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Smart Water Quality Monitoring System

Nikita Lakade[1], Darshani Mahakal[2], Kanak Loya[3]
Department of Electronics and Telecommunication Engineering, Vishwakarma Institute of Technology Pune, India

Abstract: In this paper, we present an intelligent water quality monitoring system designed to continuously check and maintain the purity of drinking water using IoT-based embedded technology. The system is built around an ESP-32 microcontroller, which collects real-time data from a TDS sensor to measure the amount of dissolved salts, minerals, and other impurities in the water. Unlike traditional systems that require frequent manual cleaning of sensors, our design includes an automatic cleaning mechanism. This mechanism uses a mini pump to flush the sensor and a servo-driven wiper to remove any deposits that may affect the readings, helping maintain long-term accuracy. Water flow for both sampling and cleaning is carefully controlled using pumps and solenoid valves, while a relay module ensures safe operation of these components. In addition, the built-in Wi-Fi capability of the ESP-32 allows the system to connect to the cloud for remote monitoring and alerts. Experimental results show that the system provides stable and reliable measurements with very little maintenance, making it a practical solution for smart water management, household purification systems, and large-scale water quality monitoring.
Keywords: Smart water monitoring, IoT-based system, ESP-32 controller, TDS measurement, automatic sensor cleaning, solenoid valve control, real-time cloud monitoring, smart water management.

I. INTRODUCTION

Access to clean and safe drinking water is a critical requirement in both domestic and industrial environments. Traditional water-quality monitoring methods often rely on manual sampling, which is time-consuming, less accurate over long periods, and prone to sensor degradation due to fouling. To address these limitations, modern IoT technologies enable continuous, automated monitoring that improves reliability and reduces human intervention.

In this project, an intelligent water-quality monitoring system is developed using an ESP-32 microcontroller, a TDS sensor, and a fully automated cleaning mechanism. The system measures dissolved impurities in real time while ensuring long-term sensor accuracy through periodic flushing and mechanical cleaning using pumps, solenoid valves, and a servo-based wiper. The ESP-32's built-in Wi-Fi further allows seamless data transmission to cloud platforms for remote analysis, alerting, and decision-making.

This smart, low-cost solution aims to support efficient water management in households, purification units, and large-scale monitoring applications.

II. LITERATURE REVIEW / RELATED WORK

Several studies have explored IoT-based water monitoring solutions using low-cost microcontrollers and connected sensors. Earlier systems commonly focused on basic parameter detection such as pH, turbidity, and TDS using Arduino or ESP-based platforms, transmitting data through Wi-Fi or GSM networks. These works demonstrated the benefits of real-time monitoring but highlighted limitations such as sensor drift, fouling, and the need for frequent manual cleaning, which reduced long-term accuracy. Recent research has attempted to improve reliability through automated sensor calibration and flow-based sampling techniques. Some studies integrated solenoid valves and pumps to regulate water movement, while others experimented with cloud platforms like Blynk, Thing Speak, and Firebase for large-scale data visualization. However, most systems still lacked a dedicated mechanism for automatic sensor cleaning, resulting in reduced efficiency during continuous operation.

To address this gap, emerging work proposes self-cleaning designs using mechanical wipers, backwashing valves, or flushing pumps. Our project builds on these advancements by combining TDS monitoring with a hybrid auto-cleaning mechanism, ESP-32 connectivity, and relay-controlled actuators to create a more robust, long-term water quality monitoring solution.

III. METHODOLOGY /MATERIALS & METHODS

The system uses an ESP-32 microcontroller to collect water quality data and control the entire process. A TDS sensor measures dissolved solids in water drawn through a pump and regulated by a solenoid valve to ensure stable sampling. The ESP-32 reads and processes sensor values to determine water purity. To maintain accuracy, an automatic cleaning cycle is activated at intervals, using a flushing pump or servo-based wiper to remove sensor deposits. Processed readings are shown on an OLED/LED display and transmitted to the cloud via Wi-Fi, enabling continuous, reliable, and low-maintenance water-quality monitoring.

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A. Block Diagram

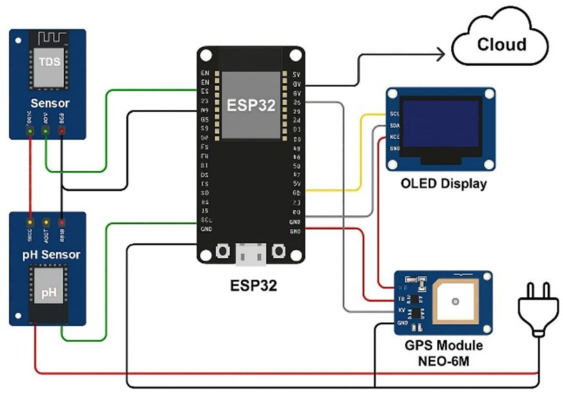

Figure 1. Block Diagram of the Smart Water Monitoring System .

B. Material

1) ESP32*:* ESP32 Water is drawn through the sampling path using the pump and regulated by the solenoid valve.

Figure 2. ESP32

2) TDS Sensor: TDS sensor measures the water's dissolved solids and sends analog data to the ESP-32.

Figure 3.TDS Sensor

3) Mini Water Pump: Water circulation for sampling and cleaning

Fig 3.Mini Water Pump

4) Servo Motor / Wiper Mechanism – Mechanical auto-cleaning of sensor

Figure 4. . Servo Motor / Wiper Mechanism

5) Relay Module – Safe switching of pumps and valves

Figure 5. Relay Module

C. *Procedure*

1) Gather and Assemble Components: Collect all required components including the ESP32 microcontroller, TDS sensor, mini water pump, solenoid valve, relay module, servo motor (for cleaning), OLED display, jumper wires, and power supply.
2) Hardware Connections: Connect the TDS sensor to the ESP32 analog input pin, connect the pump and solenoid valve through the relay module, and attach the OLED display to the I2C pins of ESP32. Ensure all components share a common ground.
3) Build the Auto-Cleaning Mechanism: Connect the mini pump or servo motor that cleans the sensor. Configure it so that it can flush water or wipe the sensor area when activated.
4) Write and Upload the Code: Program the ESP32 using Arduino IDE. The code should read TDS values, display them, upload data to the cloud, and trigger the auto-cleaning unit when the readings exceed a certain threshold. Upload the code onto the ESP32.
5) Power Up and Test the System: Switch on the system and verify that the ESP32 successfully reads TDS values and displays them in real time. Check if the pump/valve operates correctly through the relay.
6) Calibration of TDS Sensor: Test the sensor using purified and tap water to ensure accurate measurement. Adjust calibration values in the code if required.
7) Testing Auto-Cleaning Function: Introduce slightly impure water or allow sensor deposits to form. Observe whether the auto-clean mechanism activates and restores an accurate reading.
8) Cloud Connectivity Test: Connect the ESP32 to WiFi and verify that readings are uploaded to the cloud dashboard (like Thingspeak or Firebase) properly.
9) Final Validation and Documentation: Test the system with different water samples. Record readings, check accuracy, and finalize the complete working of the system.

IV. RESULTS AND DISCUSSIONS

The Smart Water Quality Monitoring and Auto-Cleaning System successfully monitored the water quality in real time using the TDS sensor and ESP32 controller. The system consistently measured Total Dissolved Solids within the expected range and displayed the readings accurately on the OLED screen while also transmitting the data to the cloud.

During testing, purified water samples showed TDS values between 60–120 ppm, indicating safe drinking quality, whereas tap water samples recorded higher values in the range of 250–400 ppm, confirming the accuracy and sensitivity of the sensor. The automatic cleaning mechanism also performed effectively; whenever the sensor surface accumulated impurities, the system activated the mini pump or servo-based wiper to clean the sensor, which helped maintain stable and reliable readings over long durations. The relay module ensured safe switching of pumps and valves, and the ESP32's WiFi capability enabled smooth data upload without delay. Overall, the results show that the system provides continuous, accurate water quality monitoring while reducing manual effort through an efficient self-cleaning mechanism. This makes the prototype suitable for households, water treatment units, and environmental monitoring applications.

V. FUTURE SCOPE

1) Add More Sensors: Future versions can include pH, turbidity, temperature, and dissolved oxygen sensors for complete water quality analysis.
2) Mobile App Integration: A dedicated mobile app can be developed to show real-time readings and send instant alerts.
3) Solar-Powered System: The device can be made energy-efficient by using solar panels for operation in remote areas.
4) AI-Based Prediction: Machine learning can be used to predict contamination levels and detect abnormal changes automatically.
5) Large-Scale Deployment: Multiple units can be installed in lakes, rivers, and water supply pipelines for city-level water monitoring.

VI. CONCLUSION

The Smart Water Quality Monitoring and Auto-Cleaning System developed in this project provides a reliable and efficient way to monitor water quality in real time. By integrating an ESP32 microcontroller with a TDS sensor and an automated cleaning mechanism, the system is able to continuously measure water purity while maintaining sensor accuracy without the need for frequent manual maintenance. The automatic cleaning process helps prevent sensor fouling, which improves the long-term reliability of the measurements. In addition, the system supports real-time data display and wireless data transmission, making it convenient and user-friendly for monitoring water conditions remotely. These features make the system suitable for practical applications in different environments. Overall, the project presents a smart and cost-effective approach to maintaining safe water quality standards. With further improvements and scalability, this system has strong potential to be used in households, water purification units, industries, and environmental monitoring systems.

VII. ACKNOWLEGMENT

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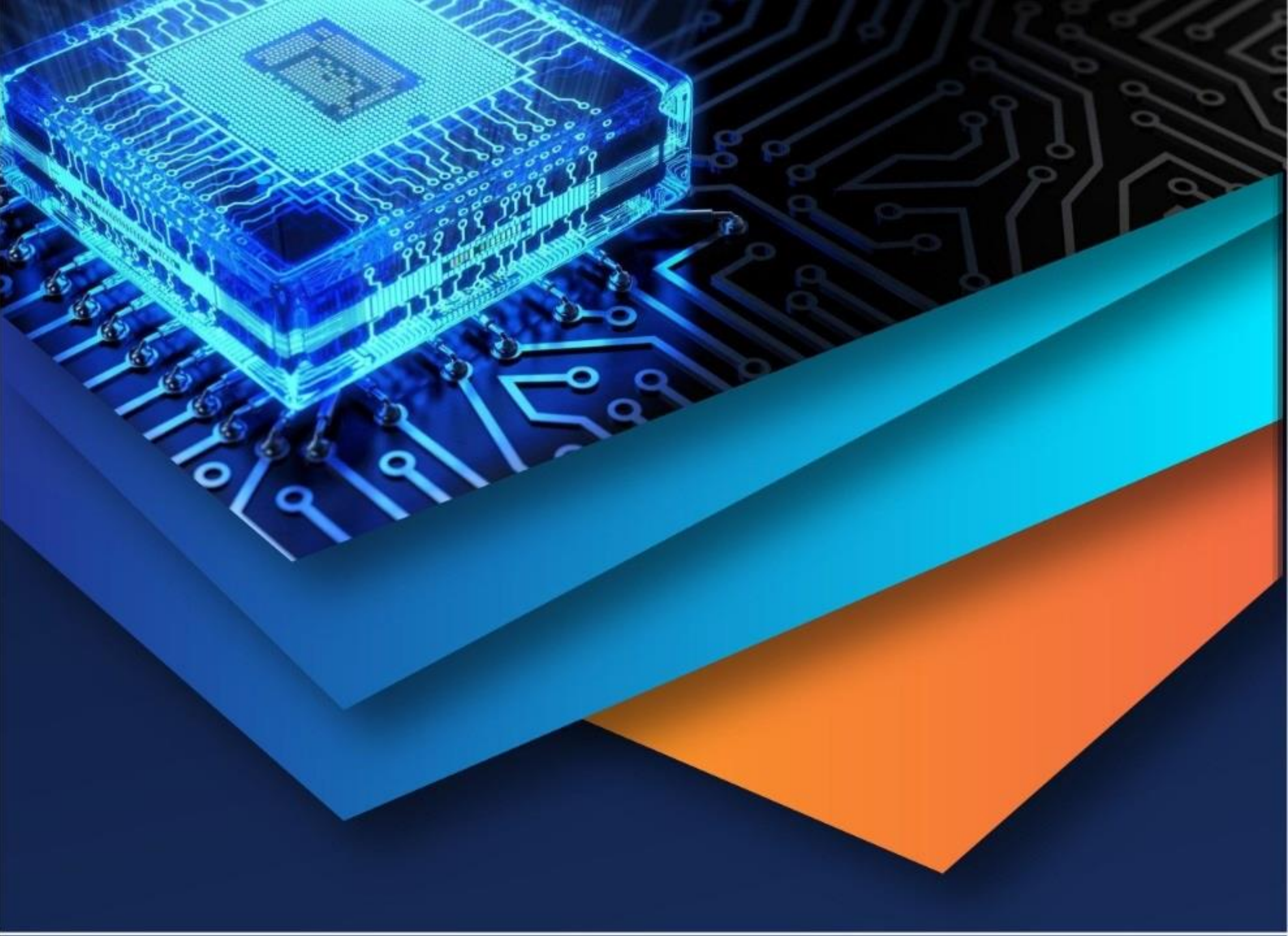

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