Design And Implementation Of Automatic Non-Contact Water Level Monitoring With Automatic Pump Control System

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***ABSTRACT*—Water pumps are devices installed beneath the ground through pipes for moving water to overhead tanks. Over the years, the inconsistency associated with manually operating water pumping machines, overflow of water during pumping, and unprecise water level in overhead tanks due to its opacity is a major problem currently faced by homes or major cities of the world. In a bid to solve this problem, a study on the design and implementation of automatic noncontact water level monitoring with automatic pump control system to monitor water levels in real-time was introduced. The study's specific objectives were to design and incorporate an interactive medium between the user and the pumping system. To design a suitable system that can reduce human labour from the convectional manual operation of the pump. This research was conducted using passive and active electrical components. The system consisted of two circuits which were the tank circuit for water level check and the pump connected circuit which controlled the ON and OFF time of the pump. The entire components were mounted on a Vero board and circuit interpretation was done through the block and circuit diagram of the system. Programming and coding of the microcontroller were carried out and analysis was done to ascertain the functionality of the system. The results showed that water level can be controlled and observed using the input command unit and visual display unit respectively. The system can also be used to monitor other fluids.**

***Keywords*—Water level, Radio Frequency (RF)), Microcontroller, Ultrasonic sensor, Water pump.**

1.0 INTRODUCTION

Water is an essential element of a person's life. The human body is composed of 75% water in infants and 55% water in the elderly ones and not drinking enough water leads to dehydration which has many detrimental effects on the body physical and mental well-being of an individual[1]. Studies show that dehydration decreases cognitive function in children and increases the risk for delirium in the elderly as water is also important in maintaining healthy functioning kidneys, gastrointestinal function, and heart function[2]. It is a common practice in Nigeria and neighbouring countries for householders to store water in overhead tanks in buildings before usage. The water is channeled to those heads with the use of pumps and subsequent usage is by flow due to gravity. When storing this water in the tanks, it is difficult to see the level of the water in the tank because of the height and opacity of the tanks in use. Hence most of the time there is an overflow of water in the tanks during pumping, thus leading to wastage of energy and water. Hence, this has led to the development of various water control schemes or systems that monitor the level of water according to the precise settings. Therefore, efficient water monitoring has necessitated research into some water level sensing technologies, and collection methods [3]. To eliminate water wastage during pumping and to care for future needs for large volumes of water, the concept of Non-Contact Water Level Monitoring with Automatic Pump Control System is being developed. Furthermore, a non-contact water Level monitoring and Automatic Pump Control System is a piece of electronic equipment that consists of two main systems The tank circuit monitors the level of water in the tank using an ultrasonic transducer that is synchronized with a microcontroller to send the process information wirelessly using radio frequency (RF) transceiver module to communicate with the pump circuit which processed the information. The pump circuit which is electrically connected to the starter of any given pump motor set will control the operation of the pump set. It Switches ON the Pump set when the water level drops below the pre-set level in an overhead tank and switches OFF the pump set when the water level in the overhead tank becomes full to the precise level. Using less costly components, this motor driver circuit can be implemented at home and in offices. The main advantage of this automatic non-contact water level monitoring with an automatic pump control system is that it automatically controls the water pump without any user interactions.

2.0 LITERATURE REVIEW

Several works have been done on the control of water pumping machines and level indication, but these systems have their disadvantages because of the method of sensing used such as Omolola (2010), who developed a prototype for a water level detector with pump control based on a microcontroller. The prototype involved the use of a digital water level detector with pump control and an instrument that indicates the level of water in a tank, using a seven-segment display to indicate the following levels: 0%, 25%, 50%, 75%, and 100%. It has an alarm that indicates when water is at the 0% level. However, the alarm emits a continuous sound for 10s indicating that the water level was 100%.

Hani and Myaing (2011), developed and constructed a microcontroller-based water flow control system. The system was a technology resource for the fluid handling industries for critical management, control, containment, and measurement of fluid. It covers products, processes, and services for efficient, reliable, and cost-effective control and delivery of fluids in a variety of industries. There are many flow control mechanisms analyzed. The automatic water flow control system was implemented and could be used as a process control system, The sensing unit, photo interrupter, and slotted disk were used to produce a pulse train for frequency input of the microcontroller. The sensor signal could be counted as frequency and converted to the flow rate by using the software program in a programmable intelligent computer (PIC16F628). This flow rate was compared to the set point value and the PIC16F628 could control the water valve by using a direct current (DC) motor to vary the water flow rate based on this comparison, the prototype was implemented using a command line or Windows-based personal computer (PC) application that provides a platform for developing assembly language code for microchips.

Johari *et al*., (2011) developed a prototype that provides detailed tank water level monitoring systems using the GSM Network. They presented the development of a water level monitoring system by integrating a GSM module to alert the person through a Short Message Service (SMS). This project gave the solution to the shortage of water supply in dense populations like hostels where students suffer from this situation because there is no system for monitoring the water level when it reaches a critical level. There was no person when the situation became worse, Due to This reasons water level was monitored, and data was collected through SMS. The system was tested to reduce the shortage of water supply but was not reliable due to network attenuation.

Asaad *et al.*, (2013) developed a prototype that uses Arduino to automate the process of water pumping into a tank by detecting the level of water in the tank per time using a floating water level sensor. This sensor was designed out of a floating material attached to the arm of a potentiometer. The system could detect the level of water in a tank, switch ON or OFF the pump accordingly, and display the status on a liquid crystal display board (LCD) screen. This system was limited to 12V pumps, therefore, making it unsuitable for industrial or domestic applications. However, the major drawback in this system design was the use of a floating sensor which sometimes could be affected by the conductivity of water and other dissolved elements present.

3.0 METHODOLOGY

The research carried out in this work entails the design and implementation of an automatic water pump control and level detection. The essential steps used in this research process include. System design which focuses on the system circuit, components, block diagram, and design description for the various sub-systems that make up the entire system; Circuit analysis with a focus on the mathematical computation of the rating of the components used in different sections of the system and tank calibration for capacity of water in litters. The system comprises two block and circuit diagrams which include the tank system and pump control system block and circuit diagram as shown in Figures 1.0 to 1.3

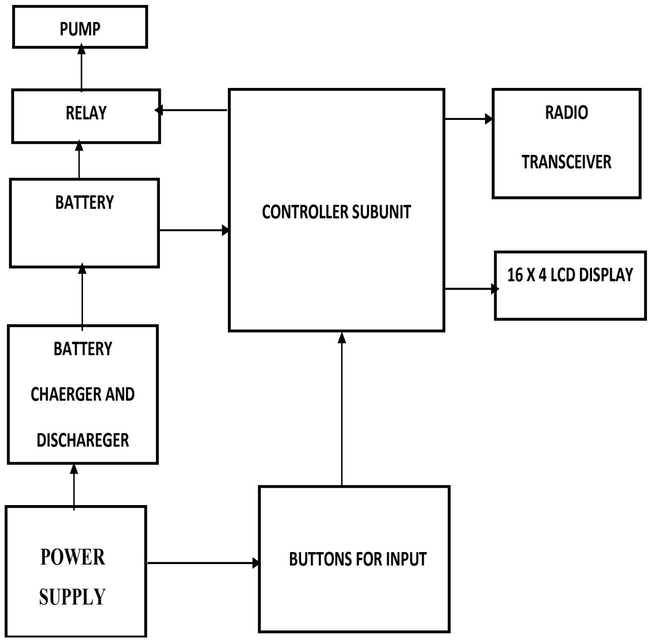

Figure 1.0 Block diagram pump control unit

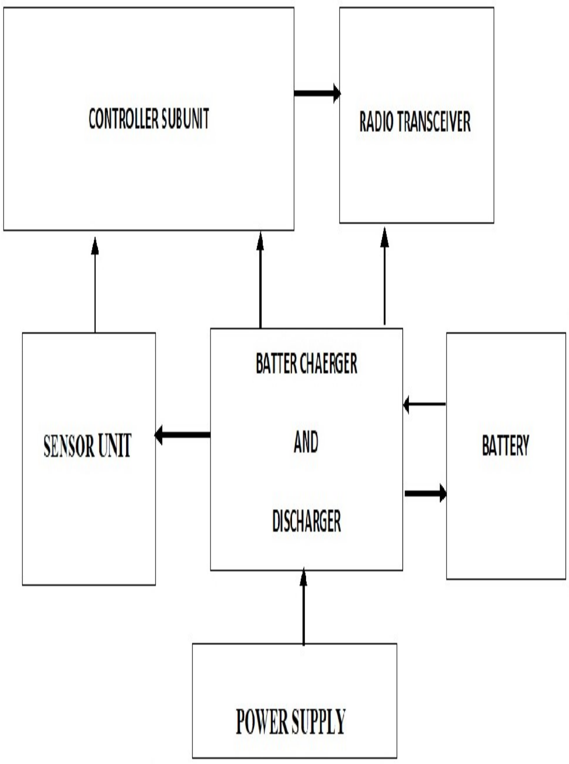

Figure 1.1 Block diagram of tank unit

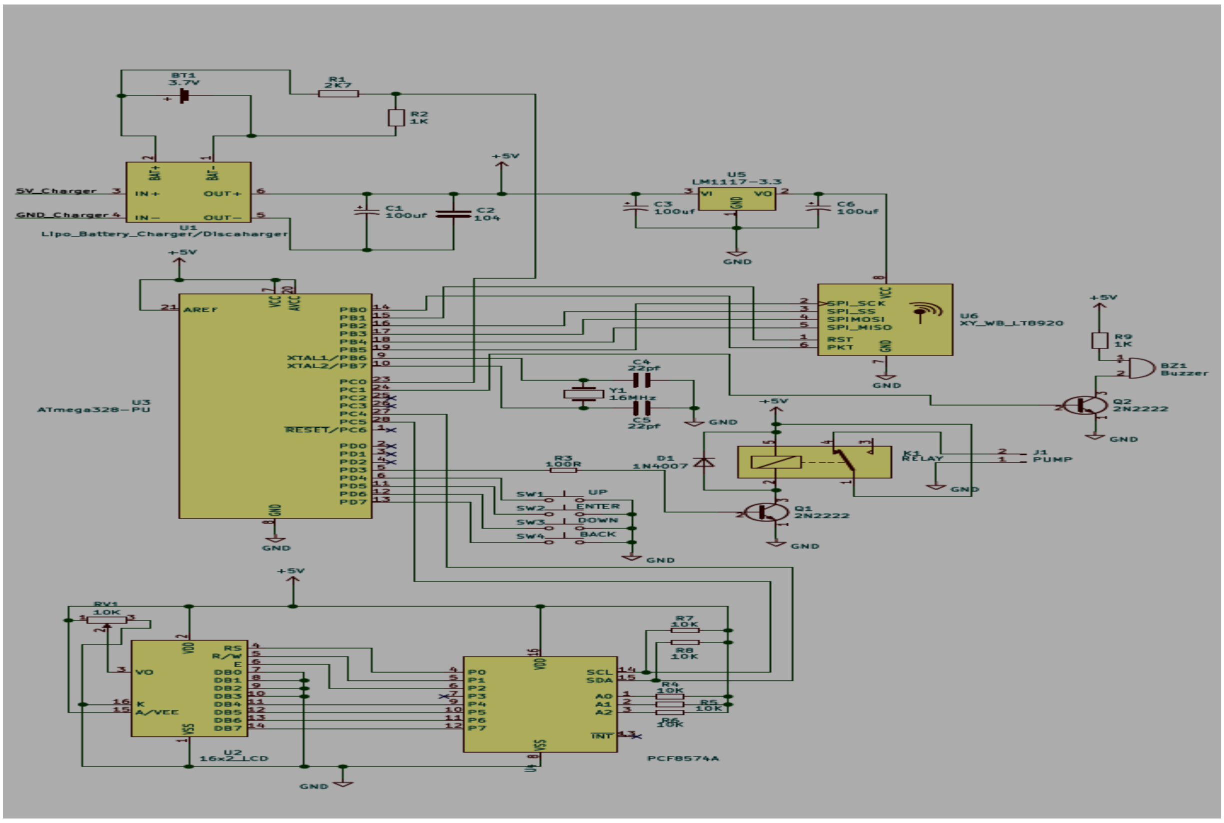

Figure 1.2 Circuit diagram for the pump control unit

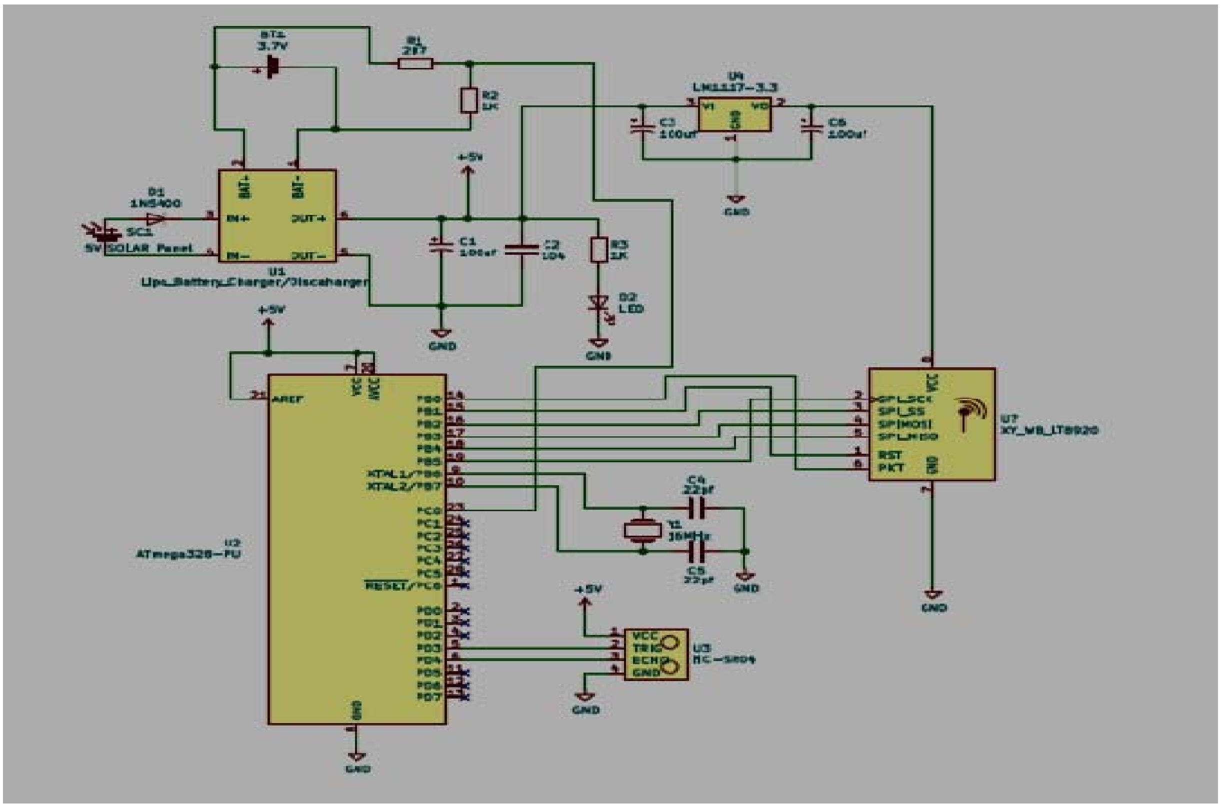

Figure 1.3 Circuit diagram for water level check

3.1 CIRCUIT ANALYSIS

Analysis was done on the passive and active components to determine their exact values. As shown below

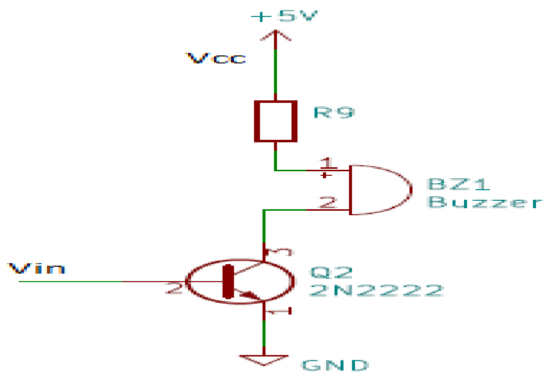

Figure 3.0 Subcircuit of current limiting unit

Figure 3.0, extracted from Figure 1.2 shows the NPN transistor with Q2 which is biased as a current limiter. From the circuit, the voltage drop across R_9 is given in equation 3.1.

$$V_{cc} = I_c R_9 \qquad (3.1)$$

Given that the base current is taken according to the transistor Q2 data book (Annymous, No date), but $V_{cc} = 5\,V$ the normal current required to trigger the buzzer from the design is given as $I_c = 5mA$ hence the load resistor value is given as:

$$R_9 = \frac{V_{cc}}{I_c}$$

$$R_9 = \frac{5}{0.005} = 1000\Omega = 1K\Omega$$

However, considering the circuit diagram of an NPN transistor shown in Figure 3.1, which is used as a switch. Transistor Q1 is biased with a base resistor of R_3 and coil resistance value of R_r. Since Q1 is used as a switch, we need to calculate the value of base resistance and the switching current which is required to switch the relay coil effectively.

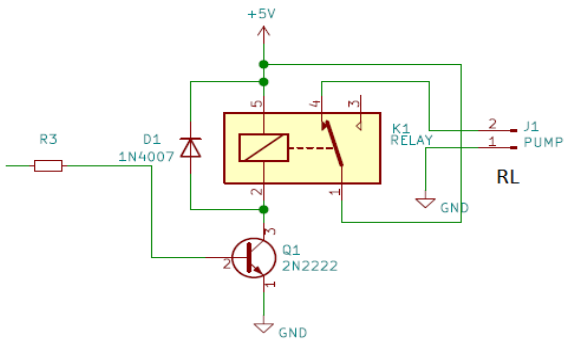

Figure 3.1 Subcircuit of the current limiting unit.

The supply voltage V_{CC} = 5.0V, transistor gain (h_{fe}) =150, input voltage (V_{in}) = 5V, relay coil resistance (R_r) = 76mΩ. The collector's current I_C is given as;

$$V_c = I_c \times R_c \qquad (3.3)$$

$$I_c = \frac{V_{CC}}{R_I} \qquad (3.4)$$

Hence, $I_c = \frac{5}{76} = 0.0657mA$

The required collector current needed to switch the relay coil effectively would be 4.2mA. using the equation below, the base current can be calculated as;

$$I_C = h_{fe} \times I_B \qquad (3.5)$$

$$I_B = \frac{I_C}{h_{fe}} \qquad (3.6)$$

$$I_B = \frac{0.0657}{150} = \quad 0.0438mA$$

The base resistance value R_3 as is given as

$$I_B R_3 = V_{CC} - V_{CE} \qquad (3.7)$$

$$R_3 = \frac{V_{CC} - V_{CE}}{I_B} \qquad (3.8)$$

But $V_{CE} = 0.7V$, hence

$$R_3 = \frac{5.0 - 0.7}{0.0430} = \frac{4.3}{0.0430} = 100\Omega$$

Hence, the base resistor required to drive the relay effectively will be 100Ω. Furthermore, the ultrasonic sensor wave emitted can be calculated as; Let **dx** and **dt** represent a certain distance from the sensor and the travel time of the incident and reflected wave respectively the total time of flight of the ultrasonic burst from the sensor to the level of the liquid and back to the receiver be given as **2dx**, therefore the speed, **V** of the wave is given in the equation below and the distance x traveled is calculated.

$$V = \frac{Vdx}{dt} \qquad (3.9)$$

$$dx = \frac{Vdt}{2}$$

$$\int dx = \int \frac{Vdt}{2}$$

$$x = \frac{vt}{2} \qquad (4.0)$$

3.2 WORKING PRINCIPLE OF THE SYSTEM AND TANK CALIBRATION

The circuit diagram in Figure 1.3 is a control circuitry that is placed on the tank. The circuit diagram comprises the ultrasonic sensor (HC-SR04), microcontroller (Atmega320), RF transceiver (XY_WB_LT8920) module, 5V solar panel, charger, and discharger module, crystal oscillator with few passive and active components. All the units work sequentially during system operation based on the designated function. The circuit monitors the water level through the ultrasonic sensor. This unit is responsible for the sensing and detection of the fluid level. To achieve this, an ultrasonic sensor (HCSR04) was used. It sends ultrasonic waves (SONAR) into the container (via TRIG pin) and then detects the reflected waves as echo (via ECHO PIN) due to the fluid surface. The distance covered by the sonar within the computed time of flight corresponds to the distance of the target. The information is sent to the microcontroller which is connected through pin **PD3** and **PD4** respectively for processing. The RF transmitter module which is an amplitude shift keying transmitter is linked up with the 32-bit microcontroller (ATMega328P). The processed data is extracted from the ATMega328P through input pin **PB0** to **PB5.** whenever the trigger pin is ON, the data is then sent out to the user end by the RF module through its antenna at a frequency of 433MHz. This required frequency is generated by a crystal oscillator connected to the microcontroller through pins **PB6** and **PB7**. Direct current is supplied to the circuitry by a 5V solar panel with a charger and discharger module which helps to charge the lithium battery incorporated in the design to ensure constant power even on cloudy days. The circuit diagram of pump control is attached to the pump as shown in Figure 1.2, the circuit diagram comprises the microcontroller (Atmega320), input buttons, liqiuid crystal displayed (LCD), RF transceiver(XY_WB_LT8920) module, PCF8574A module, crystal oscillator, NPN Transistor (2N2222), Buzzer, charger and discharger module and passive and active components. The microcontroller acts as the brain of the system which coordinates and processes all incoming and outgoing information. The transceiver has eight terminals with terminals (1, 6) connecting to the microcontroller. Terminals (7, 8) connect as ground and Vcc respectively. In the circuit diagram, the microcontroller is programmed to send a signal to the relay switch via NPN transistor Q1 to activate or deactivate the pump when the water level is below the set level or when the tank is filled to the set level. Also, the LCD has sixteen (16) terminals with terminals (4, 5, 6) connected to terminals (4, 5, 6) of the PCF8574A module and terminals (7, 8, 9, 10) connected to terminals eight (V_{SS}) which serves as a ground for PCF8574A module. Generally, the PCF8574A module provides general-purpose remote input and output expansion for most microcontroller families via the two-line bidirectional bus (a type of logic circuit whose input and output pins can be configured as input and output to receive and transmit data). The button allows users to interact with the system depending on user choice. The LCD also displays the information obtained from the tank circuit through the microcontroller. Terminal nine (9) of the microcontroller connects NPN transistor Q2 which controls the buzzer and helps to notify the user when there is no power source to pump water if the water level drops below the precise level. Generally, the exchange of data between the two systems is done wirelessly. In the tank circuit, the pump circuit receives the AC supply and converts it to DC through the charge and discharge model (UI). Voltage regulator (U4) helps to regulate and maintain a steady voltage that will power the microcontroller, LCD, and RF receiver and charge the **3.7V** battery to maintain a constant water level display and end-user interface. To determine the level of water in the tank, we must know the corresponding height of the tank and diameter as this value will enable us to calibrate the tank and calculate its volume to know the number of litters it can contain. The total height of the tank to be used is 35cm. 5cm (14.29% of the tank's height) is removed as offset which is the distance of the ultrasonic sensor to the maximum water level.). Our minimum level will be 10.5cm (3 Liters of water), about 35% of the tank's height. By making our minimum level 10.5cm, the user should not be stranded or lack water. This level can be adjusted depending on the user's choice because the system is dynamic. The ultrasonic sensor module is placed at the top of the bucket (water tank). This sensor module will read the distance between itself, and the water surface, and it will show the level of water and if the distance is less or equal to the minimum (pumping volume) the pump is activated as it begins to pump. When the distance reaches a maximum level (cutoff voltage, it turns off the pump. The volume and capacity of the tank is calculated as:

$$V = \pi\left(\frac{d}{2}\right)^2 h \quad (4.1)$$

Capacity $\frac{V}{1000}$ in litters

4.0 RESULT

Figures 4.1 and 4.2 show the construction interconnection of various units while Figure 4.3 shows the pictorial diagram of the entire setup.

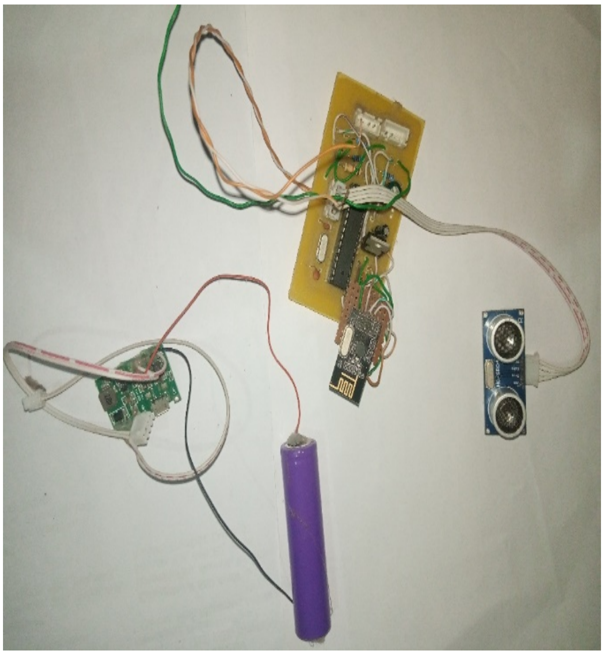

Figure 4.1: Microcontroller, ultrasonic sensor, transceiver, lithium battery, charger, and discharger unit.

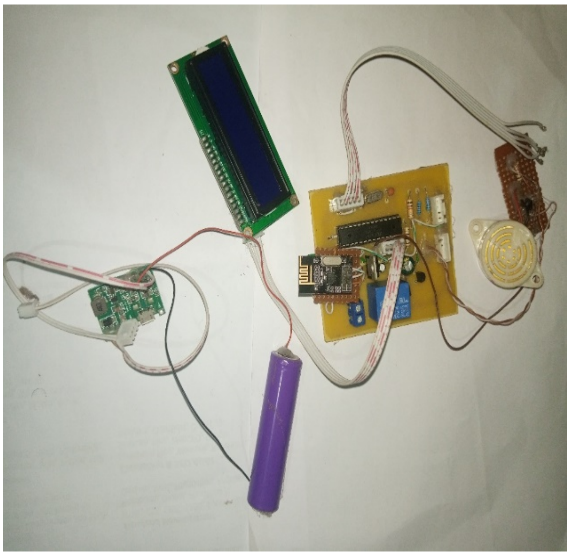

Figure 4.2: Microcontroller, Relay, LCD, transceiver, buzzer, lithium battery, charger, and discharger unit.

Figure 4.3 Pictorial view of system setup.

5.0 CONCLUSION

This work presents the design and implementation of automatic noncontact water level monitoring with an automatic pump control system. The microcontroller is the brain of this design which gives a digital input that displays the level of water in litters and turns ON the water pump when the water in the tank is less or equal to the pre-set minimum level and turns OFF the pumping machine when the water was at the pre-set maximum level. After the complete design of the system, performance evaluation of work from test results shows that the system was highly efficient since it eliminates human responsibility and improves the workable lifespan of the water pump by controlling it when to switch ON and Switch OFF the pump.

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