International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Automatic Water Level Monitoring and Pump Control System with Motor Health Monitoring using ESP32

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Abstract - Manual supervision of water storage tanks often leads to dry running of pumps or tank overflow, and the condition of the pump itself is rarely monitored. This paper presents the design of a low-cost, ESP32-based system that automatically monitors water level and controls a pump, together with a basic motor-health monitoring layer. A non-contact ultrasonic sensor measures the distance to the water surface, which the ESP32 converts into a percentage water level and compares with ON and OFF thresholds, using hysteresis to avoid repeated relay switching. A dual-channel relay module switches a 5 V pump, and an OLED display shows the water level, pump state, tank state and motor-health status locally, without a computer or cloud connection. Vibration, current and temperature sensing supply the inputs for a three-level health indication (Healthy, Warning, Critical). The system is powered by two 3.7 V Li-ion cells through a buck converter. A hardware prototype with a two-container test setup has been assembled and is described in this paper. The architecture combines process control and equipment-condition awareness in one embedded unit and is suited to domestic, agricultural and laboratory water tanks. Quantitative calibration results and threshold values remain to be established through further testing.

Key Words: Water level monitoring, ESP32, ultrasonic sensor, pump control, motor health monitoring, OLED display.

1. INTRODUCTION

Water storage tanks in homes, farms, institutions and small utilities are commonly supervised by manual observation. If the user notices the water level late, the tank may run empty or, when the pump is switched off late, overflow. Both situations waste water and energy and add to the routine workload of the user. Automatic sensing and actuation directly reduce this dependence on human supervision, and several embedded water-management systems have shown that ultrasonic level sensing combined with microcontroller-based control can automate tank monitoring and pump operation at low hardware complexity [2]–[5].

Low-cost microcontrollers and sensor modules have made such systems practical for small installations. The ESP32 is attractive for a prototype because the device provides general-purpose input/output (GPIO), analog-to-digital converter (ADC), Inter-Integrated Circuit (I²C), Serial Peripheral Interface (SPI), universal asynchronous receiver-transmitter (UART) and pulse-width modulation (PWM) interfaces on a single chip [1]. The present work uses only the interfaces required for the sensing, switching and display functions.

Most reported water-level controllers concentrate on the water level alone, and the pump is treated as an actuator whose health is not observed. A pump may continue to be commanded ON while it suffers abnormal vibration, excessive current or elevated temperature. The motor condition-monitoring literature identifies vibration and electrical signals as useful indicators of abnormal rotating-machine behaviour [6], [7]. This paper therefore treats pump control and motor condition as related supervisory functions of one embedded unit.

The main contributions of this work are: (i) an ESP32-based architecture for non-contact water-level measurement and relay-based pump control with hysteresis; (ii) a local OLED interface that shows water level, pump state, tank state and motor health; (iii) a three-level motor-health indication (Healthy, Warning, Critical) based on vibration, current and temperature sensing; and (iv) a working hardware prototype assembled with low-cost modules. The rest of the paper is organised as follows. Section 2 reviews related work, Section 3 describes the system design and methodology, Section 4 presents the prototype and discussion, and Section 5 concludes the paper.

2. LITERATURE REVIEW

2.1 Water-level monitoring and pump control

Patil et al. [4] describe an Internet of Things (IoT) based smart water management system that monitors water usage, water purity and tank level in one place, helping to detect problems such as pipe leakage, with the data shown on a user interface. Nwufoh et al. [3] designed a wireless water monitoring and pump control system around a PIC16F877A microcontroller, in which sensors placed at several levels in the tank send level information over a radio-frequency (RF) link; the pump was switched ON when the water was low and OFF when the tank was full.

Yap and Ali [5] developed a smart water management system with ultrasonic level sensors, an Arduino-based controller for automatic pump control and an I²C liquid-crystal display, aimed at preventing overflow and dry-run conditions; remote monitoring and control were added through the Blynk IoT platform. Rajanbabu et al. [2] combined an ultrasonic sensor and a Raspberry Pi with fuzzy-logic decision making and an Android application for remote monitoring and control, and reported a reduction of up to 6 % in electricity expenses under different activation timings.

2.2 Motor condition monitoring

Condition monitoring aims to detect abnormal machine behaviour early instead of waiting for failure. Nandi et al. [6] reviewed condition monitoring and fault diagnosis of electrical motors, and Gangsar and Tiwari [7] reviewed signal-based techniques for fault detection and diagnosis of induction motors, in which vibration and electrical signals are among the main sources of diagnostic information. These works address larger induction motors and use advanced signal processing. In the present prototype, the same idea is applied in a much simpler form: vibration, current and temperature are observed on a small

pump motor and interpreted against experimentally selected limits.

2.3 Research gap

Table 1 summarises the reviewed water-level systems. The abstracts of these works describe level sensing, pump control and, in several cases, remote access, but do not report monitoring of the pump or motor condition. The proposed system addresses this gap by adding motor-health sensing to a local, self-contained water-level controller.

Table -1: Comparison of related water-level systems

Ref.	Controller	Level sensing	Additional features
[2]	Raspberry Pi	Ultrasonic	Fuzzy logic, Android app
[3]	PIC16F877A	Multi-level sensors	RF link, pump ON/OFF
[4]	Not stated	Tank level	IoT, usage and purity
[5]	Arduino	Ultrasonic	I²C LCD, Blynk IoT
This work	ESP32	Ultrasonic	OLED, relay, motor health

3. SYSTEM DESIGN AND METHODOLOGY

3.1 System architecture

The proposed system follows a closed-loop monitoring and control structure, shown in Fig. 1. The ultrasonic sensor supplies the primary process variable, which is the distance from the sensor to the water surface. The ESP32 acquires and processes this value, converts it into a water level and compares it with the programmed control condition. A relay module then acts as the switching interface for the pump. In parallel, the motor-health sensors provide additional information that is evaluated by the controller and displayed locally. Sensing, decision-making, actuation and feedback are kept separate, so each subsystem can be tested independently.

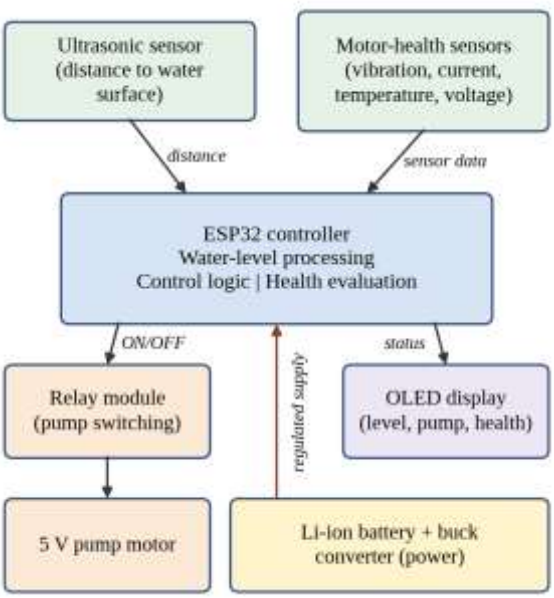


Fig -1: Architecture of the proposed water-level and motor-health monitoring system.

3.2 Hardware components

The hardware consists of sensing, processing, display, switching, power and motor-health subsystems, listed in Table 2. The ESP32 is the central controller. The relay module provides the interface between the low-voltage controller logic and the pump-switching path, and the OLED acts as the local user interface.

Table -2: Components used in the proposed system

Component	Functional role
ESP32	Main controller and signal processing
Ultrasonic sensor	Non-contact measurement of water-surface distance
Dual-channel relay module	Electrical switching interface for the pump
5 V pump motor	Actuator for water transfer
2 × 3.7 V Li-ion cells	Prototype energy source
Buck converter	Regulated supply for the electronics
OLED display	Local display of level, pump state and health
Vibration, current and temperature sensors	Observation of pump/motor condition

3.3 Water-level measurement

The ultrasonic sensor transmits a pulse and detects the returning echo. With the sensor mounted above the tank and facing the water surface, the distance d follows from the echo time t and the speed of sound v (about 343 m/s in air at 20 °C):

$$d = v \cdot t / 2 \quad (1)$$

If H is the reference height from the sensor to the tank bottom, the water height h and the percentage level L are

$$h = H - d \quad (2)$$

$$L = (h / H) \times 100\ \% \quad (3)$$

subject to calibration and the actual tank geometry. Ultrasonic readings can be affected by sensor placement, tank shape, surface ripples and unwanted reflections, so suitable mounting, consistent measurement timing and software validation or filtering are required.

3.4 Pump control logic

The control algorithm runs as a periodic task, as shown in Fig. 2. When the level L falls below the ON level L_{on}, the controller commands the relay to start the pump. When L reaches the OFF level L_{off}, the pump is stopped. Between the two levels the previous state is retained. This hysteresis ($L_{on} < L_{off}$) prevents rapid relay toggling when the water surface fluctuates around a single boundary. The threshold values depend on the tank and pump and are selected experimentally.

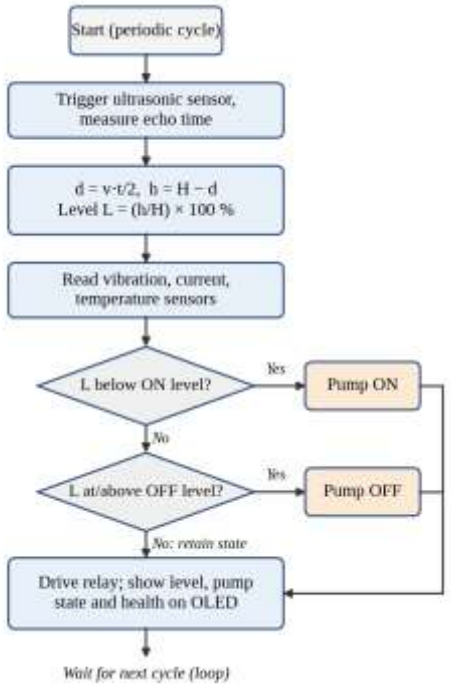


Fig -2: Water-level calculation and pump control sequence.

3.5 Motor-health monitoring

Motor-health monitoring runs alongside the level control. Vibration sensing gives information on mechanical behaviour, current sensing on the electrical load and temperature sensing on excessive heating. The ESP32 compares these inputs with experimentally selected limits. Normal operation is shown as **Healthy**. A persistent or significant deviation in one or more parameters gives **Warning**, and a deviation beyond a critical limit gives **Critical**. A single abnormal reading is not treated as a confirmed failure, so a persistence rule is used. The aim is a practical health-awareness layer for the user and not a complete industrial diagnostic system. If required, a Critical state can also be used to inhibit pump operation, provided this matches the firmware.

3.6 Power supply and firmware

Two 3.7 V Li-ion cells form the energy source, and a buck converter provides the regulated supply for the controller. The exact ratings of the relay, pump, cells and converter must be respected in the final wiring. The firmware is organised as a cyclic task that (a) reads the ultrasonic and motor-health sensors, (b) converts the distance into a water level, (c) evaluates the pump condition using the hysteresis thresholds, (d) updates the motor-health state, (e) drives the relay output, and (f) refreshes the OLED.

4. RESULTS AND DISCUSSION

4.1 Prototype implementation

The prototype was assembled on a flat board using commercially available modules. Fig. 3 shows the complete setup with two plastic containers used as the test tank: the ultrasonic sensor looks at the water surface, and the pump moves water through a flexible tube. Fig. 4 shows the electronics board, which carries the ESP32 with jumper-wire connections, the dual-channel relay module, the sensor modules, the OLED display, the two Li-ion cells in their holder, the buck converter and the 5 V pump with its tubing. In both photographs the unit is powered: the OLED is lit and the indicator LEDs on the relay and sensor modules are on.

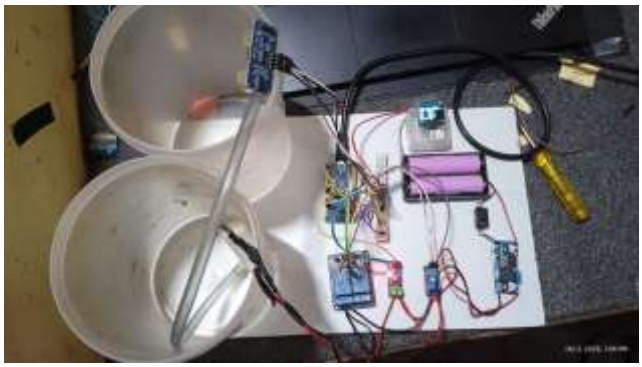


Fig -3: Prototype setup with two containers used for water-level monitoring and pump-control testing.

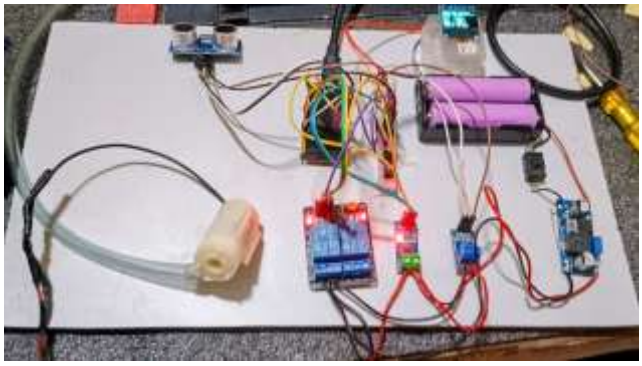


Fig -4: Assembled hardware: ESP32, ultrasonic sensor, relay module, OLED, battery pack, buck converter and pump.

4.2 Display output and operating states

The OLED gives a compact view of the system state. Its screen is headed WATER MONITOR and shows four lines: Water Level, Tank Status, Pump and Motor Health. Fig. 5 shows the display output for one operating state, in which the water level is 68 %, the tank status is FILLING, the pump is ON and the motor health is HEALTHY. This lets the user read the level, pump state and motor condition at the unit itself, without a separate computer or cloud service.



Fig -5: OLED display output showing water level, tank status, pump state and motor health.

4.3 Discussion

The integrated design links process sensing and equipment monitoring: the water level decides the normal pump requirement, while the motor-health information gives extra context on whether continued pumping is appropriate. This layered approach is consistent with the condition-monitoring concept in which several observable signals are used to identify abnormal machine behaviour [6], [7]. Compared with the systems in Table 1, the proposed unit works locally with its own display, which keeps it simple and independent of a network,

but it does not yet offer the remote access provided by the IoT-based systems [2], [4], [5].

This paper reports the design and the assembled prototype. Quantitative accuracy, response time and reliability figures, as well as the final level and health thresholds, are not reported here and must come from calibration tests on the actual tank, pump and sensors. Electrical safety also needs attention: the relay, pump supply, cells and wiring must be used within their ratings, and the prototype should not be treated as a certified safety-critical product or as the only protection against electrical, thermal or mechanical hazards.

5. CONCLUSIONS AND FUTURE SCOPE

An ESP32-based automatic water-level monitoring and pump-control system with an additional motor-health monitoring layer has been presented. The ultrasonic sensor gives non-contact level information, the ESP32 performs processing and control, the relay switches the pump and the OLED provides local feedback. The addition of vibration, current and temperature sensing extends the system from simple level automation towards condition-aware pump supervision. A working hardware prototype has been assembled using low-cost modules.

Future work can improve accuracy and robustness without changing the basic architecture: calibration, filtering and tank-geometry compensation for level estimation; event logging and fault handling in the pump logic; and recording of vibration, current and temperature trends for trend-based maintenance decisions. Data logging, remote notification and water-flow sensing can also be added in a later version, and any safety-critical use should be validated against the requirements of the final application.

ACKNOWLEDGEMENT

The authors thank the faculty of the Department of EEE and management of K.L.N. College of Engineering for the laboratory facilities and guidance provided during this work.

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