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# Design and Implementation of an Automatic Audible Water Level Controller Incorporating a Digital Display

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**Abstract:** *In order to reduce waste of water as well as elimination of human intervention during pumping of water into water tanks, it is of high importance to design a closed-loop control system which monitors the procedures involved in the water pumping processes. This paper, therefore, presents the design and implementation of an automatic audible water level controller with a digital display. This paper is designed to monitor three different water levels which have been named "low, medium and high". The design is such that the low and medium levels are fitted with Light Emitting Diodes (LEDs) for indication of the present level of water while the high is fitted with a buzzer that annunciates when water is full in the overhead tank. These indications are achieved by the switching application of NPN transistors. In order to achieve this, relevant literature studies in existence are holistically reviewed. The mathematical formulations for the design are presented. The designed low-cost circuitry is easy to maintain and powered by an independent 9V battery that is replaceable when low. It is packaged in steel casing that could be mounted at a point where visibility will be easy and alarm could be promptly heard.*

**Keywords:** *Water pumping, Water level controller, Closed-loop control, Digital display, LEDs.*

## 1. INTRODUCTION

It is a common practice in Nigeria and neighbouring countries for householders to store water in overhead tanks in buildings prior to usage. The water is channelled 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 thus leading to wastage of energy and water. To resolve this problem, a level alarm is used to indicate the level of water in the overhead tanks as well as give alarm for full level or pre-set level when filling. The cost of this water level alarm circuit is low and aside from usage in overhead tanks in building, it finds applications in swimming pools, boilers etc. The water level alarm systems are also used in factories, chemical plants, electrical substations etc [1].

Our society is faced with the challenge of wastage of water. Water being a natural resource to man is known to sustain life and also as an energy source. A continuous wastage and mismanagement of water resources by domestic and industrial consumers negate the conservation of energy in the society at large [2]. The wasteful energy driving the overflowing water to overhead tanks generates excessive costs that amount to waste. Over time, the manual labour and human input to monitor and control water indicates serious inadequacy due to forgetfulness, distraction and human error that wasted a lot of usable water yesteryears. Hence the need for an automated water level controller replacing the 'unreliable' manual monitoring and preventing energy wastage.

This paper attempts to build an electronic audible water level controller with three-level indications (low, medium and high) powered by an independent 9V DC power supply. Section 2 presents a comprehensive review of relevant literature on various techniques for designing and implementing water level controllers. Section presents the theoretical background as well as the mathematical formulations involved in the analysis. Section 4 presents the main implementation of the work. Section 5 concludes the paper.

## 2. LITERATURE REVIEW OF THE EXISTING STUDIES ON WATER LEVER CONTROLLERS

Many approaches from various authors have been developed to provide an alternative solution method to control the wastage of water by designing an automatic water level controller in the literature. The operation of this system generally works based on the principle that water conducts electricity [3]–[9]. Many authors used various numbers of water sensors or probes to implement their design, as water level rises and falls in the selected tank, sensing probes [10] and controller circuits detect the various water levels, the length of the sensor/probes are varied to indicate different water levels in the tank at any particular time instance. At least two sensors are required to indicate the two most important conditions being; when the tank is full and when the tank is empty [6].

The methods used by many authors to process the sensor input(s) were either flip-flop, transistor, integrated circuits or microcontrollers. The authors in [3] made use of four sensing probes to measure up to four water level and only transistors, to automate the process using a buzzer as an indicator. Also, the authors in [4] use 9 sensing probes, [8] this method employs a metal sensor which has two levels; low and high-level sensor [15], placed in a plastic tank and an IC to process the input signals from the sensor. The authors in [16] as takes advantage of the electrical conductivity property of water by using copper conductors as sensory elements and a comparator, that sends signals to an Atmel 89C52 microcontroller programmed in assembly language, which turns the pump ON/OFF based on the given signal from the comparator. This method claims to improve the automatic control system by eliminating the risk of electrocution by converting AC power to DC and using a calibrated circuit to indicate the water level.

Similarly, authors in [17] like [16] used six (6) metallic sensor and a PIC16F84A microcontroller embedded in C language to automate the process, while the water level status is shown on a 7-segment display in percentages, as it requires more of these displays to show more characters and by doing so consumes a lot of space, thus, a limitation. This process also considers the underground water level to protect the pump itself from damage, when the water level falls below the suction pumps. The authors of reference [5] [18] implements the automatic water level controller for two water tanks (ground tank and an overhead tank) with transistors and an NC 555 timer IC, the transistor is biased to operate as a switch and turns on the LED to indicate the level of water in the tank and can be improved by replacing the LEDs with a digital display. Research carried out in [3] made use of only transistors, transistors in that circuit acted as a switch using water to complete the conducting path, however, using transistor alone as a switch can be unstable, as the transistor is affected by the temperature of the real environment. References [9], [20], [21] use one of its sensors as a reference point, the reference sensor usually touches the base of the tank, thus, allows more precision in pumping water into the tank, unlike filling the tank with water immediately the water level falls below half. However, this method ensures the tank gets filled half-way through, which is not wholly efficient as the pump does more work more frequently. The authors in [22] tackle the water wastage problem using an ultrasound sensor which a PID and fuzzy controller designed using MATLAB/Simulink, and functions that represented the controllers were written in C programming language. The method is rather too complex due to the implementation of multiple programming languages and some complex bits of mathematics for mathematical modelling. References [23] employed the use of an Arduino as the microcontroller to automate the control process, however, authors in [23] used four sensors (aluminium wires) placed at ¼,1/2, ¾ and full levels, with a 16x2 LCD displaying important information. In [25], the authors considered the properties of the tank as non-linear and fixed, thus, utilises fuzzy controller implemented using the mathematical model of the tank in MATLAB and an ARM embedded computer using an Arduino. This approach is compared with the proportional Integral derivative (PID) control with is the traditional method used in process industry to control water level on a laboratory tank model. The authors concluded from the results obtained that the fuzzy control system has better adaptability and more satisfying results compared to the PID control. However, this work is tailored to a specific size of tank, this method is thus not versatile as it cannot be deployed in different instances/applications. Authors in [25] approaches this problem by using an ultrasonic sonar sensor, and a specified height of the tank to detect the current level of water and the signals are passed to the ATMEGA 8 microcontroller, which controls the operation of the pump via a relay and displays the current water status on a 16x2 LCD display. This method takes on quite a complex approach, as it stores the current state of the velocity of water and the total time the pump is kept running. In [26], the system consists of water level detector circuitry made of three probes or conductors which detects three levels on water in the tank, low level, very low level and critically low level. This signal is sent to a PIC16F877A microcontroller, its circuitry is integrated with GSM module, that sends a Short Message Service (SMS) on the current level of water in the tank at that time instant, to a specified technician in charge of the system for further action. The system is generally designed to monitor the critical or low water level in the tank, it does not consider when the tank is full. However, this work is susceptible to flaws, such as a case of network failure, when the SMS is sent to the operator or the technician, but it is not received by the technician due to this network failure, thus, there would be no other medium of communication thereby stopping the process of the entire system. Authors in [27] elucidates the implementation of a remote automatic water level control with radio frequency (RF) transmission and reception system which is similar to the works of [28] who proposes the signal would be sent over the internet to be received by any low costing device that can be used to control the water level. Reference [27] utilizes stainless steel as sensor probes to significantly eliminate the possibility of corrosion compared to the use of copper wire for water detection [16], this serves as the input signal which is encoded for the transmitter module and the receiver module which decodes the signal used by the PIC164877A microcontroller to control the pump. However, both methods require the replacement of the battery powering the decoder and receiver modules, as constant usage of these components would wear the battery out, also [27] makes use of an a.c. water pump which exposes individuals to the risk of electrocution since these devices would be used in homes.

## 3. THEORETICAL FRAMEWORK AND MATHEMATICAL FORMULATIONS

The principle of operation of water level controllers is based on NPN transistors operation. The positive end of the battery is channelled into the deepest point of where water could be in the container for monitoring. Then the base of a transistor is channelled into the container up to the level for which indication or alarm is desired. Upon filling water into the container, when the water level gets to the point where the base of the transistor is, it connects the positive terminal of the battery to the base of the NPN transistor thereby biasing the transistor. This makes collector current to flow in the transistor. A Light Emitting Diode which has been connected in series to a resistor that limits the collector current is lit by the collector current. This gives indication that water has gotten to the level of interest. In the same manner, a buzzer which is connected to the collector of a transistor annunciates when water gets the desired level for alarm which is the full level of the container. This full level as explained earlier would have been chosen and the base of the transistor to switch the buzzer ON would been channelled to the point. It is worthy of note that several levels of indications or alarms can be designed by simply replicating the switching circuits. Therefore, the number of levels chosen for indication and alarm will equal the number of switching circuits required. the main components required include three bc547 transistors, three resistors of 220Ω, two coloured LEDs and 9V battery and battery chip.

Using a BC547 transistor as a switch is illustrated in Figure 1.

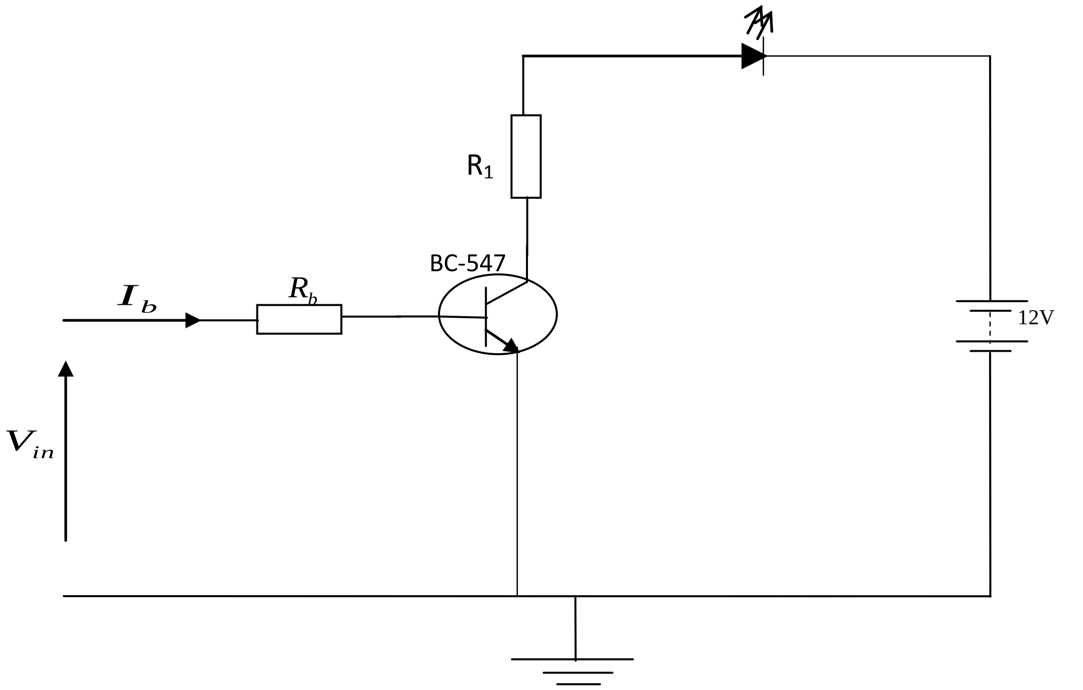


**Figure 1:** *The biasing circuit for the transistors in the Driver*

The maximum collector current of the transistor BC-547 is $I_{cm} = 100mA$ and its gain, hfe ranges from 110 to 800 as stated in [39]. We can therefore calculate the value of the base current of the transistor using the relation below:

$$hfe = \frac{I_c}{I_b} \quad (1)$$

where hfe = Gain of the transistor.

$I_C$ = Collector Current of the transistor in Amperes.

$I_b$ = Base Current of the transistor in Amperes.

Therefore the base current can be gotten as follows:

$$I_b = \frac{I_c}{hfe} \quad (2)$$

Upon substitution of the maximum value of collector current and the least gain the transistor can experience, the base current would be:

$$I_b = \frac{100mA}{200}$$

$$= 0.5mA$$

Applying KVL to the base circuit of the NPN transistor,

$$V_{in} = I_b R_b + V_{be} \quad (3)$$

where

$V_{in}$ = Input Voltage in Volts.

$R_b$ = Base Resistance in Ω.

$V_{be}$ = Base – Emmiter Voltage in Volts.

Therefore,

$$R_b = \frac{V_{in} - V_{be}}{I_b}. \qquad (4)$$

From [36], we can easily write $V_{cc} = V_{in} = 6V$

$$V_{be} = 5V$$

$$R_b = \frac{6-5}{0.5mA}$$

$$= 2000\Omega$$

$$= 2K\Omega$$

Preferred value for the resistor $R_b$ is 2.2KΩ with tolerance of $\pm 20\%$.

Similarly, applying KVL in the Collector-Emitter

$$V_s = I_c R_1 + V_{LED} + V_{ce} \qquad (5)$$

where $V_s =$ Source Voltage in Volts.

$R_1 =$ Resistance provided to Collector Current in Ω.

$V_{LED} =$ Volatage across the LED in Volts.

$V_{ce} =$ *Collector − Emmiter Voltage in Volts*.

However, $V_{ce}$ = 600mV [29] and voltage that develops across the LED is 3.3V [37] [38] when activated. Source voltage is 9V and recall maximum Collector Current to be 100mA.

Therefore, from equation 3.5

$$R_1 = \frac{V_s - V_{LED} - V_{ce}}{I_c} \qquad (6)$$

$$R_1 = \frac{12 - 3.3 - 0.6}{0.1}$$

$$= 81\Omega$$

Preferred value for the resistor $R_1$ is **100Ω** with tolerance of $\pm 20\%$.

The comprehensive circuit diagram of the Audible Water Level Controller with display can be seen in Appendix 1 of this project write-up.

## 4. EXPERIMENTAL RESULTS AND DISCUSSIONS

All individual units of the system were simulated and interconnected using Proteus 8.6 prior to the realization of the physical construction. Simulation was performed based on the three operating conditions required for the audible water level controller. This is explained as follows:

### 4.1 Low Water Level

When water is at the low level in the overhead tank, it connects the positive end of the battery to the base of the BC547 transistor, thus biasing it. The transistor switches ON making the LED on its collector to be lit. This is the indication for the low level in the tank. The simulation result for this is as shown in Figure 2 and the electrical readings powering the LED is displayed in Figure 3.

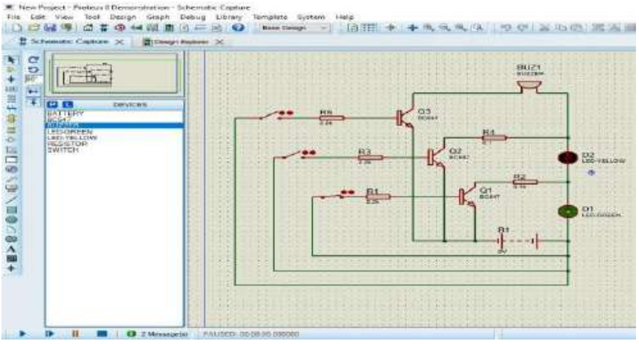

**Figure 2:** Result for Low Water Level Simulation

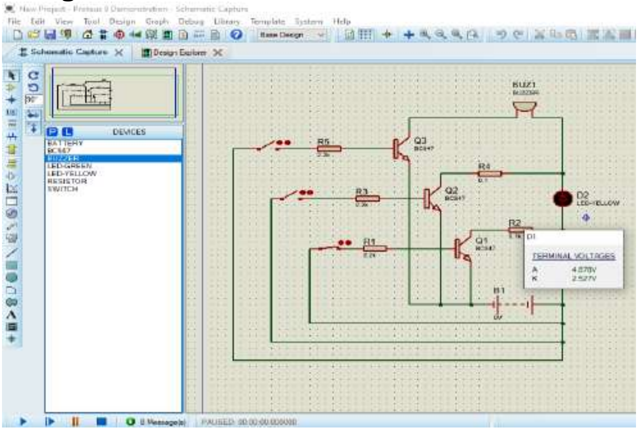

**Figure 3:** Readings of the Energized LED for Low Water Level Simulation

### 4.2 Medium Water Level

The medium water level in the tank was simulated in addition to the simulation of the low water level as earlier explained. When water is at the medium level in the overhead tank, it connects the positive end of the battery to the base of the BC547 transistor, thus biasing it. The transistor Q2 as shown in Figure 4 switches ON making the second LED, D2 to be lit alongside D1. This is the indication for the medium level in the tank. The electrical readings powering the LED is displayed in Figure 5.

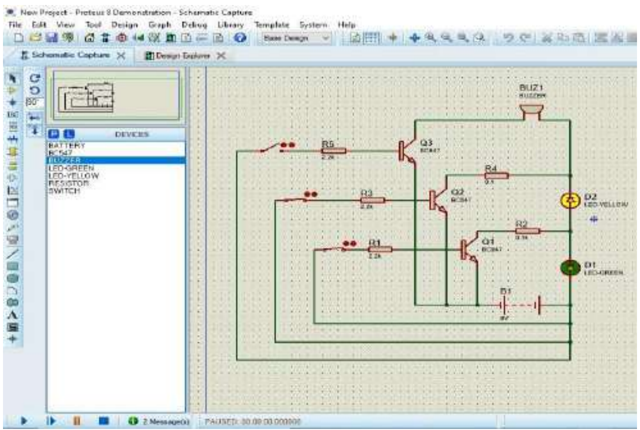

**Figure 4:** Result for Medium Water Level Simulation

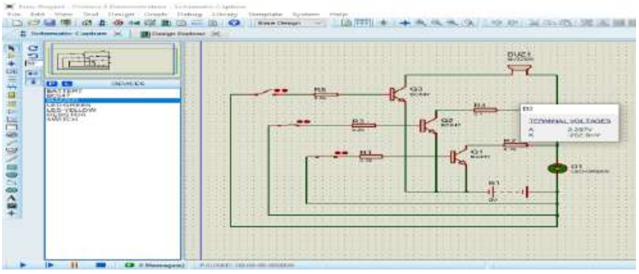

**Figure 5:** Readings of the Energized LED for Medium Water Level Simulation

4.3 High Water Level

The full water level of the tank comprises of the initial two transistors Q1 and Q2 from previous simulation result still in their ON State and transistor Q3 energizing a buzzer which gives alarm for the full water level in the tank. The simulation results and readings are as shown in Figure 6 and Figure 7 respectively.

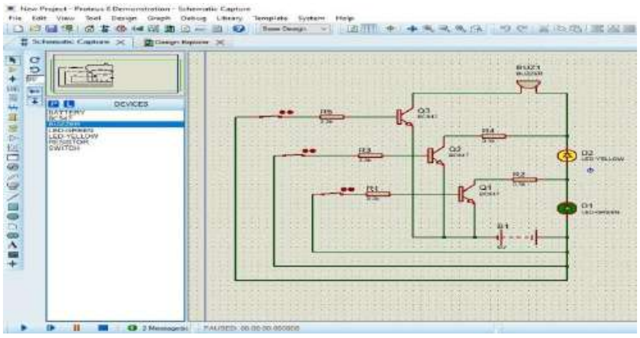

**Figure 6:** Result for High Water Level Simulation

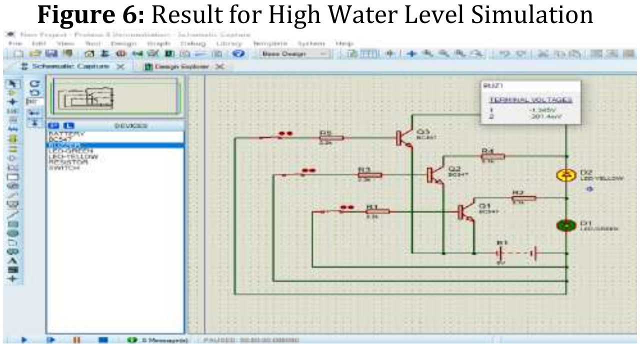

**Figure 7:** Readings of the Energized LED for High Water Level Simulation

4.3 Laying And Soldering Of Components

The components that make up the various sections of the level controller were first laid on bread broad and further testing carried out using 9V battery and multi-meter. Upon ensuring good performance of these sections and conformance with specifications, the components were therefore soldered on a vero board. Further testing was carried out after the soldering to ensure the necessary continuity in the circuits.

4.4 Coupling and Casing of the Construction

The soldered work was coupled together and put inside a casing for compactness and protection purposes.

4.5 Final Testing

As explained in the preceding sections, testing kept occurring as the construction was in progress. However, after the coupling and casing of the construction, the device was tested by inserting the lead sensors into water one after the other according to their lengths and functionalities.

## 5. CONCLUSION

Achieving this project is seen to be of low cost serving a great benefit of preventing spillage, conserving energy and preserving the environment. The project finds application in several places and so many scenarios which include water level control at home apartments, hotels, commercial complex, factories etc, monitor fuel level for engines, motor vehicles etc, liquid level in industries etc

## Recommendation

The project did not capture easy identification of faulty components in the indication/output section of the equipment. A fault in the section will lead to false judgment of the situation of things. An example is when the LED or the buzzer is bad, an operator will not know the true level of water. Therefore, it is recommended that a switch to do test the LEDs is provided as well as a means of knowing when the battery is low and due for replacement.

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