



CHITHI: The Explorer's Note

(Phonetic: CHEE-thee | Meaning: A Letter or Written Message)

System Concept of CHITHI

In the vast and harsh environment of polar waters, data is the most precious cargo. We named our float 'CHITHI' (the Bengali word for a 'Letter') to embody the essence of a silent messenger. Just as a handwritten letter carries personal thoughts through distance and remains sealed until it reaches the right hands, our float is engineered to collect oceanographic secrets under the ice, keeping them safe and 'unread' until it is recovered and ready to transmit its mission 'note' to the station.





1. Mechanical Engineering

The design structure of Chithi is determined by stringent zone-based approach to weight grading. The float is partitioned into three zones depending on the weight of the components. The heaviest components with high densities are located at the lowest level of the structure (Zone C), while the lighter components with low densities are situated in the middle and upper levels (Zones A and B). This deliberate arrangement of weights keeps the vertical position of the Center of Gravity (CG) as low as possible, while the Center of Buoyancy (CB) remains high gives hydrostatic Stability(Maximizing CB to CG distance)

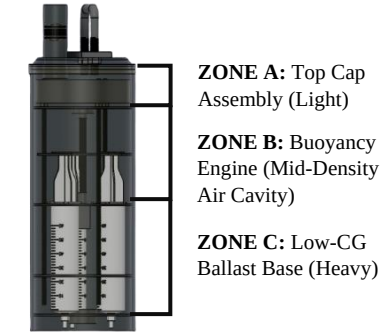


Figure 1: Weight-Graded Zonal Segmentation.

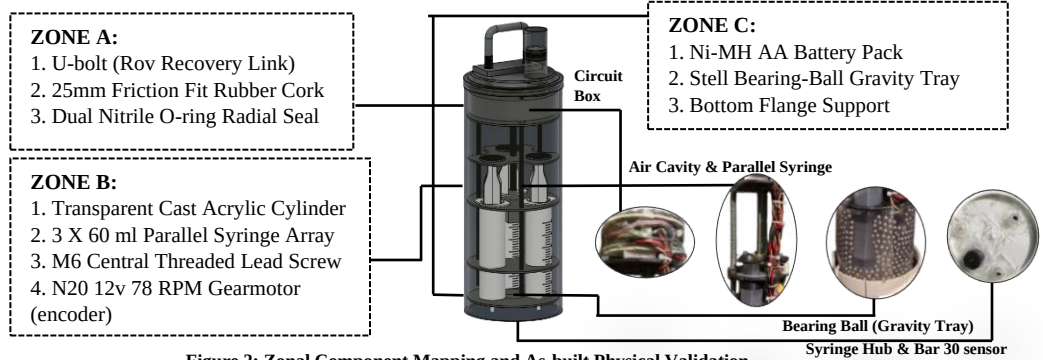


Figure 2: Zonal Component Mapping and As-built Physical Validation.

1.1 Physical Specifications & General Arrangement

The cylindrical clear-acrylic pressure hull houses the electronics stack, battery pack, and buoyancy engine end-to-end, with the depth sensor and homing switch terminating one endcap and the recovery hook integrated into the opposite endcap.

Parameter	Specification
Height	13 in (0.3302 m)
Diameter	4.2 in (0.1067 m / 10.67 cm)
Weight in Air	2.8 kg
Housing Material	Clear Cast Acrylic Tube
Recovery Hook	≥ 5 cm protrusion, ≥ 5 cm transverse width
Buoyancy Method	Volumetric (3 × 60 mL syringes, M6 leadscrew)

Table 1: Technical Specifications.

1.2 Buoyancy Engine Design & Sizing

Chithi uses a Volume Displacement Buoyancy Engine built around an N20 12 V 78 RPM Micro Metal Gear Motor driving a central M6 threaded leadscrew. The leadscrew translates a common piston-yoke that simultaneously actuates three 60 mL syringes wired in mechanical parallel. Extending all three syringes increases displaced water volume; retracting them decreases it. The motor is commanded by a TB6612FNG H-bridge with closed-loop position feedback from an N20 quadrature encoder (channels on GPIO 21 / GPIO 47).

Parameter	Value / Calculation	Description
Water Density (ρ_{water})	1025 kg/m ³	Density of polar water.
Float Mass (m)	1.85 kg (Sizing Ref) / 2.8 kg (As-built)	Mass of the float
Neutral Volume (V_{neutral})	≈1805 mL (m / ρ_{water})	Displaced volume required for neutral buoyancy (for the 1.85 kg)
Volume Authority (ΔV)	180 mL (3 X 60 mL)	Total volume adjustment, providing roughly ±10% control authority.
Max Net Force (F_{net})	≈ 1.81 N ($\rho_{\text{water}} \cdot \Delta V \cdot g$)	Net force generated at full extension.
Terminal Drag (F_d)	≈ 0.15N	Steady-state drag at a terminal velocity of 0.15 m/s ($C_d \approx 0.9$, $A \approx 0.0089 \text{ m}^2$).

Table 2: Sizing Parameters & Calculations.

1.3 Environmental Sealing & Pressure Relief

Parameter / Event	Value / Result	Analysis
Worst-Case Simulation	Peak Endcap Force ≈654 N	Derived by integrating the worst-case stall current over the projected stall duration and applying Boyle's Law to the trapped air.
Plug Calibration	Release load << 654 N	The 2.5 cm friction-fit plug is dimensioned to pop open well below the load required to displace or compromise the main structural endcap.

Table 3: Verification Parameters & Forces.

2. Electrical Engineering, Power & Communication

2.1 Onboard Power Supply & Chemistry

Chithi's battery architecture complies with rule **ELEC-NRD-003**. The pack is a 6 V 5600 mAh Ni-MH AA in 5S2P configuration (five 2800 mAh cells in series for the 6 V nominal rail, two parallel strings doubling the usable capacity to 5600 mAh at the pack terminals).

2.2 Full Load Amperage & Fuse Determination

Fuse sizing was driven by Full Load Amperage (FLA) measurements taken across the three operating regimes that bracket worst-case current draw:

Fuse Justification:

In compliance with MATE rule **ELEC-NRD-003**, a 2.0 A ATO Fast-Blow Fuse was chosen to safely accommodate the 0.78 A peak nominal draw and motor inrush, while ensuring immediate cut-off during a 1.5-2.0 A stalled N20 motor event to protect all internal electronics.

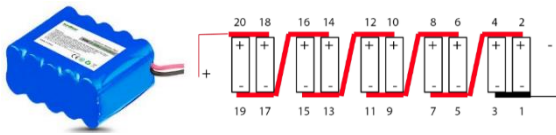


Figure 3: NiMH Battery Pack(5S2P).



Figure 4: 2amp ATO standard Regular Fuse.

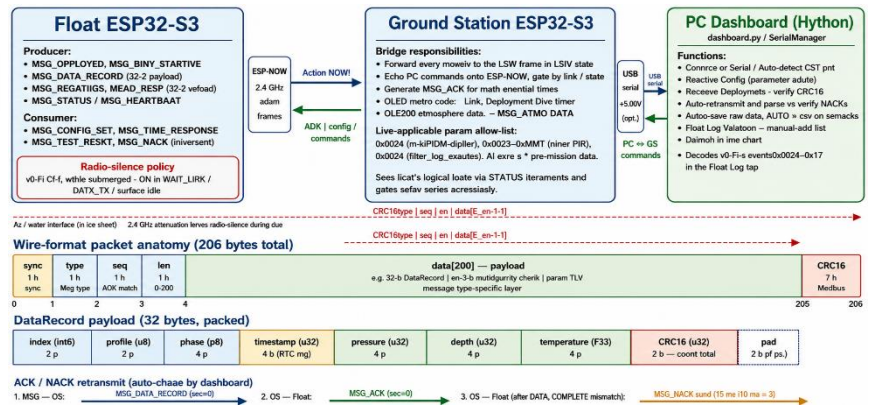


Figure 5: ESP-NOW Communication Protocol.

3. Control Systems & Software Logic

3.1 Positional Cascade PID Architecture

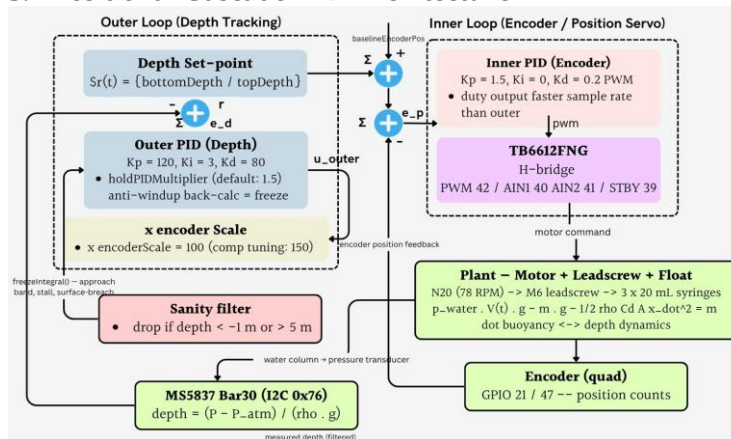


Figure 6: PID flow diagram.

3.2 Finite State Machine (FSM) & Operations Flow

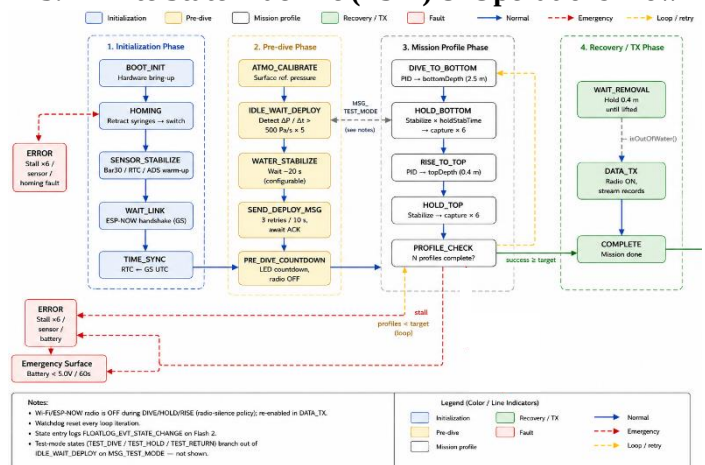


Figure 7: Finite State Machine.

The PID controller structure used for Chithi's automatic depth control is presented in Fig. 3.1. In this controller, the outer depth loop provides position references to the inner loop, which controls the motor movement via PWM feedback. Fig. 3.2 represents the FSM that controls the entire sequence of operations, including deployment detection, profiling, maintaining depth, recovery, and data transmission over radio. Collectively, these two sub-systems form an integrated control system in which the FSM manages overall tasks, and the cascade PID maintains constant buoyancy and depth of the float.

3.3 Fail-Safe Hierarchy & Emergency Override Systems

Priority Level	Fail-Safe System	Trigger Condition	Override / Recovery Action
1 (Highest)	Surface Safety Overrides	Breach: Depth ≤ 0 m. Soft Thresholds: Warning, Danger, and Min-Safe-Depth bands	Breach: Discards PID; commands emergency sink at PWM 220 .
2	Motor Stall Recovery	< 8 encoder counts within a 200 ms sampling window while motor is active.	Asserts freezeIntegral(true) and drives the H-bridge at full PWM for 500 ms . Permits up to 5 sequential recovery attempts; a 6th fault forces <code>STATE_ERROR</code> .
3 (Lowest)	Battery Low-Voltage Ascent	• Battery voltage drops and stays below 5.0 V for 60 seconds	• Aborts the mission. Commands buoyancy engine to full extension for emergency surfacing. Broadcasts <code>MSG_BATTERY_LOW</code> via ESP-NOW once radio is online.

Table 5: Safety Hierarchy.

Float System Integration Diagram (SID)

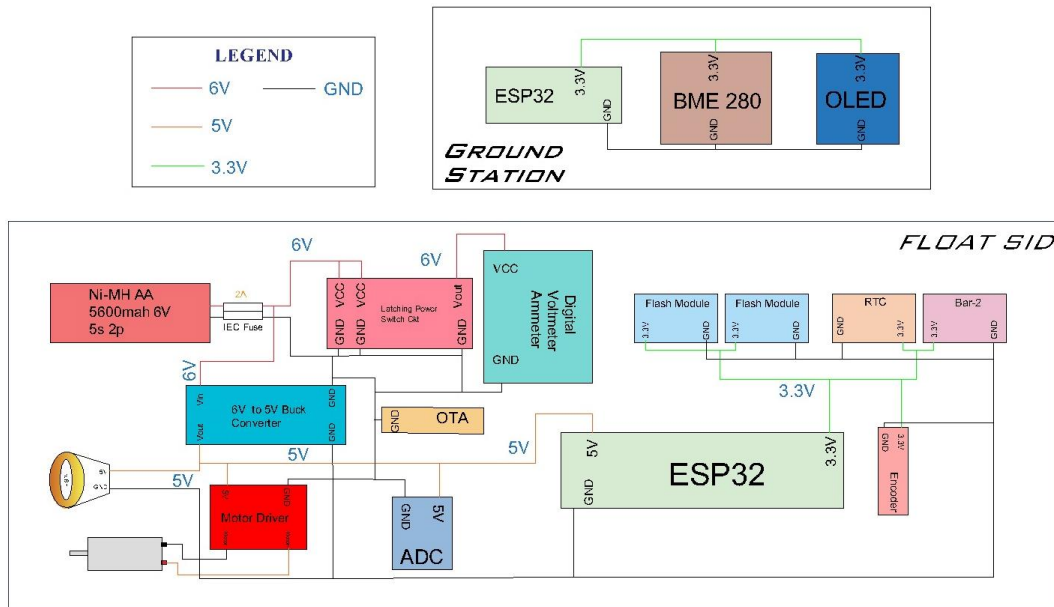


Figure 1: Electrical SID.

Float Power Calculation (Full load amps fuse measurement)

Float						
Components	Model	quantity	Voltage(V)	Current(A)	Power Per Unit(W)	Total Power(W)
Controller	ESP32 S3 DevKitC1 N16R8	1	5.0	0.5	2.500	2.500
Pressure Sensor	Bar30	1	3.3	0.00125	0.004125	0.004125
ADC	ADS1115	1	3.3	0.0003	0.00099	0.00099
Motor	N20 12V 78RPM encod	1	6	1	6	6.00
Flash Memory	W25Q64	2	3.3	0.025	0.0825	0.165
LED Module	WS2812 5050 RGB	1	5.0	0.05	0.25	0.25
RTC	DS3231 AT24C32	1	3.3	0.00365	0.012045	0.012045
Panel Meter	DC 0-100V 100A Dual LED meter	1	5	0.06	0.3	0.9
						9.83

Total **current(A)** = Total power/Voltage(V) = **9.83w/6V = 1.64A**

Ground Station						
Components	Model	quantity	Voltage(V)	Current(A)	Power Per Unit(W)	Total Power(W)
Controller	ESP32 S3 DevKitC1 N16R8	1	5	0.5	2.500	2.500
Temperature Sensor	GY-BME 280	1	3.3	0.001120	0.0036	0.0036
Display	0.96-inch I2C OLED	1	3.3	0.03	0.099	0.099

Total Current for Float main part (A) = 1.638A

Current for Ground Station (A) = 0.2213A

Thus, we will need only a 2A fuse.