
Design And Performance Evaluation Of An Esp32-Based Automatic Irrigation Sluice Gate Prototype Using An Ultrasonic Water Level

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ABSTRACT

Water gate operation in irrigation systems is generally performed manually, which may delay responses to changes in water level. Such conditions can result in inefficient water discharge regulation and increase the risk of water overflow. This study aims to design and develop a prototype of an automatic irrigation sluice gate system using an ultrasonic sensor based on an ESP32 microcontroller. The research consisted of system design, hardware assembly, microcontroller programming, and prototype performance testing. The ultrasonic sensor was employed to measure water level changes, while the ESP32 processed the acquired data to control a servo motor as the gate actuator. Experimental results demonstrated that the proposed system responded rapidly and stably to variations in water level with satisfactory measurement accuracy throughout the testing range. The implemented control mechanism successfully operated the sluice gate automatically according to water level conditions. Therefore, the proposed system has the potential to improve irrigation management efficiency while reducing human error associated with manual gate operation.

Keywords: ESP32, automatic sluice gate, ultrasonic sensor, irrigation system, control system.

INTRODUCTION

The advancement of automation technology has made a significant contribution to improving the efficiency and effectiveness of various engineering systems, including water resource management and irrigation. One of the essential components of an irrigation system is the sluice gate, which functions to regulate the water level to ensure that water is distributed according to demand. Proper water level regulation plays a crucial role in maintaining efficient irrigation water distribution while minimizing the risks of water overflow and insufficient water supply to agricultural land.

However, in many irrigation systems, sluice gate operations are still performed manually, resulting in delayed responses to changes in water level. Such conditions may lead to imbalanced water discharge, which can disrupt irrigation performance and increase the risk of flooding (Winarno et al., 2025).

Along with the rapid development of microcontroller technology, various automatic control systems have been widely implemented to improve the efficiency of water resource management. One of the most widely used

microcontrollers is the ESP32 due to its high processing capability, relatively low power consumption, and built-in wireless communication features, including Wi-Fi and Bluetooth. These characteristics enable the ESP32 to serve as the main controller in various automated systems and Internet of Things (IoT)-based monitoring applications. The implementation of the ESP32 in control systems provides greater flexibility for system development while facilitating integration with modern digital technologies (Kusriyah, 2021).

An ultrasonic sensor is one of the most commonly used sensors for distance measurement based on the travel time of reflected ultrasonic waves. In an automatic sluice gate control system, this sensor can be utilized to detect changes in the water level without direct contact with the measured medium.

MATERIALS AND METHODS

Research Method

This study employed an experimental method using a prototype development approach. This approach was selected because it allows the processes of system design, construction, testing, and evaluation to be carried out systematically until the desired system performance is achieved. The research was conducted through several stages, including hardware and software design, component integration, and system performance testing based on variations in water level (Halim & Surya, 2023).

Materials and Equipment

The materials and equipment used in this study were as follows:

- ESP32 microcontroller
- HC-SR04 ultrasonic sensor
- Servo motor
- Power supply
- Miniature sluice gate prototype
- Arduino IDE
- Google Sheets

The acquired water level information is then processed by the microcontroller to determine the appropriate control action for the actuator. The integration of the ultrasonic sensor and the ESP32 is expected to produce a responsive and reliable control system capable of automatically operating the sluice gate according to changes in water level conditions (Adella et al., 2020).

Based on these considerations, this study aims to design and develop an ESP32-based automatic sluice gate prototype using an ultrasonic sensor for water level detection. The proposed prototype is expected to provide a rapid response to changes in water level, enabling the sluice gate to operate automatically, improving operational efficiency, and reducing dependence on manual operation.

System Design

The system was designed by integrating all hardware and software components into a single automatic control system. The ultrasonic sensor was installed at the top of the testing tank to measure the distance between the sensor and the water surface. The measured data were then transmitted to the ESP32 microcontroller as the system input.

The ESP32 processed the received data based on predefined water level thresholds. The processed information was subsequently used to generate control signals for the servo motor, which functioned as the actuator responsible for automatically opening and closing the sluice gate. Through this mechanism, changes in the water level could be detected and responded to automatically without requiring manual intervention (Aprianti et al., 2025).

The proposed system employed a threshold-based control method. Under this approach, the gate opening was adjusted according to changes in the water level, allowing the gate to open gradually as the water level increased. This control strategy was intended to maintain a stable water flow while minimizing sudden fluctuations in water discharge.

1. System Flowchart

The operational sequence of the proposed system consists of the following steps:

- Ultrasonic sensor data acquisition.
- Data processing by the ESP32 microcontroller.
- Decision-making based on the predefined water level thresholds.
- Actuation of the servo motor to open or close the sluice gate.

2. Prototype Design

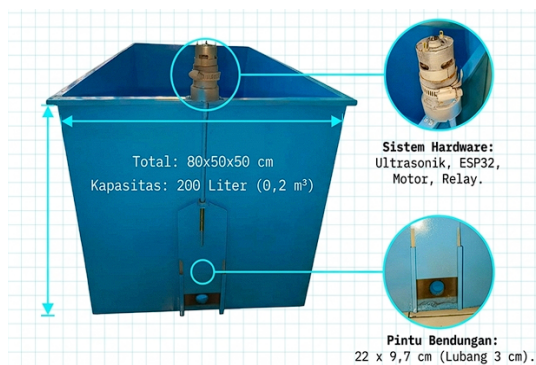


Figure 1. Prototype Design

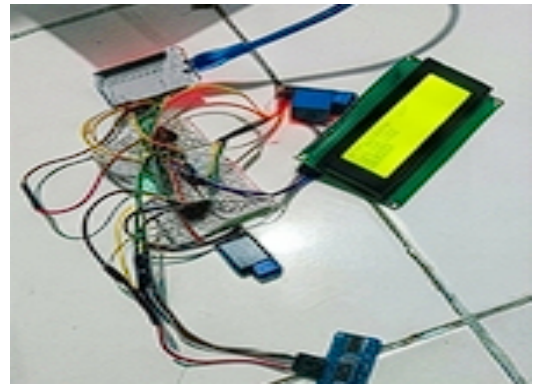


Figure 2. System Circuit Diagram

3. Testing Method

System testing was conducted by gradually increasing the water level within the range of 0–45 cm. At each water level increment, observations were made on the ultrasonic sensor readings, the response of the servo motor, and the opening and closing conditions of the sluice gate.

All experimental data were automatically recorded using Google Sheets to facilitate documentation, analysis, and system performance evaluation. The primary parameters observed included the ultrasonic sensor readings, water depth, sluice gate status, and the stability of the system response throughout the testing process.

RESULTS AND DISCUSSION

System Testhing

System testing was conducted to evaluate the prototype's capability to detect changes in the water level and automatically respond through the opening and closing mechanism of the sluice gate. The tests were carried out gradually over a water level range of 0–45 cm. The observed parameters included the ultrasonic sensor readings, water depth, and the response of the servo motor as the actuator responsible for operating the sluice gate. All testing data were automatically recorded using Google Sheets to facilitate documentation and data analysis.



Figure 3. Relationship between Ultrasonic Sensor Readings and Water Depth

Table 1. Automatic Sluice Gate Control Logic.

No.	Water Level (cm)	Gate Condition	Description
1.	0 – 15	Closed	Gate Closed
2.	15 – 20	Open	Gate Open
3.	21 – 30	Open	Gate Open
4.	31 – 40	Open	Gate Open
5.	40 – 45	Open	Gate Open

Based on Table 1, the proposed system employs a threshold-based control strategy to determine whether the sluice gate should remain open or closed. At water levels ranging from 0 to 15 cm, the gate remains closed. When the water level exceeds 15 cm, the ESP32 automatically sends a

control signal to the servo motor to open the sluice gate. This control strategy demonstrates that the prototype successfully executes the control logic according to the predefined design parameters.

Table 2. Ultrasonic Sensor Readings at a Water Level of 0–15 cm.

Time	Sensor Range (cm)	Water Depth (cm)	Description
5/5/2026 20:48:09	46.02	3.98	Normal
5/5/2026 20:48:21	45.94	4.06	Normal
5/5/2026 20:48:57	45.51	4.49	Normal
5/5/2026 20:49:06	44.78	5.22	Normal
5/5/2026 20:49:59	43.43	6.57	Normal
5/5/2026 20:50:31	42.64	7.36	Normal
5/5/2026 20:51:37	41.96	8.04	Normal
5/5/2026 20:52:13	40.83	9.17	Normal
5/5/2026 20:52:55	39.91	10.09	Normal
5/5/2026 20:53:42	39	11	Normal
5/5/2026 20:54:46	38.08	11.92	Normal
5/5/2026 20:54:59	37.85	12.15	Normal
5/5/2026 20:55:36	36.53	13.47	Normal
5/5/2026 20:56:31	35.87	14.13	Normal
5/5/2026 20:57:48	34.18	15.82	Normal
5/5/2026 20:58:01	35	15	Normal

The data presented in Table 2 indicate that, throughout the testing range of 0–15 cm, the system operated under normal conditions while the sluice gate remained closed. The ultrasonic sensor readings exhibited a consistent relationship between the measured distance and the water depth, where a shorter measured distance

corresponded to a greater water depth. This relationship is consistent with the operating principle of the ultrasonic sensor, which determines distance based on the travel time of ultrasonic waves reflected from the water surface. In addition to demonstrating a consistent relationship, the sensor readings remained

relatively stable without significant deviations. These results indicate that the ultrasonic sensor performed reliably under relatively calm water

surface conditions, allowing the ESP32 to receive accurate data for automatic decision-making.

Table 3. Ultrasonic Sensor Readings at a Water Level of 15–20 cm.

Time	Sensor Range (cm)	Water Depth (cm)	Description
5/5/2026 21:14:12	39.7	10.3	Closed
5/5/2026 21:16:39	37.18	12.82	Closed
5/5/2026 21:18:46	32.69	17.31	Open
5/5/2026 21:18:55	31.91	18.09	Open
5/5/2026 21:19:31	31.65	18.35	Open
5/5/2026 21:19:39	31.91	18.09	Open
5/5/2026 21:19:49	30.87	19.13	Open
5/5/2026 21:20:07	30.87	19.13	Open
5/5/2026 21:20:18	30.83	19.17	Open
5/5/2026 21:20:36	30.38	19.62	Open
5/5/2026 21:20:59	29.58	20.42	Open
5/5/2026 21:21:09	29.83	20.17	Open

As shown in Table 3, the system began transitioning from the closed state to the open state within the 15–20 cm water level range. Several initial observations still indicated a "CLOSED" gate status even though the measured water depth approached the predefined threshold. This behavior reflects the response delay or tolerance intentionally incorporated into the control algorithm to prevent rapid switching caused by minor fluctuations in the ultrasonic sensor readings. Such an approach improves the stability of the automatic control system.

The experimental results demonstrate that the proposed system operates according to the control strategy established during the design stage. The ultrasonic sensor was able to detect changes in the water level consistently and transmit the measurement data to the ESP32 in real time. The ESP32 processed the incoming data efficiently, enabling the servo motor to execute the gate opening command with negligible delay (Gozali et al., 2024).

Table 4. Ultrasonic Sensor Readings at a Water Level of 21–30 cm.

Time	Sensor Range (cm)	Water Depth (cm)	Description
5/5/2026 23:02:14	29.55	20.45	Closed
5/5/2026 23:02:24	28.48	21.52	Open
5/5/2026 23:03:08	27.61	22.39	Open
5/5/2026 23:03:28	26.75	23.25	Open
5/5/2026 23:04:29	25.88	24.12	Open
5/5/2026 23:05:54	24.45	25.55	Open

5/5/2026 23:07:37	23.99	26.01	Open
5/5/2026 23:08:25	22.72	27.28	Open
5/5/2026 23:08:46	22.72	27.28	Open
5/5/2026 23:08:57	21.8	28.2	Open
5/5/2026 23:17:09	22.42	27.58	Open
5/5/2026 23:17:21	21.49	28.51	Open
5/5/2026 23:17:33	20.86	29.14	Open
5/5/2026 23:18:39	18.94	31.06	Open
5/5/2026 23:18:50	18.5	31.5	Open
5/5/2026 23:19:17	23.01	26.99	Open
5/5/2026 23:19:30	19.26	30.74	Open
5/5/2026 23:19:46	18.63	31.37	Open
5/5/2026 23:19:58	18.94	31.06	Open

The experimental results presented in Table 4 indicate that the sluice gate remained predominantly in the open position throughout the testing period. Although a small number of observations recorded the gate as closed, these occurrences were relatively infrequent and did not significantly affect the overall performance of the system. Such variations were likely caused by

minor fluctuations in the ultrasonic sensor readings due to the instability of the water surface.

Overall, the system was able to return to its intended operating condition within a short period. This finding demonstrates that the implemented control mechanism possesses good stability when responding to variations in the sensor measurements during the testing process.

Table 5. Ultrasonic Sensor Readings at a Water Level of 31–40 cm.

Time	Sensor Range (cm)	Water Depth	Description
5/6/2026 14:02:06	13.67	36.33	Open
5/6/2026 14:02:26	12.63	37.37	Open
5/6/2026 14:02:53	12.29	37.71	Open
5/6/2026 14:03:01	11.93	38.07	Open
5/6/2026 14:03:10	11.24	38.76	Open
5/6/2026 14:03:37	10.9	39.1	Open
5/6/2026 14:03:46	10.21	39.79	Open
5/6/2026 14:03:55	9.51	40.49	Open
5/6/2026 14:04:04	9.79	40.21	Open
5/6/2026 14:04:47	7.84	42.16	Open
5/6/2026 14:05:13	8.48	41.52	Open
5/6/2026 14:05:22	9.52	40.48	Open
5/6/2026 14:05:30	7.52	42.48	Open

5/6/2026 14:05:40	8.16	41.84	Open
5/6/2026 14:05:49	8.61	41.39	Open
5/6/2026 14:06:01	6.68	43.32	Open
5/6/2026 14:06:12	7.91	42.09	Open
5/6/2026 14:06:21	10.14	39.86	Open
5/6/2026 14:06:29	8.16	41.84	Open
5/6/2026 14:06:42	9.79	40.21	Open

As shown in Table 5, the proposed system operated consistently with the sluice gate remaining in the open position throughout the 31–40 cm water level range. The decreasing sensor distance indicates that the water surface moved closer to the ultrasonic sensor as the water level increased. This consistent behavior demonstrates that the system achieved stable operation under relatively high water level conditions. Such performance is essential for irrigation systems, where a rapid response is required to minimize the risk of water overflow.

The experimental results presented in Tables 1–5 demonstrate a consistent relationship between the ultrasonic sensor measurements and the response of the sluice gate actuator. Table 1 illustrates the implemented control logic, in which the gate remains closed when the water level ranges from 0 to 15 cm and automatically opens when the water level exceeds 15 cm. This behavior confirms that the proposed system employs a threshold-based control strategy for decision-making. Threshold-based control is widely adopted in simple automatic control systems because it provides a fast response while requiring relatively low computational resources, making it well suited for microcontroller-based platforms such as the ESP32.

Overall, the experimental results demonstrate that the developed prototype successfully performed its

primary function as an automatic sluice gate control system. The ultrasonic sensor consistently detected changes in the water level across all testing ranges, while the ESP32 efficiently processed the measurement data and controlled the servo motor according to the predefined operating parameters.

The system performance indicates that the sluice gate opened automatically once the water level exceeded the predefined threshold. This gradual opening mechanism contributes to maintaining a stable water flow by preventing sudden changes in the gate opening position. Furthermore, the obtained results suggest that the ESP32 provides improved system performance compared with conventional microcontrollers, particularly in terms of processing speed and development flexibility (Wijoseno et al., 2025).

Although minor fluctuations were observed in several ultrasonic sensor measurements, these variations did not significantly affect the overall performance of the proposed system. The tolerance incorporated into the control algorithm successfully maintained system stability by preventing repeated changes in the gate status due to temporary disturbances in the sensor readings. Consequently, the developed system demonstrated responsive, stable, and reliable performance, fulfilling the objectives of this study.

CONCLUSION

The results of this study demonstrate that the proposed ESP32-based automatic sluice gate prototype was successfully designed, developed, and tested using an ultrasonic sensor for water level

detection. The experimental results confirmed that the system was capable of detecting water level variations within the range of 0–45 cm and automatically controlling the servo motor to open

and close the sluice gate according to the predefined threshold values. Furthermore, the ultrasonic sensor exhibited consistent measurement performance, showing a clear relationship between the measured sensor distance and the corresponding water depth. Although minor fluctuations in the sensor readings were observed due to variations in the water surface conditions, the implemented threshold-based control algorithm maintained stable system operation by preventing unnecessary changes in the gate status.

Overall, the integration of the ultrasonic sensor, ESP32 microcontroller, and servo motor enabled the prototype to perform automatic water level monitoring and sluice gate control with satisfactory responsiveness and operational stability. The developed system achieved the objectives of this study by providing a responsive, reliable, and relatively accurate automatic sluice gate control system that is more efficient than manual operation at the prototype scale. Therefore, the proposed prototype has the potential to serve as a practical reference for the future development of automatic sluice gate control systems for larger-scale irrigation applications.

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