# DESIGN AND CONSTRUCTION OF AN AUTOMATIC FLOOD LEVEL CONTROLLER


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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

# DECLARATION

I hereby declare that this project work was designed and constructed by me under the supervision of Engr. Umar .N. Dauda and has never been submitted elsewhere for the award of Bachelor's degree.

Sadiku
SADIKU ABUBAKAR.A.

05/12/2005
DATE

# CERTIFICATION

This is to certify that this project work was carried out by SADIKU ABUBAKAR ADINOYI, matriculation number: 99/8357EE of the department of Electrical and Computer Engineering, Federal University of Technology, Minna, Niger State, Nigeria.

ENGR. UMAR S. DAUDA
PROJECT SUPERVISOR

SIGN AND DATE 5/12/05

ENGR. MUSA .D. ABDULLAHI
HEAD OF DEPARTMENT

16/02/06
SIGN AND DATE

EXTERNAL EXAMINER

SIGN AND DATE

# DEDICATION

This project is dedicated to Almighty Allah, the Omnipotent, the Beneficent, the Merciful that created me and has guided me through all this years to this day and to my late grand mother MADAM ADISETU EYIHIOMO OZIOTU SADIKU of blessed memory.

# ABSTRACT

The automatic flood level controller is a system designed to detect water flooding the underground basement of industrial mills or public buildings, signal an alarm system and control a water pumping system to act as a form of control against the flood whereby the water is taken out to a drainage pit for other public use. It can also be used for any other liquid control whose resistance is under 1KΩ (i.e. between the maximum separations of the sensing probes).

The controller design consists of the power supply unit which supplies a regulated d.c. voltage of 12V, 1.5A current to the controller circuit, the transduction / detection system which detects the analogue signal from the water and converts it to its appropriate electrical signal, the controller unit that synchronizes the electrical signals from the transducers into digital logic signals used for the control mechanism, the switching units that does the switching of the control system and the indication / output system that displays a visual indication of the flood level and the operation of the pumps to act as drainage facility for the control of the flood.

To briefly review the contents of this thesis, chapter 1 provides an introduction to the reasons for level measurement and control and the concept applied in achieving this goal.

Chapter 2 presents a brief review of related concepts and the modern trends to the application of these concepts. The various components and their simplified model making up the automatic flood control system is analyzed in chapter 3 where mathematical analysis with diagrammatic representations were given for every components analyzed. Chapter 4 presents the results obtained from testing the system design and the analysis on

these tests were comprehensively detailed. The conclusion and general recommendations for subsequent efforts was presented in chapter 5 to act as a guide for future research efforts in this area.

# ACKNOWLEDGEMENT

The credit for this work goes to Almighty Allah for granting me good health and understanding throughout my academic pursuit and to my project supervisor Engr. Umar .N. Dauda, for going through the thesis to ensure both grammatical and technical order.

Also worthy of commendation is Engr. Musa .D. Abdullahi (H.O.D. Electrical / Computer Engineering) and all the other departmental lecturers for making this effort a dream come true.

My greatest indebtedness goes to my parents, Dr. Salawu Sadiku and Mrs. Nana Hawawu Sadiku for their financial, moral and spiritual contribution towards the realization of my academic dreams. May Almighty Allah bless them. I am also indebted to Engr. T. A. Abogunrin for his technical support and to a colleague of mine Mr. Christopher .O. Adeboye for assisting me with the controller design. I also seize this opportunity to thank my brothers, sisters, uncles, aunties, cousins and other relatives for their support and contributions.

I also commend my colleagues and friends who contributed in one way or the other during the course of this program. I am grateful for all your efforts and contributions and may Almighty Allah bless you all. Amin.

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# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1 INTRODUCTION

All over the world, it is often required to control the level of liquid either for domestic or industrial purposes. In the industries in Nigeria, it is often important to measure the liquid level in tanks (overhead or underground) or reserviours and it is very necessary to be able to supply water (water flow) for cooling furnaces, irrigation, etc. At the home, it is required to be able to store water in tanks so as to make domestic activities such as washing, cooking, and bathing pleasant and to be able to control the usage of stored water for maximum efficiency. [1]

For the Agricultural sector, a measurable quantity of water is needed to be stored in reservoirs and controlling the water flow into and out of the reservoir to be used for field irrigation, starting seed beds of transplanted crops before the rainy season, mixing water soluble sprays close to crops and without nozzle-blocking slit, to start fish farming in a new dam, improving dairy hygiene, etc. Also, a lot of water storage and controlling of water (in and out of reservoirs) is needed for public services provided by government like clinics, schools, cottage industries like tile and brick making, preparation of leather and natural fibers, brewing, etc. [1]

However, due to the importance and the various uses water is put into (public and industrial), little attention is given to the disastrous and devastating effects which very high water flow (flooding) have on public and industrial infrastructures.

Flooding has led to the up shooting of water turbines in hydroelectric power stations, overflowing the banks of rivers to destroy houses and properties, etc. It is also responsible for the destruction of underground cables, rusting (corrosion) of metal parts, and collapse of high rise buildings when it occurs in the underground basement of industrial mills or public buildings. These damages have led to loss of lives, revenue and properties.

In order to forestall (prevent) these damages from occurring, the idea of level measurement and control is employed whereby these underground excess waters can be channeled to drainage pits or underground wells to be put to other useful uses. Level measurement has to do with the stage by stage determination of the distance from the upper surface of the water to a pre-defined level located below the surface while Level control is the maintenance of the quantity of water in a reserviour or tank or underground basement. Level measurement and control increases the initial cost of equipment required for public or industrial processes which would be reasonably justified economically, when taking into consideration the need for sensitive and accurate level control to avoid stoppages in the operations and as safety precautions against the loss of lives and properties. [2]

## 1.2 AIMS AND OBJECTIVES

The major aim of this project work is to be able to measure the water flow level into an underground basement or reserviour, so as to be able to indicate each water level, signal when the flooding starts to occur and control the channeling of the water to the drainage pits or underground reserviours for other public or industrial use.

Moreover, the objective is to prevent damages to machineries and equipments or high buildings collapse by preventing the flooding of underground basements. This goes a long way in saving a lot of expenditure for the public or industries and also, saving a lot of lives that would have been lost when these damages occur.

## 1.3 METHODOLOGY

The project is based on the conducting property of water. Distill water (pure water) does not ionize easily (i.e. water in its pure state is a weak conductor of electricity because there are few charged ions moving in solution). Actually, water is a weak electrolyte that offers a large resistance to the flow of electricity. The conductivity of any liquid depends on its ionization (ionization being the dissociation of its electrolyte into charged particles called ions). [2]

However, water contaminated with some form of impurity normally found in industrial mills conducts electricity very strongly due to its measurable salt content as compared to distill water and this conducting mode can be determined in terms of the resistance it offers when voltages are applied (low voltages, because high voltages could lead to a circuit blow-out). This resistance depends on the type of impurity present in the water and could be generated in the following industrial processes;

1) Water control in the Rolling Mills

In industrial rolling mills, industrial water (normally from rivers, streams or seas) is poured on hot billets along rolling lines (channels). The main purpose of these is to wash off the scale from the hot billets whereby the water washes them to the scale pit where the scales settle for evacuation and the water is pumped back to the underground reservoirs for further re-circulation. As the water is poured on the hot billet, it carries along with it lubricants such as oil on the machine on which the water flows. The presence of these lubricants eventually lowers the conductivity of the water and thereby increasing the resistance of the water. The level of water in the scale pits are very critical to the operation of the mill and hence, necessitating the measurement and control of the water level in these cases. Values of resistances obtained in these cases can be as high as five hundred milliohms (500mΩ). [4]

2) Underground water control using drainage pits

In the industries, problems of underground waters are tackled using drainage pits. This is used in the basement of high rise buildings, cable tunnels, and Underground wells and is usually made to be lower than the reference level, with water flowing into the pits from where they are pumped out. The pumping has to be automated (a reference level of water is made and as soon as the water level goes beyond the reference level, a signal is sent to the electric motor (to drive the pump) that pumps the water out. The resistance of water in this case is about 50milliohms (50mΩ). [4]

3) Cooling water to furnace

The walls of high temperature furnaces are constantly cooled using industrial water in cases like the electric arc furnace, electric holding furnace, induction furnace, re-heating furnace in rolling mill, blast furnaces, etc. Arrangements are usually made for industrial water to flow through the walls of these furnaces as cooling water is considered critical to the operation of these furnaces.

Hence, signals indicating availability of water to the furnaces (water flowing through the walls of the furnaces) are sent to signaling and protection circuits. The arrangement is such that if water is not flowing to these furnaces, the main breaker supplying power for the operation of these furnaces is not ON (closed) and in many cases, where the water flow fails suddenly in the course of operation in the furnace, alarm signals are given and the protection circuits should operate after a given pre-determined time. [4]

The controller circuit designed in this project can be used in the above mentioned situations as it is an electronic device that will indicate and measure the water level in these cases, generate voltages thereby inducing electric current that will be needed to drive the electric motor of the pump to pump water into drainage pits, so as to be able to control the flooding in these environments. It also incorporates a seven segment display to indicate the water level and to show emergency situations.

# CHAPTER TWO

# LITERATURE REVIEW

Quite a number of approaches have been developed for sensing and determination of liquid levels in tanks, reserviours, basins and other environments. This knowledge is of extreme importance as other parameters can be inferred from the measurement of these liquid levels e.g. volume of the tank can be determined if the dimension of the environment is known, area of the liquid environment can also be determined. Various principles are used to determine liquid level via level measurement using differential head, electronic method, etc. [3]

Generally, this is achieved by taking into cognizance of some important physical parameters of the liquid in the environment like the temperature, pressure, weight, turbidity, etc. These parameters have helped in developing appropriate transducers to suit any particular transducer chosen. Liquid level sensing is either based on obtaining a discrete indication when a pre-determined level has been reached (also called point sensing) or obtaining an analogue representation of the level as it changes (continuous sensing). Point sensing systems are usually simpler and cheaper than continuous sensing systems and should be used when discrete indication has to be obtained. When two or more discrete levels are to be established in any environment, the use of two or more point sensors is preferable to continuous system due to the inconsistency in the accuracy of the measurement when using the continuous sensing technique. The most commonly used water level sensing device is the float system which consists of a level sensing float system which mechanically actuates a transduction element like a potentiometer, magnetic reed switch, etc. [2]

However, with the advent of semiconductor technology, electronic based water level sensing and pump actuating devices have replaced most the above early systems. One of such device is the electronic level controller which is a device used in monitoring and controlling the level of media in a vessel or tank. It can be used for pre-determined level detection with ON/OFF control and for continuous level measurement in a wide variety of process medium applications. It also includes the use of moving coil indicators i.e. Light Emitting Diodes (LED's) and digital indicators like the Liquid Crystal Displays (LCD's). Also the thyristor switches and transistor switches have replaced manual switches used as control devices of the water pump. These semiconductor switches are preferable due to their higher speed, better reliability, and longer life and since there are no moving parts in the switches, they do not wear out. [3]

This project has employed the I.C. based circuits which could be used for regenerative comparator circuits due to their higher gain, cheaper value and occupying of less space. This has an advantage over the typical circuit used in the industry utilizing discrete transistor circuitry which was found to be problematic because of certain characteristics found in this circuitry.

With the high level of development and the increase in sophistication of equipments in the world today, minimum maintainability and very high reliability is gotten as a result of the emergence of microelectronics.

# CHAPTER THREE

# THEORY OF OPERATION AND DESIGN

## 3.1 POWER SUPPLY UNIT (PSU)

Modern electronic devices and circuits require a direct voltage supply. A battery could be used to supply this direct voltage but it has disadvantages due to its limited life and the manner in which the battery's internal resistance decreases with age and the deteriorating battery condition. The effect of increased resistance is to lower the battery terminal for a given load current. Also, the effect of varying load current will cause a change in the terminal voltage of the battery. An ideal power supply will not change its terminal voltage despite changes in input voltage or output current conditions and thus, a battery is far from an ideal power supply.

Furthermore, in achieving the desired ideal power supply for the flood controller circuit, it became a matter of necessity to design power supply unit. Since, the source of electricity available is an alternating current (a.c.) mains of 240V, 50Hz; a step down transformer was used to convert these mains to a 15V, 500mA direct voltage (d.c.) amplitude level supply. This was achieved by making use of the turn's ratio of the primary windings to the secondary windings to get the desired voltage and current value i.e. the voltage applied to the primary appears across the secondary, with a voltage multiplication proportional to the turn's ratio of the transformer and a current multiplication inversely proportional to the turn's ratio. In a transformer operation, power is conserved and it also serves to "isolate" the circuit from the actual connection to the power line due to the windings of the transformer being insulated from each other. This is shown in fig 3.1.

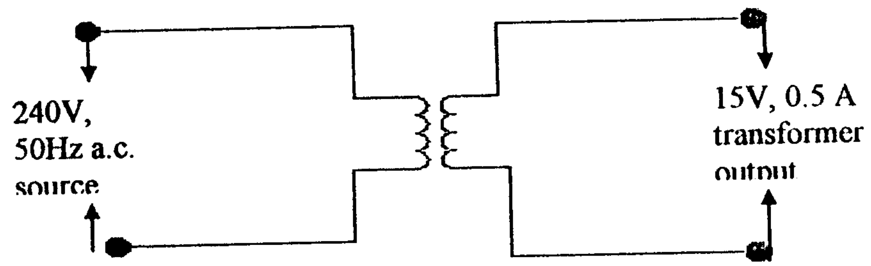


Fig.3.1 Diagram of a transformer showing its voltages

The output voltage supply from the mains is an alternating sinusoidal voltage which changes polarity during a cycle i.e. it is positive in one-half cycle and negative in the second half-cycle giving an average value of zero over a cycle. This is illustrated in fig 3.2

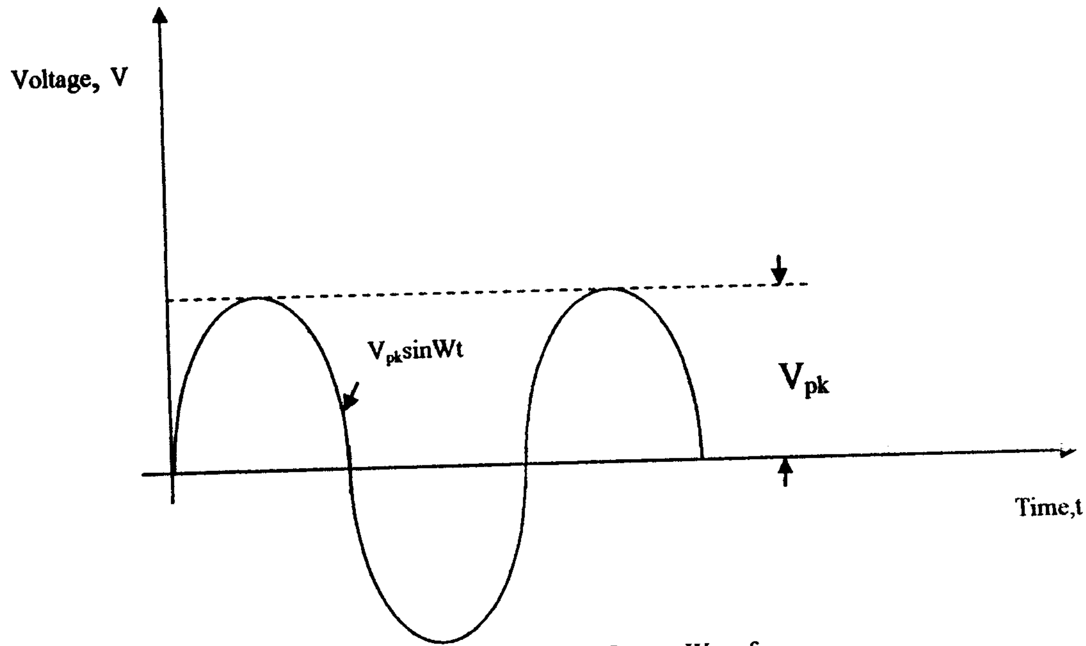


Fig. 3.2 Transformer Output Waveform

Now, $\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$

$V_p = 240V$; $V_s = 15V$; $I_s = 500mA$ (transformer values)

$\frac{N_p}{N_s} = \frac{240}{15} = 16 = \frac{I_s}{I_p}$

$I_p = \frac{I_s}{16} = \frac{500x10^{-3}}{16} = 31.25mA$

Also, $P_D = V_pI_p = V_sI_s = 500x10^{-3} \times 15 = 7.5W$

where $V_p$ = Primary voltage (from a.c. source)

$V_s$ = Secondary voltage (output voltage from transformer)

$N_p$ = Number of turns of the primary coil

$N_s$ = Number of turns of the secondary coil

$I_p$ = Primary current (from source)

$I_s$ = Secondary current (transformer output)

$P_D$ = Power dissipated by the transformer.

Rectification is then required to provide a uni-polar voltage i.e. a voltage made up of sinusoidal half-cycles but each of the same polarity, positive in this case. This was achieved using four IN5392 diodes in full-wave bridge rectifier mode as shown in fig 3.3

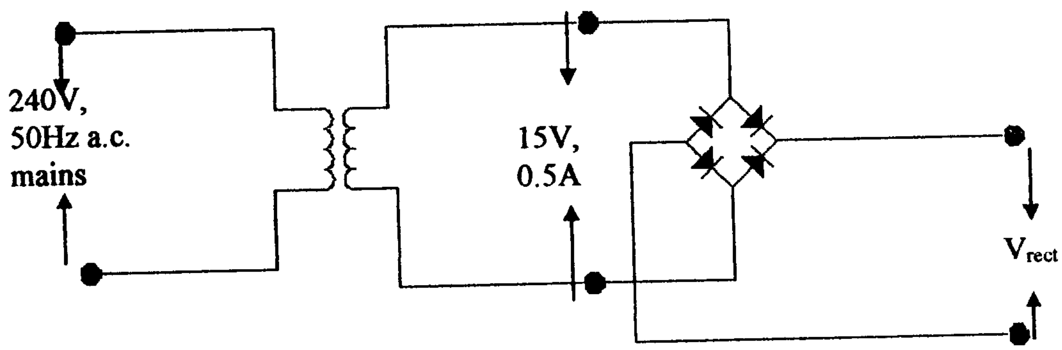


Fig. 3.3 Diagram of the rectifier circuit

The bridge rectifier consists of two pairs of diode with a pair having its common anode terminals joined together while the other pair has its common cathode terminal joined in a similar way. Actually, two diodes which are always in series with the input voltage conduct simultaneously. For instance, during the positive half cycle of the transformer, $D_1$ and $D_3$ conducts while $D_2$ and $D_4$ are reverse biased. During the negative half cycle, $D_2$ and $D_4$ conducts while $D_1$ and $D_3$ are reverse biased. This results in an average d.c. voltage output with considerable ripple component of twice the input frequency of 100Hz. Now, $V_{max} = V_{peak} = (2)^{1/2} x V_{rms}$

$V_{peak} = 15 x (2)^{1/2} = 21.2V$

where $V_{peak}$ = peak output voltage from transformer

$V_{rms}$ = root mean square output voltage of the transformer

The peak inverse voltage (PIV) rating of each of the diode is normally equal to $V_{peak}$. By standard, the acceptable PIV for a full-wave bridge rectifier is $2V_{peak} = 2 x 21.2 = 42.4V$. Thus, the diode IN5392 with PIV rating of 100V was chosen as the rectifier diodes. Also, $V_{rect} = V_{peak} - 2V_D$

where $V_{rect}$ = output voltage from the rectifier

$V_D$ = the conducting diodes instantaneous voltage drop

$V_{peak} = 21.2V$; $V_D = 0.7V$ (for silicon diodes)

$V_{rect} = 21.2 - 2(0.7) = 19.8V$

The rectified output voltage of the rectifier has the waveform shown in fig 3.4

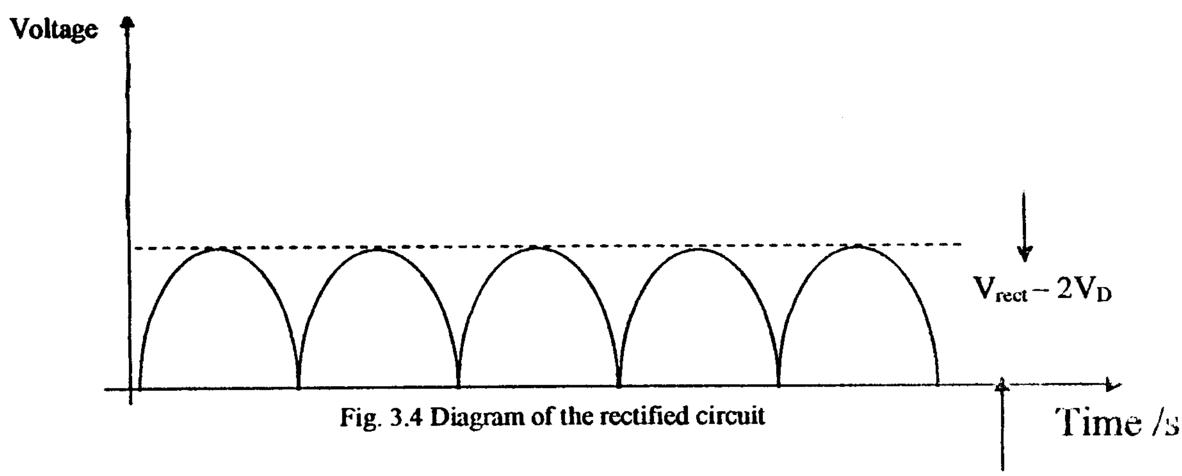


Fig. 3.4 Diagram of the rectified circuit

The rectified d.c. output voltage is normally pulsating and contains a high percentage of ripple content which needs to be filtered out to minimize the ripples and give a better approximation to the required d.c. voltage. A 35V, 3300μF capacitor was used to provide the required smoothing action by connecting it in parallel with the rectifier diodes as shown in fig 3.5

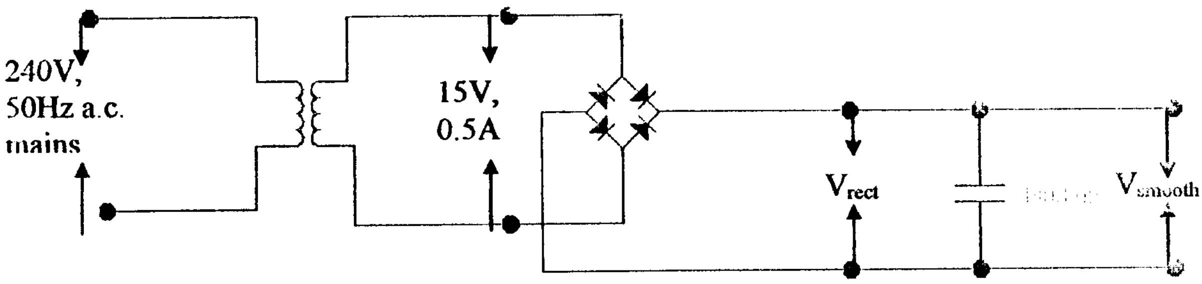


Fig. 3.5 Diagram of the smoothing circuit

The essence of having this capacitor is to prevent the output voltage from falling to zero as the diode cuts off. During the positive half-cycle of the input voltage, the diode conducts and its forward current will flow through the load as before but some will now flow through the capacitor to charge it to the peak output voltage value. As the input voltage begins to fall from the peak value, the diode becomes reverse biased since the voltage across the capacitor is now greater than the applied voltage. The capacitor now starts to lose its charge which it discharges partially through the load until it gets recharged. Thus, the voltage across the capacitor, and hence the output voltage falls exponentially with a time constant, $CR_L$ seconds. A filter capacitor with sufficiently large value was chosen to provide an acceptable low ripple voltage.

Now, $\Delta V = \frac{I_{load}}{2fC}$

where C = capacitor value = 3300μF

$I_{load}$ = transformer output current = 500mA

f = ripple frequency = 50Hz

$\Delta V$ = ripple voltage

$$\Delta V = \frac{500 \times 10^{-3}}{2 \times 50 \times 3300 \times 10^{-6}} = 0.1515V$$

$V_{smooth} = V_{rect} - \Delta V$

$= 19.8 - 0.1515$

$= 19.6485V$

The filtered (smoothed) voltage output waveform after undergoing smoothing is shown in fig 3.6.

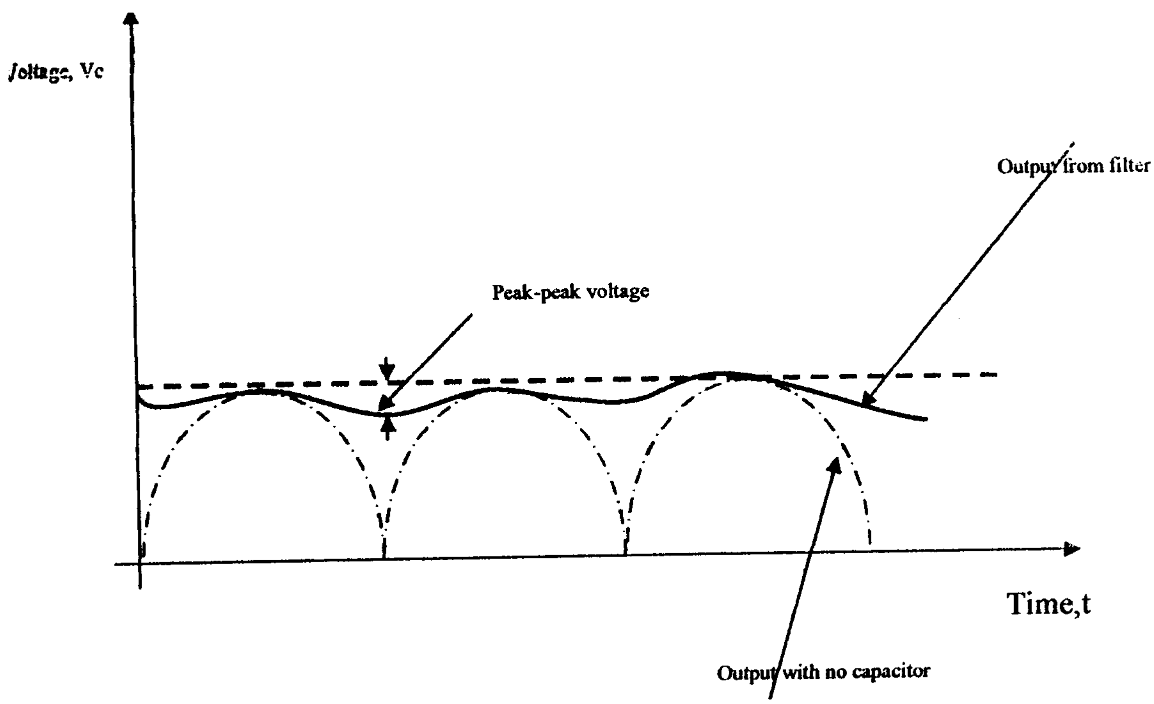


Fig. 3.6 Diagram of the smoothed voltage waveform

The amount of ripple voltage from a capacitor-smoothed rectifier could still be too great for the circuit and there are limitations on the method of reducing the ripple by increasing the capacitor value. An extra circuit was used which acts as a filter to suppress the a.c. but allows the d.c. to pass and also further reduces ripple voltage at the output. This was achieved using a 0.01µF capacitor which is effective and is known as the capacitor input filter. It was connected in parallel to the capacitor-smoothed rectifier as shown in fig 3.7. A protection diode was connected in parallel with the capacitor to prevent destructive voltages when the power supply is turned off and also prevent negative voltage from flowing through the rectifier circuit when a short occurs.

Furthermore, the power supply output voltage needed is desired to remain constant regardless of variations in direct current voltage levels and changes in load current values, which must not be allowed to affect the d.c. voltage output level. This necessitated regulation and was done using the three terminal adjustable positive voltage regulator, LM317 so as to stabilize the output voltage and also produce the desired voltage. This regulator has no ground terminal; instead it adjust $V_{out}$ to maintain a constant 1.25volts (band gap) from the output terminal to the "adjustable" terminal. The regulator puts 1.25volts across the resistor, $R_1$, so 5mA flows through it. The adjustable terminal draws very little current (50 – 100µA), so the output voltage is just $V_{out} = 1.25(1+ R_2/R_1)$ volts. Since, it does not "see" ground; it can be used for high-voltage regulators, as long as the input-output differential doesn't exceed the rated maximum of 40volts. In this case, the input voltage to the regulator is 19.6485volts and the desired output is 12.0volts. This shows that the input-output is in line with what is needed by the LM317 regulator.

Now, $V_{in} = 19.0V$; $R_1 = 240\Omega$; $R_2 = 2064\Omega$ where the resistor R2 is the adjustable resistor that was adjusted to the value above.

But, $V_{out} = 1.25(1+ R_2/R_1)$

$= 1.25(1+ 2064/240)$

$= 1.25(1+8.6)$

$= 1.25 \times 9.6 = 12.0V$

This output voltage normally contain some oscillations in frequency which was removed with the aid of 35V, 2200μF and a 0.01μF capacitors in parallel and a IN5392 protection diode was connected across the regulator to prevent it against destructive voltages when the power supply unit is switched off and also guide against negative voltage from flowing through the regulator when a short occurs. The connections are shown in fig 3.7.

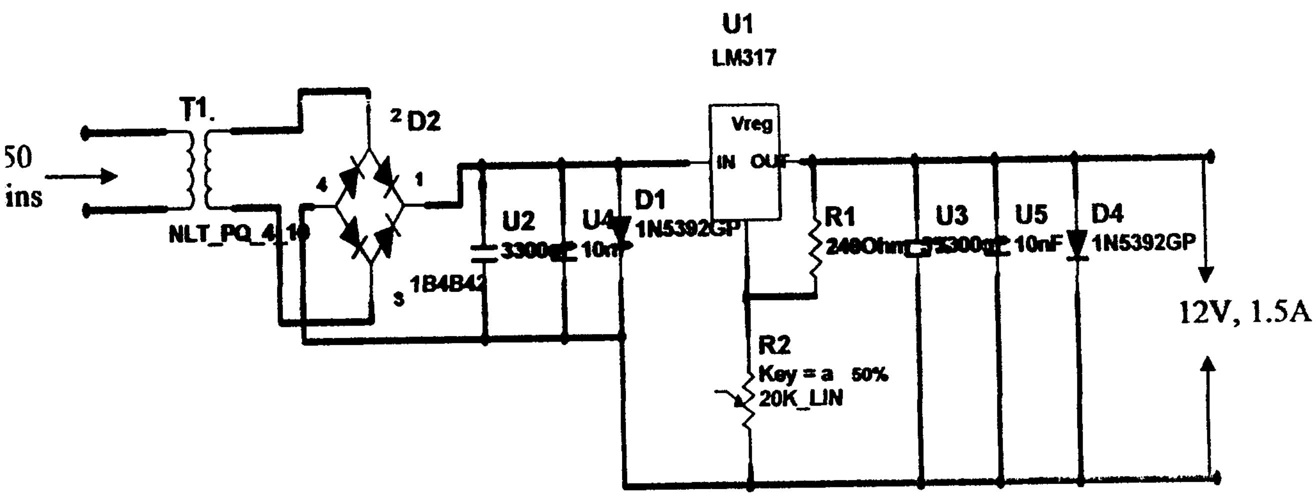


Fig. 3.7 Power Supply Unit Diagram

Thus, the output voltage level of 12V, 1.5A d.c. was achieved and taken to the controller circuit.

## 3.2 DETERMINATION OF WORKING RESISTANCE

As a result of the low conducting property of water, a simple test was carried out on industrial water (normally sourced from rivers, sea or stream) to determine the value of resistance the controller circuitry would be working with. The test was carried out with the aid of two stainless steel electrodes, a mega-ohmmeter, sample of industrial water, a bucket, and two electric cables. The two stainless steel electrodes were dipped in the bucket containing the industrial water and the cables were connected to the electrodes on one end. The other end of the cables was connected to the terminals of the mega-ohmmeter as shown in fig 3.8. Stainless steel electrodes was used due to its high sensitivity, high resistance to corrosion and its high durability compared to copper or aluminium that tends to get corroded with time and loses its durability.

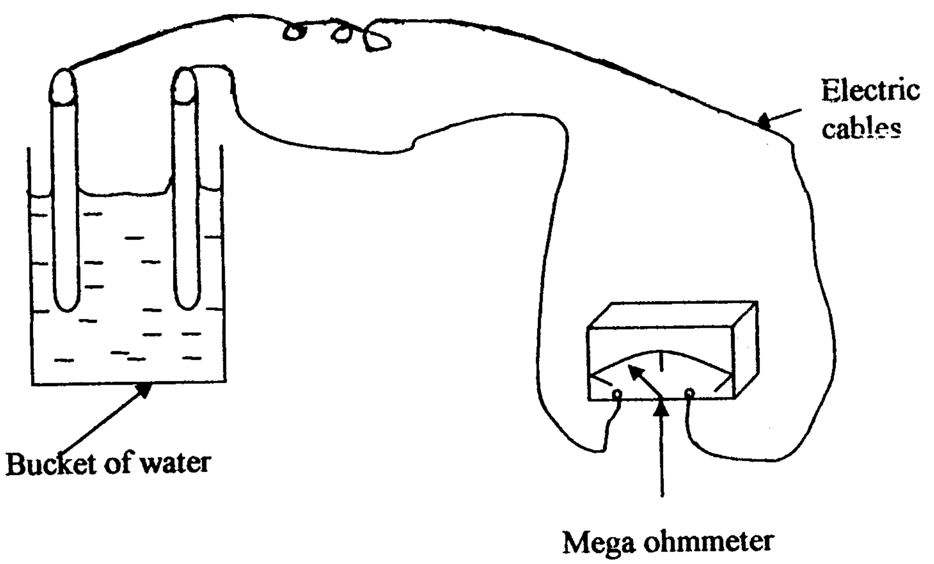


Fig. 3.8 Diagram showing the connections of the water resistance determination

The result obtained was that the water offered a resistance of about 50-100 milliohms which is not too high to allow the conduction of electricity. Hence, the controller circuit would function well in this environment. Care was taken during the test that the cables were properly wound round the electrodes and tightly screwed on the terminals of the mega-ohmmeter to ensure a proper connection. Care was also taken that the wires were properly insulated to prevent electric shock because a considerable amount of voltage can be induced when water conducts.

## 3.3 THE TRANSDUCTION / DETECTION SYSTEM

This is the system or an instrument that transforms the quantity of a material, record it and process it for utilization. Generally speaking, transducers are devices that convert some physical quantity such as temperature or light level, to voltages or some other electrical quantity which are used as signals that can be manipulated by electronic circuits, quantified by analog-to-digital converters and logged and analyzed by computers. The transducer used in this project is the stainless steel immersion electrode / resistive change transducer. Stainless steel immersion electrodes were used due to its high durability, highly sensitive nature and its high resistant to corrosion. Copper or aluminium electrodes tend to get corroded with time.

Immersion electrode is the immersion of the level sensor in a conductive material that is to be measured which is preferred due to the conductive nature of water to electricity, while resistive change means the variation of the effect of the input resistance from the negligible value to a value that appears infinite depending on the position of the electrode.

When the water level is not in contact with the electrode, the electrodes detect an infinite resistance compared to the input resistance, hence, zero volts (0V) approximately is applied across the input resistance. As the water level touches the electrodes, it detects a negligible resistance compared to the input resistance, thus, the entire input voltage is applied across the input resistance into the encoder circuitry.

## 3.4 CONTROLLER DESIGN ANALYSIS

The controller was needed to synchronize the input from the sensor to a CD4532 encoder whose logic level output are used to drive a display driver that decodes the logic levels to give a display in the seven segment display indicating the various water levels and also drive the relays controlling the sounder and the two water pumps.

An earth strobe is inserted into the water to provide an earth potential (0V) to the tank. Eight probes (stainless steel immersion electrodes) were inserted into the tank at different levels which form the input of the logic control circuit and are connected in parallel to the inverting circuits (IC CD4049 and IC CD4011) and to the supply voltage, $V_{cc}$ (12V) through a series resistor (10KΩ). The value of the resistor is such that it's infinite when compared to the resistance between the probes and the ground when the probes are not in contact with water, so that an almost zero volt is applied to the input of the inverters and the entire voltage is dropped across the resistor. When the probes come in contact with the water as the water rises, the value of the resistor is such that it's negligible compared to the resistance between the probes and the ground; as such almost the entire input voltage is applied to the input of the inverters. An inverter circuitry was required to change logic level (0 to 1) and (1 to 0) because the encoder used has an active low circuitry.

Thus, the outputs of the inverting drivers, which also are the input to the encoder circuitry, are always high (1) whenever the sensors are not in contact with water and low (0) whenever they are in contact with water. The truth table showing the input logic signal to the encoder and the output logic signal that are the inputs to the display driver and the switching circuit as shown in table 3.1.

**Table 3.1 Truth Table of the encoder circuitry**

| INPUTS | | | | | | | | ENABLE | OUTPUTS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D0 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | E | Q2/c | Q1/b | Q0/a |
| X | X | X | X | X | X | X | X | 1 | X | X | X |
| L | H | H | H | H | H | H | H | 0 | 0 | 0 | 0 |
| L | L | H | H | H | H | H | H | 0 | 0 | 0 | 1 |
| L | L | L | H | H | H | H | H | 0 | 0 | 1 | 0 |
| L | L | L | L | H | H | H | H | 0 | 0 | 1 | 1 |
| L | L | L | L | L | H | H | H | 0 | 1 | 0 | 0 |
| L | L | L | L | L | L | H | H | 0 | 1 | 0 | 1 |
| L | L | L | L | L | L | L | H | 0 | 1 | 1 | 0 |
| L | L | L | L | L | L | L | L | 0 | 1 | 1 | 1 |

The encoder circuitry operation is given in fig 3.9.

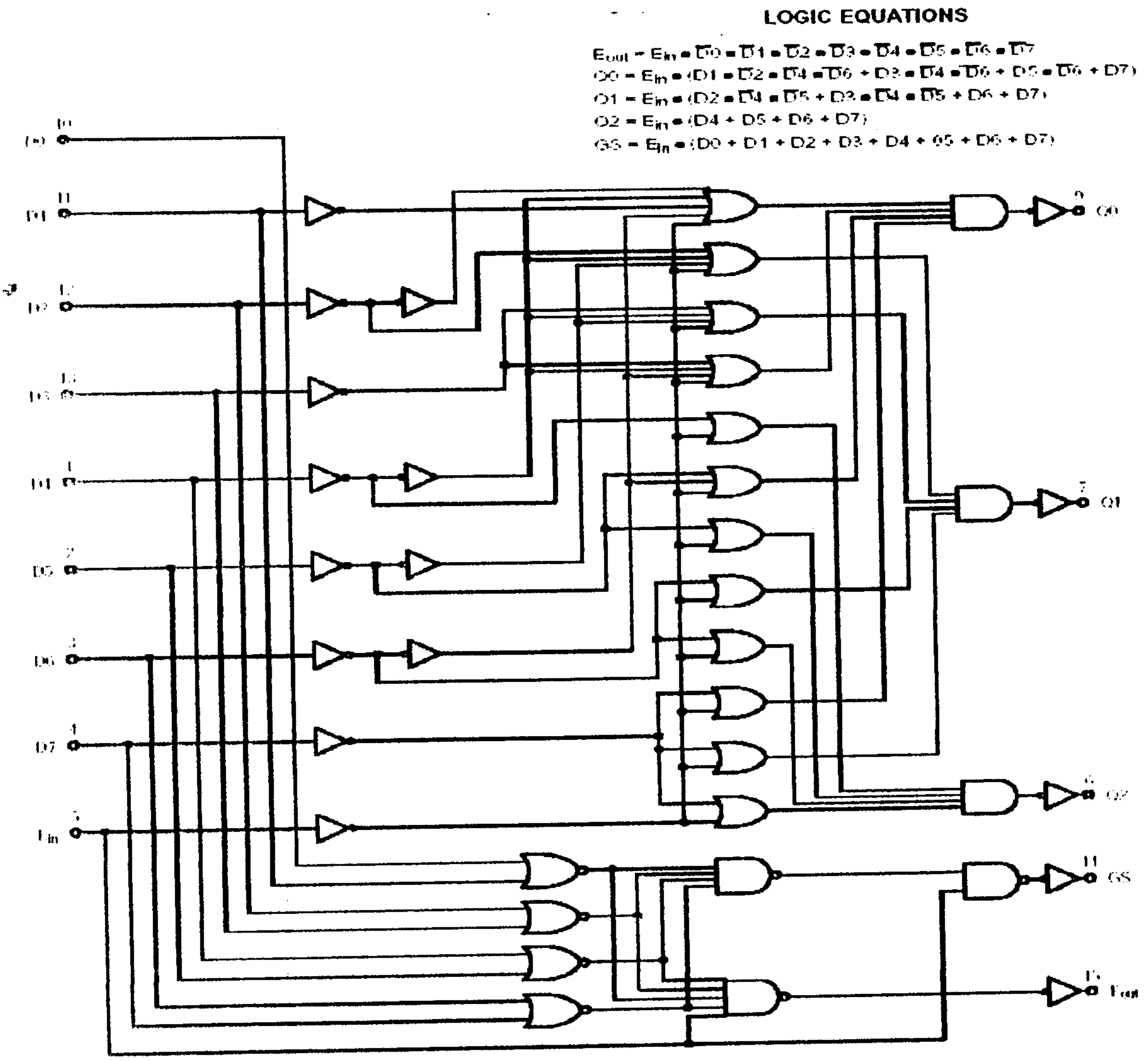


Fig. 3.9 Diagram of the Encoder Circuitry

The CMOS gate act as an inverter operates with voltages from 3V to 18V d.c. It operates with input currents between the ranges of 6μA to 2mA.

Choosing $I_{in}$ = 1.2mA; $V_{in}$ = 12V;

$R_{in} = V_{in} / I_{in} = (12/1.2x10^{-3}) = 10K\Omega$

The series resistor of the input circuit was 10KΩ as shown in fig 3.10

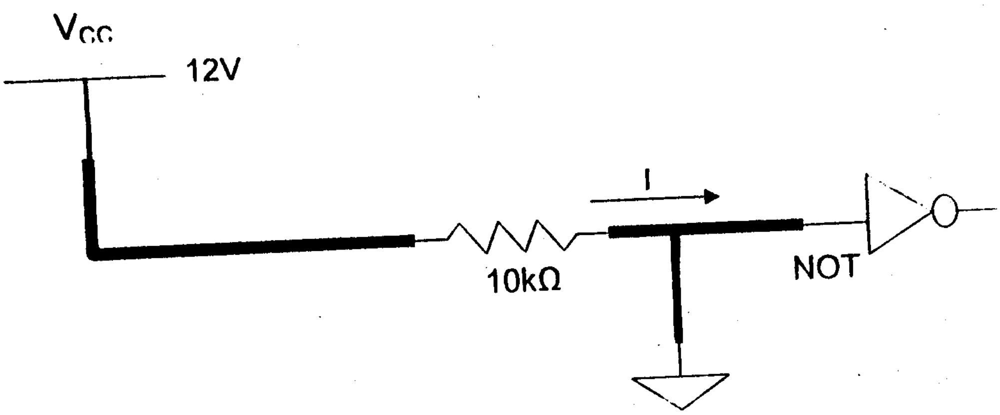


Fig. 3.10 Series Resistor of the Input Signal

The outputs logic level of the encoder, Qo, Q1, and Q2 were correspondingly used as inputs, a, b, and c to the display driver decoder and the switching circuits. The display driver decoder is a CD4511 I.C. which is switched by the encoder outputs logic level, decodes these logic levels and produces signals to the numeric seven segment display device. It also provides additional supply current to the display device and the truth table of the logic levels of the display driver is shown in table 3.2

## TABLE 3.2 TRUTH TABLE OF THE DISPLAY DRIVER

| INPUTS | | | 7- SEGMENT DISPLAY CODE | | | | | | | DISPLAY VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| a | B | C | A | b | c | D | E | F | G | |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 2 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 3 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 4 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 5 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 6 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 7 |

The display driver circuitry operation is shown in fig 3.11.

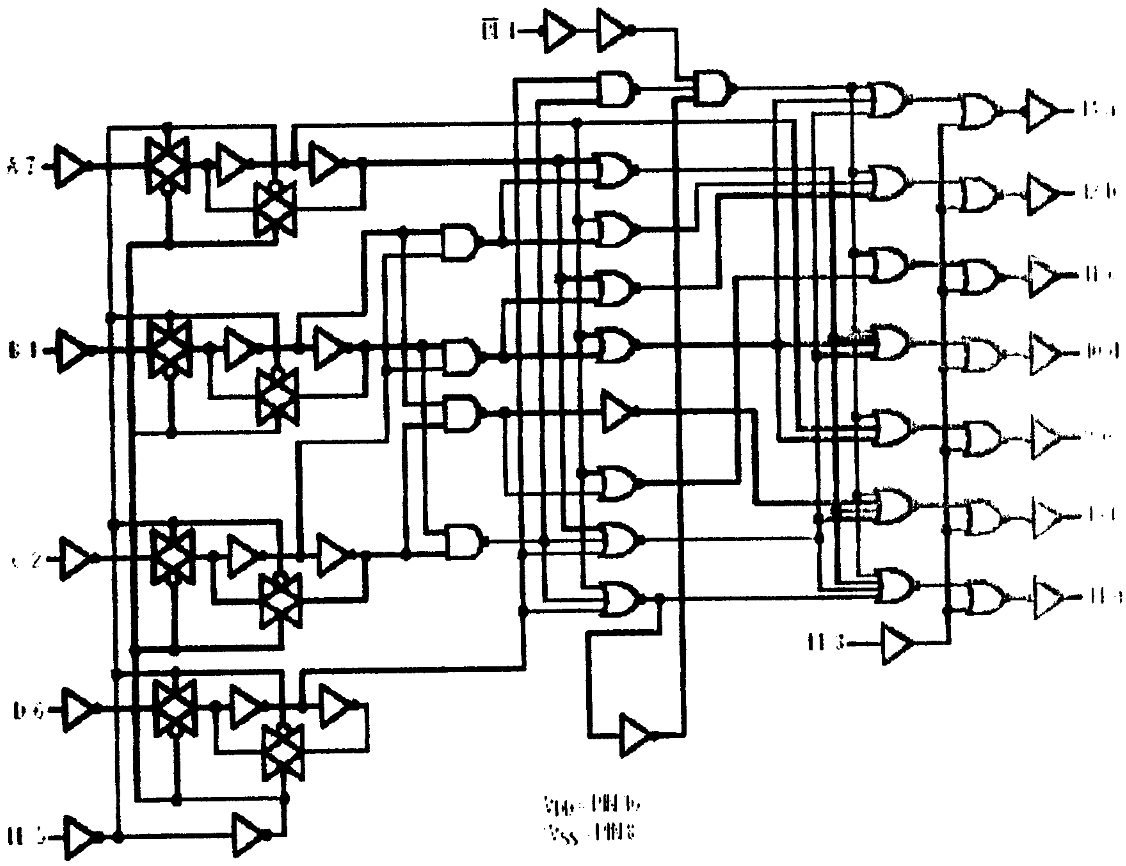

Fig. 3.11 Diagram of the Display Driver Operation

## 3.5 THE SWITCHING CIRCUIT

The logic output from the encoder is also used to drive the switching circuits whereby the outputs logic level forms the input combination of the various levels at which the various switches come ON.

The flood control system required a sounder to be operated to produce a sound when the water level reaches probe 3 corresponding to the quarter level of the underground basement or tank and should sound continuously until the water goes below this level. Also, when the water touches probe 5 corresponding to the half of the basement or tank, the control system is supposed to switch ON the primary pump (pump A) which drains water out of the basement into a nearby drainage pit where it could be used for other purposes. A secondary pump (pump B) should come ON (i.e. into operation) when the water level touches probe 7 corresponding to three-quarter of the basement or tank height and should continuously drain water to the drainage pit. The secondary pump (pump B) was required for a situation that could arise where the primary pump (pump A) fails or where the rate of flow of water (flood) is higher than the capacity of the primary pump (pump A).

From the encoder circuitry truth table, k-maps where drawn using the outputs logic level of the truth table for the situations stated above as shown below;

**TABLE 3.3 K-MAP FOR THE SOUNDER OPERATION**

| C \ BA | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 |

$F = C + B$ where F = output and "+" = logical "OR" operative.

The circuitry of operation of the sounder is shown in fig 3.12

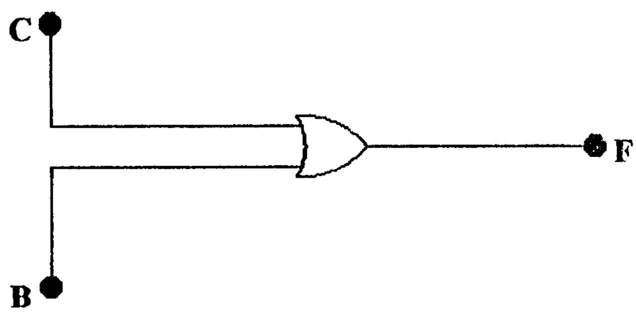


Fig. 3.12 Diagram of the sounder logic switching

Also, for the operation of the primary pump (pump A), a k-map was drawn as shown in table 3.4

**TABLE 3.4 K-MAP FOR PUMP A OPERATION**

| 1 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |

F = C where F = output

The circuitry of operation for pump A is shown in fig 3.13

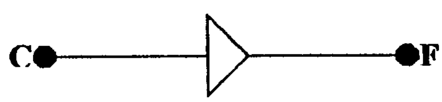


Fig. 3.13 Diagram of pump A logic switching

Lastly, the k-map for the secondary pump (pump B) is given in table 3.5

**TABLE 3.5 K-MAP FOR PUMP B OPERATION**

| C \ BA | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 |

F = BC where F = output

The circuitry of operation of the secondary pump is shown in fig 3.14.

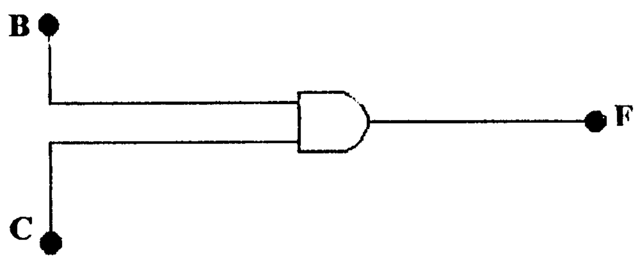


Fig. 3.14 Diagram of pump B logic switching

The weak signal output from the above circuitry operations are normally fed into a transistor which acts as a switch and a booster of the signals before they are used to ignite a relay that drives the primary and secondary pumps.

The transistor is used as an electronic switch that uses a weak control signal to turn ON or OFF an electronic device. The control signal is the output of the logic control circuit and the power level of these signals are normally weak, hence it's incapable of switching the device directly. However, these control signals are capable of providing enough base current drive signals to turn a transistor ON or OFF and the transistor in turn switches the device.

There are three types of transistor configuration (connection) viz;

1) Common Base (CB) configuration.

2) Common Emitter (CE) configuration.

3) Common Collector (CC) configuration.

In the common emitter (CE) configuration, the input signal is applied at the base and emitter junction and the output signal are taken out from the collector and emitter junction. This is the most versatile and most useful of the three configuration and is the only one capable of both a voltage gain and a current gain greater than unity. Due to its dynamic characteristic, the CE configuration was employed as shown in fig 3.15.

only one capable of both a voltage gain and a current gain greater than unity. Due to its dynamic characteristic, the CE configuration was employed as shown in fig 3.15.

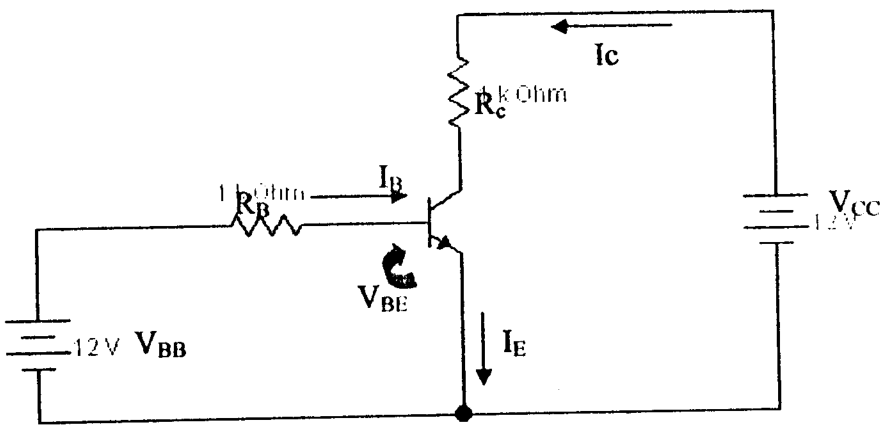


Fig. 3.15 Common Emitter (CE) Circuit Diagram

Now, $\beta = I_c/I_b$

$$I_c = \beta I_b$$

Also, $I_B = \dfrac{V_{BB} - V_{BE}}{R_B} = \dfrac{V_{BB}}{R_B}$

and $V_{CE} = V_{CC} - I_c R_c$

where $R_c$ = relay coil resistance

$V_{CC}$ = d.c. applied voltage

$V_{BB}$ = output voltage from logic control circuit

$I_C$ = collector current

$I_E$ = emitter current

$I_B$ = base current

$\beta$ ($h_{FE}$) = current gain

Also, $P_c = V_{CB} I_c = V_{CE} I_c$ = constant

where $P_c$ = collector power dissipation

The switching circuit of the pumps comprises of a 2SC1815GR silicon, NPN, unipolar transistor and a 12V, 10A relay. The transistor and relay values were;

$I_{Rmax}$ = 10A (maximum relay current); $I_c$ = 0.1A

$I_{cmax}$ = 0.15A (maximum collector current); $V_{CBO}$ ($V_{max}$) = 60V

Load resistance (relay) = 410Ω; $h_{FE}(\beta)$ = 200; Pc = 0.4W

Transistor base current, $I_B = \frac{I_c}{\beta} = \frac{0.1}{200} = 500\mu A$

Since, the relay with a cut-in voltage of 12V was used; 12V is expected to drop across the relay.

Thus, minimum relay current, $I_{min} = \frac{12}{410} = 29.27mA$

This shows that $I_c$ = 0.1A is within the safe region of operation of the transistor.

Voltage drop across $R_B$, $V_R$ = 12 - 0.4= 11.6 ($V_{BE}$ = 0.4 for silicon)

Base resistor, $R_B = \frac{V_R}{I_B} = \frac{11.6}{500x10^{-6}} = 23.2K\Omega$

Thus, 20KΩ resistor was chosen as a limiting resistor for the transistor base current.

The output signal of the transistor is used to ignite a relay which drives the pumps (pumps A and B). The relay is also an electronically controlled switch which are used in remote switching and high voltage (or high current) switching. Due to the importance in keeping electronic devices isolated from the a.c. power line, relays are useful to switch a.c. power while keeping the control signals electrically isolated.

An electromechanical relay was employed in this circuit which depends on the interaction of the magnetic field set by a fixed coil carrying an electric current and a movable steel armature. The coil is wound round an iron core and when current passes through the coil; the core becomes magnetized and attracts the pivoted movable steel armature. The armature is pulled into contact with the end of the core, and in doing so, presses two springs contacts together. The closing of the contacts completes the circuit which in turn drives the electronic or mechanical devices.

A diode is connected across the relay to damp the potential harmful e.m.f. of the relay coil as it switches OFF at the end of each process cycle and conducts the current induced away to the power line. The relay is used in the normally open (NO) mode, where the contacts close when the relay is energized.

The relay was of 12V, 10A value which is one of the normal voltage and current rating required to switch mains-powered devices running on alternating current. The a.c. powered device could be up to 240V a.c. mains which was the voltage used to power the two pumps. The electromagnetic relay is shown in fig 3.16.

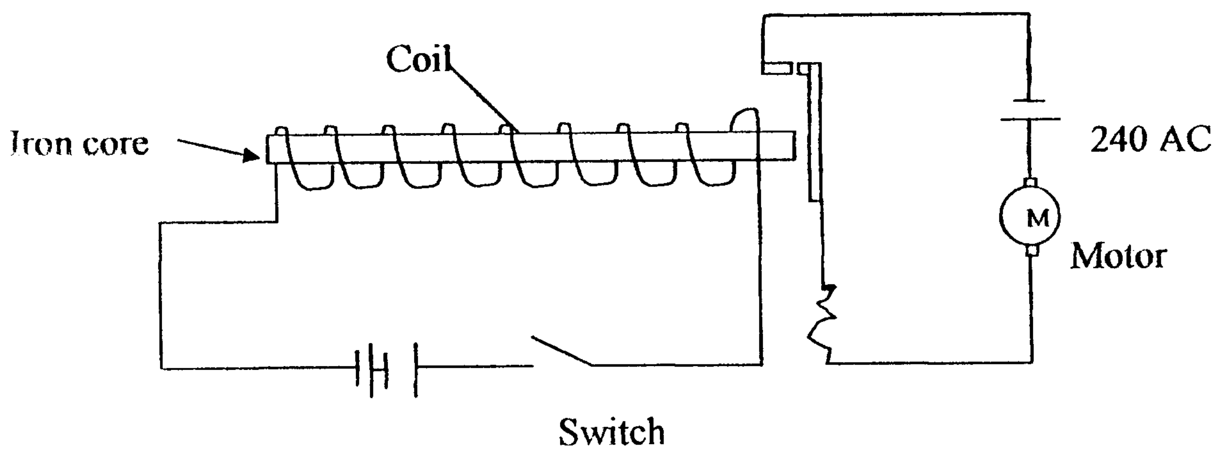


Fig. 3.16 Diagram of the operation of an Electromagnetic Relay

The sounder was switched using a silicon power transistor TIP31C, NPN, as a switch and a booster of current. The power transistor is used in a switching mode for power conversion and control and is normally held in the ON state by continual current signal at the control, or base terminal. When the signal is removed, the transistor automatically switches OFF. The power transistor was used in the common-emitter configuration as discussed above but this time, switches the device without the aid of a relay.

As shown above,

$\beta = I_c / I_B$

$I_B = V_{BB}/R_B$

But, $I_{cmax} = 3A$; $V_{CBO} = 60V$; $h_{FE}$ ($\beta$) = 40; $I_c = 9.4mA$

Transistor base current, $I_B = I_c/\beta = 9.4x10^{-3}/40 = 235\mu A$

Voltage drop across $R_B$, $V_R$ = 12- 0.4 =11.6($V_{BE}$ = 0.4 for silicon)

Base resistor, $R_B = V_R/I_B = \frac{11.6}{235x10-6} = 49.36K\Omega$

Thus, 47KΩ resistors were chosen as limiting resistor for transistor base current. Also, the $I_c$ = 9.4mA is within the safe region of operation of the transistor for it to switch the sounder.

## 3.6 INDICATION / OUTPUT SYSTEM

The design of the project is to be able to detect the water level of the flood waters in an underground basement or tank with the aid of transducers / detectors, indicate these levels using a visual display and control the flood out of the basement into drainage facilities with the aid of 240V a.c. mains powered electric water pumps.

In keeping with the above objective, a seven segment display light emitting diode (LED) display device was used to indicate each water level detected. This is a seven segment numeric indicator in which the segments obtain their luminosity from light emitting gallium arsenide or phosphate diodes and are operated at low voltages and low power. They fall into two categories, common anode (ca) and common cathode (cc).The common cathode (cc) mode was made use of in this project because it has the cathodes of all segments connected internally to a common terminal as shown in fig 3.17. Current sources are connected to the anodes, each through a series resistor.

A BCD to seven segment decoder was used to decode the outputs of the encoder and convert them into seven segment display codes which gives the values that are visually displayed by the seven segment LED's. The seven segment LED's display values 0-7 corresponding to the water levels 0-7.

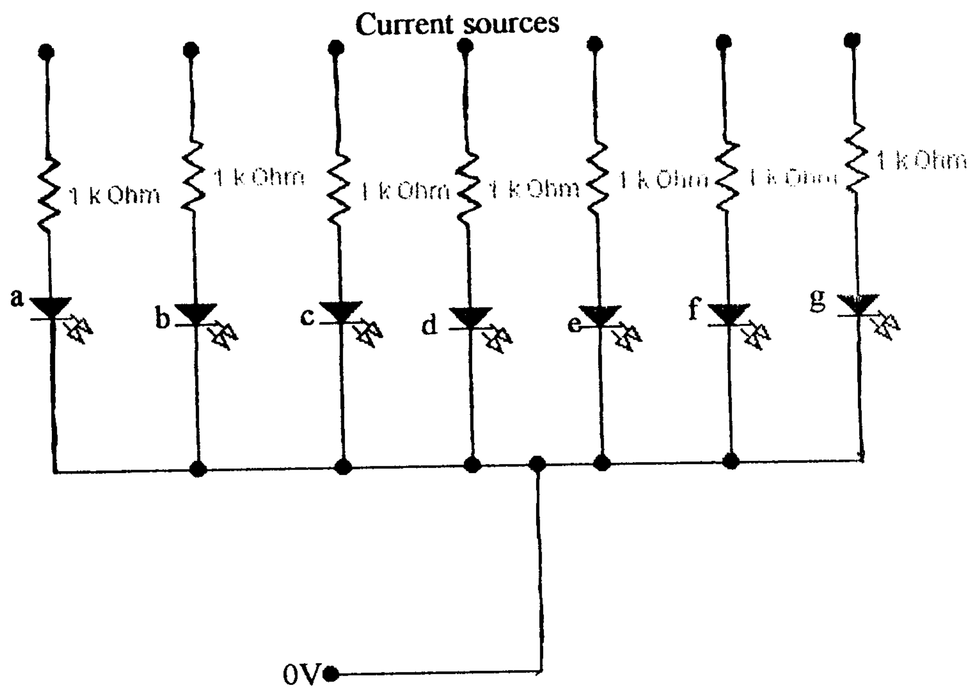


Fig. 3.17 Diagram of the common cathode mode of the seven segment display

LED's operates for input current between 10mA to 60mA. Let the input current, $I_d$ = 10mA and the forward voltage drop, $V_d$ =2V (typically for LED's). Voltage across limiting resistor, $V_R$ = supply voltage – voltage drop. $V_R = 12 - 2 = 10V$

$$R = \frac{V_R}{I_d} = \frac{10}{10\times10^{-3}} = 1000 = 1K\Omega$$

Thus, 1KΩ resistors were connected across each LED in the seven segment display.

A sounder was made use of to give an audio alarm when the water touches probe 3 signifying that the flood has reached a threatening level in case there are no operators present to check the visual display. The idea is to alert the operators who can decide to operate the flood control system manually to avoid the flood level getting higher. The sounder continues to ring until the water goes below this level and the alarm is cut-off. The sounder used was a 12V d.c. powered buzzer with a frequency of 300Hz.

When the water level touches probe 5, a 240V a.c. mains powered water pump engine (pump A) should operate because the pump is driven by the energized relay 1 and it continuously drains water out of the basement or tank to the drainage pit until the water goes below this level. For extreme situations (when pump A fails or the rate of flood is higher than the capacity of the pump), a secondary pump (pump B) should operate when the water touches probe 7 as it becomes driven by the energized relay 2 and should continuously drain water out of the basement into the drainage pit until the water goes below probe 7. The controller circuit arrangement is shown in fig 3.18.

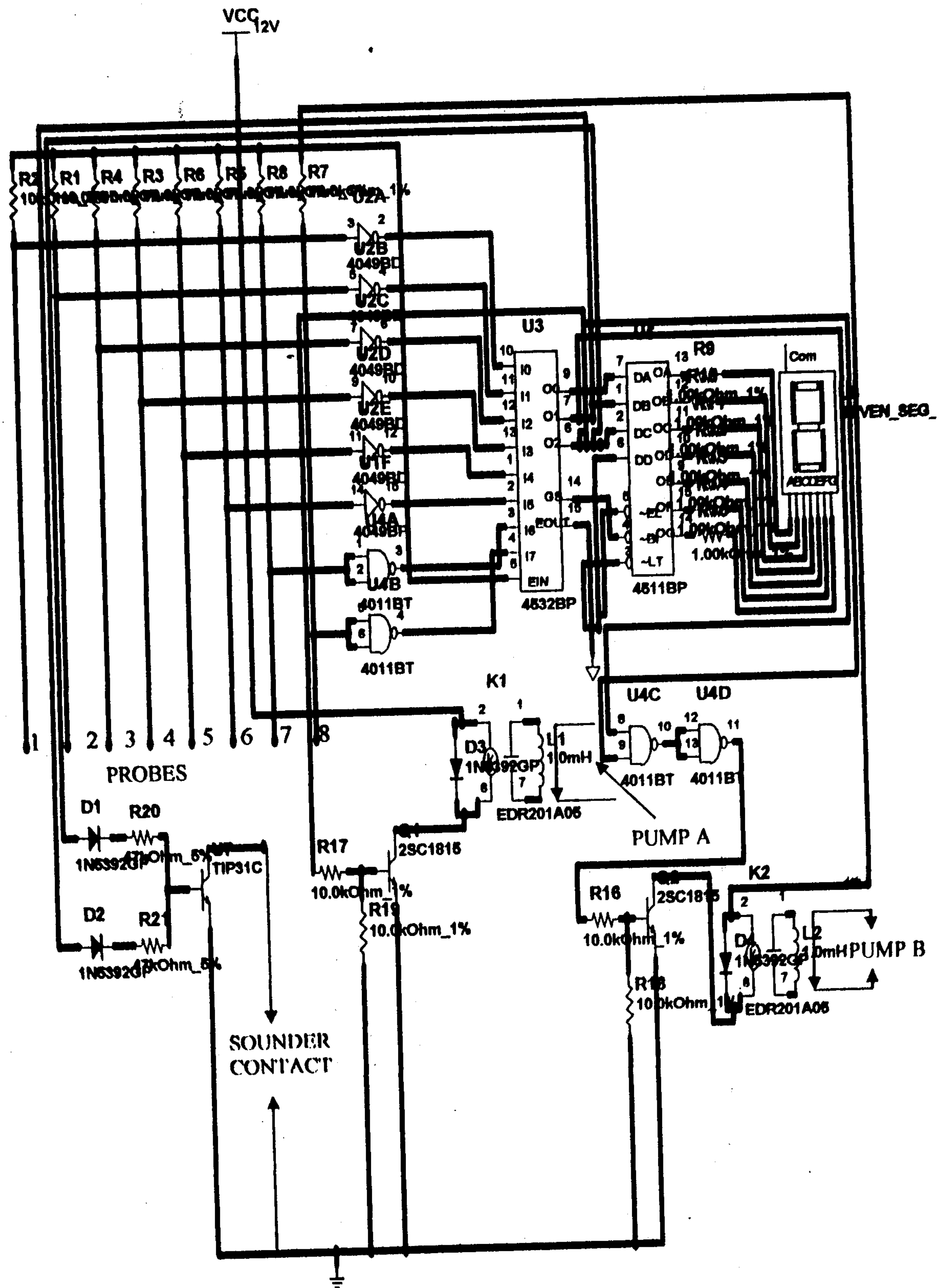


Fig. 3.17 Diagram of the arrangement of the Controller Circuit

# CHAPTER FOUR

# CONSTRUCTION, TESTING, RESULT, AND DISCUSSION OF RESULT

## 4.1 CONSTRUCTION

A prototype module of the flood level controller was constructed on a Vero board according to the circuit diagram shown in fig 3.7 and fig 3.18. The construction and assembly was done with the materials needed and was done with absolute care till the final assembly that resulted in the complete system as shown in fig 4.1. The finished model was housed in a tile box measuring 20cm x 15cm containing the circuit of the flood controller and the power supply unit. The height of the box was 8cm high and provision was made for the probes (electrodes) using AV outlets, two socket outlets was provided for the two electric water pumps, wire cable was brought out for the sounder, another wire cable was for the earth terminal and the seven segment display was provided to give the visual indication.

Tests were carried out on the constructed prototype module of the flood controller, to demonstrate the workability of the design. The results obtained from these tests were recorded. The functional block diagram of the flood level controller is shown in fig 4.2.

Fig. 4.1 Pictorial representation of the controller prototype

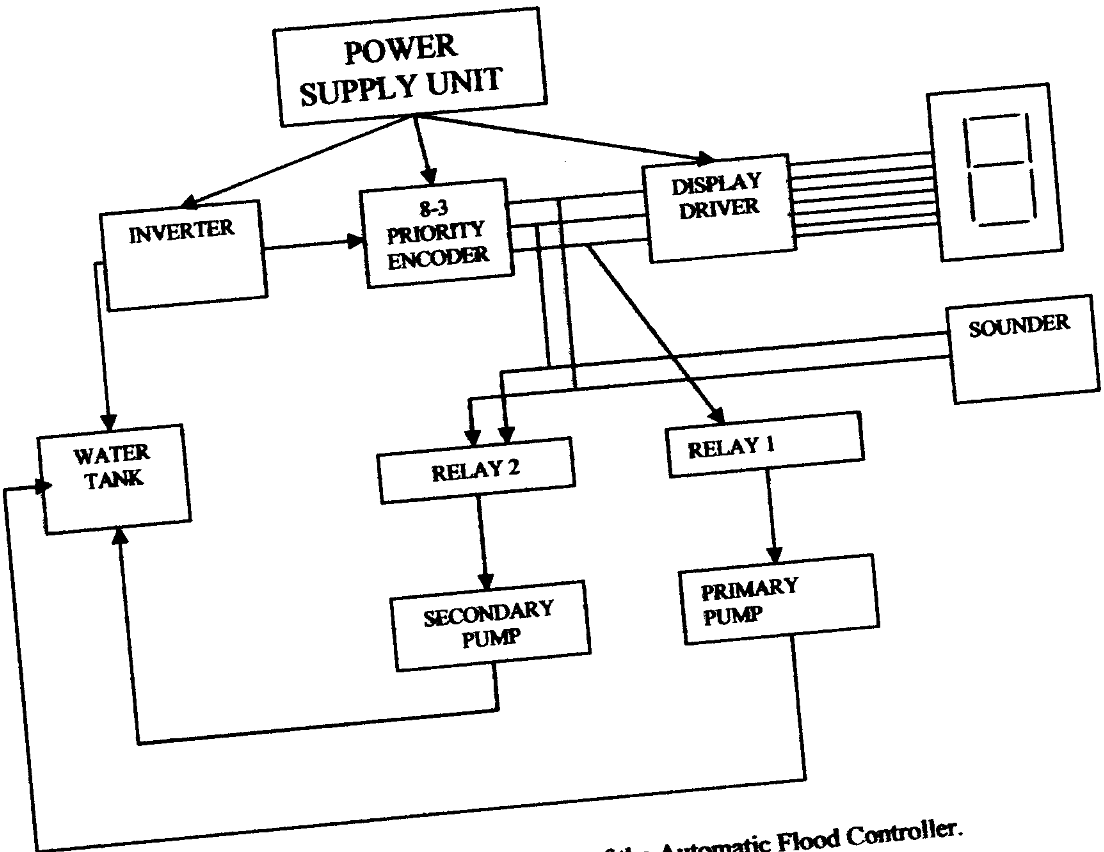


Fig. 4.2 Functional block diagram of the Automatic Flood Controller.

## 4.2 WATER LEVEL TEST AND RESULT

The eight probes (level sensors) were positioned in their appropriate levels in an empty earthed water tank. Water was poured into the tank to fill it to capacity and at each probe level, the seven segment display gave a visual indication of each level as recorded in table 4.1.

**TABLE 4.1 WATER LEVEL TEST RESULT**

| PROBES | LEVEL | SEVEN SEGMENT DISPLAY |
|---|---|---|
| | | 0 |
| 1 | 0 | 1 |
| 2 | 1 | 2 |
| 3 | 2 | 3 |
| 4 | 3 | 4 |
| 5 | 4 | 5 |
| 6 | 5 | 6 |
| 7 | 6 | 7 |
| 8 | 7 | |

When the water touched probe 3 (quarter of tank), the sounder came ON to give an audio alarm. When the water touched probe 5 (half of tank), the primary pump (pump A) came ON and started draining. When water touched probe 7 (three quarter of tank), the secondary pump (pump B) came ON and started draining.

## 4.3 SIGNAL TEST

The probes (sensors) have to pick up signals in the form of voltages and currents when the water touches them for the system to be functional. When this happens, the analogue signals of the water level produced by the transducers (sensors) are sampled and coded into digital signals by the gates of the inverters which are used by the flood controller to control the water level. Thus, different signal tests were carried out as against the expected values at different units of the circuit and were recorded.

### 4.3.1 POWER SUPPLY TEST AND RESULT

Test was carried out on the output of the transformer, rectifier smoothing capacitor and that of the voltage regulator after construction, to determine the observed values as against the expected values. This is shown in table 4.2.

TABLE 4.2 POWER SUPPLY TEST RESULT

| TEST POINTS | EXPECTED RESULT | OBSERVED RESULT |
|---|---|---|
| TRANSFORMER OUTLET | 15.000V | 14.860V |
| RECTIFIED OUTPUT | 19.800V | 19.786V |
| SMOOTHED OUTPUT | 19.6485V | 19.008V |
| REGULATED OUTPUT | 12.000V | 12.000V |

### 4.3.2 SENSOR TEST

The probes (sensors) were tested at the input to the inverters to get the value of the voltage that enters the controller so as to ascertain the control system's effectiveness. This was recorded in table 4.3.

TABLE 4.3 SENSOR TEST RESULT

| POSITION OF TEST POINTS | EXPECTED RESULT | OBSERVED RESULT |
|---|---|---|
| When water is touching any probe. | 0V | 0V |
| When water touches the probes. | 12V | 12V |

## 4.4 DISCUSSION OF RESULTS

The results obtained at each tests are hereby enumerated thus;

For the water level test, when the tank was empty, the seven segment display was OFF showing that there is no water yet in the tank. When water touched the probe 1 which is equivalent to the level 0, the display indicated the numeric number 0, showing that the water is just coming into the tank and is still at ground level. When the water touched probe 2, equivalent to level 1, the display indicated the numeric number 1, showing that water is rising up the tank. When the water touched probe 3, equivalent to level 2, the display indicated the numeric number 2, showing that the water is still rising in the tank and the sounder came ON giving an audio alarm. When the water touched probe 4, equivalent to level 3, the display indicated the numeric number 3, showing that the water keeps on rising with the audio alarm still blaring. When the water touched probe 5, equivalent to level 4, the display indicated the numeric number 4, showing that the water keeps rising in the tank. The primary pump comes ON at this level and starts draining water out of the tank with the audio alarm still blaring. When the water touched probe 6, equivalent to level 5, the display indicated the numeric number 5, showing that the water is still rising in the tank with the primary pump and sounder still operating. When the water touched probe 7, the display indicated the numeric number 6, showing that water still rises in the tank and the secondary pump comes ON and starts draining water out of the tank. The primary pump and sounder still operates at this level. When the water touched probe 8, the display indicated the numeric number 7, showing that the water is at full tank with both pumps and the sounder still operating.

For the power supply test, when the power supply switch was switched ON, the LED glows RED showing that power is in the circuit with a well regulated voltage of 12V, 1.5A circulating the controller circuit. The variations in result of this test came as a result of the fluctuations in voltage and frequency of the mains power supply.

For the sensor test, when the water level is not touching any probe, there is no indication by the seven segment display, showing that no signal comes into the controller circuit. When the water touches any of the probes, the seven segment display indicates some numeric numbers, showing that a signal of 12V comes into the controller circuit.

Hence, the model has been shown to be very efficient and reliable and is very much in conformity with the objective of the design.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

In conclusion, it is seen that the purpose of the design has been achieved since the test carried out shows that the constructed work met the stated objectives.

In the course of the design, consideration was given to operational characteristics, cost effectiveness and area of operation. Also, material selection was done to ensure durability, reliability and efficiency.

Incorporation of a seven segment display was done to make the device quite convenient for the user and it is easily adaptable for liquid level measurement and control, temperature level measurement and control, heat sensing for measurement and control, pressure head distribution of water for industrial and public use, e.t.c. All that is required is an appropriate transduction / detection element that will detect and convert the signals to electrical signals for use by the controller circuit.

It could also be applied in natural disaster monitoring that is dependent upon water regime (seasonal rise of water level). Before most of these natural disasters occur, nature tends to communicate this intelligence in the form of pressure head variation, where a digital signal processing (DSP) chip in application with error coding can be used to decode this intelligence and necessary preparation can be taken before disasters get to its full scale.

## 5.2 RECOMMENDATION

Having implemented the design as a prototype, the following recommendations are hereby made for the public and industrial application of this design.

It is worthy that my successor should employ a personal computer (PC) interface or a microcontroller interface to the encoder to get accurate level detection and better switching of the output system giving a more accurate output control. It is also recommended that a capacitive type sensor should be employed to take care of non-conductive liquids normally encountered in the industries.

# APPENDIX I

## LIST OF SYMBOLS

I = Current in amperes (A)

V = Voltage in volts (V)

R = Resistance in ohms (Ω)

PIV = Peak inverse voltage in volts (V)

C = Capacitor in farads (F)

H = High logic level "1"

L = Low logic level "0"

M = Electric motor

S = Switch

F = Frequency in Hertz (Hz)

β = Current gain ($h_{FE}$)

D = Diodes

# APPENDIX II

## LIST OF MATERIALS

1. One 240V, 50Hz / 15V, 500mA Transformer.
2. Eight 100V IN5392 Diodes.
3. Two 0.01μF Capacitor.
4. One LM317 Regulator.
5. Nine Stainless Steel Electrodes.
6. A bucket containing Industrial Water Sample.
7. Electric Cables / Wires.
8. A Mega ohmmeter.
9. One I.C. CD4049 Hex Inverting Buffers.
10. One I.C. CD4532 8-Input Priority Encoder.
11. 10KΩ Resistors.
12. 240Ω Resistors.
13. A 3KΩ Variable Resistor.
14. Two 12V, 10A Relays.
15. Two uni-polar Transistors 2SC1815GR.
16. A TIP 41C Power Transistor.
17. 47KΩ Resistors.
18. 1KΩ Resistors.
19. One Seven Segment Display.
20. A Packet of Floor Tiles.
21. A 30W Soldering Iron with Soldering Lead.

22. A DC / AC Digital Multimeter.

23. One I.C. CD4511 BCD to 7-Segment Display Driver.

24. One I.C. CD4011 Quad 2-Input Nand Gate.

25. A Veroboard.

26. Two Socket Outlets.

# APPENDIX III

## LIST OF FIGURES

# APPENDIX IV

## LIST OF TABLES

# REFERENCES


1) G. NIKOLODZE, D. MINTS, and A. KASTALSKY; Water Treatment for Public and Industrial Supply; Mir Publishers; Moscow-Russia, 1989, pp 1-30.

2) IKOLO OTARIGHO RAPHAEL (96/5186EE); Design and Construction of an Automatic Water Level Controller; Final Year Project Thesis; Federal University of Technology; Minna-Nigeria; February, 2002.

3) AWEDU PAUL OLATUNBOSUN (93/3535); Design and Construction of an Overhead Tank Water Level Indicator and Pump Actuating Device; Final Year Project Thesis; Federal University of Technology; Minna-Nigeria; March, 2000.

4) Engr. T.A. ABOGUNRIN; Tutor on Industrial Processes in Liquid Level Control; Ajaokuta Steel Company Ltd; Kogi-Nigeria; 2005.

5) OWEN BISHOP; Electronics Circuits and Systems; Newnes associates; Oxford-Great Britain; 1999; pp 153-211.

6) R.J.MADDOCK and D.M.CALCUTT; Electronics: A Course for Engineers; Longman Group Ltd; Essex-England; Second Edition; 1994; pp241-294.

7) PAUL HOROWITZ and WINFIELD HILL; The Art of Electronics; Cambridge University Press; Cambridge-Great Britain; Second Edition; 1989; pp 28-500.

8) V.K.MEHTA and SHALU MEHTA; Principles of Electronics; S.Chand and Company Ltd; New Delhi-India; Eight edition; 2003; pp 114-584.

9) B.L.THERAJA and A.K.THERAJA; A Textbook of Electrical Technology; S.Chand and Company Ltd; New Delhi-India; 2001; pp 1651-2055.

10) JACOB MILLMAN and CHRISTOS C. HALKIAS; Integrated Electronics; McGraw-Hill Book Company; Singapore-Malaysia; 1971; pp 87-620.