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Original Article

Development of a Wireless System to Check the Water Level in a Storage Tank

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Abstract *- This paper focuses on the development and execution of a wireless means of monitoring the water level in a tank. The study incorporated an Ultrasonic sensor, an ardiuno UNO board, an HC-05 Bluetooth module, an LCD JHD162 screen, and a Smartphone for data acquisition, conversion, processing, communication, and analysis of the tank's water level. In this study, the wireless means of monitoring the water level inside a tank was realized using the concepts of echo reflection, signal conversion, processing, and communication following a modular approach where level information is monitored inside the tank. The Arduino UNO uses the signal shared with the ultrasonic sensor to measure the tank's water level and monitors the level of water using a Smartphone and an LCD screen. The Visual signal received is analyzed for action to be taken. The realized wireless water level monitoring system, if deployed to our households and establishments, would be able to monitor the water level against water overflowing and energy wastage.*

Keywords *- Bluetooth module, Data acquisition, Ultrasonic sensor, Water level, Wireless communication.*

1. Introduction

Water, as one of the critical natural resources, is needed by creatures on earth, but unfortunately, water is wasted in many areas and circumstances, leading to water scarcity. To address this, Said Sulaimn et al. (2021) posited that water wastage must be checked to liberate our location, energy, and water resources. Water scarcity is a major problem, which is why Supriya and Revati (2017) said that when we adopt technologies like the one they proposed, issues such as human negligence and overloaded tanks will be addressed. A water level detecting system is a system designed and developed to put a check on water wastage by controlling the excessive pumping of liquid in a liquid storage tank to save the liquid, energy, and the environment. In this regard, Sunmonu et al. (2017) opined that the search to conserve both electrical and water resources has led to the development of automatic water level controllers with switching circuits for pumps both for overhead and underground tanks. Naskar, Samanta, Raja, and Banerjee (2020) said that control systems are grouped as open loop or closed loop, where in open loop systems, a command is given to a system with the assumption that the system performs properly, whereas in a closed loop system, a comparison of the system's out-turns is made against a desirable output and after that necessary corrective actions taken. They deduced that the closed-loop systems generally show more accurate production but cost more and have more instability tendencies.

2. Existing Systems and Related Works

Almost all the existing systems have detecting wires that are in contact with the water. Hence, there are surface coating and corrosion problems, and these also lead to contamination problems. Sunmonu et al. (2017) stated that in a bid to address the issues of premature response and incessant breakdown of contact sensors resulting from the surface coating and corrosion from water, water level control systems whose designs are based on Ultrasonic transducer (sensor) have been developed. In some of these existing systems, one end of the wires is dipped inside the tank at different levels, and in some cases, the levels are calibrated as percentages such as 10%, 20%, and up to 100%.

Oghogho and Azubuike (2013) developed a system that controls an electric water pump and automatically indicates the water level in the tank. The system uses the electrical conductivity of water to indicate the water level in a storage tank and then automatically controls the water pump. However, the system was susceptible to rust since the probes were placed in water.

Asaad and Zhang (2015) designed a system where all the wires used are of different sizes and are placed at different percentages of the tank. Liquid crystal displays (LCDs) are tied to the other ends of the wires. The design here is that as water touches the end dipped inside the tank, a circuit closes, and an LCD at the other end glows up. As the level of water rises inside the tank, the circuits that are closed will cause their

LCDs to glow up, indicating the percentage of water inside the tank.

Mani et al. (2014) designed a water level monitoring system employing an ATmega 32A microcontroller for processing, a transistor circuit for level detecting in relation to the voltage across the transistor, and an LCD for displaying the level of water. The voltage is sent to the microcontroller, which produces a corresponding output text that is displayed on an LCD. The entire circuit is comprised of two sections: the first is the microcontroller section produced on a breadboard, and the second is the transistor section that has a base inside the water storage tank. Each of these transistors has its collector's terminal connected to a +5V voltage source while their emitter terminals are hooked to the microcontroller PORT A input pins. A buzzer is also added as an alarm. Four water levels were programmed to be displayed, and these are full level, three-quarter full level, half full level, and quarter full level.

Charles (2018) designed and implemented an IoT system employed for water level monitoring employing Ultrasonic sensors and a Node MCU module. The system is a non-contact water level management one where water is pumped from groundwater or a dam into several tanks using motor pumps. Solenoid valves were employed to regulate the water flow into the tanks, and these valves were switched ON by USB6009 (DAQ Assist) with LABVIEW. The tanks' water levels were measured using Ultrasonic sensors, and the data generated was displayed on IoT devices. Received data may also be transferred to Google Cloud platforms.

Baskhara et al. (2018) designed and implemented a prototype water level monitoring system that was used to check the height and release of water and assisted in the regulation of sluice gates automatically. The system automatically moved the sluice according to the height of the water. Hence no manual movement, which contains a human error, was involved. The prototype system worked whereby water levels were detected at several stages using ultrasonic sensors. The floodgates were moved based on the dam's water level, and therefore water does not exceed the capacity that can damage the dam. The system can also display water level and dam status.

Khaled et al. (2010) designed a water level monitoring and management system that uses the water's electrical conductivity where component parts such as PIC 16F84A microcontroller, capacitors, inverter, Crystal Oscillator, LED, e.t.c. were used for the implementation. As the water in the tank decreases, so also the display LEDs will be going OFF from top to bottom, which is indicative of the level of water in the tank. With all the LEDs OFF, this means the tank is empty, and the water pump automatically comes ON. Figure 1 gives an example of an existing system for water level monitoring.

Partik (2016) developed a system where immersed and connected wires to LEDs will result in the LEDs glowing if water touches them. AS water is being drained from the tank, the LED connected to wire 7 will go OFF when the water level is below wire 7. LED 6 goes OFF when water is below wire 6, and this continues until water is below wire 1 where LED 1 goes OFF. The wires' positions represent the percentage of water in the tank.

The major problem with this type of design is the physical contact between water and the level monitoring device (wires), leading to coating/corrosion and contamination. This is why Patil and Singh (2014) suggested that the current water management systems should be improved upon. This design and implementation have addressed this problem. Moreover, this is where the need for a monitoring system with no physical contact between the monitoring device and the water, and therefore no contamination of the water results. This work aims to present the plan of an Arduino-based non-contact water level monitoring system that monitors real-time water level inside a tank and displays the water level on a smartphone and an LCD display. This work has the objective of presenting the design circuit for an Arduino-dependent non-contact water level checking system that remotely monitors the level of water using both a smartphone and an LCD display.

3. Materials and Methods

The design strategy of the monitoring system follows the block stages presented in Figure 1. The circuit arrangement of the non-contact water monitoring system is presented in Figure 2. Figure 3 shows the connection of bluetooth to Arduino Uno (https://howtomechatronics.com).

The ultrasonic sensor pins are tied to the Arduino Uno board, as shown in the circuit diagram. The ultrasonic sensor uses the principle of SONAR and RADAR systems to determine the distance of an object. High-frequency sound (ultrasound) waves produced by ultrasonic sensors are incident on an object, reflected back as an echo, and detected by the sensor receiver. The distance between the sensor and an object can be calculated by noting the time it took the echo to reach the receiver. This is how an Ultrasonic module measures distance. The HC-SR04 Ultrasonic sensor module possesses a precision range of up to 3mm and provides non-contact measurements between 2cm to 400cm range. The input pin is the Trig pin, but the output pin is the echo pin. When triggered, the Trig pin sends out 8 sonic pulses at the frequency of 40kHZ, and these sonic bursts hit the surface of the water, and the pulses are reflected and returned to the sensor's Echo pin. The Arduino then reads the Echo pin to ascertain the time in seconds it took between the pulses from the Trig pin to the pulses received by the Echo pin. The Arduino program then deduces the distance between the sensor and the water's surface, using the sound velocity as approximately 340 meters per second (m/s).

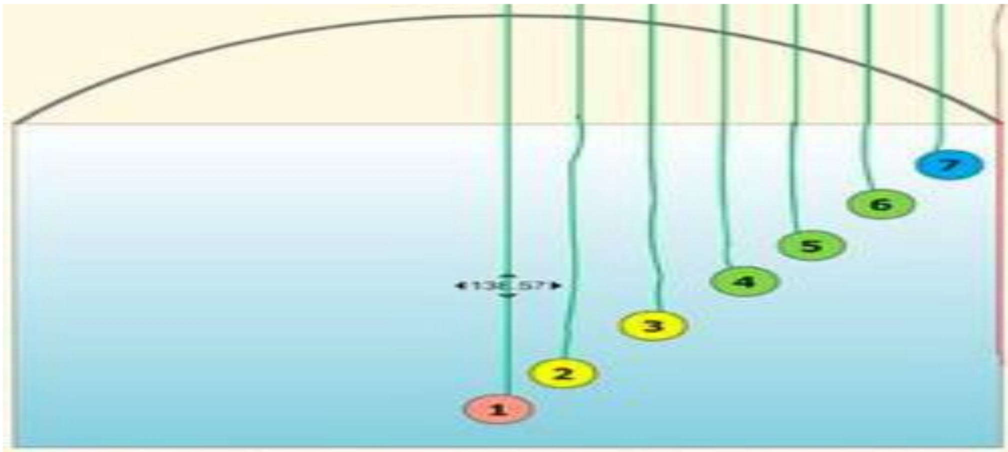

Fig. 1 An existing water monitoring system (Adapted from Varun et al., 2018)

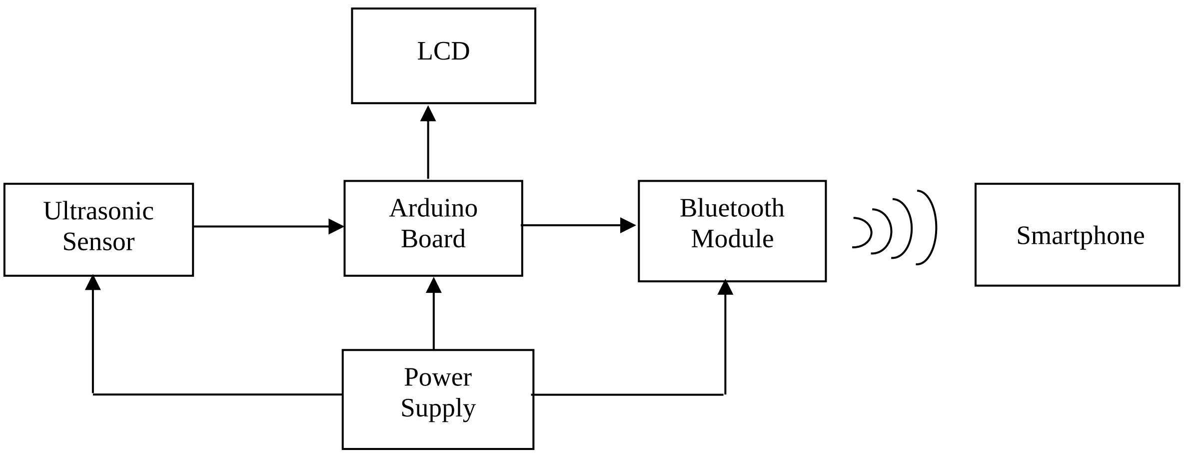

Fig. 2 System Block Diagram

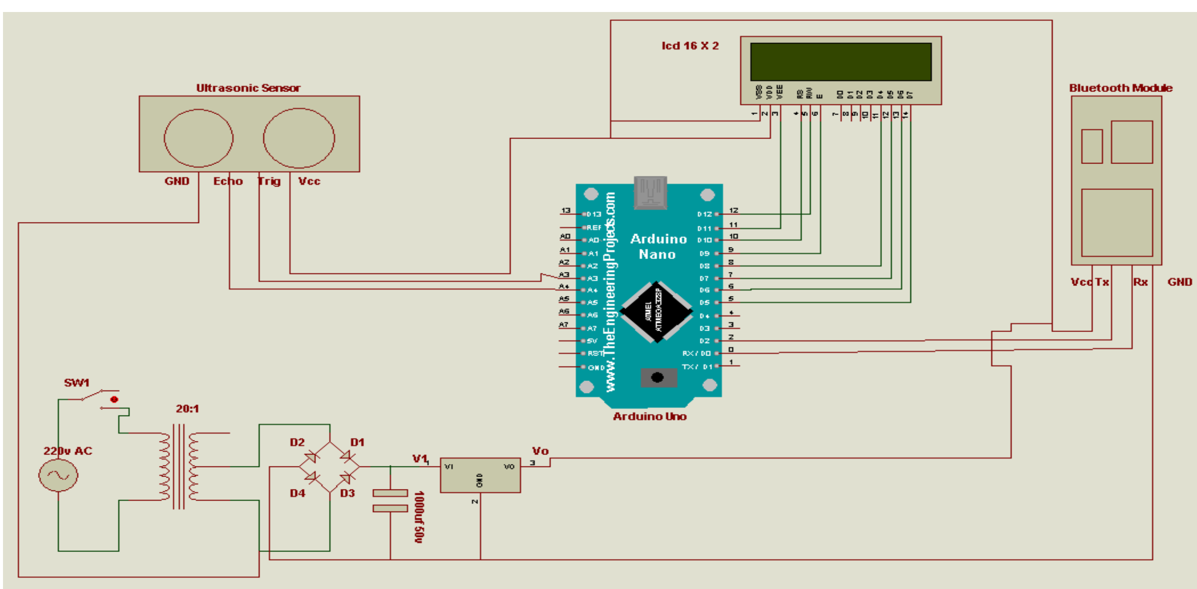

Fig. 3 Entire system Circuit diagram

The formula for this calculation is

$$d = \frac{1}{2} t X v \quad (1)$$

Where d is the distance measured in meters, t is the recorded time in seconds, and v is the velocity of sound in air (Approximately 340 m/s).

The HC-05 Bluetooth module, a full-duplex module, is tied to the Arduino Uno board, as shown in the circuit diagram of Figure 4. The transmission (Tx) pin and the reception (Rx) pin of the Bluetooth device is hooked to the RX and TX pins of the Arduino board. The HC-05 Bluetooth device may be operated in two modes, but it is operated in data mode in this design, where the enable pin is set to 'LOW'. The Bluetooth device in this circuit is employed to acquire the water level information (data) captured by the ultrasonic sensor and computed by the sensor Arduino program. The Bluetooth module then remotely sends signals to the end user (smartphone). The connection between the Bluetooth module and the smartphone is achieved using the Arduino Bluetooth Controller Mobile Application installed in the smartphone. As processed by the Arduino, the water level is displayed on the LCD module. The schematic arrangement of the experimental set-up is presented in Figure 5. For the bucket to be calibrated to achieve a high-performance level, 0.17% of volume maximum acceptable error margin should be evaluated. This error could be attributed to the fact that the accuracy of the ultrasonic sensor is affected by both the temperature/humidity of the environment and the position of the sensor (www.retautomation.co.za/ultrasonic). The minimum and maximum were set at 0.17% and 99.83% of the bucket's water volume holding capacity, respectively. This means that 4.76 centimeters were left at the bottom and top levels of the bucket. A 28-centimetre bucket was used for the experimentation. Mark 4.76 centimeter was chosen as the minimum set point, while mark 23.24 centimeter was taken as the maximum set point. This is done to ensure that the water level is always maintained in the bucket and that water does not overflow the bucket. The Arduino Development Board was programmed using the Arduino IDE 1.6.5 (Integrated Development Environment) using C programming language. Using the minimum and maximum set points, the microcontroller was programmed to read the minimum set point as the lowest level and shows it as 0% on the LCD and the maximum set point is read as the highest level and shows it as 100% on the LCD. The first calibration was to measure the empty bucket's height to know the height (H) of the bucket. This is done to set the bucket's maximum and minimum water levels. The ultrasonic sensor was placed on top of the bucket with the receiver, and transmitter ends facing the bucket's base. The bucket was then filled to level 4.76 cm. The monitoring system was then turned on, and the initial percentage of water that showed in the LCD was 0% since level 4.76 cm was programmed in the microcontroller as the minimum level set point. As more water is run into the bucket, the readings on the LCD start to increase until it gets to 100% (programmed for level 23.24 cm). While the system was switched ON and all these readings were being displayed on the LCD, we put on the smartphone's Bluetooth. This connects to the Bluetooth device of the level monitoring system via a mobile Application called the Arduino Bluetooth controller. How the application works: open the mobile application and connect the Bluetooth of the level monitoring system to the Bluetooth of the smartphone. When connected, click the terminal button that will prop up, then type the letter 'l' for level and click send. Feedback is sent back to the mobile phone stating the percentage of the water at a chosen instant. For this experiment to be performed on a storage tank or any other storage facility, the Adruino must be recalibrated to suit the dept of the storage facility to be put to use.

4. Results and Discussion

This water level monitoring system was test run in real-time to see how it works successfully and to visualize the outcomes. The system performed excellently, and the results recorded on the 28 cm bucket are presented in stages.

4.1. Stage 1: Minimum Level Set Point (4.76 cm Height)

The level value in percentage under this stage has to be checked. This is to ensure that this corresponds to 0% on the LCD. As the water was being poured into the bucket, the level of water in percentage started to increase from 0% to 100%, and this was displayed both on the LCD and on the smartphone (on demand).

4.2. Stage 2: Maximum level set point (23.24 cm height)

The water level in the bucket in this stage corresponds to 100%. The level value in percentage must also be checked in this stage to correspond to 100% on the LCD. As the water was being drained from the bucket, the level of water in percentage started to decrease from 100% to 0%, and this was displayed both on the LCD and on the smartphone (on demand). Since the smartphone is a mobile device, the water level in percentage is only made on demand.

5. Conclusion

This paper explains developing a wireless system to check the water level inside a tank (bucket) employing the following hardwares: Arduino board, ultrasonic sensor, 12C LCD module, and a Bluetooth device. With this development, we were able to visualize the water level inside a bucket by displaying the water level in percentage both on an LCD and a smartphone (via Bluetooth connection). This system has enabled non-contact monitoring of the water level inside the bucket. It thus regulates the water level in the bucket to save both water and power resources.

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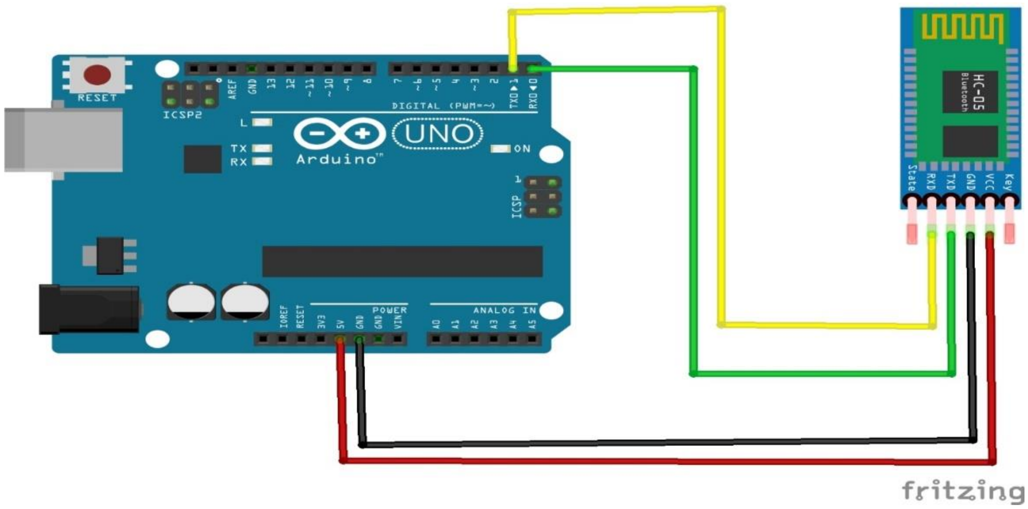

Fig. 4 Connection of Bluetooth to Arduino Uno (https://howtomechatronics.com, 2023)

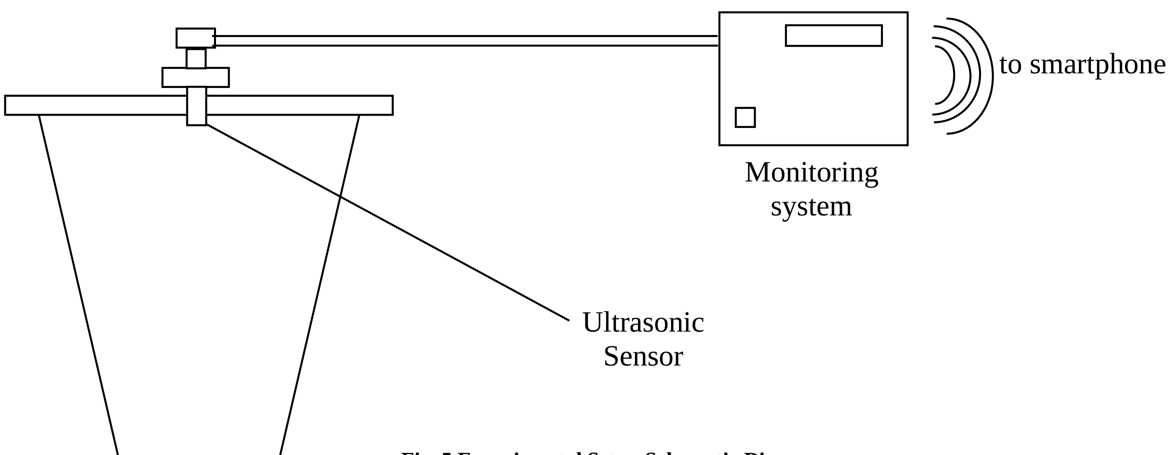

Fig. 5 Experimental Setup Schematic Diagram

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