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# Solar-Powered IOT Floating Buoy for Continuous Multi-Parameter Water Quality Monitoring

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**Abstract**—Water quality in lakes, ponds, and reservoirs is usually checked by collecting samples and sending them to a laboratory. This method is accurate but slow, and it can miss changes that occur between sampling visits. This paper proposes a solar-powered floating buoy that measures pH, total dissolved solids (TDS), turbidity, and water temperature using an ESP32 microcontroller. A solar panel charges a rechargeable battery through a charging circuit with battery management, and voltage regulators supply the electronics. Readings appear on a local OLED display, and a buzzer sounds when a parameter crosses its configured limit. An L293D motor driver controls two motors that propel and steer the buoy, and the ESP32's Wi-Fi can forward data to an IoT dashboard when a network is available. A mobile dashboard displays the four parameters in real time and provides forward, left, right, and stop controls for the motors. The paper describes the hardware architecture, power chain, and control logic.

**Keywords**—Solar-powered floating buoy, water quality monitoring, Internet of Things (IoT), ESP32 microcontroller, pH sensor, TDS sensor, turbidity sensor, temperature sensor, renewable energy, real-time monitoring.

## I. Introduction

Water supports drinking supplies, agriculture, industry, and aquatic ecosystems. Its quality depends on properties such as pH, total dissolved solids (TDS), turbidity, and temperature [1]. Industrial discharge, urban wastewater, and agricultural runoff can change these properties over time, so regular monitoring is needed to detect contamination early and manage water resources well.

Monitoring is usually done by collecting samples by hand, transporting them to a laboratory, and analyzing them. These results are reliable, but they describe conditions only at the moment of collection. Sampling is also labor- intensive and costly, which limits how often it can be repeated, so short-term changes between visits are often missed. Embedded sensors and wireless links offer a way to collect data more frequently and send alerts when limits are exceeded.

This paper presents a compact floating platform that carries pH, TDS, turbidity, and temperature sensors on the water surface. An ESP32 reads the sensors, compares each value with its configured limit, and shows the results locally. A buzzer gives an audible warning when a limit is exceeded. A solar panel and battery supply power, so the platform can operate where grid electricity is unavailable. Wireless transmission is included for use when a network and monitoring platform are available.

Floating solar photovoltaic systems have been reviewed in the literature [2], [3]. Possible applications of the proposed buoy include drinking-water reservoirs, aquaculture ponds, industrial water storage, lakes, and dams. In these settings the buoy can reduce manual sampling effort and show how water conditions change over time. The contribution of this work is the combination of these functions in a single low-cost platform.

## II. Aims and Objectives

**Aim.** The aim of this project is to design and build a low-cost, energy-efficient floating buoy that continuously monitors pH, TDS, turbidity, and temperature. The system uses an ESP32 to process sensor data, a solar-powered battery supply for power, and a display and buzzer to present readings and alerts. It is intended to reduce manual

monitoring and support timely detection of changes in water quality.

**Objectives.** The specific objectives are:

- To measure pH, TDS, turbidity, and temperature continuously with dedicated sensors.
- To charge a battery from solar energy and provide a sustainable supply for the system.
- To use the ESP32 to collect, process, and evaluate sensor readings.
- To show measured parameters on an OLED display for local viewing.
- To activate a buzzer when a parameter exceeds its threshold.
- To support wireless transmission of data for remote observation through a suitable IoT communication technology.
- To integrate a motor driver and two motors to propel and steer the buoy.
- To design a stable, durable buoy that carries the sensors and electronics while floating on the water surface.

## III. Literature Survey

Water quality assessment has moved from laboratory-only methods toward sensor networks and autonomous platforms. Solar-powered IoT water monitoring has been reported [4], as have general IoT systems for water quality management [5] and real-time monitoring platforms [6]. The studies below each address part of the problem: low-cost sensing, cloud access, autonomous operation, floating platforms, or mobile monitoring. Together they show that the components are mature, but few combine floating deployment, renewable power, and continuous operation in one system.

**Hasan et al. (2022) [7].** Hasan et al. developed a low-cost, multi-sensor buoy for real-time monitoring of Dhaka canal water. The buoy measures temperature, pH, turbidity, and TDS with an Arduino controller, sends the readings by SMS, and makes them viewable online over Wi-Fi. The authors indicate that the design could also be applied to lakes and rivers.

**Ajith Jerom B. et al. (2020) [8].** Ajith Jerom B. et al. developed an IoT system using a NodeMCU, several water quality sensors, Wi-Fi, and cloud storage, which let users view measurements remotely. The paper also discussed deep learning for analyzing sensor data. The system was not mounted on a self-sustaining floating platform, so integration with a buoy and an independent power source was left for future work.

**Maniyath et al. (2023) [9].** Maniyath et al. proposed an autonomous buoy that floats and moves under automated or manual control. The buoy carries a GPS module to locate each measurement and measures temperature, pH, turbidity, dissolved oxygen, and TDS as part of an IoT system for smart city water monitoring.

**Dutta et al. (2024) [10].** Dutta et al. describe an IoT-based water quality monitoring approach built around a floating smart device, presented as a shift in how water standards are monitored. The work is an SSRN preprint and has not been confirmed as peer reviewed.

**Singh and Nour (2025) [11].** Singh and Nour built a remote-controlled boat that measures temperature, pH, and TDS using Arduino Uno, Raspberry Pi 4B, and ESP32 boards, and sends the data to the ThingSpeak cloud platform. The boat also collects floating debris. Mobile sampling can cover several locations, but the boat requires operator control and power management, which a stationary solar-powered buoy could reduce.

**Research gap.** Existing work shows that IoT sensing, cloud platforms, and floating devices can support real-time water quality monitoring. Several gaps remain: dependence on conventional power, limited energy management, reliance on manual supervision, and difficulty operating for long periods. Some systems focus on cloud dashboards, while others focus on autonomous or mobile platforms without fully addressing energy independence. The proposed buoy combines a floating platform, water quality sensors, an ESP32 controller, wireless communication, and solar power in a single system.

## IV. Methodology

The system combines solar generation, water quality sensing, embedded processing, local display and alerts, motor control, and optional wireless transmission. The subsections below follow the order in which power and data flow through the design.

**1) Solar power and battery management.** A solar panel converts sunlight into electrical energy, which a charging circuit uses to charge a rechargeable battery. A battery management system (BMS) protects the battery from overcharging and excessive discharge, according to its specifications. Voltage regulators then supply the operating voltages required by the ESP32, sensors, display, and other electronics.

**2) Water quality sensing.** The buoy carries pH, TDS, turbidity, and DS18B20 temperature sensors. The pH sensor produces a voltage related to hydrogen-ion activity, which the ESP32 converts to a pH value after calibration. The TDS sensor measures the electrical conductivity of the water and estimates dissolved-solids concentration after calibration. The turbidity sensor measures how strongly suspended particles scatter light, which indicates cloudiness. The DS18B20 is a digital sensor that reports water temperature over a one-wire interface, with a 10 kΩ pull-up resistor on its data line as shown in Figure 2.

**3) Data processing.** The ESP32 is the central controller. At each sampling interval it reads every sensor, applies the calibration and conversion values, and compares each result with its configured threshold.

**4) Display and alerts.** Measured values appear on an OLED display for local viewing. When a parameter exceeds its threshold, the ESP32 drives a buzzer through a BC547 transistor, with a 4.7 kΩ base resistor as shown in Figure 2.

**5) Motor control.** The ESP32 sends control signals to an L293D motor driver, which drives two motors to move the buoy forward, turn it left or right, and stop. Commands are sent from the mobile dashboard. In testing, motor speed was set to a medium level of 60% PWM.

**6) Monitoring and wireless communication.** The ESP32's built-in Wi-Fi can send pH, TDS, turbidity, temperature, and alert status to an IoT platform when a network is available [5]. Users can then view trends and review the condition of the water body remotely. Local sensing, display, and alert functions continue when no network is available. Figure 1 also shows a dissolved oxygen (DO) sensor, a GPS module for location tracking, and a GSM or LoRa link as alternatives to Wi-Fi. These were not part of the tested prototype, which reported only pH, TDS, turbidity, and temperature over Wi-Fi.

**7) Floating platform and integration.** The sensors, battery, electronics, and solar panel are integrated into a floating buoy structure. The hull must remain stable on the water surface and protect the electronics from moisture and splashing. The solar panel needs adequate sunlight, and the sensor probes must contact the water. Waterproof enclosures, cable sealing, buoyancy, and weight distribution are addressed during assembly.

**8) Testing and evaluation.** The completed system was tested for sensor readings, power supply performance, buzzer activation, and motor control. Power and runtime were measured under partly sunny conditions. The buoy was then deployed in a freshwater pond to check its floating behavior and monitoring operation. Sensor readings were not yet compared with reference instruments.

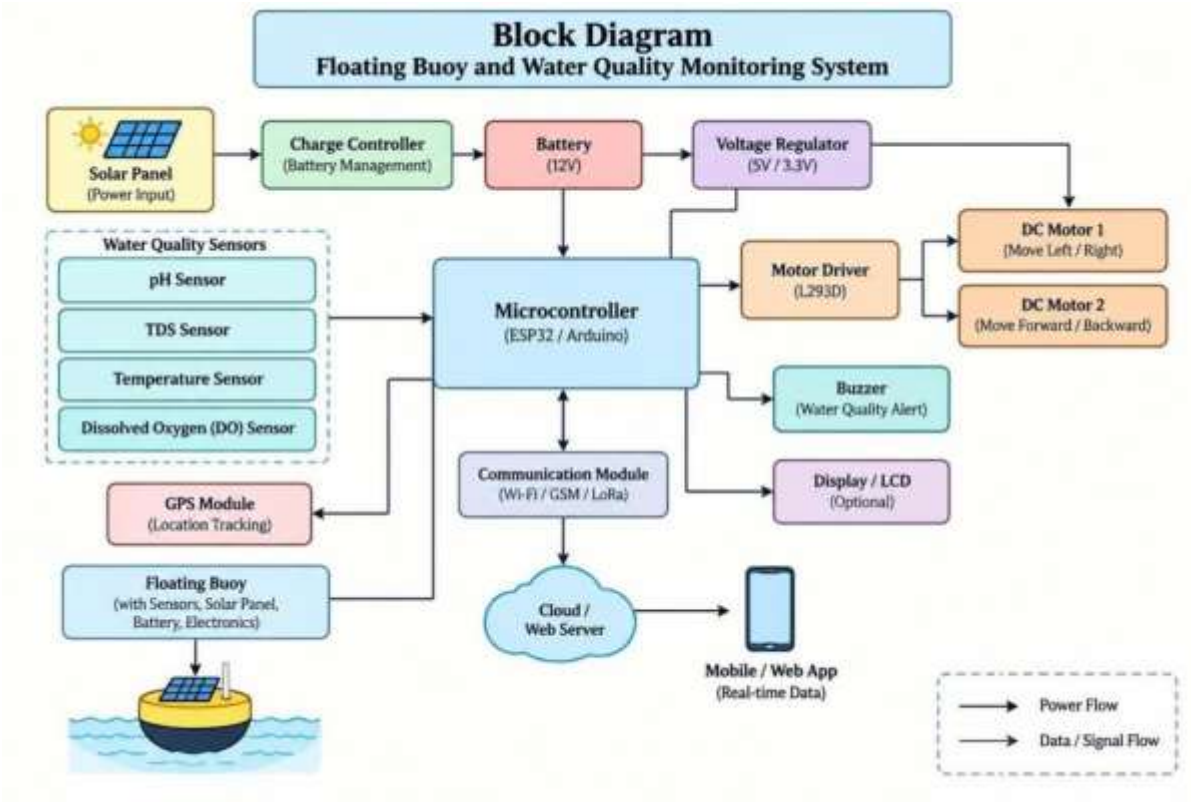



*Fig. 1. Block diagram of the proposed system.*

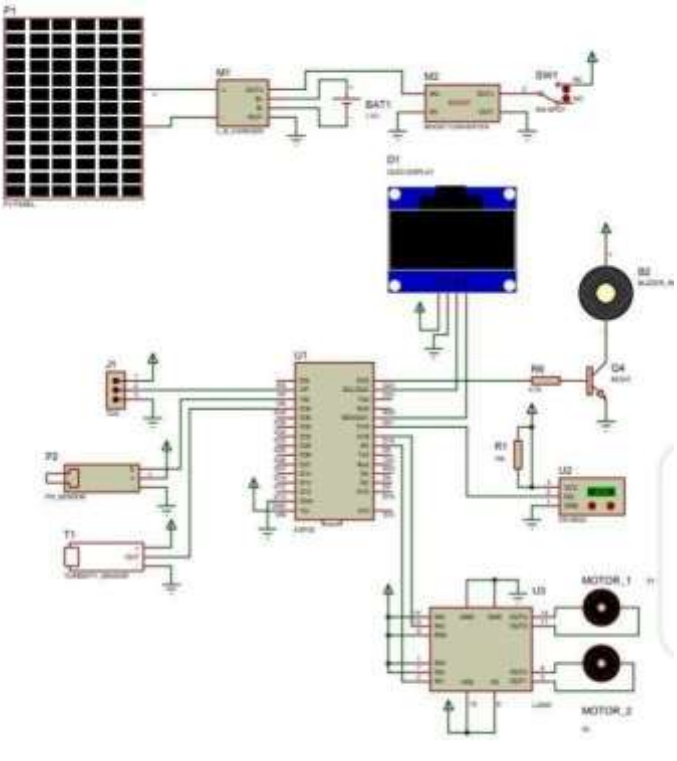


*Fig. 2. Circuit diagram of the proposed system.*

## V. Results

This section reports the measured performance of the prototype. All bracketed values are placeholders for experimental data. Replace the placeholders, then delete any row or subsection that you do not test.

### *A. Sensor Accuracy*

Table I lists the readings shown by the dashboard during testing. Accuracy will be reported once each reading is compared with a reference value.

**TABLE I. SENSOR READINGS DURING TESTING**

| Parameter | Reading shown in dashboard | Remark |
|---|---|---|
| pH | 4.14 pH | Buffer used for comparison not confirmed; accuracy not yet verified |
| TDS | 20 | Units not shown in the app; accuracy not yet verified |
| Turbidity | 100 | Gauge at its maximum; reading may be saturated |
| Temperature | 0 °C | Likely a sensor connection or calibration issue; recheck |

### *B. Power Performance*

Testing was carried out in partly sunny conditions between 10:00 AM and 2:00 PM. The solar panel delivered 12.0 V, 0.55 A, and 6.6 W. The battery was charged through a charge controller from 30% to 80%. On a full charge, the system ran for 2.5 hours with the motors running and 4 hours with the Wi-Fi module and display active.

### *C. Alert Behavior*

The alert thresholds were set as follows: pH below 6.5 or above 8.4, TDS above 500 mg/L, turbidity above 5 NTU, and temperature below 10 °C or above 35 °C. Each threshold was tested by deliberately creating the condition measured by its sensor and observing whether the buzzer activated. The buzzer sounded in 36 of threshold crossing.

### *D. Motor Operation*

Motor speed was set to a medium level of 60% PWM. The forward command rotated the motors together to propel the buoy forward. The left and right commands drove the two motors at different speeds to turn the buoy. The stop command disabled the motor drive signals.

### *E. Field Deployment*

The buoy was deployed in a local freshwater pond for 3 hours on 15 October 2026. The pond provides natural conditions for testing pH, TDS, turbidity, and temperature monitoring. Stability was assessed by observing whether the buoy remained upright, tilted, or drifted from its starting position.

Together, these results show the system's behavior during testing. Accuracy will be reported once the sensor readings are compared with reference values.

## VI. Conclusion

The solar-powered floating buoy was successfully developed to monitor water quality in real time using pH, temperature, turbidity, and TDS sensors. During testing, the system displayed a pH value of 4.14, temperature of 0°C, turbidity of 100, and TDS of 20. The application successfully displayed sensor readings and provided control options for the floating buoy. However, the temperature reading of 0°C may indicate a sensor connection or calibration issue, and the other readings require verification using standard instruments. Runtime was measured at 2.5 hours with the motors running and 4 hours with the Wi-Fi module and display active, but sensor error was not measured during this test. Overall, the project demonstrates the potential of solar-powered technology for continuous water quality monitoring, with further calibration and testing needed to improve accuracy and reliability.

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