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IoT based Embedded Process Control System for Water Level Monitoring

Repala Ashritha[1], Maganti Srinivas[2], Saini Pooja[3], Gorrepati Sai Deepak[4] and Pothuboyina Bharath Kumar[5]
[1-5]Electronics and Instrumentation Engineering, Velagapudi Ramakrishna Siddhartha Engineering College, Vijayawada, India
Email: srinivas.maganti@gmail.com, 228w1a1052@vrsec.ac.in, 228w1a1020@vrsec.ac.in, 228w1a1046@vrsec.ac.in, ashritharepala@gmail.com

***Abstract*— This paper presents an IoT-based embedded process control system designed for efficient and continuous water level monitoring using low-cost hardware components. The system is built around an ESP8266 microcontroller, which provides both processing capability and integrated Wi-Fi communication for real- time data transmission. An ultrasonic sensor is used to accurately measure the water level by calculating the distance between the sensor and the water surface. Based on the measured level, an LED indicator provides immediate visual feedback for low, medium, or high water conditions[1]. To enhance user interaction and remote accessibility, the system communicates the processed water level data to a Think Speaker, enabling voice-based alerts and notifications. This feature ensures that users receive timely warnings about tank overflow, low water levels, or abnormal conditions, even when they are not physically present near the system. The power supply module ensures stable operation of all components, supporting continuous monitoring without interruption.**

***Keywords*— IOT, ESP8266, Ultrasonic Sensor, Embedded System, Water Level Monitoring, Process Control, Smart Water Management, Wireless Communication, LED Indicator, Think Speaker Alerts, Real-Time Monitoring, Automation, Sensor Integration.**

I. INTRODUCTION

Water is a vital resource, and its efficient management has become increasingly important due to rising demand and frequent shortages in domestic, agricultural, and industrial sectors. Traditional methods of monitoring water levels in tanks and reservoirs rely heavily on manual inspection, which is time- consuming, inaccurate, and often leads to problems such as overflow, dry-run of pumps, or wastage of water [2]. With the rapid growth of the Internet of Things (IOT), automated monitoring and control systems have become an effective solution for achieving smart and efficient water management. An IOT based embedded water level monitoring system utilizes sensors, microcontrollers, and wireless communication to continuously track water levels and provide real-time feedback to users. In this project, an ESP8266 microcontroller forms the backbone of the system, enabling both data processing and Wi-Fi connectivity. An ultrasonic sensor is used to measure water levels with high accuracy, while LED are incorporated as visual indicators to instantly display water status at the tank location. To enhance user interaction, the system integrates a Think Speaker, which provides voice-based notifications and alerts about critical water levels. This makes the system more user-friendly and accessible, even for individuals who are away from the monitoring site [3].

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When combined with embedded systems, IOT provides the ability to integrate sensors, microcontrollers, communication modules, and intelligent notification mechanisms into a compact and effective solution. Such systems are increasingly being adopted in modern households, commercial buildings, smart cities, and agricultural irrigation systems due to their reliability, low cost, and scalability. The combination of embedded hardware and IOT connectivity enables remote monitoring, timely alerts, and improved decision-making. The proposed system aims to provide a low-cost, efficient, and reliable solution for water level monitoring using IOT technologies.

By minimizing manual effort, reducing water wastage, and ensuring better control of pumps or water distribution, this project demonstrates how embedded systems and IoT can contribute to smarter resource management [4]. Water management is becoming increasingly critical as population growth, urbanization, and industrial expansion place greater pressure on available water resources. Traditional methods of monitoring water levels—such as visual inspection or manual switch operations—are often unreliable, laborintensive, and prone to human error.

II. LITERATURE SURVEY

Recent research and project reports show a clear trend toward low-cost, IOT enabled water level monitoring systems that combine non-contact sensing with wireless connectivity to provide real-time status and automatic alerts. Many studies use ultrasonic sensors (e.g., HC-SR04) for reliable distance- based level measurement and pair them with ESP8266/Node MCU modules for on-board processing and Wi-Fi data transmission to mobile apps or cloud dashboards. These implementations demonstrate straightforward architectures for domestic and agricultural tanks and emphasize benefits such as reduced manual intervention, prevention of pump dry-run, and overflow avoidance.

Experimental work also evaluates the accuracy and robustness of low-cost ultrasonic and pressure sensors under varying environmental conditions, [5] and several authors report successful field and lab deployments. Experimental work also evaluates the accuracy and robustness of low-cost ultrasonic and pressure sensors under varying environmental conditions, and several authors report successful field and lab deployments. More recent projects extend the basic monitoring stack by adding voice interfaces (Alexa/Google Assistant or custom speakers) and simple control logic to allow voice queries, spoken alerts, or remote pump actuation-showing how voice-enabled IOT improves user accessibility and real-time awareness.

- Sensing approaches: Ultrasonic (non-contact) sensors are widely used for tank/tank-top measurements; pressure transducers and float/switch methods are alternatives with different cost/accuracy trade offs.
- Embedded controllers: ESP8266/Node MCU and Arduino families are common choices for data acquisition and Wi-Fi connectivity due to low cost and large community support.
- Communication & cloud: Amplitude and duration of P, QRS, and T waves.
- Local feedback & control: LED indicators, buzzers, and relay-driven pump control implement immediate local actions; many papers describe automated pump on/off logic to prevent overflow/dry-run.
- Accuracy & calibration: Literature highlights the need for calibration and occasional field tests: low-cost ultrasonic units perform well when properly mounted and calibrated, but environmental effects (temperature, splashing) must be considered.
- Applications & scale: Implementations range from single household tanks to agricultural irrigation and flood early-warning prototypes; scalability often requires added sensors (turbidity, pH) and more robust communications.

Recent literature on smart water management highlights a growing focus on IOT enabled monitoring systems that combine embedded hardware, wireless communication, and cloud integration to achieve accurate and automated water level detection.

As IOT technology evolved, ultrasonic sensors became widely adopted due to their non-contact measurement technique, high precision, and suitability for closed tanks. Many researchers chose the ESP8266 or Node MCU microcontroller because it provides a compact, low-power, and Wi-Fi-enabled platform capable of real-time data acquisition and network connectivity[6].

Several studies present systems that upload sensor data to platforms like Thing Speak, Ubidots, or Blynk, where users can visualize long-term water usage trends, receive threshold alerts, and remotely manage pump operations. Moreover, literature shows increasing interest in automation, with many works integrating Other studies focus on enhancing user interaction by incorporating mobile applications, GSM modules, or MQTT based dashboards, enabling flexible monitoring and control from any location.

III. Existing Methods

Existing methods for water level monitoring have evolved from simple manual and electromechanical techniques to modern IoT-based automated solutions. Traditional systems commonly use float sensors, conductive probes, or mechanical switches to detect water levels, but these methods suffer from corrosion, frequent maintenance, and limited accuracy. As embedded technologies advanced, researchers introduced microcontroller-based systems using Arduino, PIC, or AVR controllers paired with basic sensors to automate pump control; however, these systems generally lacked remote monitoring and data logging capabilities[7].More recent IoT- based approaches employ ultrasonic sensors to achieve non- contact and highly accurate water level measurement, combined with Wi-Fi-enabled controllers like ESP8266 or Node MCU to transmit data wirelessly to cloud platforms such as Blynk, Thing Speak, or Mobile Apps.These systems offer features like real-time tank status, push notifications, and automated pump operation through relay control. Some existing methods also integrate GSM modules to send SMS alerts where internet connectivity is limited. A few advanced solutions have started incorporating voice assistants, mobile dashboards, and MQTT protocols for improved usability and low-latency communication. Despite these improvements, many existing systems still face challenges such as limited user interaction, lack of voice alerts, dependence on stable internet connection, and absence of a fully integrated process control environment— highlighting the need for more intelligent, accessible, and feature-rich IOT based water level monitoring systems[8].More advanced methods use GSM modules to send SMS alerts, which are effective in areas with limited internet connectivity but lack real-time dashboards. Modern IOT based methods using ESP8266 or Node MCU enable Wi-Fi connectivity to cloud platforms such as Blynk, Thing Speak, or Firebase, offering real-time monitoring, alert notifications, and graphical data visualization.

Despite these advancements, limitations such as dependency on stable internet.To provide better remote monitoring, GSM-based systems were developed that send SMS alerts to users, but they cannot provide continuous monitoring or graphical data visualization.

- Float Sensor–Based Monitoring: Uses mechanical floats to detect water levels.
- Conductive/Probe-Based Water Level Detection: Uses metal probes that sense water conductivity. Easy to implement but suffers from corrosion and frequent maintenance.
- Mobile App Integrated Systems: Android/iOS apps display tank levels and send push notifications. Requires app development and stable internet connectivity.
- GSM-Based Water Level Monitoring: Sends SMS alerts using GSM modules like SIM800/SIM900.Useful in non-Internet areas but lacks real-time dashboards.

IV. Proposed Methodology

The methodology of the IoT-based embedded process control system for water level monitoring involves a step-by- step process that integrates sensing, processing, indication, and alert mechanisms to achieve realtime monitoring and control.A stable power supply is provided to all components to ensure continuous operation. The ultrasonic sensor is positioned above the water tank to measure the distance between the sensor and the water surface, and these readings are periodically processed by the ESP8266 to calculate the current water level[9]. Additionally, through Wi-Fi connectivity, the ESP8266 transmits water- level data to an IoT cloud platform, enabling users to monitor the tank remotely on their smartphones or web dashboards.IoT-based embedded process control system for water level monitoring begins with setting up a regulated power supply to drive the ESP8266 microcontroller, ultrasonic sensor, LCD display, and buzzer.The ultrasonic sensor is mounted at the top of the water tank and continuously emits ultrasonic pulses; the time taken for the echo to return is measured to accurately calculate the water level. These distance measurements are read by the ESP8266, which processes the data using programmed threshold values to determine whether the tank is in low, medium, or high water-level conditions.The calculated level is displayed in real time on the LCD screen, providing an immediate local indication to the user.

These distance measurements are read by the ESP8266, which processes the data using programmed threshold values to determine whether the tank is in low, medium, or high water-level conditions.The calculated level is displayed in real time on the LCD screen, providing an immediate local indication to the user[10].The ESP8266 is a low-cost Wi-Fi-enabled microcontroller widely used for IoT applications.It contains a powerful Tensilica LX106 core, built-in Wi-Fi module, multiple GPIO pins, and support for ADC inputs. In this project, the ESP8266 acts as the main control unit that reads water-level data from the ultrasonic sensor, processes the readings, drives the buzzer and LCD, and uploads real-time data to the IoT cloud. Its wireless capability enables remote monitoring without needing additional network modules, making the system compact and cost-effective.

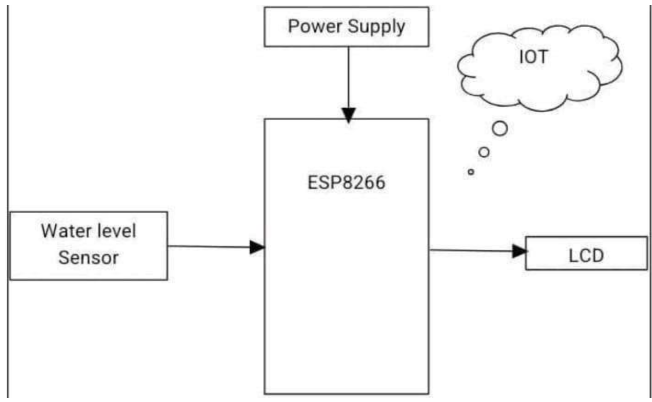

Fig.1. Block Diagram of water level monitoring

The block diagram represents the overall functioning of the IOT based embedded process control system for water-level monitoring Fig[1]. The system begins with the power supply, which provides a stable DC voltage required to operate all components, including the ESP8266 microcontroller, the water-level sensor, and the LCD display. This sensed data is sent directly to the ESP8266, which acts as the central processing unit of the system. The ESP8266 processes the sensor readings, compares them with predefined thresholds, and decides the necessary action. This sensed data is sent directly to the ESP8266, which acts as the central processing unit of the system[11].

$$\text{Water Level} = \text{Total Tank level} - \text{Distance Measured}$$

A. Power Supply

The power supply is a critical component in the IOT based embedded process control system for water-level monitoring, as it ensures a stable and reliable source of electrical energy for all modules[12]. The system typically uses a regulated 5V DC power supply, which is suitable for powering the ESP8266 microcontroller, ultrasonic sensor, LCD display, and additional indicators like buzzers or LED.

Fig .2. Power Supply

A stable power supply is essential for precise sensor readings, continuous Wi-Fi communication, and overall system reliability Fig[2]. The system commonly uses a regulated 5V DC power supply, which is compatible with key components such as the ESP8266 microcontroller, ultrasonic sensor, LCD module, and buzzer TABLE.1.

TABLE I: POWER SUPPLY SPECIFICATIONS

Parameter	Specification
Input Voltage	230VAC (Main Supply)
Output Voltage	5V DC Regulated
Powering Components	ESP8266, LCD, Ultrasonic Sensor, Buzzer
Efficiency	70%–90% depending on design
Operating Temperature	0°C – 50°C

B. ESP8266

The ESP8266 is a highly integrated, low-cost Wi-Fi- enabled microcontroller widely used in IOT applications due to its compact size, efficient performance, and built-in networking capabilities. This eliminates the need for external network hardware, greatly reducing system complexity and cost. The module supports both station and access-point modes, enabling flexible network connectivity[13].It includes GPIO pins for interfacing with sensors and peripherals, PWM outputs, ADC input.

Fig.3. ESP8266

TABLE II: ESP8266 SPECIFICATIONS

Parameter	Specification
Operating Voltage	3.3V DC
Wi-Fi Standard	802.11 b/g/n
Flash Memory	512KB-4MB
GPIO Pins	9-11

The ESP8266 is a versatile IOT microcontroller module known for its strong wireless capabilities and ease of integration. It was designed by Espress if Systems and quickly became popular due to its combination of processing power, low cost, and built-in Wi-Fi Fig[3]. Unlike traditional microcontrollers, the ESP8266 integrates both the CPU and Wi-Fi radio on a single chip, making it ideal for compact IOT devices.It can run standalone applications or act as a Wi-Fi adapter for another microcontroller TABLE.2. One of its major advantages is its ability to host a lightweight TCP/IP stack, allowing it to handle HTTP requests, MQTT communication, and cloud data exchange without additional hardware.

C. Ultrasonic Sensor

The ultrasonic sensor, commonly the HC-SR04, is a non-contact distance measurement device that uses high-frequency sound waves to detect the level of water inside a tank. It operates by emitting ultrasonic pulses from its transmitter and measuring the time taken for the echo to bounce back from the water surface to the receiver[14. In the IOT based embedded process control system for water-level monitoring, the ultrasonic sensor acts as the primary sensing unit that continuously measures water height without physical contact, making it more reliable and durable than float sensors.

Fig.4. Ultrasonic Sensor

The ESP8266 processes this distance data to determine whether the tank is full, half-full, or empty. Because the sensor is immune to corrosion and unaffected by water quality, it ensures high accuracy and long-term stability, making it ideal for automated water-level systems. Based on this reading, the system updates the LCD display, TABLE.3. triggers the buzzer when levels are too high or too low, and uploads real-time data to the IoT cloud for remote monitoring Fig [4].

TABLE III: ULTRASONIC SENSOR SPECIFICATIONS

Parameter	Specification
SensorModel	HC-SR04 UltrasonicSensor
OperatingVoltage	5V DC
Operating Current	15mA
Measuring Range	2cm to 400cm
Accuracy	±3 mm
Operating Temperature	–15°C to +70°C

D. LCD

In the IOT based embedded process control system for water-level monitoring, the 16x2 LCD display plays an important role in providing real-time visual feedback to the user.his LCD can display 16 characters per line across 2 lines, making it suitable for showing water-level values, system status messages, and alerts. LCD is interfaced with the ESP8266 microcontroller using digital pins through either 4- bit or 8-bit communication mode, with 4-bit mode often preferred to reduce pin usage[15].

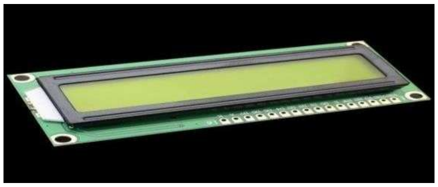

Fig.5. LCD

It includes an internal controller (HD44780) that makes communication simple and reliable. The display provides immediate and continuous information about water levels such as “Tank Full,” “Medium Level,” or “Low Level,” allowing the user to monitor the system even without internet access Fig[5].The brightness can be adjusted using a potentiometer connected through the V0 (contrast) pin, ensuring clear visibility under different lighting conditions.

E. BUZZER

In the IoT-based embedded process control system for water-level monitoring, the buzzer functions as an essential audio alert component that notifies the user about critical water-level conditions[16].

Fig. 6. Buzzer

When the water level reaches predefined thresholds— such as very low level (indicating the tank needs refilling) or very high level (indicating possible overflow)—the ESP8266 activates the buzzer through a digital output pin. The buzzer produces a loud beeping sound that immediately alerts nearby users, ensuring quick corrective action Fig[6].

V. RESULT

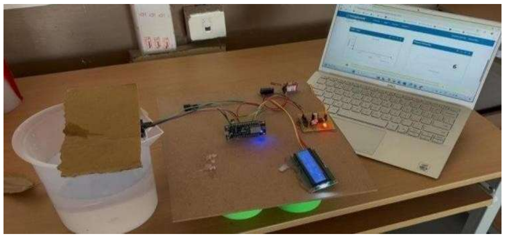

Fig.7. Predicted Low Level

The ultrasonic sensor placed above the water container detects that the water level inside the bucket is below the predefined threshold. This sensor reading is processed by the ESP8266 microcontroller, which identifies that the tank is at a low-level state.As a result, Fig[7] the LCD display on the board shows the corresponding message indicating the low level of water (such as “LOW LEVEL” or the exact distance/value). Additionally, the buzzer or LED indicator on the circuit board is activated to provide an immediate visual or audio alert.Simultaneously, the ESP8266 uploads the sensor data to the IOT platform—visible on the laptop screen, where the Thing Speak dashboard shows the real-time low-level reading (for example, the value “6” displayed)[17].

Fig.8. Predicted High level

The image represents the High Water Level condition in the IoT-based embedded process control system Fig[8]. In this setup, the ultrasonic sensor is placed on the top surface above the container filled with water. Since the water level is high, the distance between the sensor and the water surface becomes very small.

Fig.9. Alert Message

The image displays a text message alert received on a mobile phone indicating "Alert: Water Tank is FULL!" Fig[9]. This message is automatically generated by the IoT- based embedded water level monitoring system when the tank reaches its maximum water level[18]. When the ultrasonic sensor detects that the distance between the sensor and the water surface is very low—which signifies a High/Full water level.

VI. Conclusion

The IOT based embedded process control system for water level monitoring successfully demonstrates an efficient, real- time solution for managing water levels using low-cost electronic components such as the ESP8266 controller, ultrasonic sensor, LCD display, power supply module, and cloud platform integration.The system accurately detects low, medium, and high water levels, as shown in the experimental outputs where the LCD display, Thing Speak dashboard, and container setup clearly indicate changing values. In the high- level condition, the system also triggers automated SMS alerts to the user's mobile phone, ensuring instant notification when the tank becomes full[19]. These outputs prove the system's capability to monitor water levels remotely, prevent overflow, and provide continuous data recording through IOT cloud services. Overall, the project achieves reliable automation, enhances water usage efficiency, and demonstrates how embedded systems and IOT together can provide smart, practical, and user-friendly water management solutions.

Future Work

The current IOT based embedded water level monitoring system can be further enhanced by incorporating several advanced features to improve accuracy, automation, and scalability. Future work can focus on integrating machine learning algorithms to predict water usage patterns and automatically control pumps more efficiently [20]. The system can also be expanded to support multiple tanks by using a multi-node wireless sensor network, enabling remote monitoring of large buildings, farms, or industrial plants.

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