

## 1 Vertical Profiling Float

### 1.1 Mechanical Design

The float, shown in Fig. 1, is constructed from high-density polyethylene (HDPE) plates housing a sealed 60 ml syringe, operated by a 70-RPM DC motor with a torque rating of 35 kg.cm. By rotating the motor in a specific direction, the motor can overcome 4 m of water column pressure and draw or push water from the syringe. For the new requirement, an HDPE handle is designed to make the recovery of the float easier and faster. The floating enclosure is sealed using two flanges with radial O-rings. The assembly includes a 500 mm long acrylic cylinder with a 101.6 mm diameter, an upper flange with a 155 mm diameter, and a bottom flange connected to two AGRO glands for a complete seal and proper cable routing. A plug located in the bottom flange ensures that pressure inside the housing is released if it is higher than outside. A pressure sensor is mounted near the bottom flange to monitor the float depth underwater. This design ensures precise control of the buoyancy and depth of the float in underwater applications while maintaining a sealed and efficient system.

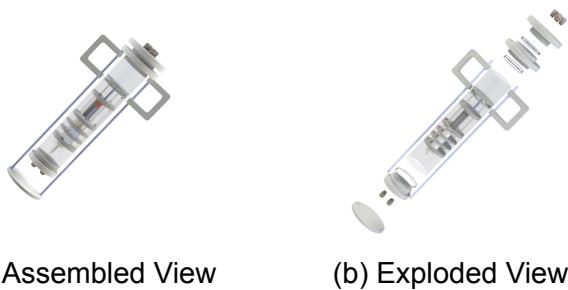


Fig. 1: Vertical Profiling Float.

The resistance force acting on the float is the sum of its gravitational force, with a mass of 7 kg, and the pressure force of the water at 4 m pressure head, resulting in a total force of 808.27 N, calculated using (1).

$$F = m \times g + \rho \times g \times h \times A \quad (1)$$

**where:**  $F$ : Total force,  $m$ : Mass of float,  $\rho$ : Water density,  $g$ : Gravitational Acceleration,  $h$ : Pressure head,  $A$ : Area of upper flange.

A power lead screw is used to convert the rotational motion to linear motion, as given in (2).

$$\frac{F \times D_m}{2} \times \frac{\pi \times D_m \times f + L}{\pi \times D_m - f \times L} \quad (2)$$

**where:**  $F$ : Total force,  $D_m$ : Screw Mean Diameter,  $L$ : Stroke length,  $f$ : Coefficient of friction.

The following coefficients were identified from the lead screw datasheet using the provided standard values.

Torque required =

$$\frac{0.80827 \times 7}{2} \times \frac{\pi \times 7 \times 0.19 + 8}{\pi \times 7 - 0.19 \times 8} \times \text{Safety factor}(1.5)$$

$$= 1.68 \times 1.5 = 2.52 \text{ N.m}$$

Equivalent to a 25.7 kg.cm motor.

### 1.2 Electrical Design

#### • Electrical System

The electrical system of the float, shown in Fig. 2, is provided with an MS5540C pressure sensor, which is used to measure its depth, and a magnetic encoder module mounted above the power screw to track the syringe position, which corresponds to the amount of water taken in by the float. The board provides robust power regulation, efficient distribution, and signal control, ensuring reliable performance for its vital functions.

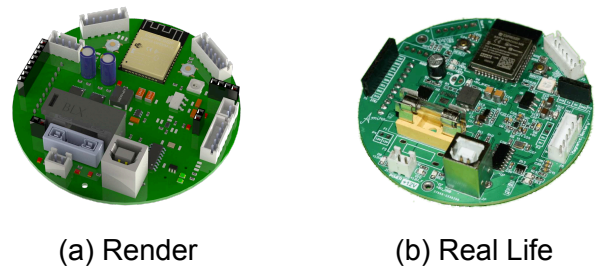


Fig. 2: Float Electrical System.

The ESP32 microcontroller manages the signal data from the pressure sensor, which measures absolute pressure. The float's depth relative to the water surface is determined using (3).

$$\text{Depth} = \frac{P}{\rho \times g} \quad (3)$$

**where:**  $P$ : Pressure,  $\rho$ : Water density,  $g$ : Gravitational Acceleration.

The measured depth is displayed on the Graphical User Interface (GUI) via a web server hosted on the microcontroller, accessible through its internet protocol (IP) address over a wireless local area network (WLAN). The ESP32 is also connected to



two limit switches that indicate the operating limits of the syringe.

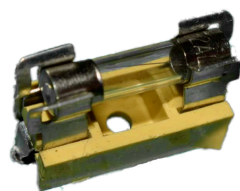
The float incorporates a red-green-blue (RGB) LED that indicates the current state of the float, whether it is ascending, descending, or holding, and also indicates if the float moves outside the defined threshold where it is supposed to remain stable.

## ► Float Power Calculations

A 12 V, 2500 mAh NiMH AA battery pack, shown in Fig. 3a, was chosen, according to **ELEC-NRD-003**, to power the float's electrical system, shown in Table 1. To account for potential variations and ensure the safety of the system, a 2 A cartridge fuse, shown in Fig. 3b, which is installed within 5 cm of the positive battery terminal, was selected based on the float's full load amps (FLA) calculation, which was 1.07 A.



(a) Battery Pack



(b) 2 A Fuse

Fig. 3: Electrical System Power Supply.

Table 1: Power Calculations.

| Component        | Operating Voltage (V) | Max. Current (A) | Quantity | Consumed Power (W) |
|------------------|-----------------------|------------------|----------|--------------------|
| DC Motor         | 12                    | 1                | 1        | 12                 |
| ESP32            | 3.3                   | 0.26             | 1        | 0.858              |
| Pressure Sensor  | 3.3                   | 0.001            | 1        | 0.0033             |
| Magnetic Encoder | 3.3                   | 0.02             | 1        | 0.066              |
| RGB LED          | 3.3                   | 0.01             | 1        | 0.033              |
| <b>Total</b>     |                       |                  |          | <b>12.9603</b>     |

## ● PID Depth Control System

This year, the system was upgraded with a depth-hold PID controller loop to achieve precise depth stability for extended periods. The new PID approach uses a magnetic encoder, which detects motor rotation to act as feedback and an indicator of syringe position, which gives the PID the ability to control the float motion, hold its position, and state in water precisely. By controlling the motor using this PID approach, the float is able to conveniently change its states, which are floating, sinking, and suspended. This new approach actively compensates for disturbances such as water currents and pressure changes, maintaining the target depth within a tight tolerance

band and meeting this year's requirement for sustained depth-holding. By determining the float's suspended point, the autonomous float has precise depth-locking capabilities after navigating to desired depths of 0.4 m and 2.5 m. The mission's profile requires the vehicle to hold at each depth for a duration of 30 seconds, with the entire sequence undergoing two full profiles or iterations.

The PID controller loop is responsible for delivering the float to its upper and lower setpoints. Moreover, it is responsible for returning the device to the required depth if it deviates from the required threshold during holding time. The PID controllers operate using the standard PID time-domain equation as in (4).

$$u(t) = K_p * e(t) + K_i \int_0^t e(\tau) d\tau + K_d * \frac{de(t)}{dt} \quad (4)$$

**where:**  $u(t)$ : Controlled output to the syringe motor,  $r(t)$ : Desired setpoint,  $y(t)$ : Measured value,  $e(t)$ : Instantaneous error (  $e(t) = r(t) - y(t)$  ),  $K_p$ ,  $K_i$ ,  $K_d$ : Tuning gains.

## ► Float PID Parameters

The PID loop uses three key terms for precise depth control: the proportional term (**Kp**) responds proportionally to immediate depth errors; the integral term (**Ki**) corrects steady-state errors by accumulating small errors over time and gradually adjusting buoyancy; and the derivative term (**Kd**) acts as a damping force that reduces rapid changes by predicting future errors based on the rate of depth variation to prevent overshoot and oscillations that occur often due to the risk of **Kp** and **Ki** aggressive values.

## ► Data Retrieving

The vertical profiling float is able to initialize a connection with the station's GUI using WebSocket. Firstly, a start signal is sent from the station's GUI, which acts as a WebSocket client to the ESP32's WebSocket server to start its mission efficiently. When the float has finished its mission and successfully finished two vertical profiles, the WebSocket client working on the station GUI will receive float's data from the WebSocket server working on the ESP32 quickly and accurately, which includes float's status, team code, accumulated pressure, accumulated depth, and the time of every packet.





## 2 Non-ROV Device SID

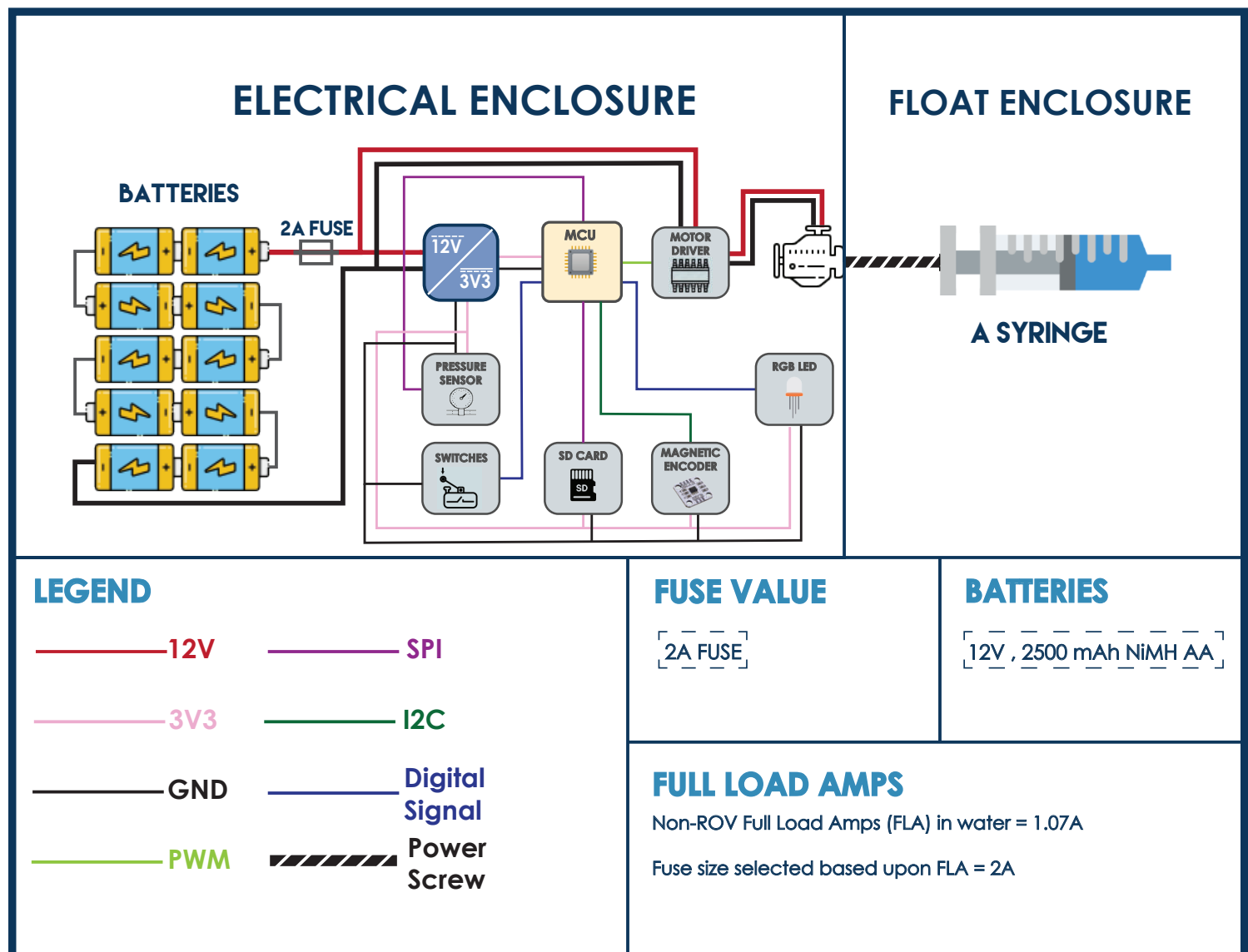


Fig. 4: Float SID.

