DESIGN AND CONSTRUCTION OF A WATER PUMP CONTROLLER

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2000/9778EE

A Thesis submitted to the Department of Electrical and Computer Engineering, Federal University of Technology Minna.

OCTOBER 2006

DEDICATION

This project is dedicated to Almighty God, the everlasting source and giver of Wisdom, Strength and Purpose.

DECLARATION

I, ADEJO ACHONU, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology Minna.

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ACKNOWLEDGEMENT

My gratitude goes to Almighty God for giving me the strength and grace to carry out this project.

Special thanks goes to my supervisor (& HOD) Engr. M.D. Abdullahi for his immense technical assistance, concern and understanding. I also appreciate all the lecturers in the department of Electrical and Computer Engineering for their invaluable contributions to my educational pursuit.

I wish to acknowledge the efforts of my parents, Arc. & Mrs. E.A. Adejo for their love and support all through; Thanks for always being there. God Bless you. I am also very grateful to Ufedo, Chide & Attah, my brother and sisters, who are wonderful and special to me. I would specially like to thank my friends, Augustine, Tosin, Kenny, Shittu, Iliyasu, Carlos, Nike, Doyin and Amaechi who contributed in many ways to the success of the project. God Bless you all!

ABSTRACT

The project involves the design of a water pump controller which is an electronic device that monitors the inflow of water into a reservoir (e.g. a tank). It electronically turns off a pump when the water has risen to a particular level determined by water probes. The aim is to conserve water by monitoring the water level in the tank and preventing water wastage which would occur if there was no means of controlling the pump. It is intended for use in homes, schools, hospitals, offices and industries where limitation of water supply necessitates the need for storage in tanks. The design is cost effective and involved the use of integrated circuits and discrete electronic components to obtain a control circuit that provided a means of turning off the pump whilst giving an alarm and light indication.

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CHAPTER ONE

Introduction

1.1 Concept and Aim of Project

Water, the common name applied to the liquid state of the hydrogen – oxygen compound H_20, is very essential for the sustenance of human life and existence. It is one of the most commonly used substances extensively employed in many domestic, agricultural, and industrial activities.

The need for water storage is due to the fact that water has to be treated and transported from its natural sources like rivers, lakes, and underground sources, to the locations where it is to be utilized. Since it is not possible to obtain water in the required form and composition everywhere it is needed, it is essential that water should be stored after transportation so that it can be available for future use over long periods of time.

Water storage takes various forms depending on the application and includes local containers, tanks, reservoirs etc. One problem associated with water storage, for e.g. in tanks, is that if the water level in the tank is not properly monitored and the water inlet to the tank constantly increases the water level, the tank eventually gets completely filled and water begins to pour from outlets at the top. This results in wastage of water.

Water wastage eventually results in huge financial losses to government, individuals and companies due to the huge cost involved in obtaining portable water and transporting it to the required destinations. The effect of water wastage is felt more in the tropical areas where water scarcity prevails due to shortage of rainfall and other sources of water.

This project aims at solving the problem of water wastage, especially in tanks used in homes, schools, hospitals, offices and industries where there is need to store water. The inlet to the tank is assumed to be an electric water pump. The water pump generates the required pressure to pump up the water, which is usually supplied on or below the ground level either from water pipes in water supply systems or from boreholes, or even from streams, rivers, and lakes. The tanks are usually on elevated platforms.

1.2 Methodology

The circuit incorporates an electronic means of detecting water presence at a particular level in the tank above which would result in water wastage. This detection in turn triggers a control system that switches off the operation of the pump. The circuit also has an alarm output and a light indicator to notify when water has reached that maximum level.

The main concept of this design relies on the electrical conductivity of water that is achieved through ionic means. Pure or distilled water is a good insulator but water always exists in impure form because many substances easily dissolve in it. [7, 10] Water conducts through the movement of ions and not electrons like in metallic materials. The conduction is poorer in contrast to metallic nature.

The device comprises of four main modules. The heart is a small platform holding two close metallic rods (conductors) which are exposed to the water contact and are bridged by traces of water which cause current flow through the circuit like if a switch turned it on. These metal rods constitute the sensor. One of the conductors is connected positive and the other is connected to the input of an amplifier which amplifies the input signal coming from these probes.

The other parts are the detection, control and the alarm units. The detection and control unit receives the resulting signal from the water sensing part after it has been amplified and then it triggers on an alarm via a speaker sound. It also digitally stores the information of the detection. A light emitting diode also blinks to give visual indication. The block diagram of the circuit is shown below:

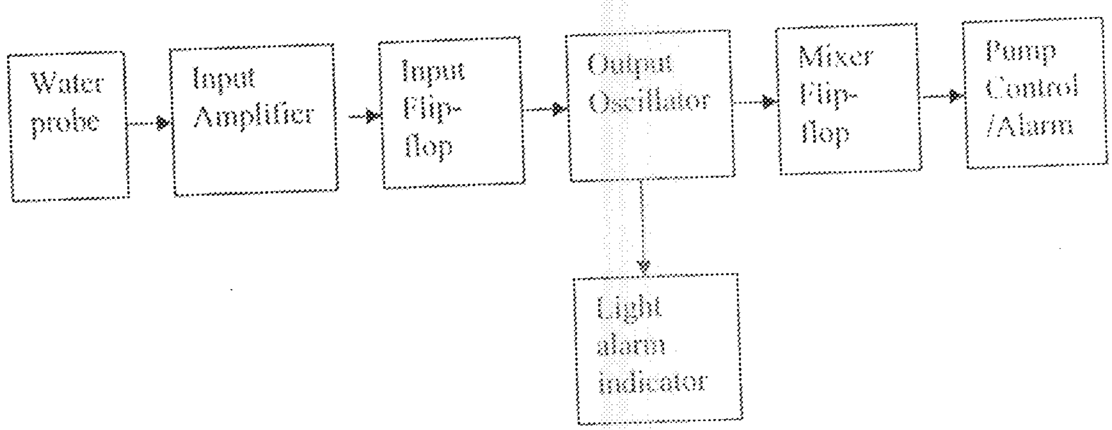


Fig. 1.1 Circuit block diagram

The design is basically simple. There is use of limited number of components for economy. Also, the design is made of low power consumption parts such as CMOS logic integrated circuits so it could be battery powered for specific operations.

The physical construction of the project involved setting the components on a Vero board according to the circuit diagram. Their pins were fixed in the right positions on the board and were soldered to the board. Connecting wires were used to connect other parts of the circuit. The finished circuit was tested and the casing was fixed.

The project design and implementation involved sourcing of relevant information on the components used and their functions, from textbooks, encyclopedias, journals, the internet, etc. It is a cost effective design because the materials used for the construction are easily accessible and relatively inexpensive integrated circuits and electronic components.

This device is therefore very useful in homes, schools, hospitals, agricultural stores, industries, offices, etc wherever there is need to control water entry into a tank. It could also be modified to suit a particular application if necessary.

CHAPTER TWO

Literature Review

2.1 Historical Background:

The need for monitoring and detecting water presence and water levels has always been in existence. The earliest methods involved manual inspection of containers that stored water, wells and tanks, etc. Equipments that required no water contact as well as those that could leak water through their outlets were also carefully monitored. These methods are still being employed today but science and technology has always provided systematic and logical alternatives that give more accuracy and efficiency over traditional manual techniques. Developments in analogue and digital electronics have resulted in the design of a number of devices, the water pump controller inclusive.

Many devices that monitor certain properties of water have been invented over time. These include the water meter, water – level gauge, rain gauge, hygrometer, and the water level detector. A few of these devices are briefly discussed below:

* A rain gauge is a metal instrument used to measure rainfall and other forms of precipitation like snow and hail. It consists of a copper cylinder with a metal funnel which leads into a smaller copper container or a glass bottle. Measurement of rainfall is done using a graduated cylinder after the contents of the container are emptied into it.

- A water meter is a device used for measuring the amount of water that flows through a pipe. They can be used to register the quantities of water received and discharged by water works, and the amounts of water delivered to customers. Types of water meters include the disk (displacement) meter, velocity meter, compound meter, orifice meter, venturi meter. [6]
- A gauge is an instrument used for measuring and indicating a quantity. A water level gauge is used on equipments as boilers. The gauge is a vertical glass tube whose upper end is connected by tubing to the steam compartment above water level, the lower end to the bottom of the boiler and the height of water in gauge always equals that of the water in the boiler. [7]

2.2 Theoretical Background

The water pump controller relies on the electrical conductivity of water to bridge the input contacts. This is the same principle of operation as the water level detector.

The water level detector evolved over the years from the use of float regulator mechanism to measure and monitor water levels in containers, to the use of dipsticks, which consisted of a metal bar with a scale etched on it and fixed at a known position in the liquid containing vessel so that when removed from the vessel, the level of water can be measured by reading how far up the scale, the liquid was wetted. [12]

Transducers have also been used to measure the level of float on surfaces of liquids e.g.

- Potentiometers are used to monitor the level of oil in motor vehicle fuel tanks.

- Pressure measuring devices were used for water level measurement based on the principle that the hydrostatic pressure due to a liquid is directly proportional to its depth and hence the level of its surface i.e. $h = P / \rho g$. These devices utilized appropriate pressure transducers inserted at the bottom of the vessels to measure water levels. [12]
- Capacitive devices were also used, where two base metal capacitor plates in form of concentric cylinders are immersed in a liquid, and the liquid behaves as a dielectric between the plates according to the depth of the liquid. Conducting liquids required that an insulator be used to encapsulate the capacitor plates.
- Radiation methods utilized radiations sources and systems located in a liquid filled tank. The absorption of both beta and gamma rays varies with the amount of liquid level. Cesium – 137 is an example of a gamma ray source that is commonly used for this purpose. [12]
- Vibrating level sensors, consisting of two piezoelectric oscillators fixed to the inside of a hollow tube, which generates flexural vibrations in the tube at its resonant frequency. This resonant frequency of the tube varies according to the depth of its immersion in the liquid and a phase locked loop (PLL) circuit is used to track the changes in resonant frequency and adjust the excitation frequency applied to the tube by the piezoelectric oscillator. Liquid level measurement is therefore obtained in terms of output frequency of the oscillator when the tube is resonating. [11]
- Ultrasonic level gauge principle uses energy from an ultrasonic source above the liquid reflected back from the liquid surface into an ultrasonic energy detector, measurement of the time of flight allows the liquid level to be inferred. This can be

employed in sensing water level in channels, lakes or streams for input to a data logger or other monitoring unit.

- The Stevens submersible depth transmitter is a sensing device designed for water level measurement applications. Low range units are ideal for open channel flow applications; a stainless steel pressure transducer is used as the primary sensing element, and it measures the water depth by pressure above the unit. [11]

The water pump controller applies the principle of water detection monitors water presence at a particular level in a tank and control the pump at its inlet

This project involves the use of discrete electronic components as well as digital IC circuits which have evolved as a result of advances in electronics which will be explained briefly below:

The 19th century physicists proved that electric current consisted of the flow of particles of charge but the nature of these charges was not understood. Questions about their polarity and even on the basic structure of matter were resolved by experiments that began with the study of electric discharges in evacuated tubes.

William Crookes (1832 – 1919) studied electrical discharges in gases, and this led to the development of the cathode ray tube by Pluecker and Hittorf whose observations of cathode rays and the dark space at the cathode led to the discovery of x-rays and the electron by Joseph John Thompson (1856-1940). [8]

This signaled the beginning of the technological revolution of the 20^{th} century in the world of electronics. Notable inventions that followed include wireless telegraphy, vacuum tubes, radio, television, radar, electrons and waves, and then transistors.

Transistors are 3 terminal solid state electronic devices that could amplify electrical signals and also be used to make electric switches. Transistors were smaller than vacuum tubes, were faster, and consumed less power. However, circuits based just on individual transistors become too large and difficult to assemble because there were many components to deal with.

Transistors were later cascaded to build up very complicated logic circuits called Integrated circuits (ICs) which are much faster than individual transistors and which consist of several transistors and electric components made at the same time and on the same piece of semiconductor. All components and the chip are made out of the same block (monolith) of semiconductor material. [8]

ICs are found in microprocessors for computers, and in almost every modern electrical device, just like the water pump controller.

CHAPTER THREE

Design and Implementation

3.1 Circuit Design

The circuit design of the water pump controller was analyzed under different modules. The overall circuit was broken down into these units:

- Power supply unit.
- Detection unit.
- Control unit.
- Output unit.

When the device is switched on, the power supply unit delivers the required dc voltages (12V and 5V) needed for the circuit. This is achieved via stepping down the 240V voltage, rectification of the 12V output, filtering off ripples and regulating the voltage to a constant 5V level. The mode of operation of the device would then depend on two conditions:

1. If the initial water level in the tank is high enough to reach the water sensor, the exposed wires of the sensor would be bridged. As they conduct, they alarm will be triggered, the LED will come on and off repeatedly and the pump will be turned off. The circuit remains in this state till the reset switch is pressed.
2. On the other hand, if the water level isn't high enough to bridge the sensor, the water pump will be switched on and will begin pumping water into the tank until the water level reaches the sensor's position. At that point, the pump will be automatically

switched off, the alarm will be turned on and the LED will begin blinking. This state is maintained till the reset switch is pressed.

The circuit operation is achieved via an input amplifier which amplifies the signal from the probes, an input flip-flop which holds the information, controls the switching of the pump and also triggers an oscillator to generate the signal frequencies which cause the speaker to come on and the LED to blink. Switching is aided by MOSFETs.

3.2 Power Supply Unit

Most electronic circuits require dc (direct current) source for their operation. Dry cells and batteries are one form of dc source that are portable and ripple free but their voltages are low, they need frequent replacement and are expensive. [3]

The most convenient and economical source of power is the domestic ac (alternating current) supply at a voltage of 240V at 50Hz. This ac voltage has to be converted to dc voltage of a smaller value through a process called rectification. [3]

The power supply unit consists of the ac mains, a 240V / 12V step down transformer, a full wave bridge rectifier, a filter (capacitor) and a voltage regulator, as well as the power switch, LED (Light emitting diode), and resistors.

The block diagram is shown below:

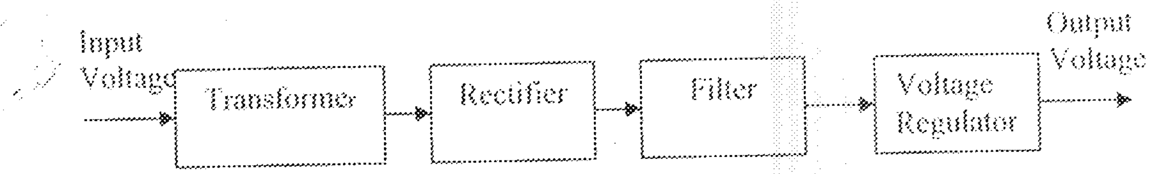


Fig 3.1 Block diagram of Power supply unit.

3.2.1 Transformer Specifications.

The ac supply available is 240V which must first be stepped down in the circuit since the components require lower voltages of 12 and 5V.

A transformer is a device by means of which electric power in one circuit is transferred into electric power of same frequency in another circuit. It can raise or lower the voltage in a circuit with a corresponding decrease or increase in current. The physical basis of a transformer is mutual induction between two circuits linked by a common magnetic flux.

Two inductive coils are electrically separated but magnetically linked through a path of low resistance. The first coil, in which electric energy is fed from the ac supply mains, is called the primary winding and the other from which energy is drawn out is called the secondary winding. [3]

The two types of transformers are; the step-up and step-down transformers. The circuit symbol and the waveforms associated with the input and output of the step-down transformer is shown below:

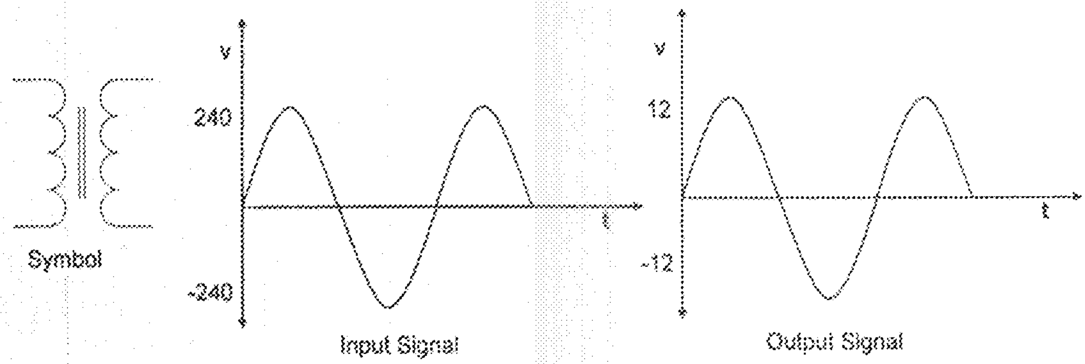


Fig 3.2 Symbol and waveforms of a step-down transformer

From the E.M.F. equation of a transformer, the rms values of induced E.M.F. in primary and secondary windings, E_1 and E_2 respectively are;

$E_1 = 4.44fN_1\Phi_m = 4.44fN_1B_mA$ ---------------------- (1)

$E_2 = 4.44fN_2\Phi_m = 4.44fN_2B_mA$ ---------------------- (2)

Where N_1 = Number of turns in primary.

N_2 = Number of turns in secondary.

Φ_m = Maximum flux in core in webers.

$= B_m \times A$

B_m = Flux density.

A = Area.

f = Frequency of ac input in Hz

= 50Hz.

From equations 1 and 2;

$E_1/N_1 = E_2/N_2 = 4.44f\Phi_m$

Therefore;

$E_2/E_1 = N_2/N_1 = K$ ---------------------- (3)

Where K = voltage transformation ratio. For the step down transformer used,

$N_2 < N_1$, so $K < 1$.

Also, for an ideal transformer, $E_1 = V_1$ and $E_2 = V_2$, therefore

$V_2/V_1 = N_2/N_1$ ---------------------- (4)

Where V_1 = Primary voltage and

V_2 = Secondary voltage.

Also, input VA = output VA

$V_1 I_1 = V_2 I_2$ ---------------------- (5)

And from equations 4 and 5;

$I_2/I_1 = V_1/V_2 = 1/K = N_1/N_2$ ---------------------- (6)

Let $V_1 = 240V$ and $V_2 = 12V$, therefore the turns ratio would be obtained thus;

240V/12V = 20.

$N_1: N_2 = 20: 1$, from equation 6

$N_1 I_1 = N_2 I_2$

$N_1/N_2 = I_2/I_1 = 20$

For $I_2 = 500mA$

$I_1 = I_2/20 = 0.5/20 = 25mA$, and from equation 5,

VA = 500mA x 12 = 6W

The transformer also provides isolation from the supply line for safety considerations. [3]

3.2.2 Rectifier Specifications.

Alternating current flows in both directions, while direct current flows in only one direction. The voltage output from the transformer is still a 12V ac supply which must be converted by rectification to dc (as required by the circuit). Diodes are used for this purpose.

To forward bias a diode, the anode must be made positive with respect to the cathode, while the reverse is the case if the diode is reverse biased. A single diode gives a half wave rectified output since the negative half cycle is suppressed when the diode is reverse biased during the negative input half cycle. [2]

A full wave bridge rectifier circuit is used instead to give a full wave output. The circuit is shown below:

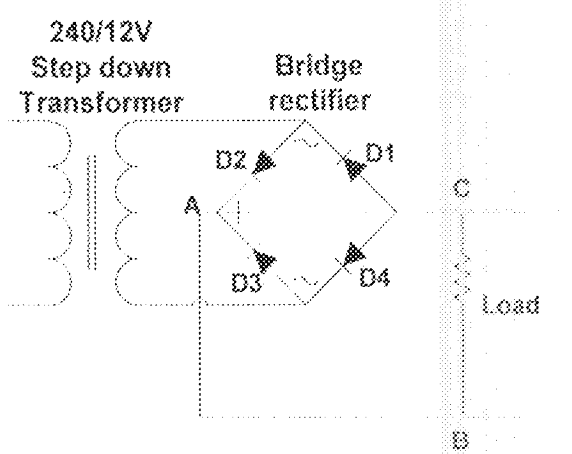


Fig 3.3 Diagram showing Bridge rectifier

It consists of four diodes (IN4001) arranged as shown. During the positive half cycle of the secondary voltage, diodes D2 and D4 are forward biased and current flows through D2, terminal ABC and through D4. During the negative half cycle, diodes D1 and D3 are forward biased and current flows through D3, terminals ABC and through D1. [3]

The current keeps flowing through the load (across BC) in the same direction during both half cycles of the ac input supply. Point A of the bridge rectifier acts as an anode and Point C as cathode. The output voltage across R_L is shown below:

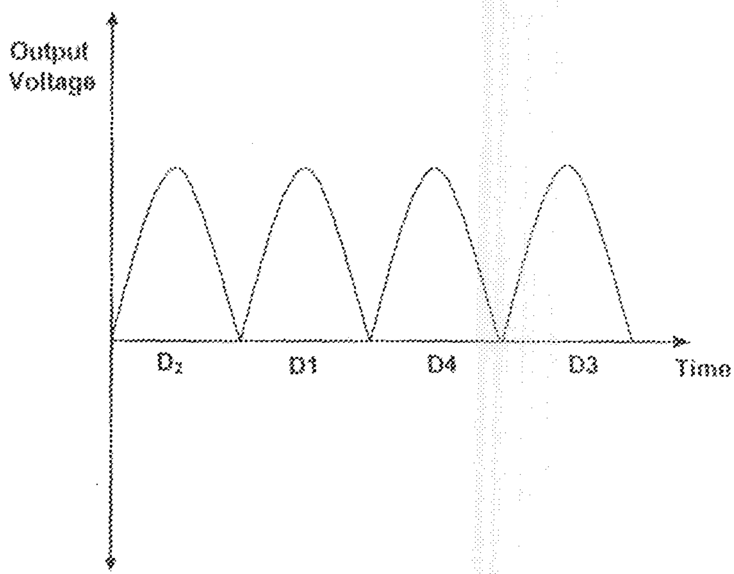


Fig 3.4 Output waveform of Rectifier

The maximum secondary voltage of the transformer is:

$V_{ps} = \sqrt{2}\ V_{rms}$

$V_{rms} = 12V$

$V_{ps} = \sqrt{2} \times 12V = 16.97V$. Also, the average dc voltage across terminal AB is:

$V_{dc} = 2\ V_{ps} / \Pi$

$V_{dc} = (2 \times 16.97) / 3.142$

$= 10.8V$

Also, the Peak Inverse voltage (maximum voltage that occurs across rectifying diode in the reverse direction) is:

$PIV = 4 \times V_{ps} = 4 \times 16.97 = 67.88.$

3.2.3 Filter Specifications

The rectifier gives a pulsating dc output because some ac components still remain. The ac components in a dc power supply are called ripples, and much of the ripple must be removed before power delivery to circuit components. [2]

Filters are circuits that can be used to remove the ripple. They can produce a very smooth waveform that will approach a pure dc. The filtering circuit used in this design is the simple capacitive filter connected to the rectifier output. [2]

Capacitors are energy storage devices that take a charge and later deliver it to a load. When the rectifiers are producing peak output, the capacitor charges and when the rectifier output drops off, the capacitor discharges and furnishes the load current. The voltage across the load will be maintained and this reduces the ripple.

A large electrolytic capacitor (2200μF) was used since it gives a longer discharging time and better filtering results. Since the filter capacitor charges to the peak value of the ac waveform, the 25V rating is sufficient for the circuit. [2] The circuit symbol and the filtered waveform are shown below:

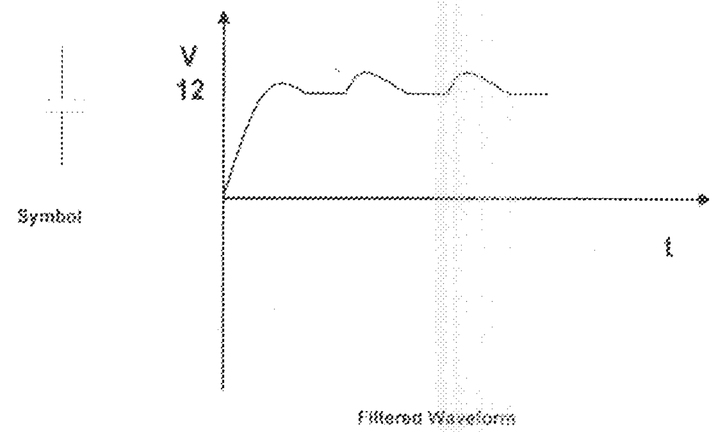


Fig 3.5 Capacitor symbol and filtered waveform

3.2.4 Voltage regulator

A voltage regulator circuit (used to provide regulated power supply), is an electronic control circuit which is capable of providing a nearly constant dc output voltage even when there are variations in load or input voltage. Regulated dc power is essential in the water pump controller circuit just like in other electronic systems. [3]

Voltage regulators can be linear or switching regulators. In linear regulators, the transistor operates somewhere between saturation and cut-off (it is always ON and dissipates power).

In switching regulators, the transistor operates like a switch i.e. it is either saturated or cut-off. [2]

The 7805 voltage regulator is used in the power supply unit to maintain a constant 5V voltage supply to the circuit. It is a 3 terminal device that produces a fixed positive output voltage. The terminals are:

- Input
- Output
- Ground

The diagram is shown below:

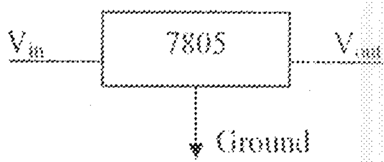


Fig 3.6 Voltage Regulator

A 47μF capacitor is connected at the output terminal of the regulator to filter any ripple left at the supply line.

Other components of the power supply unit are the LED (Connected with a limiting resistor) which indicates power flow in circuit and the switch which connects and disconnects the circuit to ac power.

3.3 Detection Unit

This unit forms the input to the circuit. It comprises the input amplifier with the water probes incorporated.

3.3.1 Input Amplifier

The water probes are two very close conducting wires which are exposed to possible water contact. They act as sensors; to detect water presence and feed this information to the circuit. The water conducts because it isn't pure and salts split into electrically charged particles (ions) when they dissolve in water. These ions move through the water to conduct electricity. [9] The factors that determine the degree to which water will carry electrical current includes;

- Concentration or number of ions.
- Mobility of the ion
- Oxidation state
- Temperature of water.

The water supplied by the pump will contain impurities and dissolved salts from its source with an estimated conductivity between 0.0005 – 0.5 Sm^{-1}. [9] Water contact at the probes causes a little current flow aided by their closeness and the current is immediately amplified by the input amplifier which is a 2-stabe BJT amplifier.

The bipolar junction transistor is a 3 terminal device consisting of two PN junction diodes back to back. It is an active device used to amplify (boost) an electric signal and its operation depends on both positive (holes) and negative (electrons) charge carriers. The BJT structure involves a sandwich of a thin layer of semiconductor material, called the base, between two pieces of opposite conductivity type regions known as the emitter and collector. This gives rise to the NPN and PNP transistors. The emitter – base junction is forward biased while the base – collector junction is reversed biased. It also has three circuit configurations which are the common emitter, common base and common collector configurations, and its operation characteristics are determined by the voltage sources and external devices connected across its terminals. [4]

Greater gain is achieved when two or more amplifier stages are coupled and in this circuit, this configuration gives the required amplification that boosts the signal from the probes. The diagram of the input amplifier is shown below:

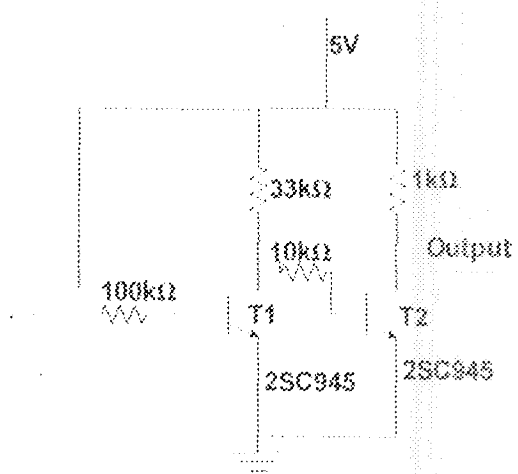


Fig 3.7 Input Amplifier

Where

$V_{CC} = 5$ volts

$\beta = 100$ (β = current gain of transistor)

When water bridges the input probes, transistor T1 operates in its saturation region.

Therefore.

$V_{CE} = 0$

The collector current I_C is given by

$I_C = V_{CC} / R_C$

$= 5V / 33k\Omega$

$= 0.152mA.$

Also, $I_B = I_C / \beta$

$= 0.152mA / 100$

$= 0.00152mA.$

Transistor T2 conducts and gives an output of 5V, thereby acting like a switch for the input amplifier connected across its output.

In summary, when the input conductors are bridged, T1 goes into saturation, while T2 conducts giving an output voltage of 5V which translates to a high (1) at the reset pin of the flip-flop connected to the output.

3.4 Control Unit

This comprises the main control section of the circuit and it comprises the input flip-flop, output oscillator, and mixer flip-flop.

3.4.1 Input flip flop

Combinational circuits are logic circuits whose output levels at any instant of time are dependent on the levels present at the inputs at that time. They have no memory. Most digital systems are made up of combinational circuits and memory elements. [13]

The flip-flop is the most important memory element which is made up of an assembly of logic gates. The general symbol of the flip-flop is shown below:

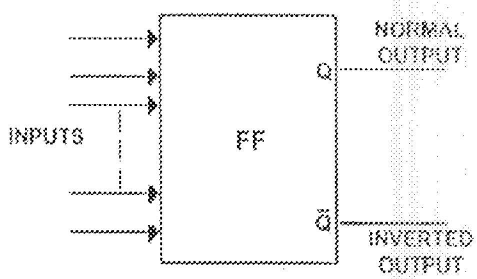


Fig 3.8 General Symbol of flip-flop

The outputs Q and Q^{l} are the inverse of each other. The Flip-flop has two possible operating states:

1. The HIGH or 1 state ($Q = 1 / Q^{l} = 0$) is called the SET state.
2. The LOW or 0 state ($Q = 0 / Q^{l} = 1$) is called the RESET state.

Flip-flops usually have a SET input and/or RESET input that is used to drive the flip-flop into a specific output state. Most flip-flop inputs need only to be pulsed (momentarily activated) in order to cause a change in the flip-flop output state which remains in that new state even after the input pulse is over. This is the flip-flops memory characteristic. [13]

A low pulse on the SET input will always cause the flip-flop to end up in a Q = 1 state, while a low pulse on the RESET input causes the flip-flop to end up in the Q = 0 state. The flip-flop remembers the last input that was activated and will not change states until the opposite input is activated. [13]

The 4013B IC is used as the input flip-flop in the design. It consists of 2 identical, independent data-type flip-flops. Each flip-flop has independent data, set, reset, and clock inputs and Q and Q' outputs. The pin diagram is shown below:

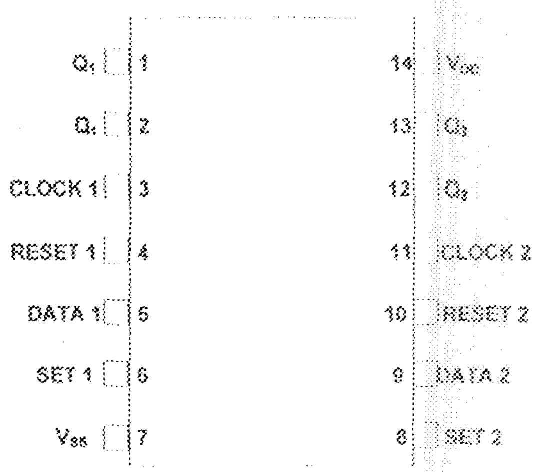


Fig 3.9 Pin diagram of 4013B IC

Setting or resetting is independent of the clock and is accomplished by a high level on the set or reset line respectively. The truth table for the 4013B IC is shown below:

Table 3.1 Truth table of 4013B

CLK	D	R	S	Q	Q'
PGT	0	0	0	0	1
PGT	1	0	0	1	0
NGT	X	0	0	Q	Q'
X	X	1	0	0	1
X	X	0	1	1	0
X	X	1	1	1	1

PGT = Positive going transition

NGT = Negative going transition

x = don't care condition.

The flip-flop's reset pin is connected to the output of the input amplifier, and when water bridges the contacts, a high level will occur on the reset line resulting in the resetting of the flip-flop (Q = 0) and Q is connected to the output oscillator (pin 12) as well as the pump. The pump is switched off while the output oscillator is triggered.

The external reset switch of the water pump controller is connected to the set pin of the flip-flop and is used to reset the entire circuit. This means the condition R = S = 1 is not obtainable. R = 1 gives the circuit control value while S = 1 resets the circuit back to its normal state. [13]

3.4.2 Output Oscillator

The output oscillator is a 4060B IC which is connected to the Q output of the 4013B. Its function is to generate the waveforms needed to drive the speaker and light indicator.

Electronic Oscillators are circuits that produce repetitive electronic signals (waveforms), mostly sine waves or square waves. Most electronic instruments make use of oscillators or waveform generators of some sort. [1] The oscillations produced by an oscillator are sustained (continuous). To achieve this, the following are required:

- A source of power (usually an amplifier).
- A positive feedback from output of amplifier to input. [5]

There are two main types of electronic oscillators:

- Sinusoidal (harmonic) oscillators.
- Non sinusoidal (relaxation) oscillators.

Square wave relaxation oscillators (like the 4060B) can be used to provide clock signals for sequential logic circuits. A simple relaxation oscillator consists of a capacitor which is charged through a resistor, then discharged rapidly when the voltage reaches some threshold, and then begins the cycle anew. The diagram is shown thus:

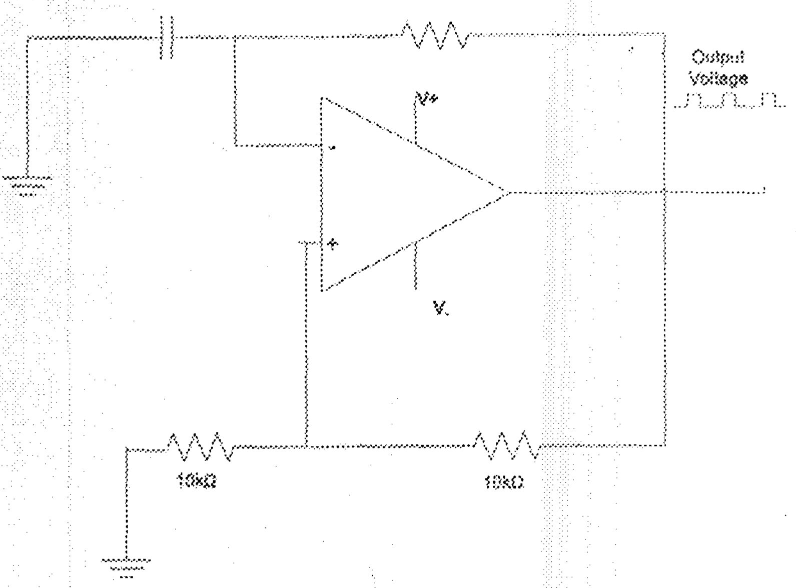


Fig 3.10 RC Relaxation Oscillator

The 4060B IC is a 14 stage binary ripple counter with an on chip oscillator buffer. The oscillator configuration allows design of either RC or crystal oscillator circuits. It also has a reset function which places all outputs into the zero state and disables the oscillator. A negative transition on the clock will advance the counter to the next stage. The pin Assignment and truth table are shown below:

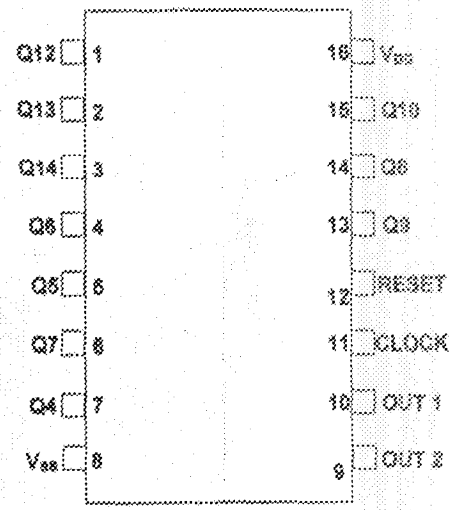


Fig 3.11 Pin Assignment diagram for 4060B

Table 3.2 Truth table for 4060B

CLK	RESET	OUTPUT STATE
PGT	0	No Change
NGT	0	Advance to next stage
X	1	All outputs are low

The Reset pin (pin 12) is connected to the Q output of the input flip-flop and when low, the clock pulse is generated.

The RC configuration for the oscillator circuit is shown below:

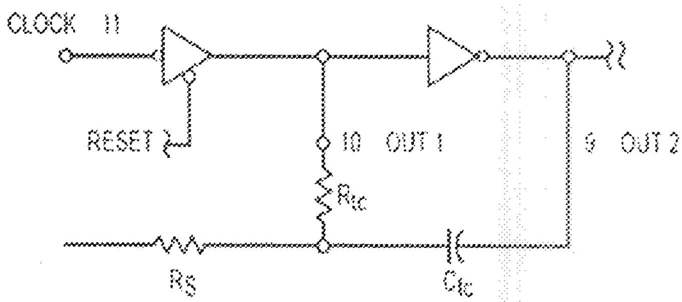


Fig 3.12 RC configuration for oscillator circuit

$R_{tc} = 33\ k\Omega$

$R_S = 100\ k\Omega$

$C_{tc} = 0.001\mu F$

The 4060B IC generates its square wave output based on the RC configuration on its pins 9, 10, 11. For the conditions;

$1\ kHz \leq f \leq 100\ kHz$ and

$2R_{tc} < R_S < 10R_{tc}$, the frequency of oscillation is given by:

$F = 1 / (2.3 \times R_{tc}C_{tc})$

$F = 1 / (2.3 \times 33k \times 0.001\mu)$

$F = 1 / (2.3 \times 33 \times 10^{3} \times 0.001 \times 10^{-6})$

$F = 13kHz$

This is the audio frequency at which the speaker produces its sound for the alarm output. The outputs of the oscillator divide this frequency and for pins 6 and 3, the values are:

* Pin 6 (Q7) gives 13kHz / 7 = 1.8 kHz, and
* Pin 3 (Q14) gives 13kHz / 14 = 930Hz.

Pins 6 and 3 are connected to the reset and clock inputs of the mixer flip-flop respectively and the frequencies they produce drive the flip-flop to give the required repeated sound during the high and low transitions of the pulses.

3.4.3 Mixer Flip-flop

Digital systems can operate either asynchronously or synchronously. In asynchronous systems, the outputs of logic circuits can change state any time one or more of the inputs change while in synchronous systems the exact times at which any output can change states are determined by a clock signal. The clock signal is a rectangular pulse train or a square wave which is distributed to all parts of the system and the system outputs can change state only when the clock makes a transition. When the clock changes from a 0 to a 1, this is called the positive going transition and when the clock goes from 1 to 0, this is the negative going transition. [13]

The 4013B IC was operated as a mixer flip-flop. It receives the square waveform generated from the output oscillator and provides the right frequency combination for the alarm output which is connected after it. The output pins 6 and 3 of the 4060B are connected to the R and CK input of the mixer flip-flop (4013B IC). Its output Q is used to transfer the frequency to the 3 watts speaker.

The logic symbol for a clocked S – R flip-flop that is triggered by the positive going edge of the clock signal is shown below:

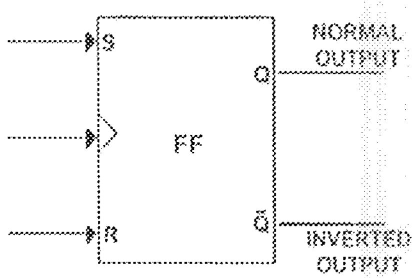


Fig 3.13 Logic symbol of clocked S-R flip-flop

The truth table is same as Table 3.1 drawn above.

3.5 OUTPUT UNIT

This consists of the Alarm circuit, Light indicator and pump control sections which when combined, give the required control of the pump (turning it OFF), with a sound alarm and light indication.

3.5.1 Alarm Circuit

A 3 watts 8Ω speaker powered with 12V output and is switched by an N – channel MOSFET (IRF40 IC) connected via a 10kΩ resistor connected to the Q output of the mixer flip-flop.

A MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a 3 terminal unipolar solid state device controlled by voltage rather than current. In a MOSFET, charge carriers, such as electrons, flow along channels. The width of the channel, which determines how well the conducts, is controlled by the gate, which is separated from the channel by a thin layer of oxide insulation. The logic symbol of the MOSFET is shown below:

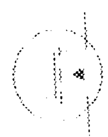


Fig 3.14 Logic symbol of MOSFET

A MOSFET can either be:

- An enhancement mode or
- A depletion mode.

The speaker is switched by an enhancement mode MOSFET which doesn't conduct with zero (or negative) gate bias and is driven to conduct by bringing the gate positive with respect to the source.

3.5.2 Light Indicator

This is a light emitting diode (LED) limited by a 1kΩ resistor and connected to the pin 2 of the 4060B IC. The LED blinks according to the input pulse from the oscillator. The voltage level sufficient to trigger on an LED is within the range of 1.5 to 3.3V. To limit the high current from the destroying the component, a resistance is connected across the LED. The diagram is shown below:

Fig 3.15 Diagram of LED

Maximum current needed for the LED used is 3mA [0.003A]

$R_{LED} = (V_{CC} - V_{LED}) / I_{LED}$

Where V_{CC} = Supply voltage = 5V

$R_{LED} = (5 - 2.3) / 0.003$

$= 2.7 / 0.003$

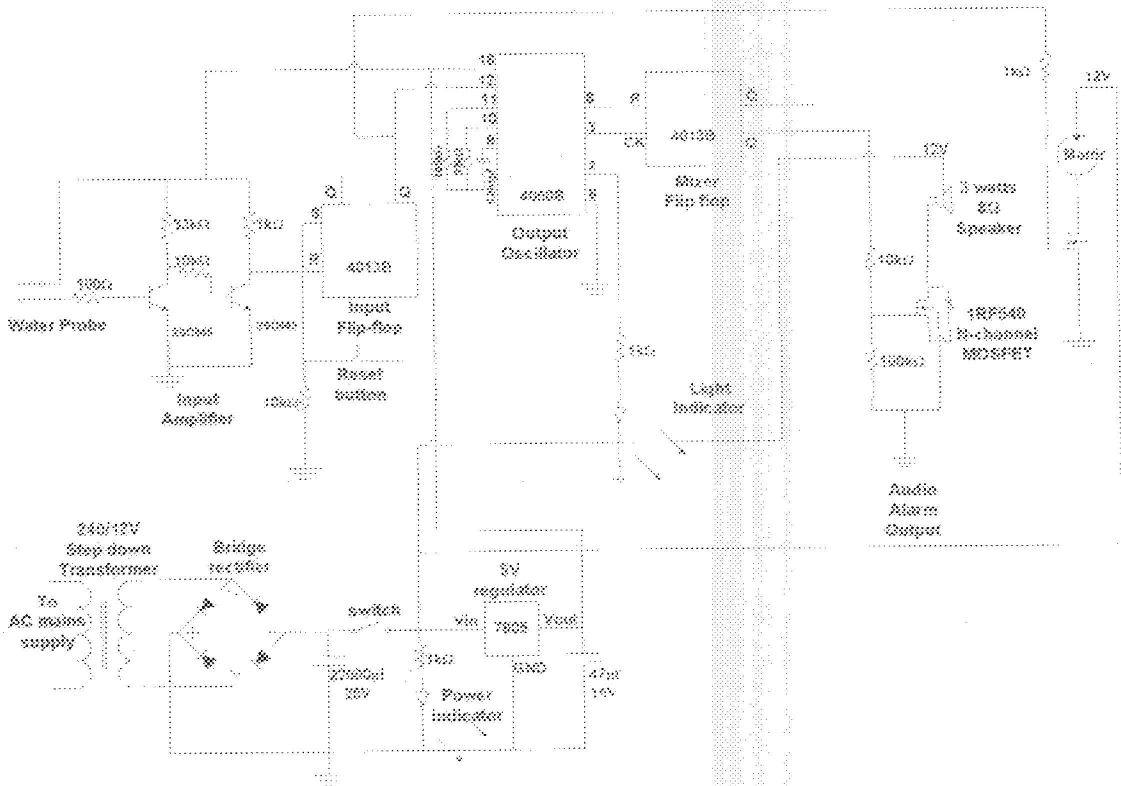
$= 900\Omega$

Therefore a resistance of 1kΩ was used.

3.5.3 Pump Controller

The pump is turned on when the device is powered, and when the water reaches the level of the probes, is switched off by a MOSFET which is also in enhancement mode.

3.6 Circuit Diagram



CIRCUIT DIAGRAM OF WATER PUMP CONTROLLER

CHAPTER FOUR

Construction, Testing and Results

4.1 Construction

The water pump controller was constructed using some tools, materials and electrical measuring and testing instruments which are described below:

I. Circuit Simulator: A software simulator is a tool used to simulate an electronic circuit so as to visualize the output before physical construction.

II. Breadboard: This is a reusable device used to build a (generally temporary) prototype of an electronic circuit and for experimenting with circuit design. Breadboards have strips down one or both sides either as part of the main unit or as separate blocks clipped on to carry the power rails. They consist of a perforated block of plastic with numerous tin plated phosphor bronze spring clips under the perforations.

III. Veroboard: This is a type of electronics prototyping board characterized by regular grid of holes, with wide strips running one way all the way along one side of the board. The ICs, other components, and wire connections are permanently soldered to form the final constructed circuit.

IV. Soldering Iron: This is a device for applying heat to melt solder (lead) for soldering two metal parts together. It is composed of a heated metal tip, with an insulated current. Heating is achieved electrically by passing a current through a resistive heating element. It is used for permanent connection of components to the veroboard.

V. Soldering lead: This is a metal (lead) with low melting point used to hold components and connecting wires in place on the veroboard.

VI. Lead sucker: This is a tool used to suck up excess molten lead from the veroboard so as to prevent short circuit (bridging) or undesired electrical connections.

VII. IC sockets: These are used to protect ICs from the effects of excess heat. They are connected to the veroboard before inserting the ICs into them.

VIII. Wires and connectors: These are used to connect and solder different components of the circuit on the veroboard, and to external parts of the construction.

IX. Wire cutters/strippers: These tools are used for cutting wires to the desired sizes and to strip insulations of the wires to expose the conductors for proper and neat soldering.

X. Multimeter: This is an electronic measuring instrument that combines several functions in one unit. The most basic instruments include an ammeter, voltmeter and ohmmeter used to measure current, voltage and resistance. It is also used to test continuity.

After the water pump controller was designed, the circuit was simulated using multism to analyze the result at various stages and compare with the expected values.

The circuit components were then laid out temporarily on the breadboard to observe the result and ensure the expected output response was obtained, after which the breadboard was dismantled.

The final construction of the circuit was on the veroboard. The components were carefully arranged according to their units and were inserted into the holes on the board starting with the power supply unit, then to the input amplifier unit, oscillator unit and finally the output unit.

The integrated circuits (ICs) were protected with IC sockets due to their sensitivity to heat. These sockets, as well as all components and connecting wires were inserted properly into the holes and then soldered using good soldering joints by ensuring good contacts with the copper track of the veroboard.

4.2 Precautions:

1. All excess solder were removed from the board.
2. IC sockets were used to prevent overheating of IC.
3. Pieces of solder crossing copper traces were broken with soldering iron.
4. Connections were made shining rather than dull.
5. All soldered joints were tested for continuity to avoid unnecessary open circuits.

6. Soldering operations weren't delayed unduly to avoid overheating which could damage components.

The circuit board was housed in an 8.5cm by 6.5cm mild steel sheet casing which was cut into a shape that properly fitted the circuit and holes were drilled at various positions for the sensor wires, power cables, switches and also to aid ventilation. A plastic container was used to model the tank where the probe was placed.

4.3 Testing and results

The output of the entire circuit as well as different units was tested at various stages during construction. Testing was carried out after the components were arranged on the breadboard. The outputs of the bridge rectifier and voltage regulator were tested using the multimeter to ensure that the voltages were within acceptable limits of tolerance. The output of the input amplifier unit was also tested and amplification of current was confirmed for water input at the probes. Components and connecting wires which were soldered were also tested for continuity using the continuity alarm tester of the multimeter.

After completion of the construction, the circuit was finally tested. The sensors were placed at a marked position in the plastic container via cables connected to the input of the circuit and a water pump was also connected to the circuit. Power was supplied and water from another container was gradually pumped into the container which had the sensors until the water level reached the sensors. The alarm was triggered and the LED came on, whilst the pump was automatically turned off. The input flip flop was manually reset to turn off the alarm.

4.4 Problems encountered & troubleshooting.

1. Oversensitivity of the water probes resulting in difficulties with resetting the device. This was corrected by reducing the gain of amplification.
2. Fluctuations in ac voltage induced voltage drops in the circuit and created difficulties in powering the pump effectively.
3. There were initial problems with switching the pump with a BJT so a MOSFET was used instead.

CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion

The water pump controller circuit was designed, constructed and when tested, the water pump was switched off when the water reached the level set by the wire probes. This was accompanied with an alarm output and light indication; thus the aim of the project was achieved. The device would be useful in homes, hospitals, schools, offices etc and would help conserve water especially in places of limited supply.

5.2 Recommendation

The following suggestions are made for possible improvements on the design:

1. The design could be improved upon to also control turning on the pump by incorporating another sensor at a lower level. This would make the switching completely automatic.
2. The use of a back-up battery could be incorporated.
3. The circuit could be achieved with better and more compact integrated circuit technology.

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APPENDIX 1

BILL OF ENGINEERING MEASUREMENTS AND EVALUATION

S/No	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
1	Transistor,2SC945	2	LOT	₦ 5	₦ 10
2	Flip flop IC,4013B	2	LOT	₦ 120	₦ 240
3	Oscillator IC,4060B	1	LOT	₦ 120	₦ 120
4	MOSFET,1RF540	2	LOT	₦ 150	₦ 300
5	5V regulator,7805	1	LOT	₦ 40	₦ 40
6	Diode,IN4001	4	LOT	₦ 5	₦ 20
7	12V Transformer	1	LOT	₦ 120	₦ 120
8	Capacitor (2200µF 25V)	1	LOT	₦ 50	₦ 50
9	Capacitor (0.01µF)	1	LOT	₦ 50	₦ 50
10	Capacitor (47µF 16V)	1	LOT	₦ 20	₦ 20
11	Light emitting diode	2	LOT	₦ 5	₦ 10
12	Soft touch button	1	LOT	₦ 40	₦ 40
13	Speaker (3W 8Ω)	1	LOT	₦ 100	₦ 100
14	Resistor	11	LOT	₦ 5	₦ 55
15	Switch	1	LOT	₦ 50	₦ 50
16	Water Pump	1	LOT	₦ 350	₦ 350
	Total				₦ 1575