Water Level System - Technical Documentation

1. Introduction

The Water Level Detection and Automation System is an IoT-based solution designed to intelligently monitor and control the water levels in both overhead and underground tanks. Leveraging float sensors, an ultrasonic sensor, and a powerful ESP32 microcontroller with integrated Wi-Fi, the system enables remote real-time monitoring through a mobile application. It features automatic and manual operation modes, providing flexibility, efficiency, and convenience for domestic, agricultural, and industrial water management.

The system uses float sensors installed in overhead tanks to detect four distinct levels: empty, below medium, above medium, and full. An ultrasonic sensor (JSN-SR04T) in the underground reservoir provides continuous distance-based water level measurements. A well-engineered control box with LED indicators displays real-time status locally, and a compact PCB ensures a reliable, space-saving design.

Initially developed on Arduino, the project evolved into a more robust system using the ESP32 for Wi-Fi-based mobile integration. Challenges like voltage regulation heat issues were resolved with heat sinks and component optimization, including a 5V 30A relay for motor control. The result is a practical, compact, and reliable embedded system for sustainable water resource management.

2. System Architecture

The architecture consists of float sensors in overhead tanks, an ultrasonic sensor in the underground tank, an ESP32 controller, a relay-based motor control circuit, and a mobile application interface. The system operates in automatic or manual modes, with the ESP32 managing logic based on real-time sensor input.

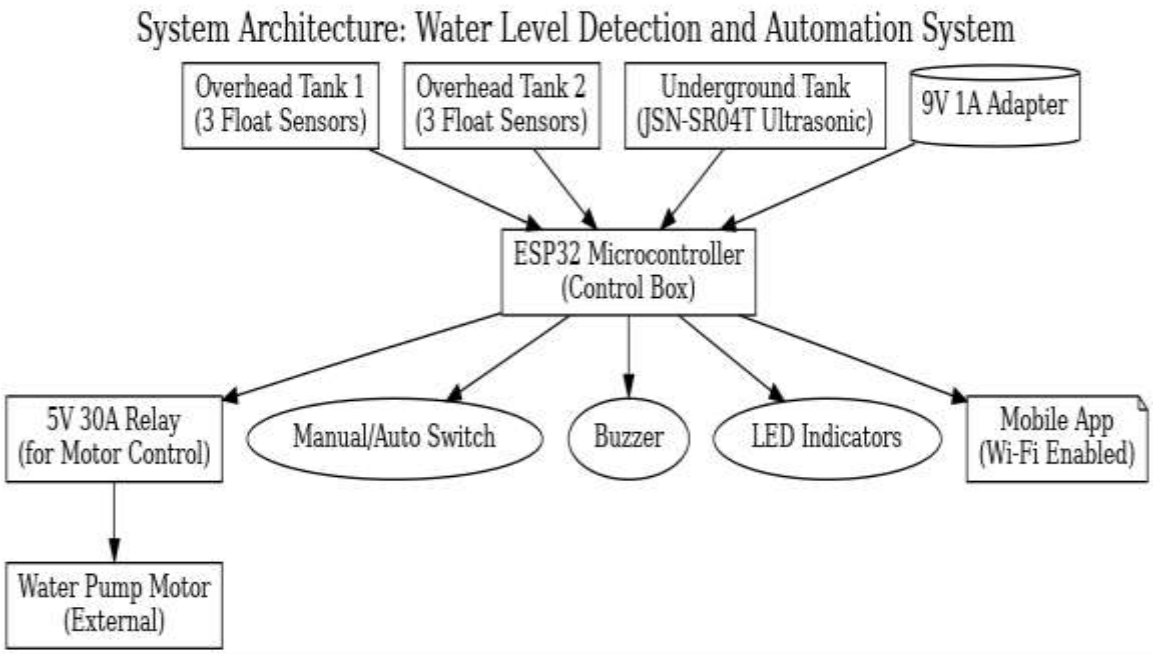

Fig. System Architecture of Water Level Automation System

3. Addressing Water Management Challenges

Manual water management is often inefficient, error-prone, and lacks timely intervention. Overflowing tanks, dry running motors, and water wastage are common consequences. Traditional systems rarely offer remote access, multi-tank support, or automated control logic.

The Water Level Detection and Automation System tackles these problems through real-time data acquisition and decision-making. It monitors multiple tanks simultaneously and ensures the motor only operates when conditions are met—such as the underground tank not being empty and the overhead tank not being full. This intelligent control reduces human error, conserves water, and lowers electricity consumption by preventing unnecessary motor use.

4. Hardware Components

1. **ESP32 Microcontroller Unit:**
    - Acts as the brain of the system, responsible for data processing, decision-making, and communication with other hardware components and the mobile application.
    - Utilizes its built-in Wi-Fi capabilities for wireless communication with the mobile application.

2. **Custom PCB:**
    - Houses various components including the relay, switch, LED indicators, and power supply.
    - Provides a centralized platform for connecting and interfacing with sensors and actuators.

3. **Sensors:**
    - **Float Sensors (3)**:
        - Installed inside the overhead tank to detect three water levels: low, medium, and high.
        - Send signals to the ESP32 microcontroller indicating the current water level.
    - **JSN-SR04T Ultrasonic Sensor**:
        - Mounted underground to measure the distance to the water level in the underground reservoir.
        - Sends distance measurements to the ESP32 for further processing.

4. **5V DC Power Supply:**
    - Provides stable power to all system components, ensuring continuous operation.

5. Software Components

1. **Firmware:**
    - Developed for the ESP32 microcontroller to handle data processing, decision-making, and control logic.
    - Implements algorithms for water level monitoring, motor control, and communication with the mobile application.
    - Utilizes the ESP-IDF (Espressif IoT Development Framework) for efficient development and deployment.

2. **Mobile Application:**
    - Provides a graphical user interface (GUI) for users to interact with the system.
    - Allows users to:
        - Monitor real-time water levels in the tank and underground reservoir.
        - Control the motor remotely, turning it on or off as needed.
        - Switch between automatic and manual operation modes.
        - Receive alerts and notifications about water level changes or system malfunctions.

6. Operation

The Water Level Detection and Automation System operates through a series of coordinated steps involving sensor data acquisition, automated decision-making, motor control, and user interaction through the mobile application. Let's explore each aspect in detail:

Sensor Data Acquisition

1. **Float Sensor Data Acquisition:**
    - The system continuously monitors water levels in the overhead tank using three float sensors positioned at different levels: low, medium, and high.
    - Each float sensor sends signals to the ESP32 microcontroller indicating the current water level.

2. **Ultrasonic Sensor Data Acquisition:**
    - The underground reservoir's water level is measured using a JSN-SR04T ultrasonic sensor.
    - The ultrasonic sensor emits ultrasonic pulses and measures the time taken for the pulses to reflect back from the water surface.
    - The measured distance is converted into water level data and transmitted to the ESP32 microcontroller.

Automated Control

1. **Automatic Mode:**
    - In automatic mode, the system autonomously manages the operation of the motor based on real-time water level data.
    - If the water level in the overhead tank falls below a certain threshold (low level), indicating the need for refilling, the system activates the motor to start pumping water.
    - The motor continues to operate until the water level reaches a predefined maximum level (high level), at which point it is automatically turned off to prevent overfilling.

2. **Manual Mode:**
    - Users have the option to switch to manual mode via the mobile application.
    - In manual mode, users can control the motor manually, overriding the automated operation if necessary.
    - This mode provides flexibility and allows users to intervene in the system's operation as needed.

Motor Control

1. **Motor Activation:**
    - Upon receiving signals from the ESP32 microcontroller, the motor control unit activates the motor to start pumping water from the underground reservoir to the overhead tank.
    - The motor operates at a predetermined speed and duration, ensuring efficient water transfer while minimizing energy consumption.

2. **Motor Deactivation:**
    - Once the water level in the overhead tank reaches the desired maximum level, as detected by the float sensors, the motor control unit deactivates the motor to stop pumping water.
    - This prevents overfilling of the tank and conserves water resources.

Mobile Application Interaction

1. **Real-Time Monitoring:**
    - Users can monitor water levels in the tank and underground reservoir in real time through the mobile application.
    - The application displays visual indicators or numerical values representing the current water level status.

2. **Remote Control:**
    - Users can remotely control the motor's operation through the mobile application.
    - They can turn the motor on or off, switch between automatic and manual modes, and adjust system settings as needed.

3. **Alerts and Notifications:**
    - The mobile application sends alerts and notifications to users in case of abnormal water levels, system malfunctions, or other critical events.
    - This feature ensures timely awareness and enables users to take appropriate action to address issues.

Safety Measures

Fail-Safe Mechanisms:

- The system incorporates fail-safe mechanisms to prevent accidents or damage in case of sensor or equipment failures.
- For example, redundant sensors may be used to cross-validate water level data, and emergency shutdown procedures may be implemented in case of critical errors.

7. Features

The Water Level Detection and Automation System offers a wide range of features designed to provide efficient water management, user convenience, and system reliability. Let's explore each feature in detail:

1. Real-Time Water Level Monitoring

- **Continuous Monitoring**: The system continuously monitors water levels in the tank and underground reservoir in real time.
- **Sensor Accuracy**: Utilizes advanced sensors to provide accurate and reliable water level measurements.
- **Visual Feedback**: Displays water level status graphically or numerically through the mobile application interface.

2. Automated Operation

- **Automatic Mode**: Allows the system to autonomously manage the motor's operation based on real-time water level data.
- **Optimized Water Usage**: Ensures efficient water management by automatically filling or emptying the tank as needed.
- **Energy Efficiency**: Minimizes energy consumption by controlling the motor's operation based on demand.

3. Manual Override

- **Manual Mode**: Provides users with the option to manually control the motor's operation, overriding automated settings if necessary.
- **Flexibility**: Allows users to intervene in the system's operation as needed, providing greater control and customization.

4. Remote Control

- **Mobile Application Interface**: Enables users to monitor water levels and control the motor remotely through a dedicated mobile application.
- **Convenience**: Allows users to manage the system from anywhere, providing flexibility and convenience.

5. Alerts and Notifications

- **Real-Time Alerts**: Sends alerts and notifications to users in case of abnormal water levels, system malfunctions, or critical events.
- **Timely Awareness**: Ensures users are promptly informed of any issues, allowing for quick response and resolution.

6. Safety Features

- **Fail-Safe Mechanisms**: Incorporates fail-safe mechanisms to prevent accidents or damage in case of sensor or equipment failures.
- **Overload Protection**: Includes overload protection features to safeguard the motor and other components from damage due to excessive load or power surges.

7. Customizable Settings

- **User Preferences**: Allows users to adjust system parameters and operating modes to suit their specific requirements.
- **Personalization**: Provides customization options for notifications, alerts, and other system settings through the mobile application.

8. Historical Data Logging

- **Data Logging**: Optionally logs historical water level data and system performance metrics for analysis and troubleshooting.
- **Insightful Analytics**: Enables users to analyze trends and patterns in water usage over time, facilitating informed decision-making.

9. Integration with Cloud Services

- **Cloud Connectivity**: Optionally integrates with cloud platforms to enable data synchronization, remote monitoring, and management.
- **Scalability**: Provides scalability and flexibility for expanding the system's capabilities and integrating with third-party services.

8. Some Hardware diagrams:

Fig. PCB design of Water level Automation System

Fig. Water level Automation System

Fig. ESP-32 Microcontroller

9. Conclusion

The Water Level Detection and Automation System represents a refined, compact, and field-tested solution for intelligent water management. Its ability to monitor multiple tanks, operate in both manual and automatic modes, and communicate status in real-time via a mobile app makes it highly adaptable to various user needs.

With each iteration—from Arduino prototyping to the final ESP32-powered version—the design evolved to enhance reliability, user interface, and performance. Incorporating practical solutions like LED indicators, PCB-based assembly, and heat management for voltage regulation demonstrates a thorough engineering approach.

This system not only solves everyday challenges of water monitoring and motor control but also paves the way for smarter, IoT-enabled infrastructure. Its scalable design and modularity ensure that it can be extended to support more tanks or integrate with cloud-based analytics in the future.