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Mobile Application-Based Wireless Automatic Water Level Controller

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Abstract

This paper presents the design and implementation of an android mobile application-based wireless automatic water level controller that efficiently controls the level of water in storage tank. The device utilizes HC-SR04 ultrasonic sensors to monitor the water level by sending and receiving sound waves, and the time taken is converted to distance by the Arduino Uno microcontroller which gives corresponding digital outputs to either turn ON the water pump (when the water level in the tank is at a chosen minimum level of 0.09 m) or turn OFF the water pump (when the water exceeds the preset maximum level of 0.29 m). The digital output from the microcontroller is interfaced with an android mobile application named Water HMI (human machine interface) by means of ESP8266 Wi-Fi module unit. The Water HMI mobile application makes it possible to have a picture of what is happening in the storage tank in real time, thus increasing the flexibility of controlling the water pump. The device was tested and it turned ON and OFF the water pump at the preset minimum and maximum levels, and the corresponding water level was shown on the interface of the mobile application.

***Keywords**: Water Level Controller, Wireless, Water HMI, Microcontroller, Ultrasonic Sensors*

1. Introduction

Water is an important resource that is utilized in domestic, commercial and industrial applications. Although water is a common resource to man, its availability in some regions has become an issue due to poor water allocation, inefficient use, and lack of adequate and integrated water management [1]. This has necessitated efforts to store water using various water storage schemes such as reservoirs, wells, artificial lakes and water storage tanks, and retrieve it when needed [2-4]. Storing water in overhead storage tanks requires the use of electric pumps. By means of an electric pump, water is pumped from the source (a lower surface) to where it is stored and treated (a higher surface) after which it is distributed to where it will be utilized, usually at different surface levels [5]. The use of electric pumps to pump water from a source to where it will be utilized presented some challenges that bother on achieving high energy efficiency and extended lifespan of the pump by controlling when to pump, when to stop pumping and how to monitor the level of water in a storage tank [6,7]. It is almost impossible for an individual to be able to keep track of the water level in a non-transparent overhead tank without a proper water monitoring system in place. It is difficult to know when the water storage tank is empty or when it is filled up. Hence, proper monitoring of the water level is necessary to avoid wastage of water and to ensure adequate and proper water management, in addition to preserving the lifespan of the pump.

Several methods have been developed to achieve this monitoring and control. For example, [8] presented a microcontroller based automatic water level control system which utilizes copper conductors as the water level sensor. Since this system offers a form of water level detection that involves contact between the sensor and the water, the sensor is susceptible to corrosion which reduces its sensitivity and poses threat to health. Also, [9] utilized a metallic sensor encased in a plastic tubing but immersed in the tank and connected to a regulator by well insulated output cables. This system requires the use of complex wiring and it is prone to wire damage. Interestingly, it is possible to achieve this monitoring and control using wireless means by utilizing ultrasonic sensors [5] [10] [11] [12], Global System for Mobile Communication (GSM) technology [13], programmable logic controllers (PLCs) [14], radio frequency (RF) communication [15] [16] and Zigbee technology [17]. While the above wireless systems can monitor and control the water level in the storage tanks, they do not have the flexibility of being controlled remotely by the user.

This paper is focused on developing a wireless automatic water level controller that incorporates an interactive medium between the end user and the machine by means of the Water HMI mobile application. The level of the water in the storage tank is seen in real time on the android mobile application interface, and the system has the flexibility of being controlled remotely by the user. This creates an avenue for the user to be the major deciding factor on whether or not water should be in the tank.

2. Methodology

The developed mobile application-based wireless automatic water level controller consists of an Arduino Uno microcontroller programmed to carry-out all the control functions and to give corresponding digital outputs that turn the water pump ON and OFF at the preset minimum and maximum levels, HC-SR04 ultrasonic sensors installed at the top of the tank to monitor the water level by sending and receiving sound waves (echoes), an android mobile application named Water HMI that makes it possible to have a picture of what is happening in the storage tank in real time and also increases the flexibility of controlling the water pump, ESP8266 Wi-Fi module unit which enables the mobile application to communicate with the system, a DC-to-DC converter that converts 12V DC to 3.3V DC which is used by the Wi-Fi module, a 5V DC Relay (SRD-05VDC-SL-C) that switches the water pump ON or OFF, and the DC water pumping machine. The block diagram of the mobile application-based wireless automatic water level controller is shown in fig. 1.

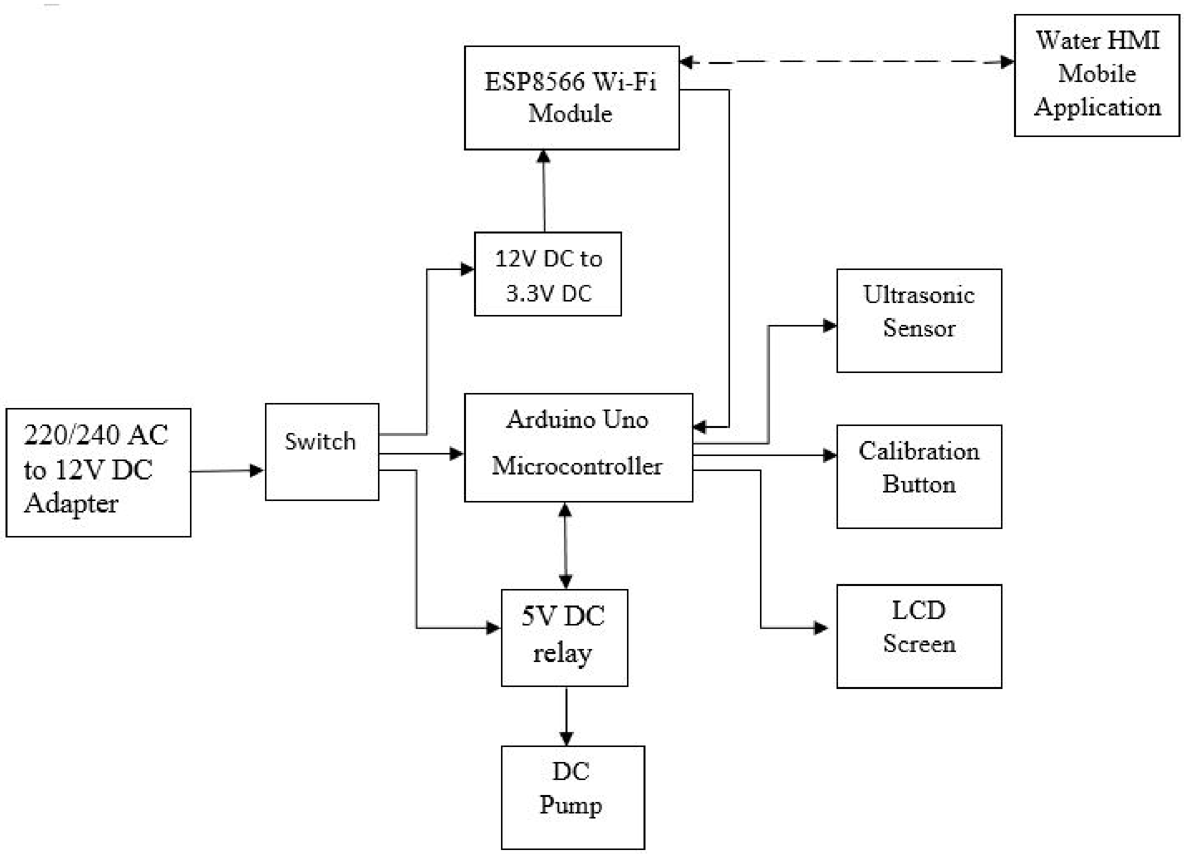

Fig. 1: Block diagram of the mobile application-based wireless automatic water level controller

2.1 Microcontroller Unit

The Arduino Uno microcontroller unit is programmed to send a pulse of 10 µs to the trigger pin of the sensor, after which the sensor is enabled to send and receive an 8 x 40 KHz sound wave. When the water level rises, the time it takes to send and receive the sound waves is converted to distance by the microcontroller using Eq. (1).

$$Distance = \frac{delay\ time \times ultrasonic\ speed}{2} \qquad (1)$$

The value of the distance is compared with the preset value in the program. When it gets to the preset minimum or maximum value, the microcontroller gives a digital output to trigger the 5V DC Relay to switch the water pump ON or OFF respectively.

2.2 Ultrasonic Sensor

Ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the delay time, that is, the time between the emission and reception. The HC-SR04 ultrasonic sensors mounted at the top of the tank are triggered by the microcontroller to send and receive sound waves. The ultrasonic level transmitter transmits an ultrasonic pulse down into the tank. This pulse, travelling at the speed of sound which is 343 m/s, is reflected back to the transmitter from the liquid surface. The transmitter measures the time delay between the transmitted and received echo signal and the on-board microprocessor calculates the distance to the liquid surface using Eq. (1). Once the transmitter is programmed with the bottom reference of the application – usually the bottom of the tank – the liquid level is calculated by the Arduino Uno microcontroller using Eq. 2.

$$Liquid\ level = Tank\ height - Distance \qquad (2)$$

The height of the tank used for this design is 0.30 m and using Eqs. (1) and (2), the different water levels are calculated as shown in table 1. When the water level gets to the preset minimum or maximum values, the microcontroller then gives out a corresponding digital output that triggers the 5V DC Relay to switch the water pump ON or OFF.

Table 1: Water level monitoring

Water level (m)	***Distance from sensor (m)***	***Time taken (ms)***
0.09 (minimum level)	0.21	0.61
0.15	0.15	0.44
0.20	0.10	0.29
0.25	0.05	0.15
0.29 (maximum level)	0.01	0.03

To Interface the ultrasonic sensor with the microcontroller, the terminals tagged VCC and GND are connected to +5 V and 0 V respectively. The pins labeled trigger are used to actuate the ultrasonic transmitter while the echo pin is connected to the digital input terminal of the microcontroller for detecting the reflected signal. Fig. 2 shows the HC-SR04 ultrasonic sensors interfaced with the Arduino Uno microcontroller.

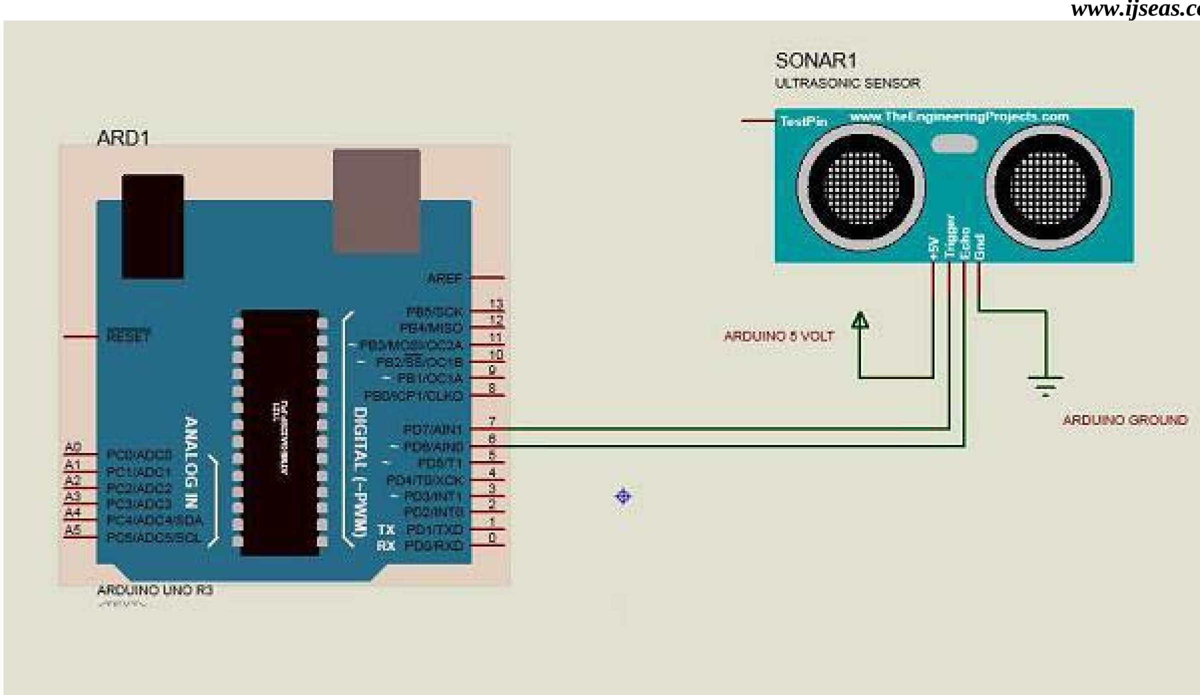

Fig. 2: HC-SR04 ultrasonic sensors interfaced with the Arduino Uno microcontroller

2.3 Wi-Fi Module

The ESP8266 Wi-Fi Module shown in fig. 3 is a low-cost Wi-Fi microchip, with a full TCP/IP stack and microcontroller capability. This small module allows the Arduino Uno microcontroller to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. It integrates a Tensilica L106 32-bit RISC processor, which achieves extra-low power consumption and reaches a maximum clock speed of 160 MHz. The Real-Time Operating System (RTOS) and Wi-Fi stack allow about 80% of the processing power to be available for user application programming and development.

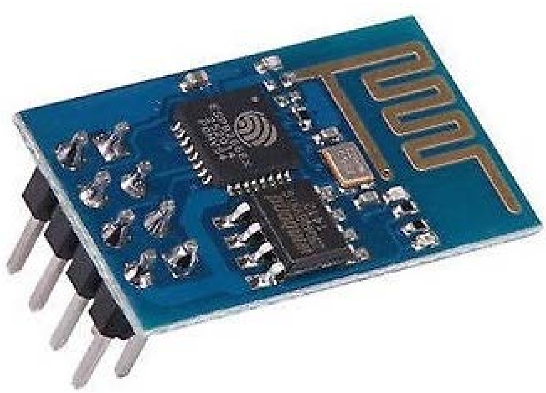

Fig. 3: Picture of the ESP8266 Wi-Fi Module

2.4 Program Development

The wireless automatic water level controller program was written in ***C*** programming language and developed using the Arduino Integrated Development Environment (IDE). The flow chart of the program is shown in fig. 4.

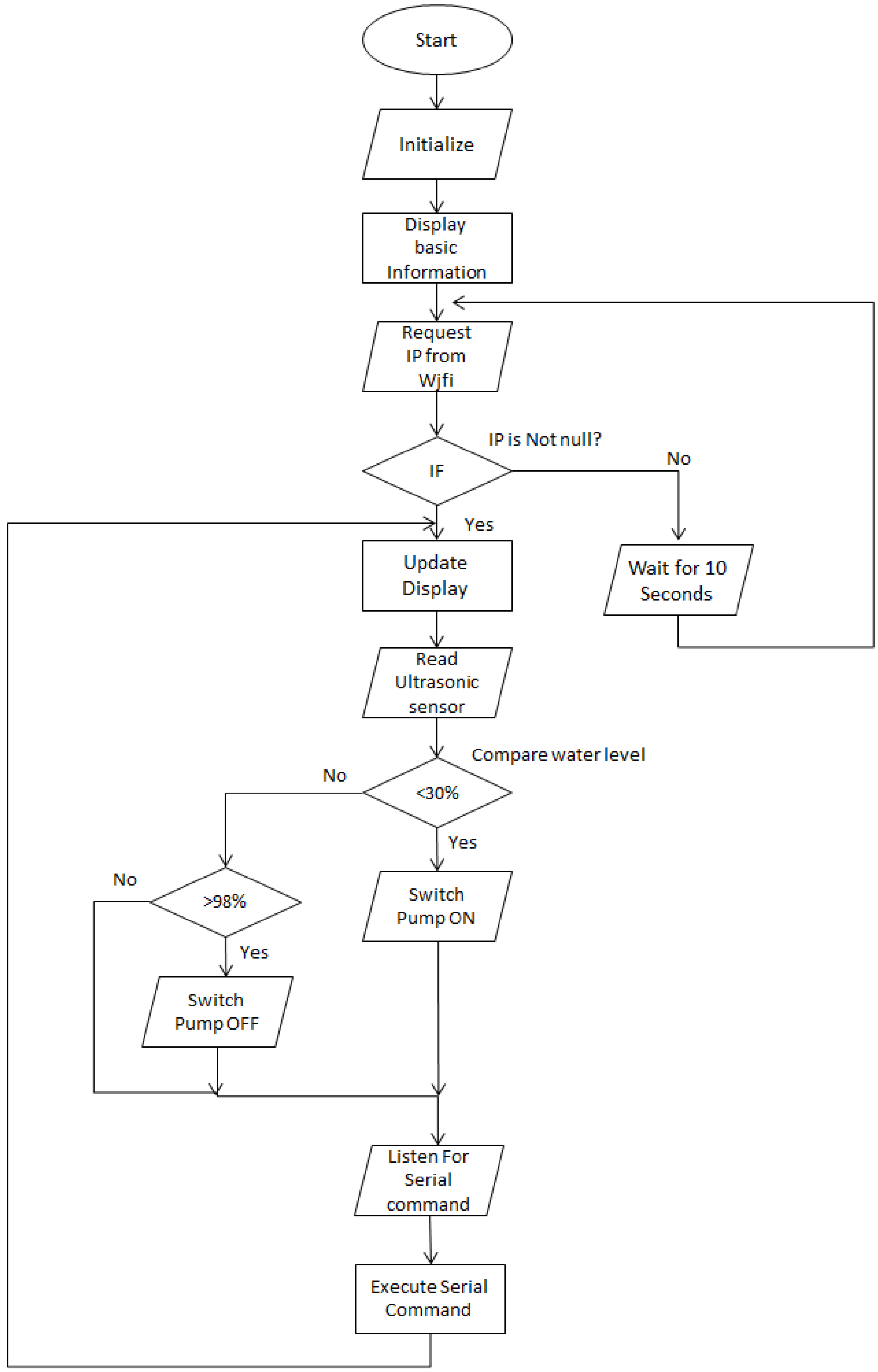

Fig. 4: Flow chart of the mobile application-based wireless automatic water level controller program

2.5 Water HMI Application Development

In order to make an Android smartphone to function as a monitoring tool that can display the water level in the storage tank and at the same time detect the state of the pump, an application named Water HMI was built on the flutter software. Fig. 5 shows the Water HMI application interface. The graphical user interface consists of a cylindrical shaped container which has a blue background color with variable height. The background height is determined by the calculated tank level received from the microcontroller.

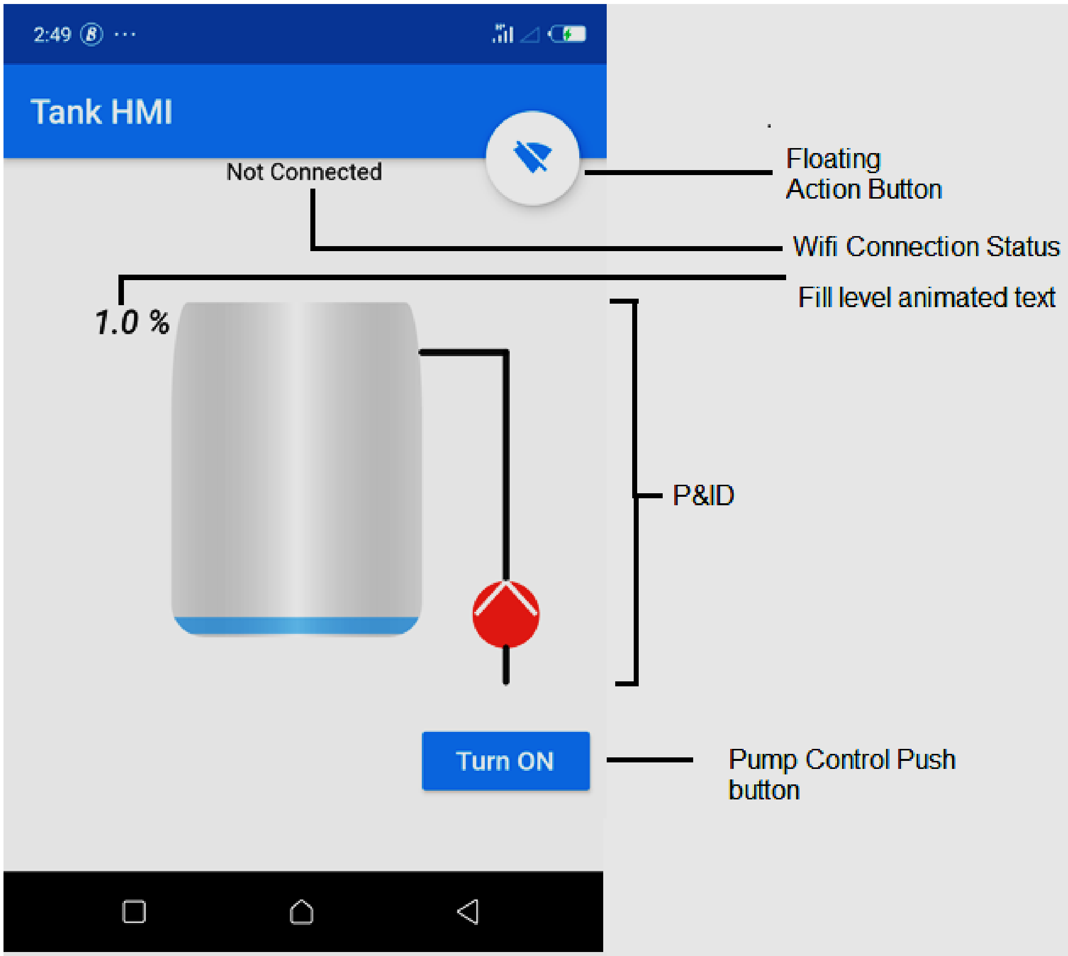

Fig. 5: Water HMI application interface

3. Mode of Operation

The circuit diagram of the mobile application-based wireless automatic water level controller is shown in fig. 6.

The HC-SR04 ultrasonic sensors mounted at the top of the tank are triggered by the microcontroller to send and receive sound waves. When the system is switched ON, the Arduino Uno microcontroller sends a pulse of 10 µs to the trigger pin of the sensor. The sensor then transmits an 8 x 40 KHz sound wave to enable the echo pin, after which the reflected sound wave is received to disable the echo pin.

As the water level rises, the corresponding time it takes to send and receive the sound waves is converted to distance by the microcontroller. The microcontroller continuously compares the value of the distance with the preset value in the program. When the water level gets to the preset minimum value of 0.09 m or the chosen maximum value of 0.29 m, the microcontroller gives out a corresponding digital output that triggers the 5V DC Relay to switch the water pump ON or OFF respectively. This process continues.

At the same time, the ESP8266 Wi-Fi module unit enables the Water HMI mobile application to communicate with the system, enabling the mobile application interface to display a picture of what is happening in the storage tank in real time.

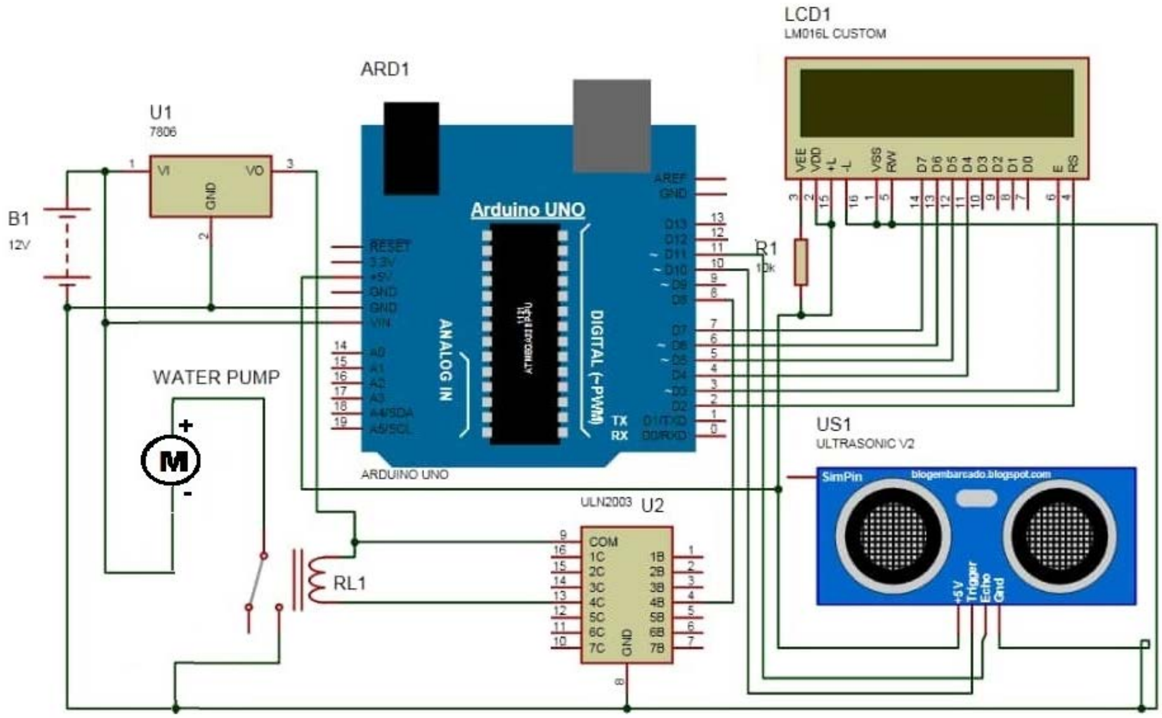

Fig. 6: Circuit diagram of the mobile application-based wireless automatic water level controller

4. Test and Results

The system was tested with two experimental water storage containers, one representing the underground source of water and the other representing the overhead storage tank. This is shown in fig. 7.

(a) Front view (b) Rear view

Fig. 7: Pictorial views of the developed mobile application-based wireless automatic water level controller

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The overhead water storage tank was made of a transparent plastic material. When the system was connected to 240 V AC supply and powered ON, the pumping machine was automatically switched ON since the overhead storage tank was empty. As the water level rises, the picture of the tank's content was displayed on the graphical user interface of the Water HMI mobile application. When the water level rose to the maximum set point of 0.29 m, the pumping machine was automatically switched OFF. The screenshots of the Water HMI mobile application user interface at various water levels are shown in figs. 8-12.

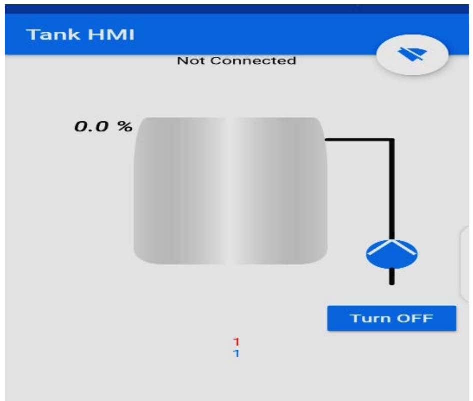

Fig. 8: Screenshot of the Water HMI mobile application interface when the tank was empty

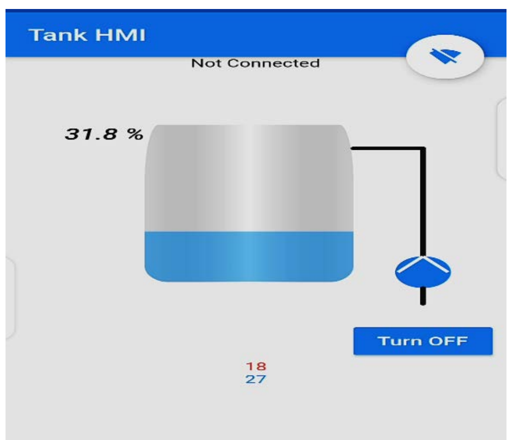

Fig. 9: Screenshot of the Water HMI mobile application interface when the tank was at 31.8%

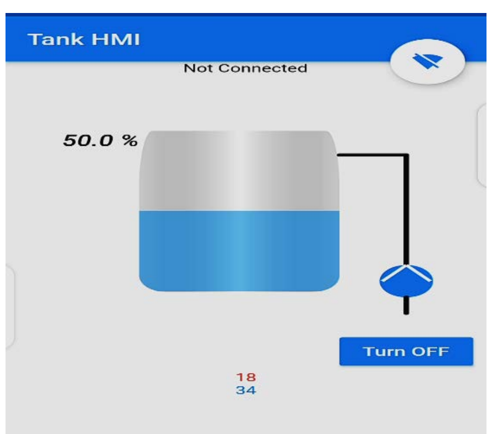

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Fig. 10: Screenshot of the Water HMI mobile application interface when the tank was at 50%

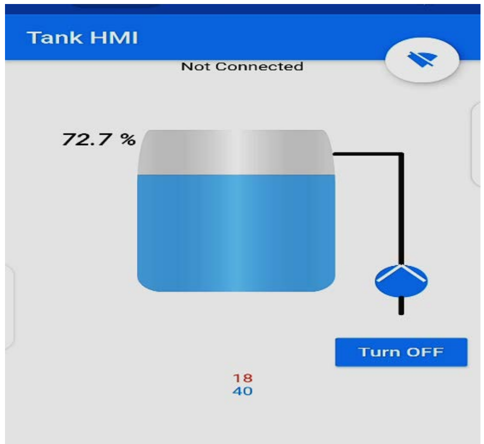

Fig. 11: Screenshot of the Water HMI mobile application interface when the tank was at 72.7%

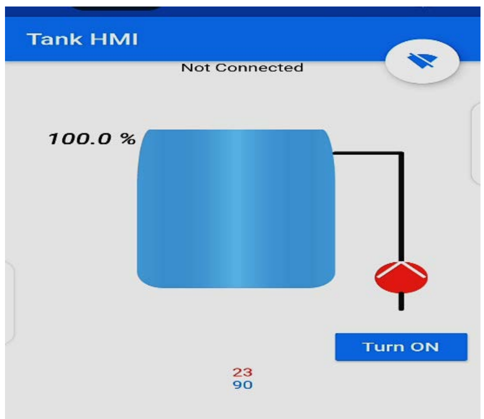

Fig. 12: Screenshot of the Water HMI mobile application interface when the tank was at the maximum preset level

5. Conclusion

This work presents the design and implementation of an android mobile application-based wireless automatic water level controller that efficiently controls the level of water in storage tank. Based on the results obtained from the tests carried out, it is obvious that this system is more flexible than the existing wireless water level monitoring and control systems as it creates an interactive medium between the end user and the machine by means of the Water HMI mobile application, thus having the flexibility of being controlled remotely by the user.. The system when commercialized could be utilized in various applications that require liquid level sensing and control.

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