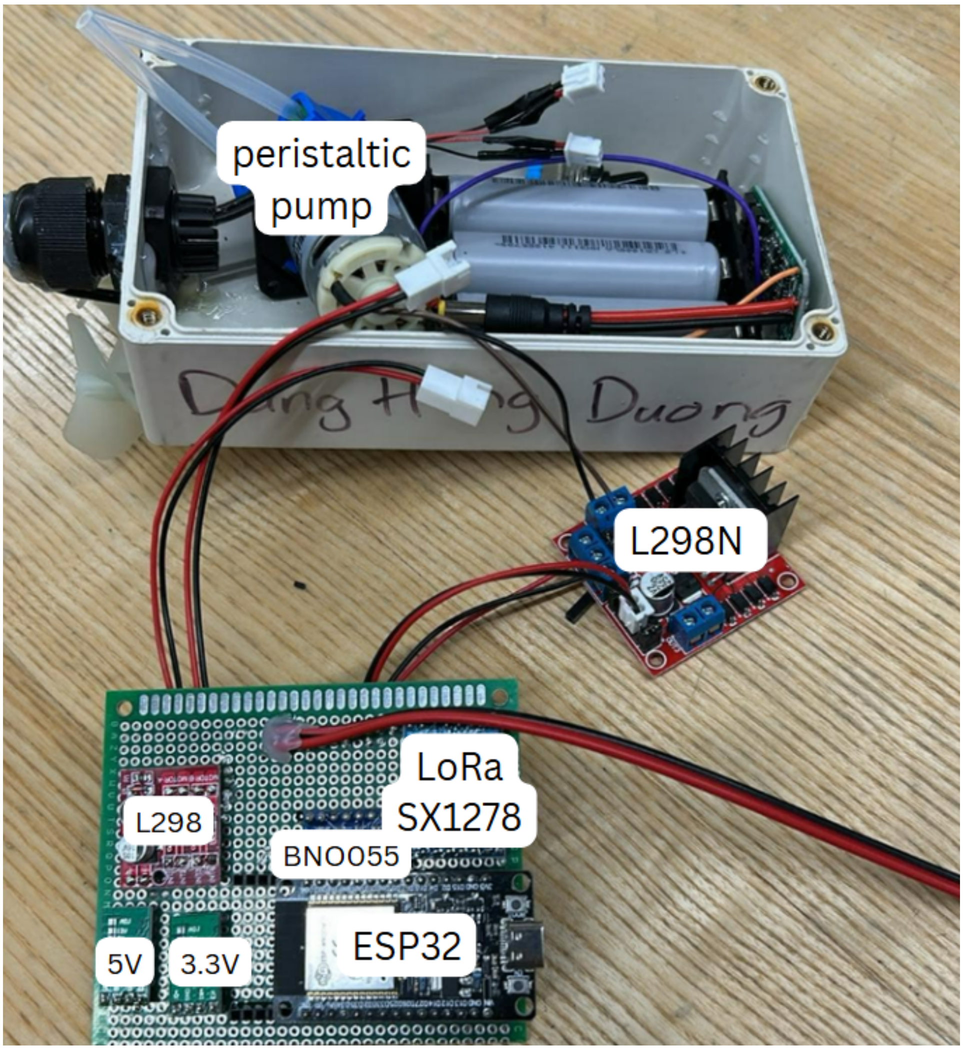

Figure 1: Submarine Circuit Connections

2.2 Base Circuit

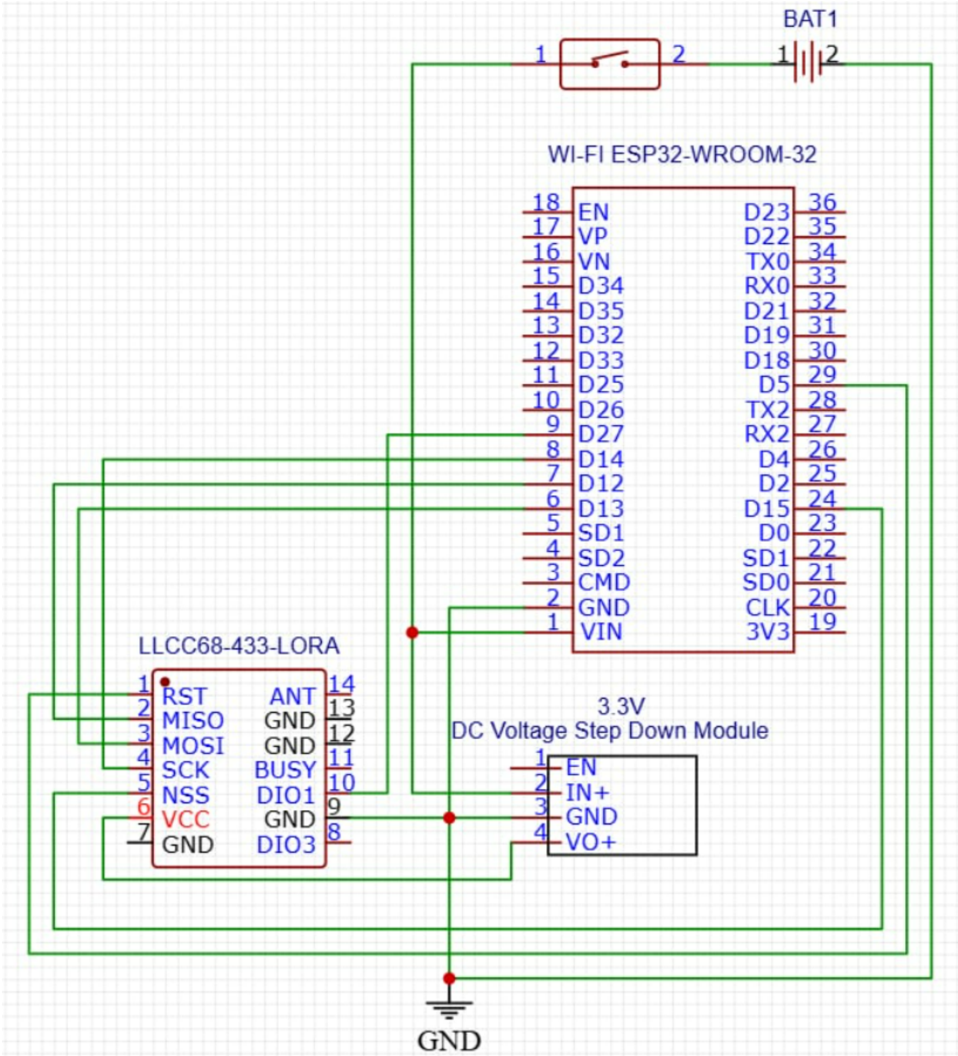

Figure 2: Base Circuit Diagram

3 Model Prediction and Real-World Testing - Physics and Control Aspect

3.1 Physical Quantities and Constants

3.1.1 Constants

- Drag Coefficient (C_d): 0.66
- Buoyant Force (F_b)
- Fluid Density (ρ): $1000\,\mathrm{kg/m^3}$ (for freshwater)
- Gravitational Acceleration (g): $9.81\,\mathrm{m/s^2}$
- Mass of the Submarine (m):
  - Sinking: 0.88 kg, including 0.675 kg (submarine body), 0.205 kg (lead ballast), and 60 ml of water in the cylinder
  - Rising: 0.82 kg, including 0.675 kg (submarine body) and 0.205 kg (lead ballast)
- Cross-sectional Area (A): $0.0054\,\mathrm{m^2}$
- Volume of Submarine (V): $0.000864\,\mathrm{m^3}$

3.1.2 Other Physical Quantities

- Time (t): Duration of sinking and rising
- Acceleration (a): Derived from net force
- Velocity (v): Submarine's instantaneous velocity
- Depth (d): Distance traveled by the submarine
- Drag Force (F_d): Resistance due to fluid

3.1.3 Formulas Used

- Net Force during Sinking:

$$F_{\text{net sinking}} = F_b - F_g - F_d$$

- Net Force during Rising:

$$F_{\text{net rising}} = F_b - F_g - F_d$$

- Gravitational Force (F_g):

$$F_g = m \cdot g$$

- Buoyant Force (F_b):

$$F_b = \rho \cdot g \cdot V$$

- Drag Force (F_d):

$$F_d = 12 \cdot C_d \cdot \rho \cdot A \cdot v^2$$

- Newton's Second Law:

$$F_{\text{net}} = m \cdot a$$

  Where a can be calculated as:

$$a = \frac{F_{\text{net}}}{m}$$

3.1.4 Assumptions

- The drag coefficient (C_d) remains constant for both sinking and rising phases.
- The submarine's motion is predominantly vertical, with negligible horizontal displacement.
- The water is treated as an incompressible fluid with uniform density ($\rho = 1000\ \text{kg/m}^3$).
- The submarine's shape and surface area remain consistent during sinking and rising.
- External factors like turbulence and rotational motion are ignored.

3.2 Modeling

3.2.1 Sinking

Using the formulas above, the model predicts that the submarine accelerates downward due to the difference between buoyant and gravitational forces, countered by drag.

The calculated sinking time was **1.62 seconds** to reach a depth of **1.024**

meters, while the actual observation indicated **30.25 seconds** to sink **0.12 meters**. The significant discrepancy may stem from underestimating drag and real-world resistances.

1,62	-24,383545667	-3,441376948	-1,024486828	21,104360187	-21,457520187

Figure 3: Sinking

3.2.2 Rising

During the rising phase, buoyant force exceeds the combined effects of gravity and drag, leading to upward acceleration.

The model predicted the submarine would rise to its original depth in **2.3 seconds**, while the experimental result showed it took **3.21 seconds** to rise the same distance. This deviation could be due to additional resistances not captured in the simplified model, such as turbulence or uneven weight distribution.

2,3	0,003562482	0,361222799	0,001222332	0,232518765	0,002921235

Figure 4: Rising