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A Microcontroller-Based Water Level Indicator using Radio Frequency (RF) Technology and Ultrasonic Sensor

Ifeanyi Chinaeke-Ogbuka, Augustine Ajibo, Cosmas Ogbuka

Abstract— The design and construction of a prototype microcontroller-based water level indicator using radio frequency (RF) technology and ultrasonic sensor is presented. The objective is to minimise water, energy and time as well as the attendant risks associated with the conventional designs of water level indicator used in homes and industries. An ultrasonic sensor is used to obtain the level of water which is fed to an Arduino Uno microcontroller which automatically switches ON/OFF the water pump whenever the level of water is low or full respectively. Specifically, the design has the unique features of monitoring the water level at four different levels namely; Low, Medium, Third Quarter and Full. The level obtained by the sensor is transmitted wirelessly to a receiver system located some distance away from the tank using RF communication which then displays the result on an LCD. The design was successfully implemented and tested. Accurate results were obtained confirming the accuracy of the design.

Index Terms—Arduino Uno Microcontroller, Radio Frequency (RF), Ultrasonic Level Sensor, Water Pump

1 Introduction

Wastage of water, energy and time at homes and industries have persisted as users have to constantly monitor overhead tanks to know when to switch on/off the water pumps [1]. The energy loss, in particular, is undesirable due to the global energy crisis necessitating aggressive researches in renewable energy [2, 3]. In addition, users run the risk of falling inside the tank or falling off the ladder during water level inspection. Perfectly Automatic Water Level Controllers can provide solutions to these problems to ensure adequate and constant supply of water for multipurpose. Microcontroller based Water level indicator can either be designed as a manual or an automatic control system [4]; the former requires efficient and effective human assistance while the later does not.

The idea of a microcontroller based water level indicator is not new. Many designs have been carried out by others in recent times. For instance, float switch sensor and ATMEGA32A microcontroller were used by [5]. This method monitors and controls the level of water contained in a tank using float switch as a sensor which senses the level of water in the tank in terms of voltage or current signal to automatically start or stop the electric pump when the tank is empty or full respectively. A ping sensor and a common 27MHz wireless remote control module were used by [6]. The major problem with this method is that the distance of propagation is limited (in this case a maximum of 5 metres).

In this paper, RF technology was used to establish wireless communication between a transmitter and a receiver. The system employed an RF module, an ultrasonic sensor and an Arduino Uno

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microcontroller to automate the process of water level monitoring in an overhead tank. A similar work was done in [7] using an encoder and a decoder to encode and decode signals between the transmitter and the receiver. Also [7] used sensors composed of rod, nozzles and rubber to sense the level of water based on the fact that water conducts electricity thereby making the system a little bit complex.

Here, the level of water is obtained using an ultrasonic sensor in term of time of flight (i.e. the total time it takes the sensor to emit an ultrasonic wave and the emitted wave to be reflected back to the sensor placed on top of the tank). The value obtained is then used by the microcontroller to obtain the level of water in terms of distance using the formula S=VT where S is the distance (or level) of water in the tank, T is the time of flight and V is the speed of sound. With this design, the level of water in an overhead tank can be easily monitored and controlled with ease from a distance.

The choice of RF is because it can travel through larger distances making it suitable for long distance applications. RF signals can travel even when there is an obstruction between the transmitter and the receiver, RF communication uses a specific frequency. These make RF transmission is more reliable than IR transmission and microwave [8, 9].

2 Block Diagram Description of the System

A combined block diagram of the transmitter and receiver circuits is shown in Figure 1. A description of the features and functionalities of the basic components of the system is made in the following subsections.

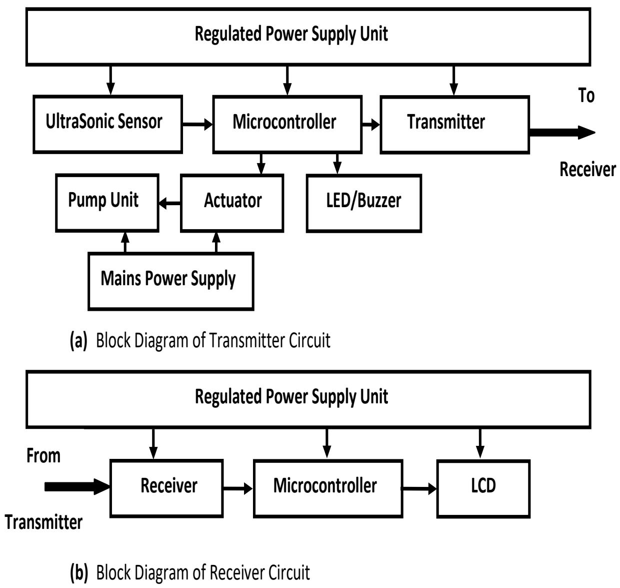

Fig. 1. Block Diagram of Transmitter and Receiver Circuits

2.1 Arduino Uno Microcontroller

Arduino Uno Microprocessor was used because it is an open-source physical computing platform based on a simple microcontroller board and a development environment for writing soft-
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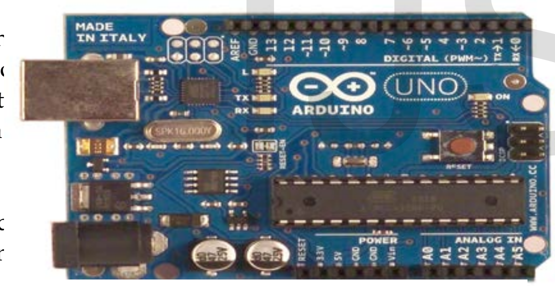

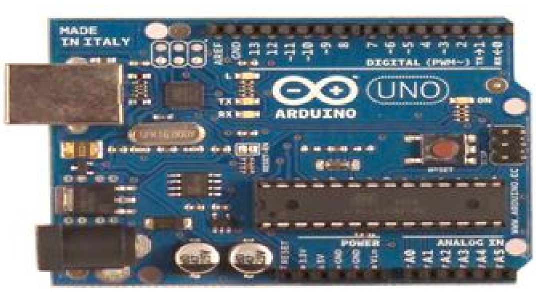

Fig. 2. Arduino Uno Microcontroller

2.2 Electric Water Pump

A 0.5Hp water pump is used to pump water from a reservoir into an overhead tank whenever the water contained in the tank is not at the required level. The automatic water level indicator controls the water pump through the relay by sending a HIGH (5V) or a LOW (0V) to the Darlington driver IC which then activates or deactivates the relay for switching. The microcontroller takes decision on whether to activate the pump or not based on the level being obtained from the sensor.

2.3 Ultrasonic Level Sensor

An ultrasonic sensor is a non-contact sensor used to measure the distance between the sensor and objects in its path by calculating the time interval between sending out sound waves and receiving back the sound waves (in form of echo) to determine its distance to an object. They are excellent at suppressing background interference and employ sound waves for detection of liquid level and usually work over the frequency range between 20 kHz to 200 kHz. They emit short, high-frequency sound pulses at regular intervals which propagate in the air at the velocity of sound. The time taken by the sound wave to return back is directly proportional to the distance between the sensor and the water in the tank. This time duration is measured by the sensor which is then further used by the microcontroller to calculate the level of liquid in the tank. Depending on the result of the ultrasonic level sensor, the level of water in an overhead tank can be controlled and monitored. Table 1 shows the electrical parameters of ultrasonic sensor.

Table 1

Electrical Parameters of Ultrasonic Sensor

Working Voltage	DC 5V
Working Current	15mA
Maximum Range	4m
Minimum Range	2cm
Working Frequency	40Hz
Measuring Angle	15 degrees
Dimension	45*20*15mm

The sensor is located at the top of the tank in such a way that it sends out the sound pulses in downward direction to the water in the tank under level measurement so as to obtain accurate values.

2.4 RF Transmitter and Receiver Pair

An RF Module (radio frequency module) is a small electronic device used to transmit and/or receive radio signals between two devices. It allows microcontrollers to communicate wirelessly with other microcontrollers, or with radio frequency (RF) controlled devices that operate in the same frequency (433MHz in this case) as seen in [7,8]. The RF module makes use of an external antenna to transmit the signal. This external antenna serves to increase the distance of communication between the transmitter system and the receiver system; and the length of the antenna is usually one-fourth of the wavelength of the signal where wavelength is calculated from $v = f \lambda$, where v is the speed of sound and f is the frequency (in this case 433MHz) [7]. In an embedded system, it is often desirable to communicate with another device wirelessly and this wireless communication may be accomplished through optical communication or through radio frequency (RF) communication. In this project, as already mentioned, the medium of choice is RF since it does not require line of sight and travels longer distance than optical communication. RF communications incorporate a transmitter and a receiver; meaning both a transmitter and a receiver is needed to communicate with each other over a distance. The RF module used in this project is RF 433MHz whose range lies between 20 and 200 metres and is Amplitude Shift Keying modulated. Figures 3 shows the RF transmitter and receiver modules used while Tables 2 shows the pin descriptions of the modules.

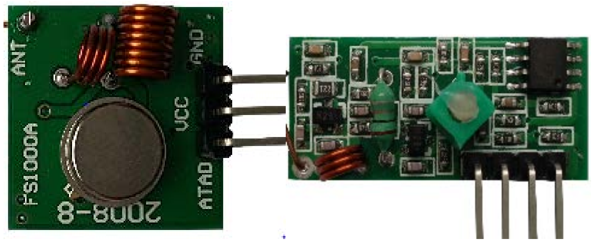

Fig. 3. RF 433 Transmitter (Left Hand Side) and RF 433 Receiver (Right Hand Side)

2.5 Light Emitting Diode (LED)

They are solid state light emitting devices made using semiconducting materials that emit less heat and last longer than other light sources such as conventional incandescent bulbs. LEDs were used as indicator lamps in the design given their characteristics of compactness and low power consumption [11].

2.6 Liquid Crystal Display (LCD)

A liquid crystal display (LCD) is a video display that utilizes the light modulating properties of liquid crystals to display pictures or texts on a screen [11]. They are energy efficient and consume between 1 and 300 microwatts per square centimeter thus producing minimal amount of heat during operation. A 16*2 LCD has been used in this design since it is easily available and cost effective where 16 denotes the number of columns and 2 the number of rows.

2.7 Relay

A Relay is a simple switch that can be operated both electrically or mechanically and consists of an electromagnet and a set of contacts [12]. It was employed in the design as a switching unit that simply triggers the pump on or off depending on the signal received from the microcontroller.

2.8 Voltage Regulator

Voltage regulator is a regulator circuit used to step down the voltage source to the level required by microcontrollers [13]. In this project; 7805 and 7812 regulators were used to regulate the voltages to 5V and 12V respectively after being passed through the transformer and rectifier to convert from AC to DC. They were used in the design to get a low DC voltage from a high DC voltage.

2.9 ULN2803A Darlington Transistor Array

The ULN2803A is a high-voltage, high-current Darlington transistor array which consists of eight NPN Darlington pairs that feature high-voltage outputs with common cathode clamp diodes for switching inductive loads. The collector-current rating of each Darlington pair is 500 mA. It was used in the design to drive the relay used in turning on/off the water pump. The Figure 4 shows the diagram of the ULN2803A Darlington driver.

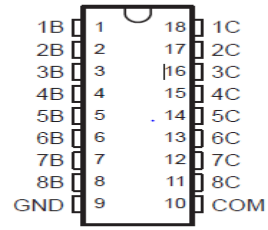

Fig. 4. ULN2803A Darlington Driver IC

3 WORKING PRINCIPLE OF THE TRANSMITTER SYSTEM

This transmitter circuit uses an ultrasonic sensor to determine the level of water in the tank. The sensor is fixed so that it directly faces the water in the tank and is connected to the transmitter circuit using connecting wires. The sensor measures the distance between it and the water using sonar. An ultrasonic pulse is transmitted from the sensor; and distance to target is determined by measuring the time required for the echo return. Output from the sensor is a variable width pulse that corresponds to the distance to the target. This is then feed to the microcontroller. The microcontroller, upon receiving data (or signal) from the sensor, transmits it wirelessly to the RF receiver placed some distance away using the transmitter and also indicates the level of water through a series of LEDs. This system indicates four levels of water which are low, medium, third-quarter and full and at every level; only one LED is ON. When there is no enough water in the tank, the microcontroller switches ON a water pump by triggering the relay ON and when the tank is full; the pump is turned OFF. The buzzer is used as a feedback mechanism to sound an alarm whenever there is a malfunction in the operating system of the transmitter. This system malfunction could be as a result of the sensor not sensing an accurate value or the water pump not being able to pump water when it is supposed to. An antenna is connected to the transmitter to help increase the signal strength and also to ensure that the signal gets to the receiver. The flow chart shown in Figure 5 is used to describe the algorithm used by the transmitter to process the data gotten from the sensor. The circuit diagram of the transmitter system for the wireless water level indicator is shown in the Figure 6 as simulated in Proteus 8.1.

4 WORKING PRINCIPLE OF THE RECEIVER SYSTEM

The transmitted data is received using RF 433 receiver. The receiver, upon receiving these signals, sends them to the Arduino Uno microcontroller which takes logical decisions based on the data received. The microcontroller then displays the level of water using a liquid crystal display. The flow chart that describes the algorithm used by the receiver to process the data gotten from the transmitter is shown in Figure 7. The circuit diagram of the receiver system for the wireless water level indicator is shown in the Figure 8 as simulated in Proteus 8.1.

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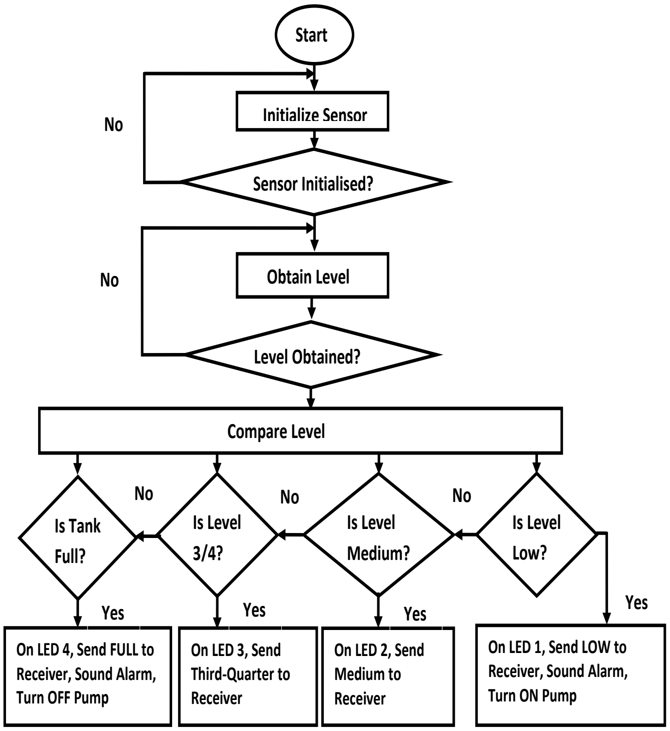

Fig. 5. Flow chart description of the transmitter system

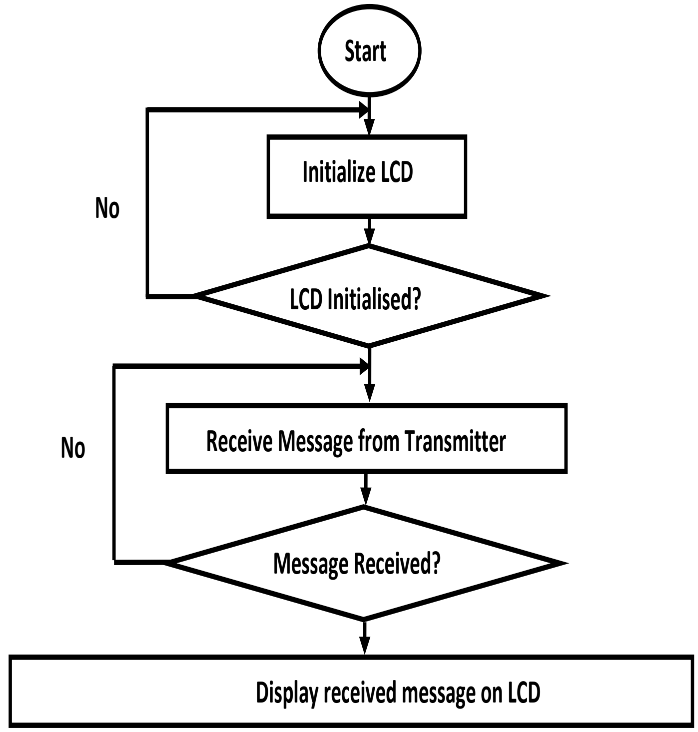

Fig. 7. The flow chart description of the Receiver System

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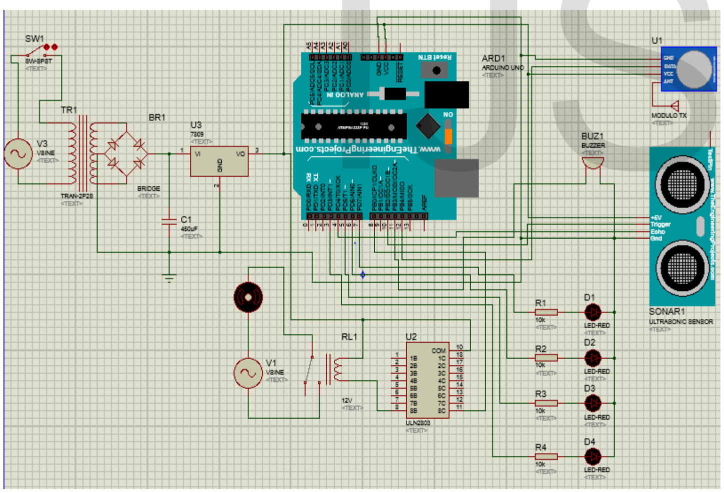

Fig. 6. Circuit Diagram of Transmitter System on Proteus 8.1.

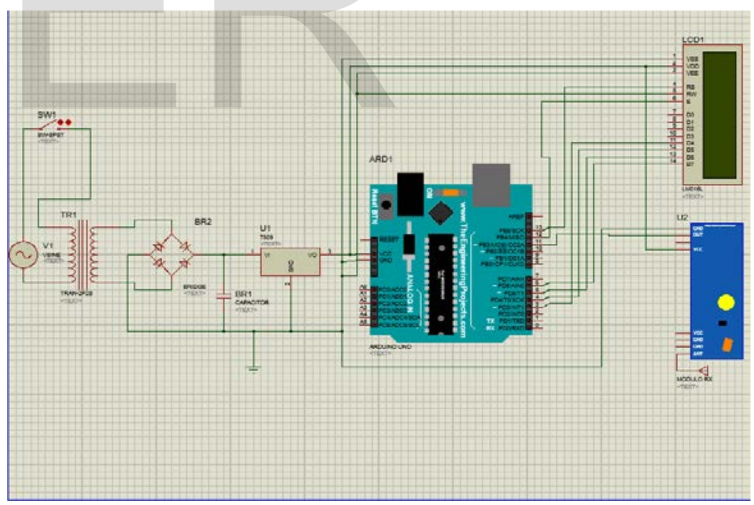

Fig. 8. Circuit Diagram of Receiver System on Proteus 8.1

The circuit diagram of the receiver system for the wireless water level indicator is shown in the Figure 8 as simulated in Proteus 8.1.

5 Testing

The complete implemented design is shown in Figure 9. All the scenarios (Low, Medium, Third Quarter and Full) were tested and accurate performances obtained after 100 trials. It is satisfied that the design works accurately.

Fig. 9. The complete implemented design

6 CONCLUSION

The microcontroller based wireless water level indicator was successfully designed and developed. The water pump is turned OFF and ON according to the water levels. Compared with other conventional designs; the automatic wireless water level controller shows excellent performance and is more effective, reliable and is not expensive. The system is designed in such a way that it will be able to prevent the wastage of water and transmit the different water levels wirelessly to a receiver system placed some distances away from the tank. The whole system operates automatically and thus; does not need manual intervention. It can be seen from the above points, that the design was able to fulfil the aim and objectives of the research and has also gone a long way in having additional features that would serve it as an excellent device compared to other conventional methods of water level monitoring.

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