
PROTOTYPE AUTOMATIC WATER PUMP CONTROL SYSTEM USING ULTRASONIC SENSOR FOR REAL-TIME MONITORING

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Abstract

A prototype of an automatic water pump controller based on the HC-SR04 ultrasonic sensor has been developed for real-time monitoring and control of water volume and level. This system is designed for application on standard water pumps or those enhanced with additional technologies. The HC-SR04 ultrasonic sensor measures distance and water levels, with data processed by an Arduino Uno microcontroller and displayed on an I2C LCD. The system includes a relay module for automatic pump control, preventing overflowing when the water level reaches a predefined threshold. From the five tests conducted on the device. Results indicated water levels ranged from 9.10 cm to 9.33 cm, with volumes between 575.63 cm³ and 594.56 cm³. Measurement error rates ranged from 2.00% to 6.60%, which remain within acceptable limits for a prototype. The system consistently refilled water within an average duration of 34–42 seconds, automatically stopping the pump at the specified level. This simple prototype offers an energy-efficient and effective solution for water management and has the potential for further development on a larger scale. With added features such as integration with remote monitoring systems, this device has significant potential for diverse applications.

Keywords: Arduino Uno, Automatic water pump, HC-SR04 ultrasonic sensor, Prototype, Water level monitoring.

INTRODUCTION

Water is a very important need. Water plays a very important role in the survival of living things in the world and is one of the basic needs that must be there every day. Water will be very useful for life on earth in proportional amounts. Humans use water for various needs, in households for example for consumption, bathing, washing and so on. In addition, water is also used in industry for hydroelectric power plants, transportation, irrigation and others. The amount of water that is lacking or excessive can have various impacts. (Suryantoro, 2019). Every household always needs water for daily activities, such as bathing, cooking, washing, and others. Currently, house construction is always equipped with water tanks to store water produced by the Regional Drinking Water Company (PDAM) to save water usage. In addition, the use of tanks functions to check the total water usage each month (Hakim, 2018).

However, there are often empty water tanks when the water is going to be used. This hampers activities that must be done immediately if the homeowner is in a hurry. In addition, negligence in filling the water tank to overflowing water is also a problem in the household. If this happens often, it will result in water waste which will have an impact on the swelling of PDAM bills. (Said Sulaimn Ambu Saidi *, 2021) In addition, water management in the tendon has been developed through a

float system or often also called a water tank radar. This radar system uses a float where the float will regulate the opening and closing of the water according to the water level in the tendon. (Lauhil Mahfudz Hayusman¹, 2020). When the water in the tank is about to run out, the float will hang and make the float pull the switch body at the top which causes the switch to turn on and vice versa if the water starts to fill up, the float starts to rise and when it reaches the specified limit, the float touches the spring in the switch body, causing the switch to turn off.

The weakness of the water tank radar is the automatic system that has been determined. When you want to change the specified limit, you need to change it manually. In addition, the pump will turn on more than once a day because when the water starts to decrease, the float will automatically start hanging, causing the float to pull the switch so that it turns on. If this happens repeatedly, it will cause a power surge. (Imam Muklisin, 2017).

Based on the explanation above, a solution is provided by designing a prototype of "Automatic Water Pump Control System Using Ultrasonic Sensors for Real-Time Monitoring" to monitor the height of the water level in the water tank using ultrasonic sensors, Arduino Uno, water pumps, relays and displays. By utilizing Arduino Uno and ultrasonic sensors to turn the water pump on and off automatically and the display provides information about the condition of the water in the tank so that users do not need to worry if the water pump is still on or not. The author's goal is to design a prototype that is capable of monitoring Arduino Uno-based water pumps.

LITERATURE REVIEW

Solving a problem requires a literature review as a reference in analyzing and solving the problem. This literature review consists of how ultrasonic sensors work and the theoretical basis related to the use of tools or components for monitoring water levels and controlling automatic pumps.

Ultrasonic sensors such as the HC-SR04 use ultrasonic waves to measure distance. The distance calculation process of this sensor involves several steps:

Signal Transmission (Trigging) The sensor emits ultrasonic waves from the transmitter transducer (trigger) in the form of a high-frequency sound signal (usually around 40 kHz). This signal is then reflected by the object in front of it. **Signal Reception (Echo)** The receiving transducer (echo) detects sound waves reflected by the object.

1. **Travel Time Measurement** The travel time of a signal, from when the signal is sent until it is received back after being reflected by an object, is measured by the sensor. This time is called duration in the Arduino code.
2. **Distance Calculation Formula** Distance is calculated based on the basic formula for the relationship between speed, distance and time.:

$$d = \frac{v \times t}{2}$$

Where :

- **d** is the distance (in cm),
- **v** is the speed of sound in air (about 343 meters per second or 0.0343 cm/μs),
- **t** is the travel time of the wave from the sensor to the object and back (in microseconds),

- Division by 2 is done because the time measured by the sensor is for a round trip (sensor to object and back to sensor).
3. Implementation in Arduino Code The formula above is applied in Arduino code with:

$$distance = \frac{duration \times 0.034}{2}$$

Where duration is the reading from the pulseIn() function which calculates the travel time of the ultrasonic signal in microseconds, and 0.034 is the conversion factor for the speed of sound in cm/μs.

Sensor Ultrasonik HC-SR04

The HC-SR04 ultrasonic sensor is used to measure distance using ultrasonic waves. This device has two transducers: one to transmit sound waves and the other to receive the reflected waves. This sensor can measure distances between 2 cm to 400 cm with good accuracy, and is very useful in distance measurement applications such as water level measurement projects.

Arduino UNO R3

The Arduino Uno is an ATmega328P-based microcontroller board that is popular with hobbyists and developers. It has 14 digital I/O pins, 6 analog pins, and supports serial, I2C, and SPI communications. The Arduino Uno can be programmed with the Arduino IDE software and has 32 KB of flash memory and 2 KB of SRAM. The board operates at 5V and can accept external inputs between 7-12V, making it an ideal choice for a variety of electronics prototyping applications.

Liquid Crystal Display I2C (LCD I2C)

I2C LCD is a display module that allows communication with a microcontroller using two pins (SDA and SCL) via the I2C protocol. This module is very efficient for displaying data in text format, such as water levels measured from ultrasonic sensors. By utilizing the I2C protocol, I2C LCD reduces the number of pins required for connection, making it easier to set up in projects.

Amphibious Water Pump

Amphibious water pumps are a type of pump designed to move water in a variety of conditions, including wet environments. These pumps are often used in applications that require lifting water from reservoirs or reservoirs. In this project, the pump is controlled through a relay module to activate or deactivate the water flow based on the level data received from the sensor.

Modul Relay 5V

The 5V relay module acts as an electronically controlled switch, allowing the microcontroller to control high-power devices such as water pumps. This module usually has multiple channels and can be easily connected to an Arduino. By using the relay module, the user can set the water pump to function based on the measured water level.

RESEARCH METHOD

1. Research Type

This research uses an experimental method to design, implement, and test a prototype of an automatic water pump and monitoring system. The system uses an ultrasonic sensor to measure

water levels and controls the pump based on user-defined parameters. The primary goal is to evaluate the system's reliability and functionality in real-time water level control.

2. Workflow and Diagram

The system operates through a predefined workflow represented in diagrams and flowcharts. These illustrate the operational steps of the prototype, starting from the measurement of water levels to automatic motor control.

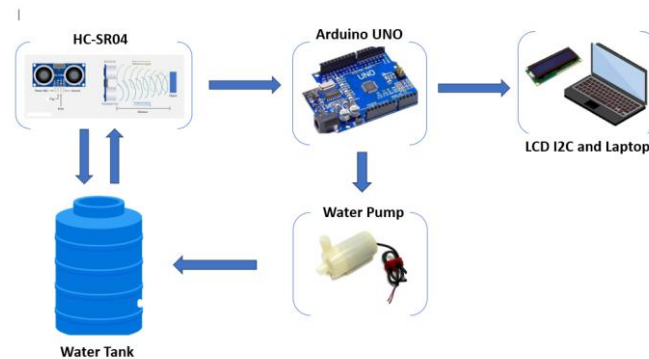


Figure 1. System workflow diagram

The diagram outlines how the sensor collects data, processes the information, and decides when to activate or deactivate the pump.

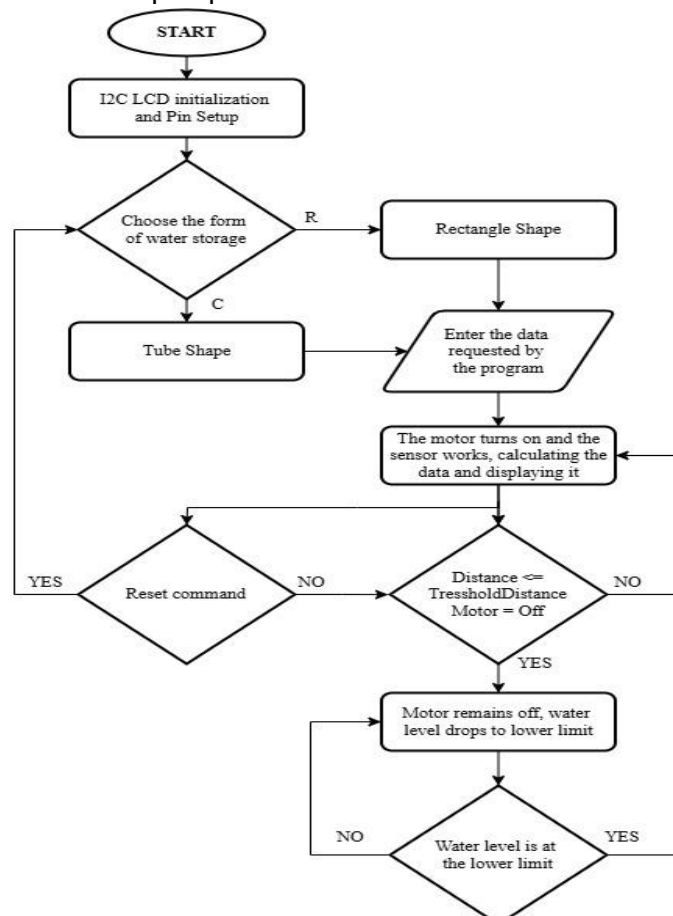


Figure 2. Program flowchart

The flowchart explains the software logic, including initial setup (container type and parameters), continuous data monitoring, and pump control based on the threshold and water level.

3. Type and Source of Data Collection

The data collected in this research is primarily quantitative, including measurements of the distance between the ultrasonic sensor and the water surface (in cm), the calculated water height (in cm), and the estimated water volume (in cm³ or liters). These measurements are used to evaluate the performance and accuracy of the system. The data is obtained through controlled prototype testing with containers of varying shapes, such as cylindrical and rectangular, to observe how the system adapts to different configurations. The data collection process involves direct observation of the system's performance during operation, including sensor readings, pump activation, and displayed results on the LCD.

4. Data Analysis Techniques

The collected data is analyzed using mathematical formulas to calculate water level and volume and evaluate system performance.

Ultrasonic sensor distance formulas

$$Distance = \frac{Time * Speed\ of\ Sound}{2}$$

Where the formula for wave propagation time is,

$$Time = \frac{Distance * 2}{Speed\ of\ Sound}$$

Water Height Formulas

$$Water\ Height = Sensor\ to\ Bottom\ Distance - Distance$$

Water volume formulas

For cylindrical containers

$$Volume = \pi * Radius^2 * Height$$

For Rectangular container

$$Volume = Length \times Width \times Height$$

RESULTS AND DISCUSSION

1. Wiring and Prototype Results

The wiring configuration of the prototype involves several components connected through specific pins of the microcontroller. The HC-SR04 ultrasonic sensor uses the Trig pin connected to digital pin 9 and the Echo pin connected to digital pin 10 for distance measurement. The water pump is controlled via a relay module connected to digital pin 7, while the buzzer, for alerting the transition of motor states, is connected to digital pin 6. An LCD module, interfaced via I2C, displays the water height and volume, making the system user-friendly. Power for the components is supplied through the microcontroller, which itself is powered via a USB connection. This arrangement ensures seamless communication between the components and efficient operation of the water monitoring and control system.

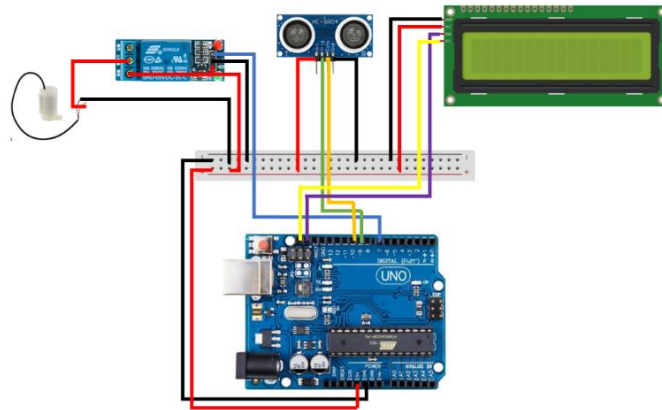


Figure 3. Wiring configuration

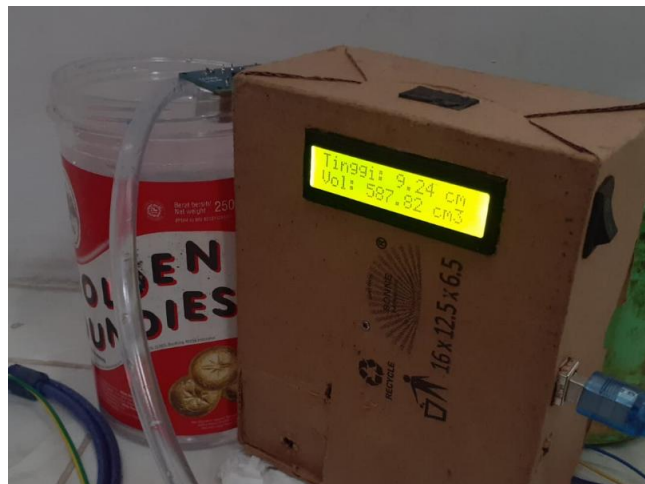


Figure 4. Prototype result

2. Prototype Testing

The system was tested with a cylindrical container having a radius of 4.5 cm and a height of 14 cm. After setting the threshold at 3 cm and initializing the system, the water pump began filling from an empty state (0 cm). The motor stopped when the water reached the threshold height of 5 cm, and resumed only after the water level dropped below the threshold due to usage. Data for "Motor ON" (filling phase) and "Motor OFF" (standby phase) were recorded over multiple cycles to verify system reliability and accuracy.

```
20:26:30.178 -> Pilih tipe wadah:  
20:26:30.211 -> C - Tabung  
20:26:30.211 -> R - Persegi Panjang  
20:26:37.648 -> Masukkan jari-jari tabung (cm):  
20:26:42.956 -> Masukkan jarak sensor ke dasar wadah (cm):  
20:26:50.578 -> Masukkan threshold jarak sensor ke permukaan air (cm):  
20:27:31.048 -> Pengaturan selesai:  
20:27:31.048 -> Wadah: Tabung, Radius: 4.50 cm  
20:27:31.082 -> Jarak sensor ke dasar: 14.00 cm  
20:27:31.114 -> Threshold jarak: 5.00 cm
```

Figure 5. Data input process

3. Data Result

Table 1. Off conditioning

Testing	Distance (cm)	Water Height (cm)	Volume (cm ³)
1	4.93 cm	9.07 cm	577.01 cm ³
2	4.71 cm	9.29 cm	591.09 cm ³
3	4.74 cm	9.26 cm	588.90 cm ³
4	4.98 cm	9.02 cm	573.76 cm ³
5	4.69 cm	9.31 cm	592.15 cm ³
6	4.91 cm	9.09 cm	573.09 cm ³
7	4.68 cm	9.32 cm	593.23 cm ³

During the "Motor OFF" state, the pump deactivates when the water reaches the defined threshold. As shown in Table 1, at Testing 1, the measured distance from the sensor to the water is 4.93 cm, with a corresponding water height of 9.07 cm and a calculated volume of 577.01 cm³. Using the formula:

$$\text{Water Height} = \text{Sensor to Bottom Distance} - \text{Distance}$$

$$\text{Water Height} = 14\text{cm} - 4.93\text{cm}$$

$$\text{Water Height} = 9.07 \text{ cm}$$

This matches the recorded value, validating the accuracy of the height calculation. Similarly, the water volume is computed as:

$$\text{Volume} = \pi * \text{Radius}^2 * \text{Height}$$

$$\text{Volume} = 3.14159 * (4.5)^2 * 9.07$$

$$\text{Volume} = 577.01 \text{ cm}^3$$

This calculation aligns with the recorded data, confirming the system's reliability. Across other tests, the water height and volume remained consistent, showing minimal variation, which demonstrates the system's stability in detecting and maintaining the water level near the threshold.

Table 1. On Conditioning

Testing	Distance (cm)	Water Height (cm)	Volume (cm ³)
1	14.13 cm	0.00 cm	0.00 cm ³
2	11.17 cm	2.83 cm	180.10 cm ³
3	11.29 cm	2.71 cm	172.53 cm ³
4	11.19 cm	2.81 cm	179.02 cm ³
5	11.02 cm	2.98 cm	189.83 cm ³
6	11.08 cm	2.92 cm	185.51 cm ³
7	11.10 cm	2.90 cm	184.43 cm ³

When the water level drops below the threshold, the pump activates to refill the container. For example, in Testing 1 of Table 2, the water height is 0.00 cm, corresponding to a sensor reading of 14.13 cm and a volume of 0 cm³. This activation point matches the programmed logic. Using the ultrasonic time formula:

$$\begin{aligned} \text{Distance} &= \frac{\text{Time} * \text{Speed of Sound}}{2} \\ \text{Distance} &= \frac{0.034 * 831.18\mu\text{s}}{2} \\ \text{Distance} &= 14.13\text{cm} \end{aligned}$$

The calculated time confirms the sensor's precision in detecting empty conditions. As the motor continues filling, the water height gradually increases until the threshold is reached again. For example, in Testing 2, the water height rises to 2.83 cm (distance of 11.17 cm), resulting in a volume of 180.10 cm³. These values are consistent with the sensor's readings and the programmed logic, confirming the system's ability to monitor and regulate the water level effectively.

One critical aspect of the control logic is the deliberate delay in motor reactivation after the water level drops below the threshold. The motor does not immediately turn on when the water level decreases slightly below the threshold, but instead waits until the water level decreases further, reaching a residual height of 3 cm (as specified). This feature is designed to protect the pump from frequent on-off cycles, which could reduce its lifespan due to overheating or mechanical wear. The system operates in cycles, with the motor turning on when the water height drops below the threshold and turning off when it reaches the threshold. Minimal variation in measurements (e.g., water heights and volumes during "Motor OFF" and "Motor ON" phases) indicates high precision in sensor readings and stable motor control. This demonstrates the system's ability to manage water levels dynamically, making it suitable for practical applications.

CONCLUSION

The automatic water pump and monitoring system prototype successfully fulfills its intended functionality. The device accurately measures water height and volume using an ultrasonic sensor and displays the data in real-time on an LCD. The motor control logic effectively manages the water filling process by activating the pump only when the water height drops to 3 cm below the threshold, preventing frequent on-off cycles. This mechanism enhances the pump's durability and energy efficiency. From testing with a cylindrical container (radius: 4.5 cm, sensor-to-bottom distance: 14 cm, and threshold: 5 cm), the system demonstrated consistent performance. The motor filled the container to the threshold water height (e.g., 9.07 cm, corresponding to 577.01 cm³ of volume) and remained off until the water level dropped significantly, restarting only at the set residual height. These results validate the accuracy of the control logic and data processing. Overall, the system is reliable for automatic water level monitoring and management, making it a practical solution for water conservation and pump health optimization.

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