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IoT Based Water Quality Monitoring System Using ESP32

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Abstract

This project, titled "IoT Based Water Quality Monitoring Using ESP32," focuses on developing a low-cost, real-time, and scalable system to continuously monitor water quality, addressing the limitations of traditional manual testing methods. The system utilizes the ESP32 microcontroller due to its affordability and built-in Wi-Fi and Bluetooth capabilities, making it ideal for real-time remote monitoring. Key physicochemical parameters monitored include pH value, turbidity, and temperature, along with others like Total Dissolved Solvents (TDS), Electrical Conductivity, and flow. The methodology involves connecting these sensors to the ESP32, programming it using the Arduino IDE, and transmitting the collected data wirelessly to a cloud platform like Thing Speak for analysis and storage. The system allows users to view real-time data, receive instant alerts if parameters fall outside safe limits, and even potentially control the water flow in the pipeline. Ultimately, the project contributes to sustainable water resource management and public health protection by enabling early detection of contamination and providing a more efficient solution for water quality surveillance in various settings, including urban, rural, and industrial areas.

Keywords: ESP32, Temperature, TDS, pH

1. Introduction

We consume water every day. It is an essential part of our lives. Therefore, water should be checked now and then. Since water has a direct effect on life on earth; it has become crucial to check whether the water is in a good condition to use. Checking the standard of water requires a great deal of hard work. Since water dissolves most of the materials that exist on Earth, it is very difficult to determine the amount of the matter mixed in it. Water being a universal solvent varies from place to place, depending on the condition of the source of water and the treatment it receives. The WHO (World Health Organization) estimated that, in India, around 77 million people are suffering due to not having access to safe drinking water. In fact, 21% of diseases in India are related to unsafe drinking water. Also, more than 1600 deaths alone are caused due to diarrhoea in India daily.[2] Therefore, it has become necessary, with the evolving technology, to devise a quick and efficient method to determine the quality of water.

In order to ensure the safe supply of the drinking water the quality needs to be monitored in real time. Our project focuses on monitoring factors such as the pH value, turbidity and temperature of water which can be verified on a daily basis. The normal method of challenging Turbidity and pH is to collect samples manually and send them to laboratory for a water quality check. However, it has been seen that the samples are unable to reach the water quality examining in real time. We propose a low cost system for real time water quality monitoring and controlling using IoT. The system consists of physio chemical sensors which can measure the physical and chemical parameters of the water such as Temperature, Turbidity, pH and Flow. Finally the sensed values are visible on the cloud via cloud computing. Also, according to the sensor values, the flow of water in the pipeline can be controlled. Rapid urbanization and inadequate infrastructure maintenance have led to drainage congestion, which is a big problem in India (Banakar et al., 2019). There are a lot of other parameters which can be found in water, but these three parameters turbidity, pH and temperature are crucial in determining the quality.

These parameters are considered the main parameters for water quality testing. As a whole, this project contributes to determining the quality of water in a convenient, compact and user friendly method. IoT extends its support to predict real-time environmental factors in addition to Industry 4.0. Various sensors collect the data transmitted to the internet through the Arduino gateway

2. Research Objectives

The "IoT Based Water Quality Monitoring Using ESP32" project aims to create a low-cost, real-time, and scalable water quality surveillance system using the ESP32 microcontroller. Its primary objective is to monitor critical parameters like pH, turbidity, and temperature continuously, and transmit this data wirelessly to a cloud platform for analysis and storage. This system addresses the limitations of manual sampling by providing instant insights, enabling early detection of contamination, and facilitating prompt interventions to safeguard public health and manage water resources efficiently. The ability to monitor remotely and continuously makes it an ideal solution for various applications, contributing to safer water usage and sustainable environmental practices.

2.1 Operational Modes

The operational mode of the IoT-based water quality monitoring system begins with the data collection phase, where various sensors (pH, turbidity, temperature, etc.) continuously measure the physical and chemical parameters of the water. These readings are processed by the ESP32 microcontroller. Next, the device enters the data transmission phase, utilizing its integrated Wi-Fi capabilities to send the collected sensor readings wirelessly to a cloud platform, such as Blynk IoT. Finally, in the data retrieval and display phase, the readings and analytical reports are transferred from the cloud to a personalized web-based page portal or a mobile application. where the user can view the sensor values and reports in real-time.

3. SYSTEM ARCHITECTURE AND METHODOLOGY

The implemented system employs a modular architecture comprising sensing, processing, communication, and actuation components. This hierarchical design ensures robust operation while maintaining flexibility for future enhancements and modifications.

3.1 Hardware Configuration

The proposed system's circuit design is composed of several key hardware components, primarily including physical sensing elements, a micro-controlling unit, and a wireless transceiver chip.

- Central Processing Unit: The ESP32 microcontroller was selected for its integrated Wi-Fi capabilities, sufficient analog-to-digital conversion resolution, and support for peripheral communication protocols, including I^2C.
- Particulate Matter Detection: Turbidity Sensor Measures the cloudiness or haziness of the water, indicating contamination levels.
- TDS Sensor: Detects the concentration of total dissolved solids. A high TDS means high mineral or contaminant concentration.
- DS18B20 Temperature Sensor: A waterproof digital sensor ideal for measuring water temperature with high accuracy.
- Analog pH Sensor: Measures the acidity or alkalinity of the water. Outputs analog signals that are processed using ESP32 ADC.
- User Interface Components: A 16x2 character LCD with I^2C interface provides local readouts, while the Blynk IoT platform enables remote monitoring and control through smartphone applications.

3.2 Operational Principles

Sensing and Measurement :The operational cycle begins with physical sensing components deployed in the water source. Various sensors, such as those for pH, turbidity, and temperature, measure the physicochemical properties of the water. The sensors sense the water and provide the output to the ESP32. For analog sensors, the data is converted to digital data (real-life data) using an Analog-to-Digital Converter (ADC).

Processing and Microcontrolling: The ESP32 microcontroller acts as the data processing unit. It is programmed (typically using the Arduino IDE) to read and process the values from the connected sensors. The processed values are then transmitted remotely.

Data Transmission (Wireless): The ESP32 uses its integrated Wi-Fi capabilities to connect to the internet. The processed sensor readings are then sent wirelessly to a cloud-based platform, such as the Blynk IoT cloud platform. This enables remote data analysis and storage.

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User Interface and Alerting: The final principle involves presenting the data to the user. The readings and analysis reports are transferred from the cloud to an end-user interface. This interface can be a mobile application (developed using tools like MIT App Inventor) or a personalized web-based page portal, which displays the collected sensor values and readings in pictorial or tabular formats.

3.3 Software Implementation

The Software Implementation for the IoT-based water quality monitoring system centers on the firmware written for the ESP32 and the cloud infrastructure for data handling. The microcontroller is programmed using the Arduino IDE to read sensor values and manage the integrated Wi-Fi connection. Processed readings are transmitted to a cloud platform, such as Blynk IoT , which serves for remote data storage and analysis. Finally, a user interface, like a mobile application developed using MIT App Inventor or a web portal, is used to display the collected sensor values and analytical reports to the end-user.

Block Diagram

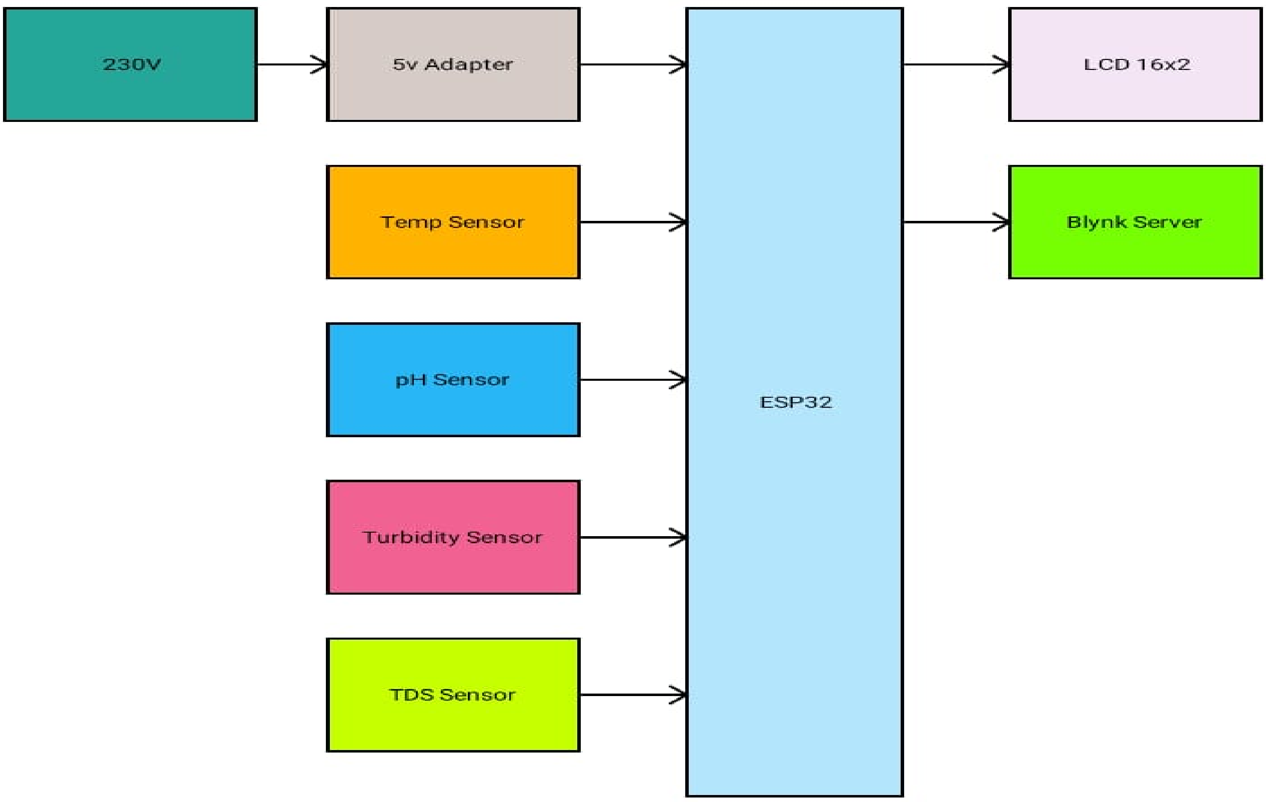

Fig -1: block diagram

Circuit Diagram

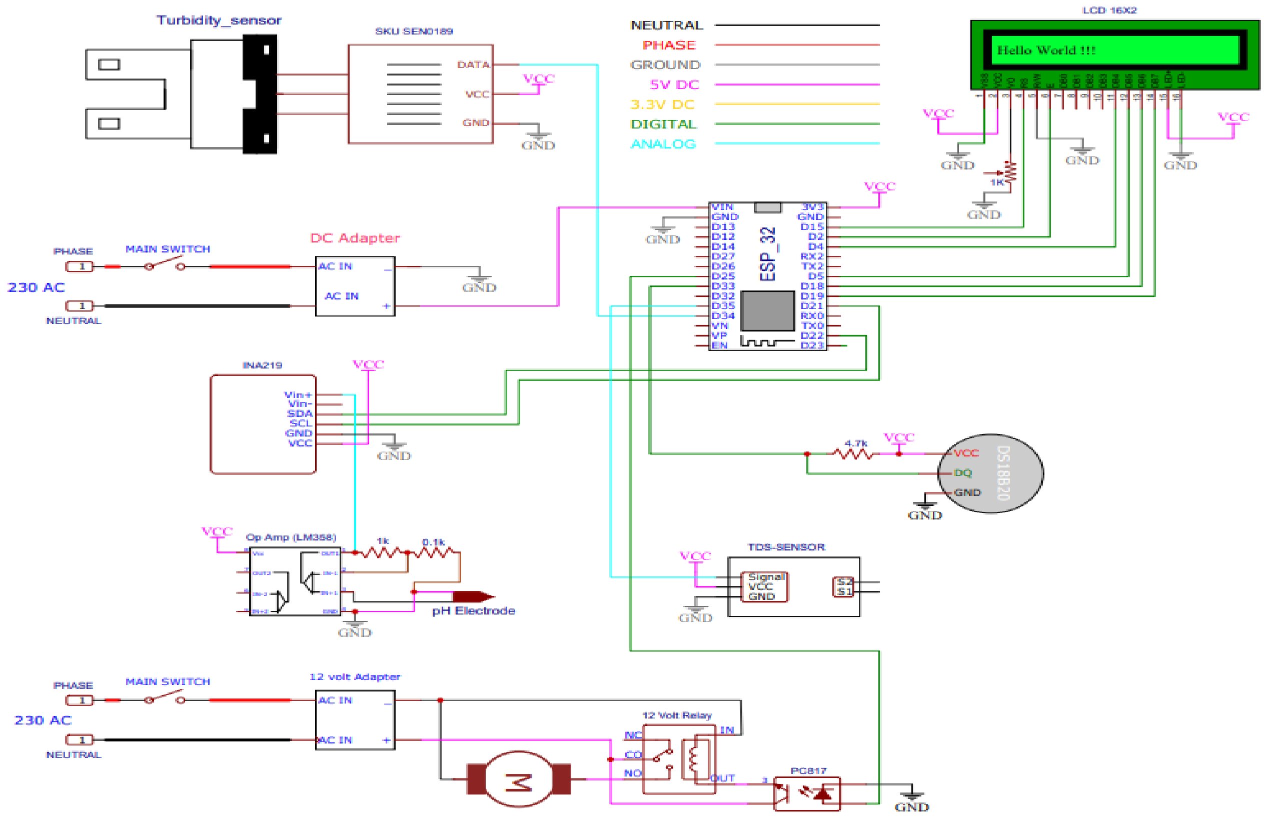

Fig. -2: Circuit architecture

4. Results and Performance Analysis

The prototype system underwent comprehensive testing in a controlled laboratory environment and simulated residential settings to evaluate performance characteristics under varied conditions.

4.1 Sensor Response Characteristics

The fundamental characteristic of the sensors in this system is their capability for real-time measurement. The overall system, which relies on the sensors, is expected to exhibit high performance based on referenced studies, Since most physical sensors output analog signals, the conversion characteristic is crucial.

Table -1: WHO Safe Limits for Drinking Water

SL.No	Parameter	Range
1	pH	6.5-8.5
2	Turbidity	0-1NTU
3	Temperature	10° -20° C
4	TDS	Up to 500mg/L

4.2 Control System Performance

The project primarily focuses on monitoring water quality, but the control aspect and system performance are addressed through a direct control mechanism and a comparison against traditional methods.

The performance of the system is highlighted by its advantages over traditional methods and its projected outcomes. Real-Time and Efficiency: The system is low-cost, efficient, and scalable. It enhances decision-making and responsiveness by enabling real-time monitoring and providing timely alerts, which traditional methods lack. Accuracy and Consistency: The use of sensors and IoT is expected to deliver accurate and consistent data in real-time. Related studies cited in the report confirmed the system's ability to find testing parameters like pH and TDS with high accuracy, matching laboratory results.

The system continuously monitors key parameters like Temperature, Turbidity, pH, and Flow. Once the sensed values are processed, the data is made visible on the cloud via cloud computing, enabling real-time surveillance and timely intervention.

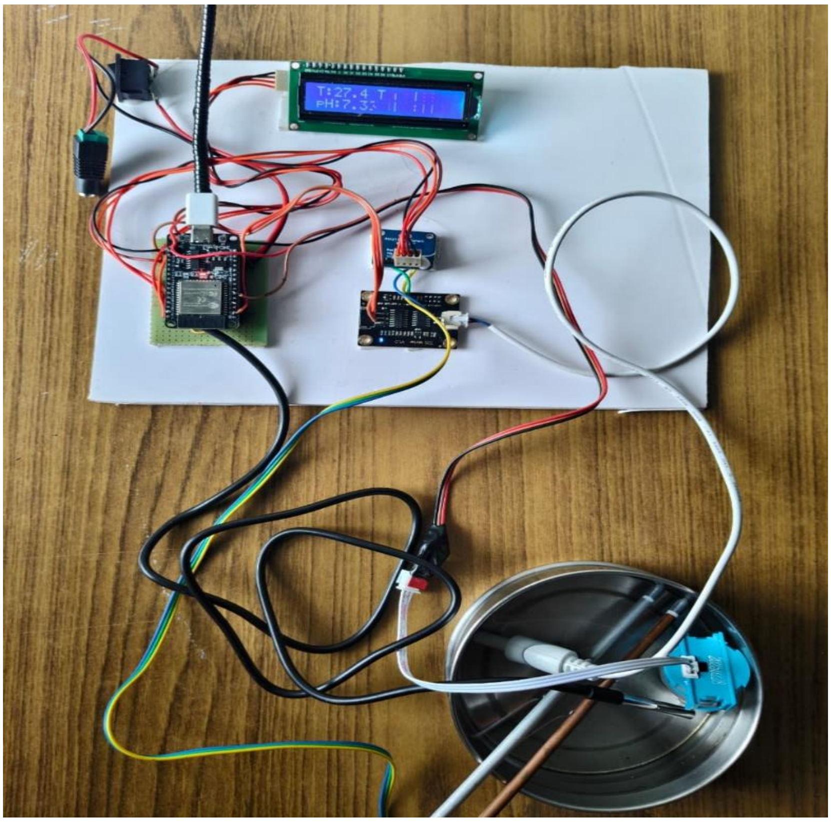

Fig 1: Complete circuit setup of IoT based water quality monitoring

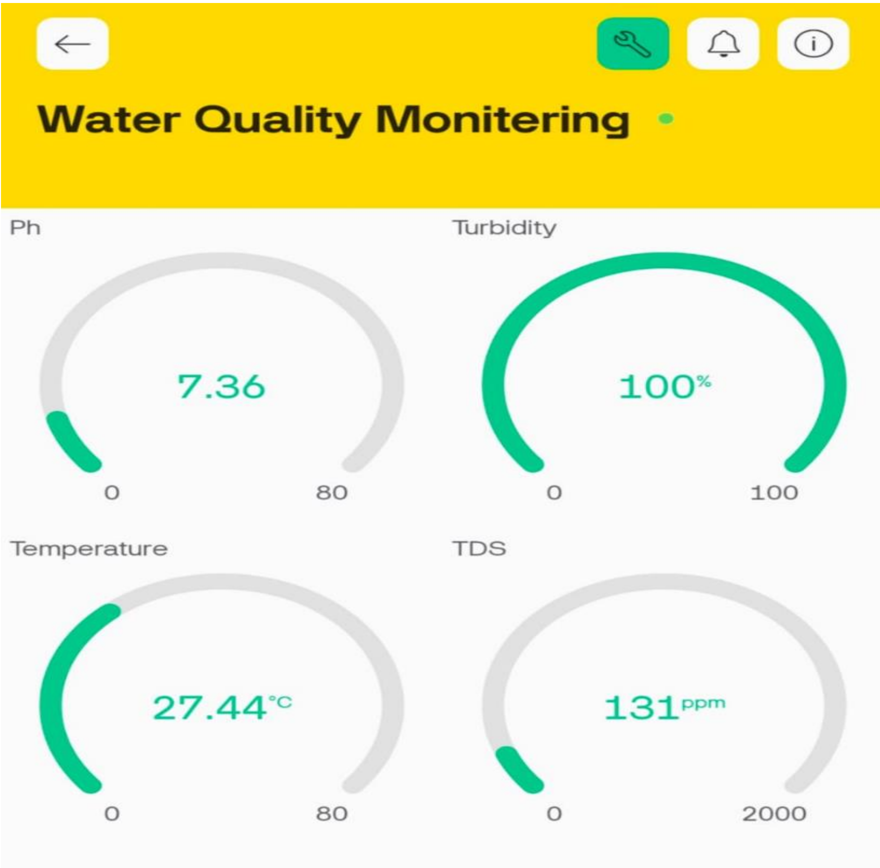

Fig.2 : Readings of sensors in Blynk IoT

5. Conclusions

Based on the results of the research that has been done, it can be concluded that a water quality monitoring system based on the Internet of Things using a temperature sensor, pH sensor, turbidity sensor, and salinity sensor can monitor water in terms of temperature, pH, turbidity, and salt content whose data is displayed. we discuss the latest technology that can help to Early detection of contaminants: IoT-based water quality monitoring systems can detect contaminants in water at an early stage, before they can become a major health hazard. This can help prevent outbreaks of waterborne diseases and reduce the risk of contamination in the water supply.

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