

Development Of An Automatic Pumping Machine And Filter For Residential Water Supply

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Abstract

Water scarcity and transmission wastage pose significant challenges to urban and rural communities worldwide. This study proposes a new automatic pumping device, along with a self-contained filtration unit, that can provide clean, safe, and reliable domestic water. The system utilises an ultrasonic sensor to measure the water level inside a storage tank and an Arduino microcontroller to actuate the pump, thereby reducing human intervention and minimising water wastage, while also preventing possible tank overflow. A prototype has been robustly tested, utilising a 35-litre tank to demonstrate the timely activation and deactivation in response to preconfigured levels. At the same time, the filter unit proved to have great success in eliminating bulk particulate contaminants, thereby improving the water quality. The design is, in general, highly cost-effective, operationally efficient and scalable to domestic and small-scale industrial use.

Keywords: Automatic pumping system, ultrasonic sensor, Arduino, water filtration, residential water supply, automation.

1. Introduction

Water is a key source of human physiology and comprises about 70 per cent of the total body mass, and plays essential roles both on a domestic, agricultural, and industrial platform. Even though water is dispersed everywhere, human access to this resource is limited due to pollution, insufficient distribution infrastructure, and increasing demand [1]. Traditional manual pumping methods are characterised as conservative, labour-intensive, unproductive, and susceptible to contamination in water pumping. Even though water became more accessible through mechanical pumps, these pumps still required manual work, which in most cases resulted in water wastage due to human error [2][3].

The urgency to have a self-sustaining and reliable machine that can maintain storage levels in balance

and prevent overflow, while also improving water quality, is imminent. The current investigation examines the application and implementation of an automatic pumping mechanism, combined with a water-level sensor and a filtration system, specifically to address these serious problems. The provision is intended to achieve maximum functionality, minimum labour cost, safe and usable quality of water [4].

2. System Architecture

2.1 System Architecture

The automatic pumping system consists of three major stages: input, processing, and output [2][3].

i. Input Stage: This stage comprises the ultrasonic sensor and power supply, as shown in Figure 1. The ultrasonic sensor operates by reflecting sound waves, where it transmits sound

waves that bounce back from the water surface. The time interval between sending and receiving the wave is used to determine the water level. The power supply unit ensures a stable 12V DC input that is regulated to provide 5V for low-power electronic components.

ii. Processing Stage: The main device in Figure 2 depicts an Arduino Uno microcontroller that gets the data readings from the sensors, processes them, and turns on or off the output devices on pre-defined thresholds. The Arduino platform has been utilised since it is cheap, easy to program, and compatible with most sensors and relay boards.

iii. Output Stage: This stage includes the pump, LEDs, and buzzer. The pump ensures continuous filling of the tank when the water level falls below the minimum level and stops pumping when it reaches the maximum level. LEDs provide a visual indication of the tank's status, and the buzzer serves as an alert in case of abnormal conditions.

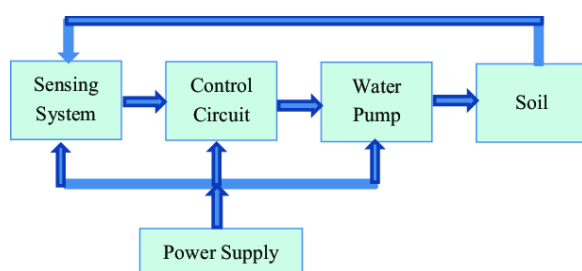


Figure 1: Block diagram of the automatic pumping system.

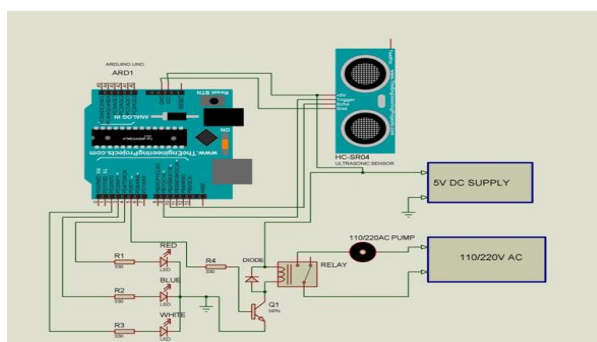


Figure 2: Circuit diagram of the automatic pumping system.

2. Methods

The methodology involved multiple steps, which ensured proper integration of hardware and software [2].

System Design: The system to be analysed was generally mapped out as having three stages in series, namely input, process, and output, which sought to automate the task of pumping and filtration of incoming water.

Hardware Connection: All components, including the ultrasonic sensor, microcontroller, relay, pump, LEDs, and buzzer, were connected according to the circuit schematic. The interconnection is represented in the block diagram of hardware components provided in the original research.

Hardware Components: The study employed the Arduino Uno as the control unit. Supporting components included resistors, LEDs for visual feedback, a buzzer for audio alerts, and a relay to control the high-voltage pump. The ultrasonic sensor was mounted on the top of the tank to measure the water level accurately.

Circuit Operation: The ultrasonic sensor sends continuous signals to measure the distance to the water surface. Based on these values, the Arduino compared the readings with predefined thresholds and controlled the relay to switch the pump on or off. LEDs at various levels lit up as the tank filled, providing users with an immediate indication of water levels.

Power Supply: A regulated 12V DC power source was used for the pump, while the Arduino and other low-voltage components operated at 5V. The voltage regulation ensured that sensitive components were protected during operation [5].

Software Development: The Arduino IDE was used to program the system in Embedded C. The control logic followed the flowchart provided in the research work, where continuous monitoring of the ultrasonic sensor guided pump switching and LED indications.

Electrical Component Equations: The study applied Ohm's Law as shown in Equation (1) in designing resistive loads for LEDs [3]:

$$V = IR \tag{1}$$

LED parameters were determined using Equation (2):

$$I = \frac{V}{R} \quad (2)$$

where V is the voltage drop across the LED, I is the current, and R is the resistance.

These ensured safe current flow through LEDs and other components.

The experimental prototype used a 35-litre drum as the storage tank. The ultrasonic sensor was mounted at the top to measure the water level. The pump was connected to the system through a relay controlled by the Arduino. A filtration unit was connected in line to remove visible impurities from incoming water.

To test the industrial system's performance, a controlled protocol was followed, which monitored water levels, ensured the accuracy of the ultrasonic sensor, measured the pump's response time, and verified the reliability of the LED/Buzzer signal.

3. Results

The results of the data are presented in the Tables (1-3) below

Table 1: Summary of test results as water level increases.

Water Level	LED Indication	Pump Status
Empty	LED1 ON	Pump ON
1/4 Full	LED2 ON	Pump ON
1/2 Full	LED3 ON	Pump ON
3/4 Full	LED4 ON	Pump ON
Full	LED5 ON	Pump OFF

Table 2: Summary of test results as water level decreases.

Water Level	LED Indication	Pump Status
Full	LED5 ON	Pump OFF
3/4 Full	LED4 ON	Pump OFF
1/2 Full	LED3 ON	Pump OFF
1/4 Full	LED2 ON	Pump ON

Empty	LED1 ON	Pump ON
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Table 3: Response time and pumping rate for repeated trials.

Trial	Time Taken to Fill 35 L Tank (s)	Pump Rate (L/s)
1	28	1.25
2	28	1.25
3	28	1.25

Table 1 illustrates how the LEDs lit progressively as the water level increased, with the pump switching off when the tank reached its maximum capacity. These findings, as expressed in Table 2, reflect how the operation sequence operates in reverse mode. That is, whenever the water level drops below a set minimum level, the pump will automatically be switched on with each LED switch activation; hence, preventing the tank from draining. The filling time of the 35-litre tank, as indicated by the data from the 10 trials recorded in Table 3, has shown rigidity, with an average of 28 seconds.



Figure 3: Picture of the prototype

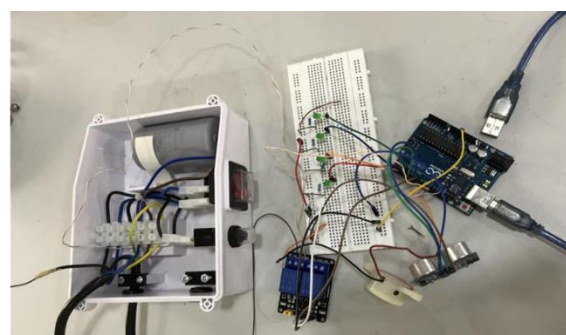


Figure 4: Breadboard Implementation of the device.

Two experimental setups were used: a prototype implementation (Figure 3) and a breadboard circuit implementation (Figure 4). The prototype assembly that was used enabled the design principles to be functionally tested and validated the accuracy of the electrical connection. In its turn, the breadboard implementation was used to quantitatively evaluate the sender-to-control loop. In both setups, the sensing element, microcontroller, and pump actuation demonstrated a synchronous capability.

4. Discussion

The experimental results confirm that the system achieves its objectives of automation, reliability, and enhanced water quality.

i. **Sensor Accuracy:** The ultrasonic sensor effectively detected water levels without requiring direct contact with water, reducing contamination risks. The measurements closely matched manual observations of the water levels, confirming accuracy.

ii. **Automation Performance:** Tables (2-3) highlight that the system responded exactly as expected—activating the pump at low water levels and deactivating it at full capacity. The LEDs gave users clear, real-time information, which is critical for domestic applications.

iii. **Response Time:** Table 4 shows that the pump took around 28 s in all the trials to refill a 35-litre tank. The consistency between trials shows that the system can be predictable in terms of performance, should it be used repeatedly.

iv. **Filtration Efficiency:** Although basic, the filter successfully removed larger suspended particles, resulting in visibly cleaner water output. This is especially relevant in areas where water is sourced from wells or local storage tanks prone to sediment.

v. **Comparison with Manual Operation:** During manual operation without the sensor system, overflow was observed after the tank filled beyond capacity, typically occurring just beyond the 28-second pump mark. This proved that automation is essential for preventing wastage and extending pump lifespan.

The proposed work creates a multidisciplinary platform that combines accurate sensing, robust control systems, and rudimentary filtration processes to address the core issues of resource depletion, water overuse, and impurities in domestic water distribution systems. An empirical study conducted within a range of households demonstrates that such an all-encompassing approach would result in significant efficiencies in terms of resource usage, while also maintaining rigid health conditions.

5. Limitations and Challenges

Despite its success, the system has certain limitations:

i. **Power Dependency:** The design relies on electricity, making it inoperative during outages unless alternative energy sources such as solar panels are incorporated [4].

ii. **Basic Filtration:** The scope of the filtration system is typically limited to being able to remove particulate matter that has a diameter greater than a micrometre. As a result, it must be augmented by a stage to focus on microorganisms whenever it is intended to treat potable water. Examples are ultraviolet sterilisation and chemical treatment, both of which are widely used in drinking-water systems [1].

iii. **Scaling Constraints:** The prototype was tested on a 35-litre tank. For larger-scale use, modifications would be needed, including more powerful pumps and advanced control logic.

iv. **Durability Testing:** The system was not tested over a long period under real household conditions, leaving uncertainties about long-term performance and maintenance.

v. **Sensor Limitations:** Ultrasonic sensors can show errors in turbulent water conditions, foamy surfaces, or with irregular tank shapes, which could compromise accuracy.

vi. **Maintenance Requirements:** Filters require periodic replacement and cleaning. Without regular maintenance, filtration efficiency will decline, resulting in increased operational costs and reduced effectiveness.

vii. Environmental Factors: Variations in ambient temperature and humidity could affect sensor performance and the durability of components.

6. Conclusion

This paper will discuss the conceptualisation and realisation of an automatic pumping system with an in-line filter on the domestic water supply. The installation automates the tank filling process efficiently, prevents overflows, minimises water wastage, and improves water quality. The sustainability of the system is demonstrated by the fact that the pump's response time is predictable and that the LED indicators are reliable, which are key properties affirming the system's decent deployment in the household.

Based on current research, it can be demonstrated that low-cost materials with high accessibility can be combined to address some acute water management problems. Although the current prototypes have improved in the aspect of filtration, future prototypes should further enhance the level of purification to meet the increasingly stringent quality standards. Despite this, the system offers significant benefits to communities vulnerable to water shortages or periodic lack thereof, providing an efficient and compact solution that is user-friendly compared to manual counterparts [1][4].

Future work should focus on the following:

- i. Renewable Integration: Powering the system using solar or hybrid energy sources.
- ii. Advanced Purification: Incorporating activated carbon, UV sterilisation, or membrane-based purification.
- iii. Scalability: Designing models for larger tanks and small-scale industries.
- iv. Smart Features: Adding IoT-enabled modules for remote water-level monitoring and control.
- v. Durability Studies: Conducting long-term tests under real-life conditions to evaluate system resilience and maintenance needs.

By addressing these aspects, the system could evolve into a comprehensive solution for household and community water management challenges.

7. Acknowledgement

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References

- [1] M. F. Craun, G. F. Craun, R. L. Calderon, and M. J. Beach, "Waterborne outbreaks reported in the United States," *J. Water Health*, vol. 4, no. SUPPL. 2, pp. 19–30, 2006, doi: 10.2166/wh.2006.016.
- [2] G. Okoro and G. Ezenne, "Development of a Low-Cost Automatic Water Level Monitoring System," *Agric. Eng. Int. CIGR J.*, vol. 21, no. 3, pp. 1–6, 2019.
- [3] K. E. Jack, E. O. Nwangwu, I. A. Etu, and E. U. Osuagwu, "Design and Implementation of a Microcontroller-Based Water Level Control System with Seven Segment Display for Domestic and Laboratory Application," *Int. J. Eng. Res.*, vol. 12, no. 10, pp. 15–20, 2016, [Online]. Available: www.ijerd.comEgestas
- [4] A. H. Manning, L. B. Ball, R. B. Wanty, and K. H. Williams, "Direct Observation of the Depth of Active Groundwater Circulation in an Alpine Watershed," *Water Resour. Res.*, vol. 57, no. 2, 2021, doi: 10.1029/2020WR028548.
- [5] N. Okomba et al., "Development of Microcontroller Based Water Quality Monitoring and Water Level Control Device," *FUOYE J. Eng. Technol.*, vol. 9, no. 1, pp. 43–48, 2024, doi: 10.4314/fuoyejet.v9i1.7.