Aqua-Bot User Manual

Model: Version1.0

IoT-Enabled RC Boat for Automated Water Sampling

Contents

Abstract

Manual provides comprehensive instructionsfor thesetup, operation, and maintenance of your Aqua-Bot, a custom web-controlled surface vessel designed for remote water collection and environmental monitoring.
The Aqua-Bot is built using durable PVC components, powered
by a high-capacity LiFePO4 battery system, and utilizes a suite of sensors for navigation, power management, and real-time visual feedback, all accessible through its onboard web server.

1.1 System Overview

The **Aqua-Bot** is an innovative, custom-built robotic catamaran designed for precise water sampling and navigation. The entire vessel structure is fabricated from **PVC pipe and fittings**. Its core functions are controlled remotely through a web interface hosted directly on the onboard Raspberry Pi server. The primary function is to remotely collect water samples into dedicated sample bottles secured in **3D-printed holders**.

1.2 Key Features

- **Construction Material:** Fully constructed from **PVC** (Polyvinyl Chloride).
- **Water Sample Collection:** Internal enclosure includes **3D-printed holders** for secure mounting and easy removal of sample bottles.
- **Main Controller:** Raspberry Pi.
- **Propulsion:** Two **12–24V DC Underwater Thrusters** (CW/CCW) controlled by **30A–40A Brushless ESCs**.
- **Power System: 12.8V (4S) 20Ah LiFePO4** battery managed by a **4S 60A BMS**.
- **Charging: 12V/24V 30A Solar Charge Controller** for both charger and future solar panel integration.
- **Power Distribution:** Custom PCB with **fusing**, **power switch**, and two **buck converters** (5V and 3.3V).
- **Camera Control:** Two **Servomotors** (pan/tilt) to remotely control the Pi Camera view angle.
- **Sensors and Actuators:** GPS Module, Pi Camera, INA3221 Sensor, Gyro Sensor, and four 5V Water Pumps controlled by a 4-Channel Relay.
- **Interface:** A web application for control and real-time data display.

1.3 Safety Guidelines

S.1 Water and Electronics: Ensure the main enclosure is securely sealed and water-tight before deployment.

S.2 Battery Handling: Monitor the INA3221 readings. Charging of the **LiFePO4 battery (12.8V)** must only be performed through the approved **Solar Charge Controller**.

S.3 Fusing: The custom PCB includes a main fuse for safety. Check the fuse if the system fails to power on.

S.4 Propulsion Safety: Ensure the thrusters are disabled when handling the Aqua-Bot out of the water. Keep hands clear of propellers.

S.5 Power Off: Always use the main power switch on the Custom PCB to safely power down the system after use.

2.1 Vessel Construction and Structure

The Aqua-Bot utilizes lightweight, durable, and corrosion-resistant **PVC pipe and fittings** for its hull structure, providing excellent buoyancy. The main enclosure contains custom **3D-printed holders** to stabilize water sample bottles, allowing for quick and secure insertion and removal after collection.

2.2 System Modules and Core Components

2.2.1 Power and Charging System

- **Main Battery: 12.8V (4S) 20Ah LiFePO4** battery pack provides primary power.
- **BMS:** A dedicated **4S 60A BMS module** protects the LiFePO4 pack against over-charge, over-discharge, and short-circuit.
- **Charging Controller:** A **12V/24V 30A Solar Charge Controller** manages battery charging and is used for both external wall charging and future solar panel integration.
- **Custom Power PCB:** This board includes the main system **on/off switch**, a safety **fuse**, and two integrated **buck converters** to supply clean **5V** (for RPi/Pumps) and **3.3V** (for sensors).

2.2.2 Propulsion, Movement, and Actuation

- **Thrusters (2x):** Two **Underwater Jet Boat Thruster Engines** (12–24VDC, 20A max each, CW/CCW pair) for movement.
- **ESCs (2x):** Two **30A–40A Brushless ESCs** control the speed and differential steering of the thrusters via PWM signals from the Raspberry Pi.
- **Camera Servos (2x):** Two **Servomotors** provide remote **horizontal (pan)** and **vertical (tilt)** control over the Pi Camera view angle via web commands.
- **Water Pumps (4x):** Four independent 5V DC Water Pumps used for sample collection.
- **Relay Module:** A **4-Channel Relay Module** safely switches the high current to the 5V pumps using low-voltage GPIO signals.

2.2.3 Data Acquisition and Sensing

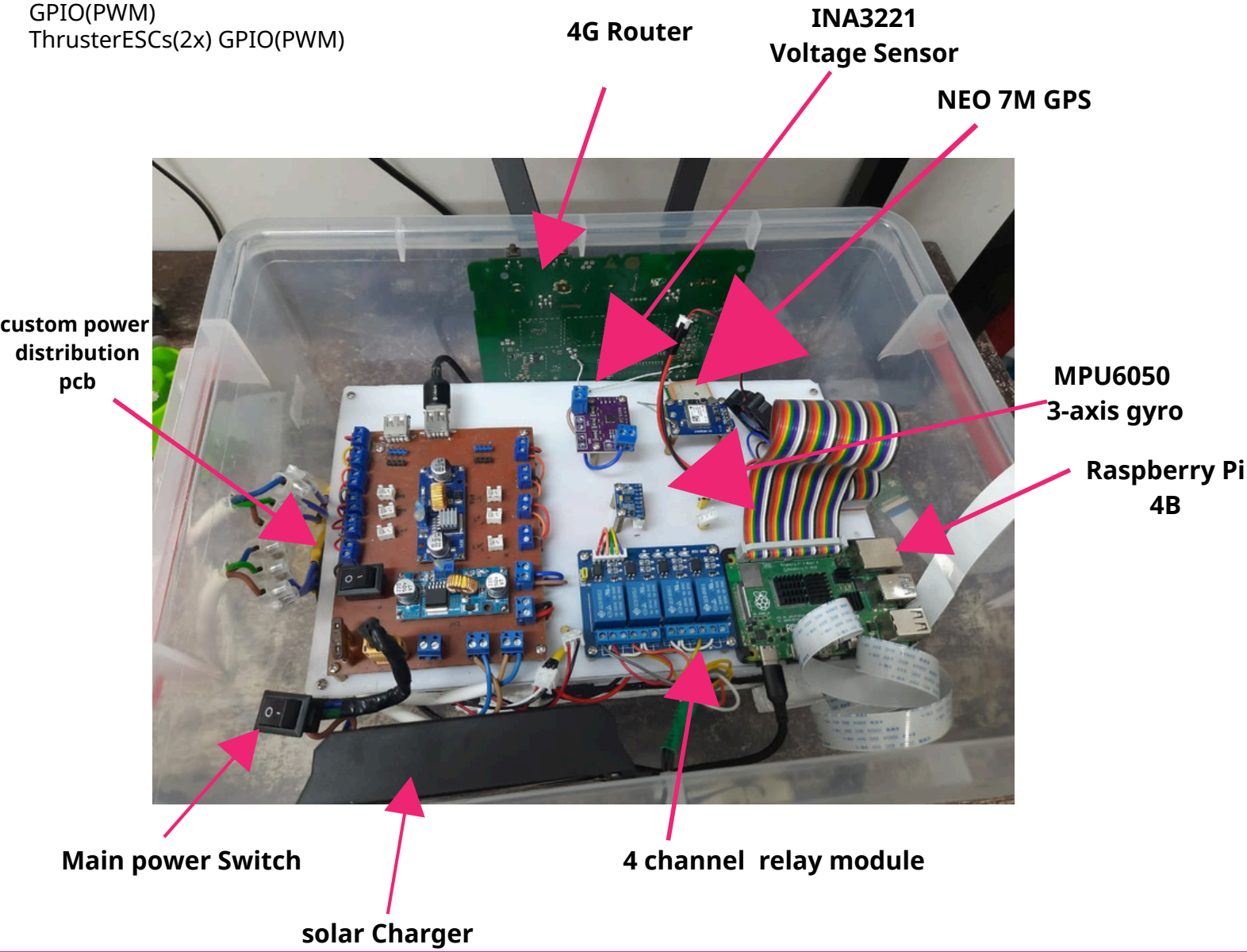
- **Main Controller:** Raspberry Pi (Central processing unit and web server).
- **GPS Module:** Provides latitude, longitude, and timing data.
- **INA3221 Sensor:** Measures **Bus Voltage** and **Shunt Current** for real-time battery status and power consumption monitoring.
- **GyroSensor:** Measures angular velocity and orientation (roll, pitch, yaw) for stability monitoring.
- **Pi Camera:** Streams real-time video to the web interface.

2.2.4 Interface Summary

Table 2.1: Essential Component Interfaces to Raspberry Pi

Component	PrimaryFunction
RaspberryPi	Control,DataLogging,WebHost
GPSModule	Location(°,°)
INA3221Sensor	BatteryV/A/%
GyroSensor	Orientation(Roll/Pitch/Yaw)
PiCamera	LiveVideoStream
CameraServos(2x)	Pan/TiltControl
4-ChannelRelay	MotorSpeedandDirection
GPIOPins(4total)	PumpON/OFFControl

PiInterface
Server/OS
UART(Serial)
I2C
I2C/SPI
CSIPort
GPIO(PWM)
ThrusterESCs(2x) GPIO(PWM)



Web Interface and Operation

The Raspberry Pi is configured to work as a web server, hosting the main control application, accessible from any device connected to the same network.

3.1 Server Access

W.1 Power On: Use the main **power switch on the Custom PCB** to activate the system. Wait for the Raspberry Pi to fully boot and start the web server service.

W.2 NetworkConnection: ConnectyourcontroldevicetothesameWi-FinetworkastheRaspberry Pi.

W.3 Access URL: https://boat.afnan.work (Navigate to the Aqua-Bot's network address) http://aqua-bot.local).

3.2 Control Panel Features

3.2.1 Real-Time Status Dashboard

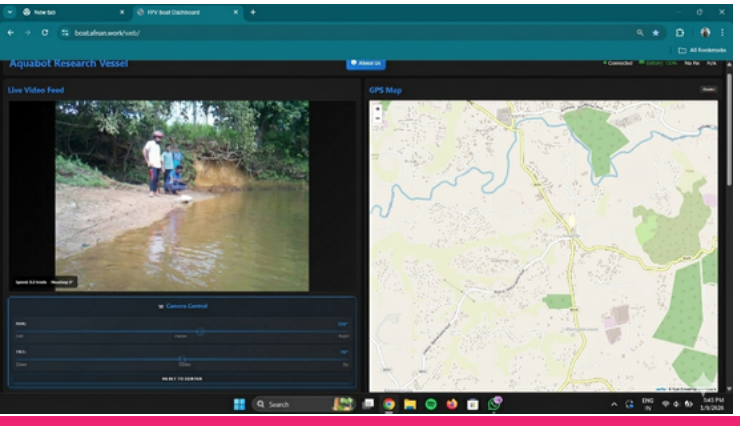
- **GPS Location:** Current coordinates and map display.
- **BatteryHealth(INA3221):** LiveVoltage,CurrentDraw,andestimatedBatteryPercentage for the **12.8V LiFePO4** pack.
- **Orientation (Gyro):** Readouts of the Pitch and Roll angles.

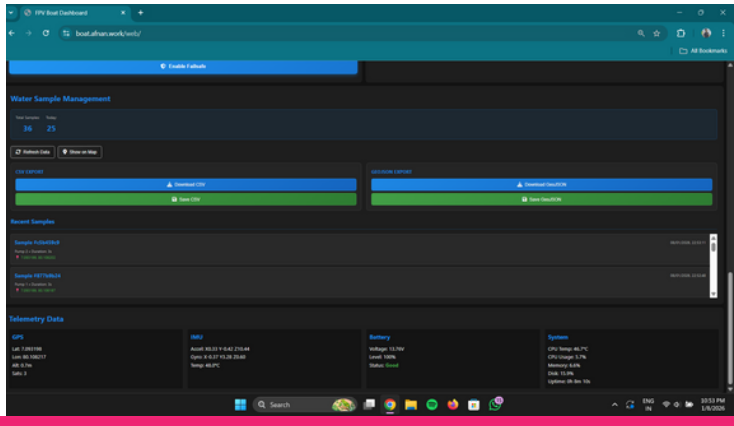
3.2.2 MovementandViewControls

- **Thruster Controls:** Controls (joystick/buttons) send PWM signals to the ESCs to manage speed and differential steering.
- **Camera View Controls:** Dedicated controls send PWM signals to the two servomotors for remote **pan** (horizontal) and **tilt** (vertical) camera movement.

3.2.3 WaterCollectionControls

- **Pump Toggles:** Four independent buttons (**PUMP 1** to **PUMP 4**) toggle the corresponding relays to start/stop the water collection motors.





4.1 Pre-Deployment Checklist

P.1 Physical Security: Verify the electronics enclosure is sealed. Ensure sample bottles are secured in the **3D-printed holders**. Confirm the PVC structure is intact.

P.2 Power Check & Charging: Confirm the main LiFePO4 battery is fully charged (around 13.6V). To charge, connect the charger to the **Solar Charge Controller**.

P.3 System Ready: Confirm the web interface is loaded and all controls (thrusters, servos, pumps) respond briefly to test commands.

4.2 WaterSamplingProcedure

S.1 Deployment: Gently place the Aqua-Bot into the water.

S.2 Navigate: Use the web movement controls to maneuver the vessel. Adjust the camera view using the **pan/tilt controls** for obstacle avoidance.

S.3 Start Collection: Click the control button for the desired pump.

S.4 Monitor: Observe the Camera Feed and the battery drain via the INA3221 data.

S.5 Stop Collection: Click the pump control button again to stop the motor.

S.6 Retrieval&PowerOff: SafelyretrievetheAqua-Bot,removesamplesfromthe**3D-printed holders**, and use the main power switch on the Custom PCB to power down the system.

Component Parts List

This chapter lists the primary hardware components used in the construction and operation of the Aqua-Bot.

Table 5.1: Aqua-Bot Bill of Materials (BOM)

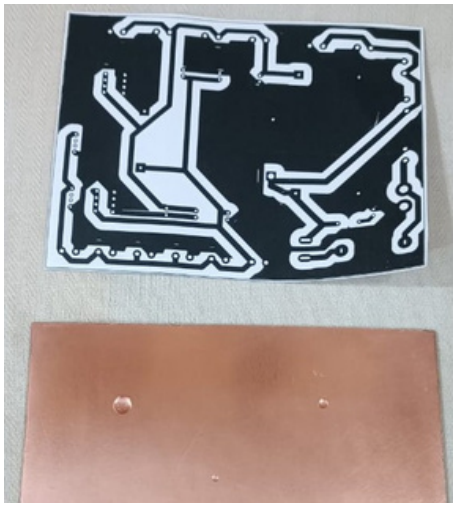
Component Category	Item	Specifications
Power and Charging		
Battery Pack	LiFePO4Battery	12.8V(4S),20Ah
Protection Module	BMS	4S,60A
Charging Unit	Solar Charge Controller	12V/24V,30A
Power Monitoring	INA3221Sensor	VoltageandCurrentSensing
	Custom PCB	Fuse,Switch,5V/3.3VBuckConverters
Power Distribution Control and Sensing		
Navigation	GPS Module	Real-Time Location Tracking
Balancing	Gyro Sensor	Roll,Pitch,Yaw Monitoring
VisualFeedback	RaspberryPiCamera	Live Video Stream
CameraControl	Servomotors(2x)	Horizontal and Vertical Pan/Tilt
Actuation and Structure		
PropulsionMotors	UnderwaterThrusters(2x)	12–24VDC,20Amax,CW/CCW
MotorControllers	BrushlessESCs(2x)	30A–40A
SamplingPumps	5VDCWaterPumps(4x)	WaterSuction/Collection
PumpControl	4-ChannelRelayModule	IsolationandSwitching
VesselFrame	PVCPipeandFittings	HullStructureandBuoyancy
SampleHolders	3D-PrintedHolders	BottleRetention

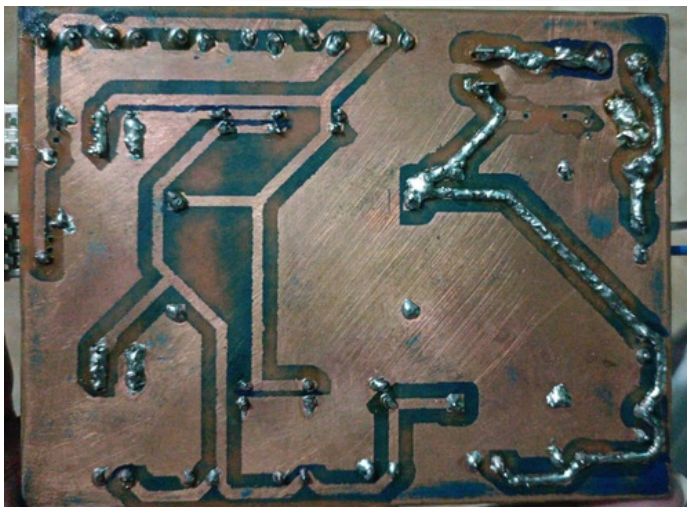
LiFePO4 20A Battery

CW 12V Thruster motor

solar charger

dual axis Servo





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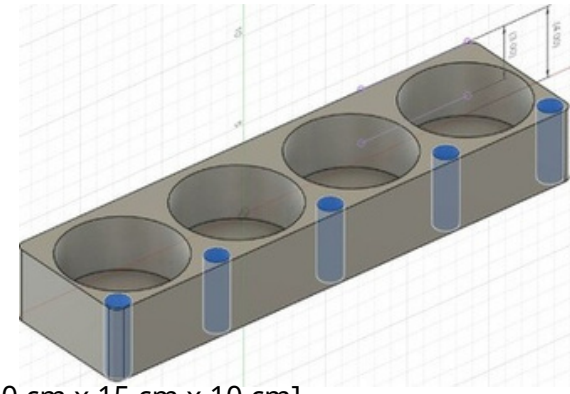
Dimensions and Specifications

This chapter outlines the key physical dimensions and performance specifications for the Aqua- Bot. Note that all dimensions are approximations based on the PVC construction.

6.1 Vessel Dimensions



- **Hull Material:** Polyvinyl Chloride (PVC) pipe.
- **Overall Length:** [Insert Length Here, e.g., 80 cm]
- **Overall Width:** [Insert Width Here, e.g., 50 cm]
- **Draft (Waterline):** [Insert Draft Here, e.g., 10 cm]
- **Main Enclosure Size (L x W x H):** [Insert Dimensions Here, e.g., 20 cm x 15 cm x 10 cm]
- **Weight (Dry):** [Insert Weight Here, e.g., 5 kg]

6.2 Electrical Specifications

- **Main Operating Voltage:** 12.8 VDC (Nominal)
- **Total Battery Capacity:** 20 Ah
- **Thruster Current Draw:** Max. 20A per motor (40A total)
- **Low-Voltage Supplies:** Onboard 5V and 3.3V Buck Converters

Troubleshooting

7.1 Common Issues and Solutions

Table 7.1: Aqua-Bot Troubleshooting Guide

Problem	PossibleCause	Solution
System will not power on	Power switch off or main fuse blown	Check power switch on Custom PCB, If fuse is blown, determine source of short/ overload before replacing.
Thrusters do not respond	ESC not armed/calibrated or motorfailure	Check PWM signal from RPi to ESCs, Ensure ESC's are properly armed.
Camera view is static	Servo motor connection error	Check PWM signal connections to the two servo motors
Pump does not run	Relay connection or RPi GPIO error	Check RPi GPIO pin connections to the 4channel relay module.
Battery voltage dropping fast	High load or battery near depletion	Check INA3221 for high current draw.

7.2 Further Support

For advanced troubleshooting related to the core components (e.g., RPi software, ESC programming, or custom PCB diagnostics), please refer to the extensive online documentation for the Raspberry Pi, INA3221, Solar Charge Controller, and your specific ESC and servomotor models.