DESIGN AND CONSTRUCTION OF AN AUTOMATIC CONTROL OF WATER LEVEL IN AN OVERHEAD TANK, HAVING ALARMS AND CONTROL BACKUP FOR REFILLING FAILURE

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DECEMBER, 2009

DECLARATION

I hereby declare that this project work "Design and construction of an automatic control of water level in an overhead tank, having alarms and control backup for refilling failure" was carried out by me for the award of Bachelor of Engineering Degree in the Department of Electrical and Computer Engineering and has never been presented elsewhere.

--------------------------------------- 27/01/2010
Godwin Bioli Aboi Date

CERTIFICATION

This is to certify that the project work titled "Design and construction of an automatic control of water level in an overhead tank, having alarms and control backup for refilling failure" was carried out by Godwin Bioli Aboi with Registration Number 2004/18763EE, under the supervision of Engr. (Dr.) M. N. Nwohu and submitted to the Electrical and Computer Engineering Department, Federal University of Technology, Minna in partial fulfillment for the award of Bachelor of Engineering (B. Eng.) degree in Electrical and Computer Engineering.

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DEDICATION

This project is dedicated to my parents, Mr. and Mrs. J. S. Aboi for their love and support.

ACKNOWLEDGEMENT

My profound gratitude goes to God Almighty for giving me life and grace to see this day. I also wish to extend my thanks to my parents for their financial support and my siblings- Susan, Deanna, Florence, Anne and my cousins- Ruth, Zacharia for their encouragement. I wish to express my gratitude to my project supervisor, Engr. Dr. M. N. Nwohu for his constant scrutiny and advice. Finally, my thanks go to my friends, Ted, Floyd, Samuel, Chinedu, Chijioke, Uba, Nnamdi, Julius, Yinka, Gabriel and Ifeanyi for helping me out in many ways.

ABSTRACT

The project is a system designed to monitor the minimum and maximum level of liquid in a tank. It gives a signal to activate a tap when the liquid level falls below its maximum level and stops refilling when it reaches its maximum level. A red light emitting diode (LED) is switched on when it reaches its minimum level, and a green LED is switched on when it reaches its maximum level. And yellow LEDs are used to indicate the water levels in the tank. At a point below the minimum level, an alarm is activated in case the pump fails to refill, and at a point above the maximum level, another alarm is activated in case the pump does not stop refilling. However, where the maximum alarm point fails or is exceeded, the control backup switches the pump off.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The need and struggle for water cannot be over emphasized as the use of water has increased steadily over the century. It is unlikely that this trend will change the continued growth of population and the ever-increasing utilization of water. This situation has given rise to much concern for the availability of adequate water supply to accommodate the future needs of the society. Surface water resources are already being used to the maximum capacity in various parts of the world, for example, in the southern United States, water is used for farm irrigation, for recreation, for domestic use and for fountains.

Water is one of the basic necessities of life that finds wild application in agriculture, forestry, industries, power generation, for recreation and for domestic use. As hydrology provides much of the knowledge and understanding on which development and management of available water resources are based, they are of fundamental importance.

In 1965,[1] the United Nations Educational Science and Cultural Organization (UNESCO), initiated the international hydrological decade (IHD), a ten years program that provides an important impetus to international collaboration in hydrology. Many developing countries remain highly susceptible to disease because of contaminated and grossly inadequate water supply. This has been known in recent times by several droughts in the Sahel region of Africa in the period 1969 to 1974 and 1982 to 1985 [1].

As need arises on how water can be supplied in terms of quality and quantity, storage of water is also a necessity which brings about storing of water in tanks. The installation of these tanks in offices, industries and residential apartments ensure the continuity of flow of water. Some of these tanks are placed underground, some on ground level and some above ground level. Manually refilling these tanks can be very tedious and boring for the tank operator. This is the reason why automatic tank refilling system is necessary, as it is aimed at eliminating the burdens of the operator and manual control of the refilling system.

Hence, the design and construction of an automatic tank refilling system with liquid level indicators, having alarms and control backups for cases of refilling failures to monitor the minimum and maximum levels of liquids in a tank. It refills the tank when it falls below its maximum level and stops when it reaches its maximum level. Two control mechanisms are involved in correcting problems of over-flow. The first control stops the water flow in the tank when it reaches its maximum level and the second stops the flow of water into the tank in case the first control fails to work. This, of course, will avert the over-flow to its possible maximum level.

1.2 Aims and Objectives

Engineering is aimed at practising physical theories that make life better. This project is aimed at achieving the following:

1) Monitoring and refilling of a water tank.
2) Indication of water level in a tank.
3) Reduction of cost of hiring manpower to manually operate a water tank.
4) It eliminates the burdens of an operator, monitoring a water level of the tank and manually refilling it.
5) Adequate provision for alternative control in case of refilling errors.

1.3 Motivation

My motivation is as a result of the inadequate water supply, experienced in Niger state, where people have to waste their valuable time to search for water. Some people have to trek miles away with buckets to get water. I thought a way of solving this problem could be through the construction of a prototype of an over-head tank, which can be placed in public places or in private residence to ensure the continuity of water supply.

Furthermore, the water level in the overhead tank should be monitored to ensure adequate storage of water in the overhead tank. This, of course, is effectively done by incorporating an electrically controlled device that is mechanically inter-locked. Hence, the consideration of this project work.

1.4 Scope Of Work

The project is supposed to refill when the water level falls below its maximum level and at which a red LED is switched on until the water level reaches its maximum level. Between the minimum and maximum levels are some yellow LEDs which are switched on to indicate the water levels. As the tank liquid levels increases or decreases, so are the yellow LEDs switched on accordingly. When the water level reaches its maximum level, a green LED is switched on but switches off when the water level goes below its maximum level. Hence, the pumping machine stops pumping water into the tank.

However, if there is a problem that affects the normal operation of the pumping machine, the alarm is triggered on and consequently, the alternative control backup is activated to stop the pump. If the water is used up to the minimum level and the pump does not refill and it goes below its minimum level, the alarm is also activated. All the alarm tones show that the tank has some control problems and hence need check-up. The two control methods are used for the maximum level to ensure that water is not wasted and to prevent over-flow.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A water tank is a storage device used for holding and protecting water for later use; it is used to ensure continuity of supply of water. Water tanks are found both in domestic and industrial areas, as the need for water increases. Distribution storage tanks, serve two purposes: equalizing storage and emergency storage [2].

Equalizing storage is the volume of water needed to satisfy peak hour demands in the community. During the late night hours and early morning hours, when water demand is very low, high-lift pumps fill the tank. Distribution storage tanks are built on ground level on hilltops higher than the service area. In areas with flat topology, the tanks may be elevated above ground on towers in order to provide adequate water pressures, or ground-level storage tanks with booster pumping may be provided.

Tanks can either be installed over-head or under-ground and their mode of pumping water differs as in over-head, there is always enough pressure to push the water down to the pump, but in under-ground, there is no pressure to supply the pump, hence, a pumping mechanism is needed to supply the necessary pressure to transport the water to the pump.

An automatic tank refilling system is one, in which a mechanism monitors the water level and appropriately controls the refilling process. It is controlled by the action of relay switches and transistors, acting as switches. The control can be made more sensitive by the introduction of Darlington pair, which is the combination of two or more transistors in cascade.

Sensors for automatic tank refilling systems generally use the principle of conductivity of water. Two probes are inserted at both ends of the tank. If the water level rises to a certain level, it causes a link between the two probes, thereby sending sufficient voltage to switch a transistor, acting as a switch in a circuit. The sensitivity of the sensor can be enhanced by the introduction of Darlington pair, which is the combination of two or more transistors in cascade. It has advantage of its gain being more than a single transistor.

Sensing circuits for automatic tank refilling systems can be designed in different ways using the same general technique, depending on the sensitivity and desired behavior of the system. Other techniques for sensing include the use of infra-red sensors, of which water is not allowed to touch the infra-red device.

2.2 History of Water Tanks

There is much archaeological evidence to indicate that ancient people were concerned with their water supply. Wells were sufficient for small communities, and rivers provided enough water for civilizations along the Tigris and Euphrates, the Nile and the Indus rivers; but as population grew, wells had to be dug deeper and water had to be brought in from more distant sources. These ancient systems included storage reservoirs at water sources, canals and aqueducts for water conveyance to points of use and water distribution system. The outstanding features of this system were the 11 aqueducts totaling 359 miles (578 kilometers) in length of which 30mi were supported on stone arches that delivered some 50000000 gallons (189000000 liters) of water to the city daily. The water was distributed from large storages to public fountains and baths by an elaborate system of lead pipes [3].

During the middle ages, water supplies were largely neglected and epidemic caused by waterborne organisms were common. In the 17th and 18th centuries, distribution water utilization cast-iron pipes, aqueducts and pumps were installed in London and Paris [3]. During the 19th century, the pollution of most water supplies became so serious that slow-sand filtration was initiated and by the end of the century, the realization that diseases could be transmitted by water led to the use of sterilizing chemicals, usually chlorine compounds [3].

To ensure continuity of water supply after treatment, water is pumped either into the distribution system or to the elevated storage location, such as a water tank. For adequate distribution, water system must operate under pressure. In some cases, the gravity drop of water from its elevated storage location provides enough pressure; otherwise, it is supplied by a pumping station at adequate pressure ranging between 30 and 100 pounds per square inch (2 and 7 kilograms per centimeter square) [3]. Many communities base water pressure requirement on what it thought to be adequate to fight fire, where pressure of up to 75 pounds per square inch are sometimes necessary. Materials used in transporting water to homes and industries includes pipes of cast iron, steel, concrete and asbestos cement. Meters record water usage at the site of consumption and charges are levied to help pay for the operation and maintenance of the system.

2.3 History of Automation

One of the first automatic control was James watt's use of the fly ball governor in 1987, to keep the steam engine, he invented at constant speed [4]. An earlier example was Edmund Lee's (England 1745) use of a small pilot windmill to keep a large windmill faced into the wind direction. The Dutch windmill of the 17th century was kept facing the wind by the action of an auxiliary wave that moved the entire upper part of the mill. Roman engineers maintained water level for their aqueduct system by means of floating valves that opened and closed at appropriate levels. The most famous example from the industrial revolution is the device that regulated steam engine to maintain constant engine speed despite a changing load [4].

The first theoretical analysis of a control system, which presented a differential equation model of the watt governor, was published by James Clerk Maxwell, the Scottish physician, in the 19th century [5]. The 1930s saw the development of electrical feedback in long-distant telephone amplifiers and of the general theory of the servomechanism, by which a small amount of power controls a very large amount and makes automatic corrections. The pneumatic controller, basic to the development of early automated systems in the chemical and petroleum industries and the analogue computer followed. All of these developments formed the basis for elaboration of control-system theory and applications during World War 2, such as anti aircrafts batteries and fire-control systems.

2.4 History of transistors

The transistor was invented in 1947 to 1948 by three American physicists, John Bardeen, Walter H. Brattain and William B. Shockley at the American telephone and telegram company's bell laboratories [6]. The transistor proved to be a viable alternative to the electron tube and by the late 1950s, low heat generation, high reliability and low power consumption made possible a breakthrough in the miniaturization of complex circuitry. During the 1960s and 1970s, transistors were integrated into integrated circuits, in which a multitude of components (example; diodes, resistors and capacitors) are formed on a single chip of semiconductor material.

The first commercial application of transistors was for hearing aids and pocket radios during the 1950s. With their small size and low power consumption, transistors were desirable substitutes for the vacuum tube (known as valves in Great Britain). They were used to amplify weak electrical signals and produce audible sounds. Transistors also began to replace vacuum tubes in the oscillator circuit used to generate radio signals, especially after structures were developed to handle the higher frequencies and power levels involved. Low-frequency, high-power applications, such as power supply inverters that convert alternating current (AC) into direct current (DC), have also been transistorized. Some power transistors can now handle currents of hundreds of amperes at electric potentials over a thousand volts.

By far, the most common application of transistors today is in computer memory chips including solid-state multimedia storage devices for electronic games, cameras and MP3 players, and microprocessors, where millions of components are embedded in a single integrated circuit. Here, the voltage applied to the gate electrode, generally a few volts or less, determines whether current can flow from the transistor's source to its drain. In this case, the transistor operates as a switch, that is, if current flows, the circuit involved is on, and if not, it is off. Similar applications of transistors occur in complex switching circuits used throughout modern telecommunications systems. The potential switching speeds of these transistors now exceed a gigahertz or more than a billion on-and-off cycles per second.

CHAPTER THREE

DESIGN AND CONSTRUCTION

3.1 Methodology

The method employed in the design is based on the conductivity property of water to send information to some transistors in Darlington pair which activates the base current, thereby sending signals from the emitter to the collector. Some relay switches were used for stopping it. Multiple points sensing technique was used for the water level indicators. The pulse generating property of a 555 timer is also employed in producing sound to the speaker.

The circuit design of the automatic tank control system can be represented with the block diagram below.

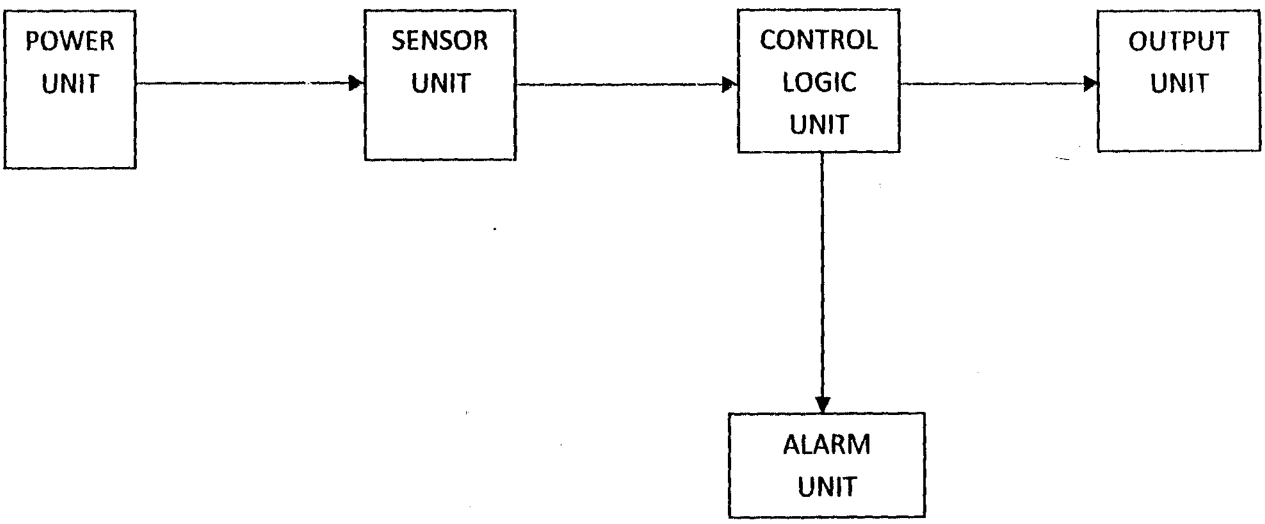


Figure 1: Block diagram.

The block diagram consists of the power unit, the control logic unit, the alarm unit and the output unit which controls the tap and the Light Emitting Diodes (LEDs).

The power supply unit was designed to supply 9 volts regulated Direct Current (DC) voltage. A 230 to 12 volts step-down Alternating current (AC) transformer was used as the power input to the circuit, with its primary terminal connected to the AC mains supply from

Power Holding Company of Nigeria, PHCN and its secondary terminals connected to a bridge rectifier. The bridge rectifier circuit is made up of four diodes which convert the 12 volts AC from the transformer to 12 volts DC to the circuit. The voltage at this stage is not stable, hence, the need for smoothening. A filtering capacitor (C_1) is used to filter out the ripples, when connected across the positive and negative terminals of the power supply. Again, at this point, if the voltages from the mains supply increases or decreases, it will affect the output from the capacitor, so a regulator is needed to stabilize the voltage. Therefore, an L7809 regulator is used, which gives an output voltage of 9 volts. In selecting a regulator to use in a circuit, it is important to note that the regulator value to be used should have at least 2 volts below what is to be supplied to it.

3.2 The power supply unit

The power supply unit comprises the transformer, bridge rectifier, capacitor and the regulator. Each of these components will be discussed in details later.

Transformer only

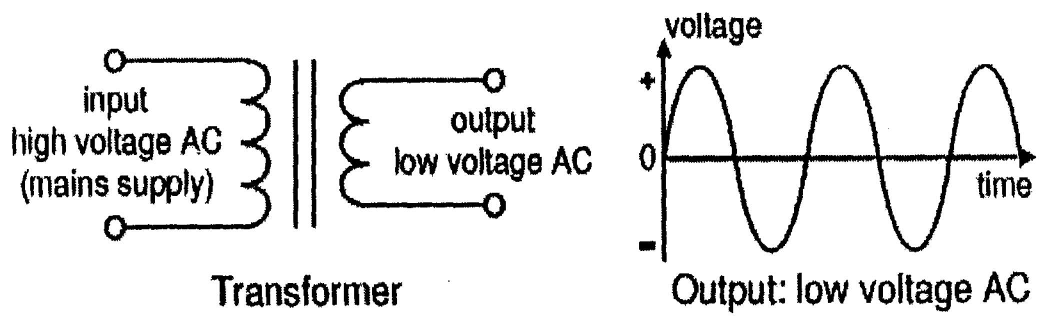


Figure 2: Diagram of the output waveform from a transformer.

In 1831, English physicist Michael Faraday demonstrated the phenomenon of electromagnetic induction. The concept is best understood in terms of lines of force that describe the direction and strength of a magnetic field. When a second, independent loop of wire is immersed in a changing magnetic field, a voltage will be induced in the loop. The voltage will be proportional to the time rate of change of the number of lines of forces enclosed by the loop. If the loop has two turns, such induction occurs in each turn, and twice the voltage results, if the loop has three turns, 3 times the voltage results, and so on. The concurrent phenomena of mutual induction between the coils and self-induction in each coil form the basis of transformer action. For a power transformer to do its job effectively, the coils must be coupled tightly and must have high self-induction. That is, almost all the lines of force enclosed by the primary also must be enclosed by the secondary, and the number of lines of forces produced by a given rate of change of current must be high. Both conditions can be met by wrapping the primary and secondary coils around an iron core [7].

Iron core increases the number of lines of force generated in the transformer by a factor of about 10,000. This property of iron is referred to as permeability. The iron core also contains the lines so that the primary and secondary coils can be separated spatially and still closely coupled magnetically. With the principles of the transformer firmly established, American industrialist George Westinghouse and his associates made several key refinements that made practical transformers possible. The iron core was constructed of thin sheets of iron cut in the shape of the letter E. Coils of insulated copper wire were wound and placed over the center element of the core. Straight pieces of iron were laid across the ends of the arms to complete the magnetic circuit. This construction still is common today. Note how the low-voltage and high-voltage windings are stacked on top of each other.

In an ideal transformer, all lines of force pass through all the turns in both coils. Because a changing magnetic field produces the same voltage in each turn of the coil, the total voltage induced in a coil is proportional to the total number of turns. If no energy is lost in the transformer, the power available in the secondary is equal to the power fed into the primary. In other words, the product of current and voltage in the primary is equal to the product of current and voltage in the secondary. Thus, the two currents are inversely proportional to the two voltages, and therefore, inversely proportional to the turns ratio between the coils. This expression of power and current in a transformer is true only for an ideal transformer. Practical limitations prevent the perfect transformer from being constructed.

The key properties of importance in transformer core design include:

- Permeability
- Saturation
- Resistivity
- Hysteresis loss [8].

Electrical resistivity is desirable in the core because it minimizes energy losses resulting from eddy currents. Furthermore, increase in permeability and saturation has often been sought for in the design of transformers in order to minimize losses. However, hysteresis undermines the efficiency of a transformer. A variety of core materials, including silicon iron in various forms, have been used. Transformer efficiency is defined as follows

$$E = \frac{P_{out}}{P_{in}} \times 100 \quad \text{---} (1)$$

where,

E= efficiency in percent

P_{out} = transformer power output in watts

P_{in} = transformer power input in watts

Losses in a transformer are the result of copper losses in the windings and core losses. The copper losses vary with the square of the current; the core losses vary with the input voltage magnitude and frequency. Because neither of these quantities depends on the power being consumed by the load, power transformers are rated by the volt-amperes (VA) that flow through them. The regulation specification of a power transformer is a measure of the transformer's ability to maintain a constant output voltage under varying loads. The primary voltage is held constant at the value required to produce the rated voltage on the secondary at full load [9]:

$$R = \frac{V_{so} - V_{sfl}}{V_{sfl}} \times 100 \quad \text{--------------------} \quad (2)$$

where,

R = regulation in percent

V_{so} = secondary voltage under no load

V_{sfl} = secondary voltage under full load.

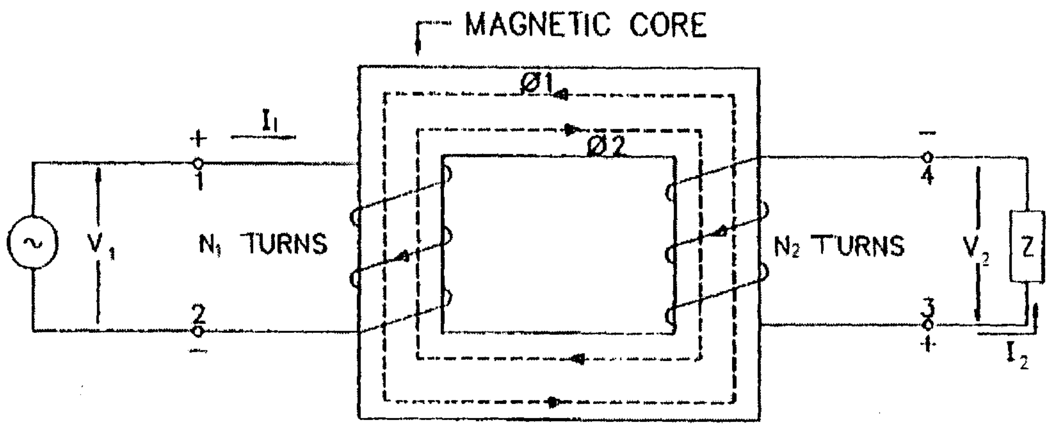


Figure 3: Diagram of the internal structure of a Transformer.

Although no transformer is ideal in its characteristics, transformers approach their ideal characteristics in the operating range for which they were designed. The ideal transformer has no coil resistance and no core losses, so that it has no power loss. It also has no leakage inductance, because the permeability of the core is infinite, and the core material is able to carry an infinite amount of flux without saturating. Therefore, the mutual inductance is also infinite. The capacitance in an ideal transformer is negligible [10]. The equations for an ideal transformer are given as follows:

$$V_1 I_1 = V_2 I_2 \quad (3)$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \quad (4)$$

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} \quad (5)$$

where,

V_1 = voltage in the primary

V_2 = voltage in the secondary

I_1 = current in the primary

I_2 = current in the secondary

N_1 = turns in the primary

N_2 = turns in the secondary

Transformer + Rectifier

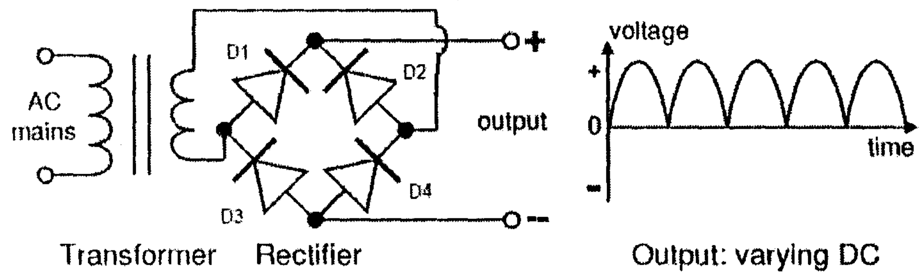


Figure 4: Diagram of the output waveform from a transformer and a rectifier.

Bridge Rectifier

The full-wave rectifier requires a center-tapped transformer. The bridge rectifier is an alternative implementation of the full-wave circuit. This rectifier uses four diodes and does not require a center-tapped transformer. During the positive half cycles of the input voltage, *Vi* is positive and the current is conducted through diode D1 and diode D2. Meanwhile, diodes D3 and D4 will be reverse-biased. During the positive half cycle, because two diodes are conducting, the output voltage will be $Vi - 2VDO$. During the negative half cycle, the voltage *Vi* will be negative, and diodes D3 and D4 are forward-biased. During positive half cycle, the reverse voltage across D3 can be determined from the loop formed by D3 and D2 as

$$VD3(reverse) = VO + VD2(forward) \text{ --- } (6)$$

where,

Vi = Input voltage

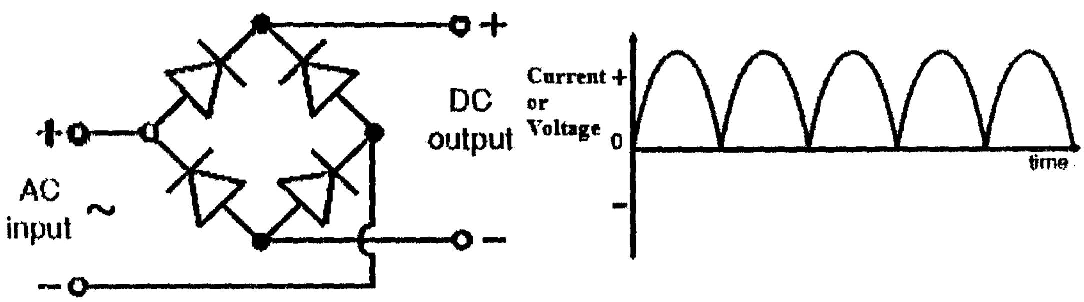
VDO = Voltage drop across the conducting diode

$VD3$ = Voltage across diode 3

$VD2$ = Voltage across diode 2

VO = Output voltage

Bridge rectifiers are available in special packages containing the four diodes required. It is called a full-wave rectifier because it uses the entire A.C wave (both positive and negative sections). 1.4V is used up in the bridge rectifier because each diode uses 0.7V when conducting and there are always two diodes conducting. Bridge rectifiers are rated by the maximum current they can pass and the maximum reverse voltage they can withstand (this must be at least three times the supply r.m.s voltage so the rectifier can withstand the peak voltages) [11].



Transformer + Rectifier + Smoothing

Figure 5: Diagram of the output waveform from a rectifier.

Alternating pairs of diodes conduct, changing over the connections so the alternating directions of AC are converted to the one direction of DC [12].

Peak Inverse Voltage (PIV) Rating for diodes,

$$V_{dc} = \frac{2}{\pi} \times V_{max} \text{(For full wave)} \text{ ------------------------------------ (7)}$$

$$V_{max} = \frac{\pi}{2} \times V_{dc} = \frac{\pi}{2} \times 12 = 18 \cdot 85 \text{ volts.}$$

$$\text{PIV} = V_{max} = 18 \cdot 85 \text{ volts.}$$

Diode Rating (apply a safe factor of 2)

18.85 × 2 = 37.70 volts.

This is approximately 38 volts.

Transformer + Rectifier + Smoothing

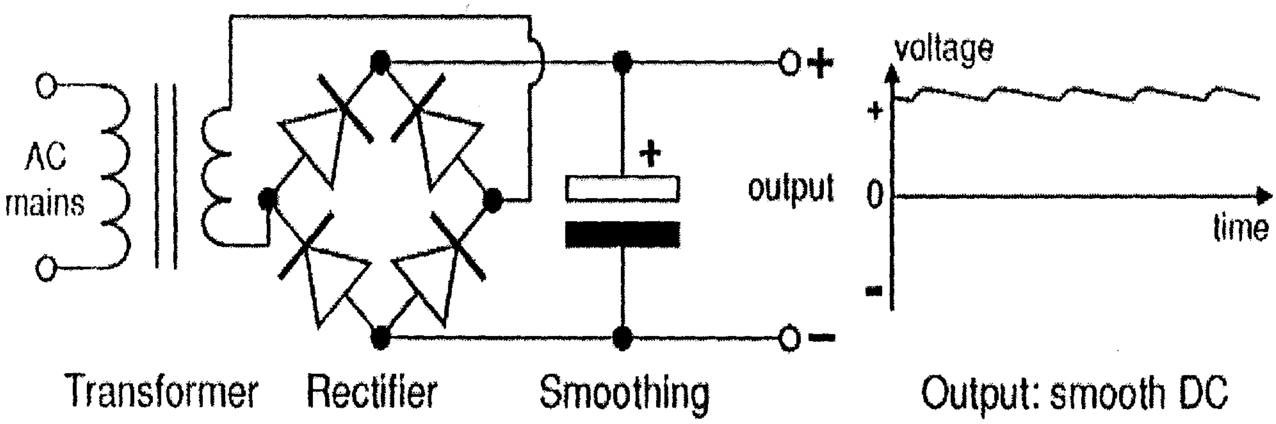


Figure 6: Diagram of the output waveform from a capacitor.

Smoothing

Smoothing is performed by a large value of electrolytic capacitors connected across the DC supply to act as a reservoir, supplying current to the output when the varying D.C voltage from the rectifier is falling. The diagram shows the unsmoothed varying DC (dotted line) and the smoothed DC (solid line). The capacitor charges quickly near the peak of the varying DC, and then discharges as it supplies current to the output.

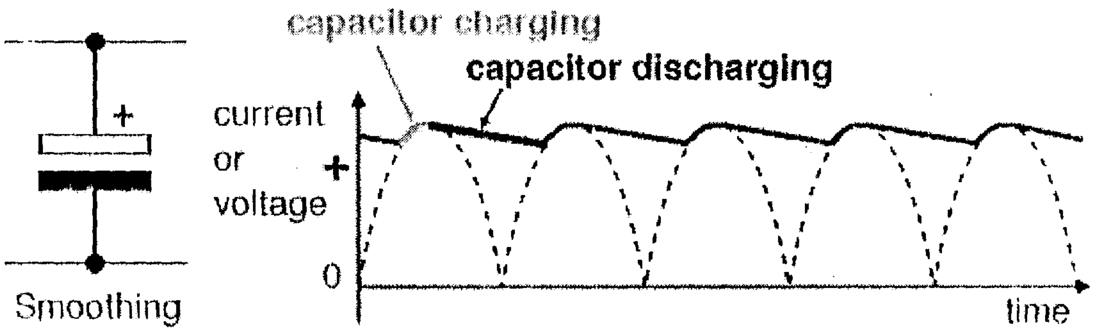


Figure 7: Diagram of waveform produced by a capacitor.

Note that smoothing significantly increases the average DC voltage to almost the peak value (1.4 × r.m.s value). For example 6V r.m.s AC is rectified to full wave DC of about 4.6V r.m.s (1.4V is lost in the bridge rectifier), with smoothing this increases to almost the peak value giving 1.4 × 4.6 = 6.4V smooth DC [12].

Smoothing is not perfect due to the capacitor voltage falling a little as it discharges, giving a small ripple voltage. For many circuits a ripple which is 10% of the supply voltage is satisfactory and the equation below gives the required value for the smoothing capacitor. A larger capacitor will give fewer ripples. The capacitor value must be doubled when smoothing half-wave DC.

Smoothing capacitor for 10% ripple, $C = \dfrac{5 \times I_o}{V_s \times f}$ -- (8)

C = smoothing capacitance in farads (F)

I_o = output current from the supply in amps (A)

V_s = supply voltage in volts (V), this is the peak value of the unsmoothed DC

f = frequency of the AC supply in hertz (Hz), 50Hz in the UK

CAPACITOR CALCULATIONS

For 17% ripple content, V_P after filtration with a peak voltage V_P

V_R = Ripple voltage

$$V_R = \frac{17}{100} \times V_P$$

But V_p = Regulated supply + Voltage drop across rectifier circuit

V_P = (12 + 1.2) volts = 13.2volts.

$$V_R = \frac{17}{100} \times 13 \cdot 2 = 2 \cdot 244 \text{ volts.}$$

Time between cycles $dt = \frac{1}{2}T = \frac{1}{2} \times \frac{1}{f}$

where T is the period for one cycle and f is the frequency = 50Hz.

$$dt = \frac{1}{2} \times \frac{1}{50} = \frac{1}{100} = 0 \cdot 01 \text{ seconds.}$$

the current rating of the diode is 1amp.

$$I = C\frac{dv}{dt} \quad \text{-- (9)}$$

where $dV = V_R$ and C is the capacitance value.

$$I = C\left(\frac{2\cdot 244}{0\cdot 01}\right)$$

$$C = \frac{0\cdot 01}{2\cdot 244}\times 1 = 0\cdot 00445633F = 4456\cdot 33\mu F$$

In this project, 4500μF was used because it is the nearest value, available in the market.

Transformer + Rectifier + Smoothing + Regulator

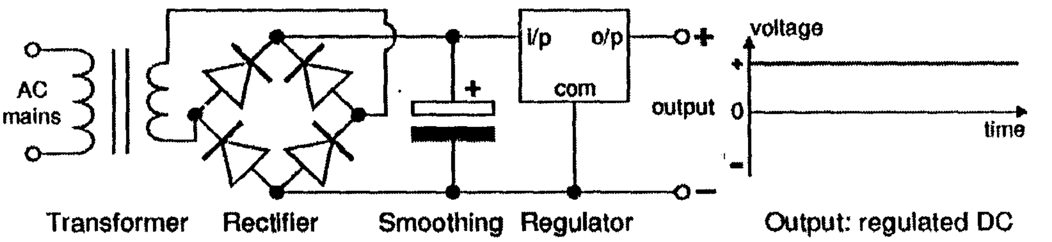
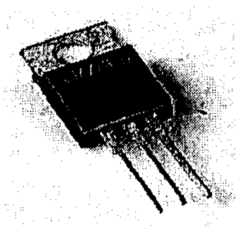


Figure 8: Diagram of the output waveform from a regulator.

The regulated DC output is very smooth with no ripple. It is suitable for all electronic circuits.

Regulator



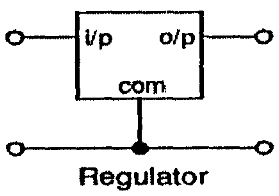


Figure 9: Diagram of a regulator.

Voltage regulator ICs are available with fixed (typically 5, 9, 12 and 15V) or variable output voltages. They are also rated by the maximum current they can allow to pass through them. Negative voltage regulators are available, mainly for use in dual supplies.

Most regulators include some automatic protection from excessive current (overload protection) and overheating (thermal protection).Many of the fixed voltage regulator ICs has 3 leads and look like power transistors, such as the 7805 +5V 1A regulator shown above. They include a hole for attaching a heat sink if necessary [12].

3.3 THE SENSOR UNIT

The sensor unit consists of the water transmitting section and the signal amplifier. The signal amplifier circuit consists of transistors, arranged as Darlington pairs in the common emitter configuration as shown below.

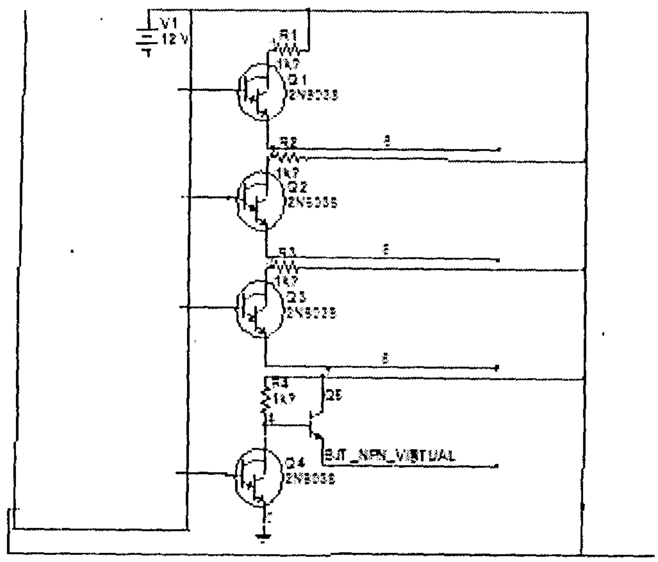


Figure 10: Diagram of the sensor unit.

To eliminate high base current requirements, Darlington configurations are commonly used. They are available in monolithic or in isolated packages. Darlington configuration presents a specific advantage in that it can considerably increase the current switched by the transistor for a given base drive. The saturation voltage for the Darlington is generally more than that of a single transistor of similar rating with corresponding increase in on-state power loss. During switching, the reverse-biased collector junction may show hot-spot breakdown effects that are specified by reverse-bias safe operating area (RBSOA) and forward-bias safe operating area (FBSOA). Normally, a well-designed switching aid network constrains the device operating well within the safe operating areas (SOAs) [13].

3.3.1 The Water Transmitting Unit

The water transmitting section uses the conductivity property of water. In this case, when the water rises to the level of the first probe, which is connected directly to the V_{cc} of the circuit, a base current is transferred to the transistors, which then switches on the transistor, thereby, sending the voltage to the other side of the tank, which contains the other probes. The probes at this stage are connected to the amplifier unit to be amplified, as the resistivity of water is high.

3.3.2 The Amplifier Unit

This helps to increase the sensitivity of the voltage, being sent through the water. As the resistivity of water is high, the voltage might not be enough to switch on the Light Emitting Diodes (LEDs) and the relays. Darlington pairs are introduced, however, to increase the sensitivity of the voltage signal.

This unit consists of S9014 NPN transistors, arranged in Darlington pair in the common emitter configuration. The transistors have a current gain of approximately 200 each. Due to the high impedance characteristic of water, a 1kΩ resistor is connected across the collector of the transistor Q_1, to link with the base current. The current at the collector I_{c1} of Q_1 is:

$$I_{c1} = \frac{V_{cc}}{R_1} \quad \text{------------------------------} \quad (10)$$

$$= \frac{9}{1000} = 0 \cdot 009\, Amps.$$

The base current I_{b1} is

$$I_{b1} = \frac{I_{c1}}{h_{fe}} \quad \text{------------------------------} \quad (11)$$

where h_{fe} = (200 x 200, this is from the gain of a Darlington pair) is the current gain of the transistor

$$I_{b1} = \frac{0 \cdot 009}{40000} = 0.00000023\, Amps \cdot$$

The value of the base current is low, but sufficient to turn on the transistor. KN3904 transistors are placed before the relays as they can accommodate the current a relay draws when it switches on and are very cheap for the design.

3.4 The Control Logic Unit

The control logic unit is responsible for the control of the switching.

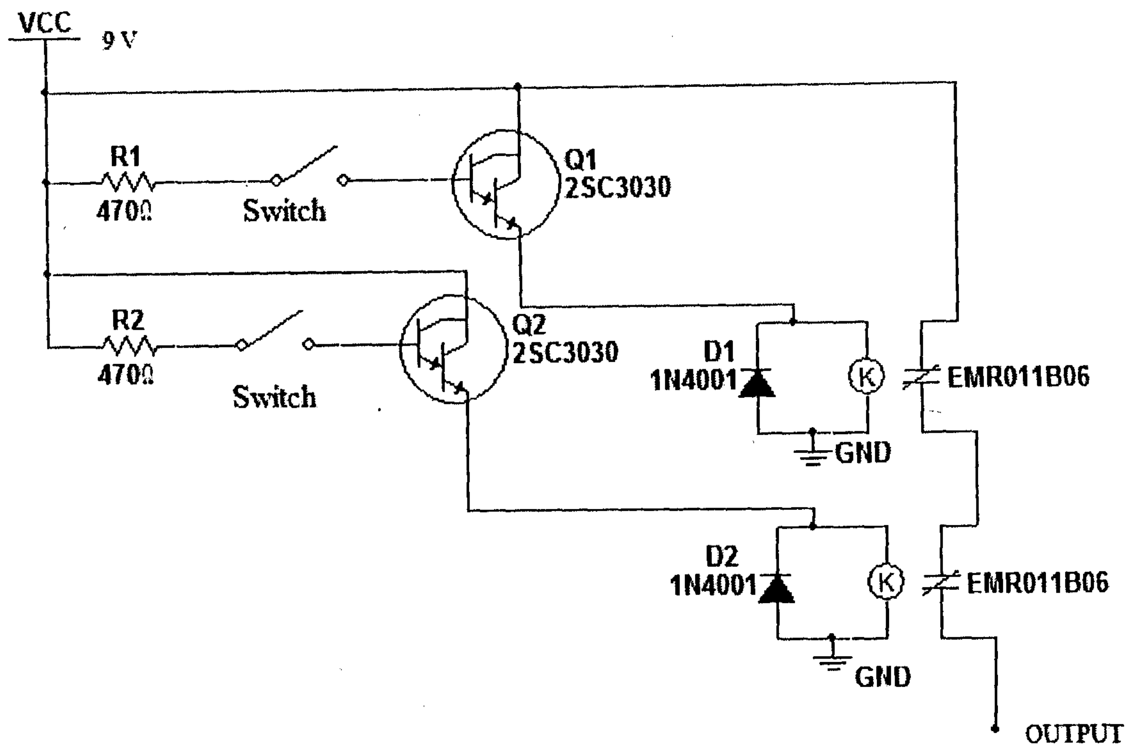


Figure 11: Diagram of the control logic unit.

The switching is done by the transistors in Darlington pair and the relays. When the input and output probes of the tank are linked by the water, a base current flows from the first transistor, which switches the second transistor on, thereby, sending a voltage signal to the relay for switching. The transistor placed before the relay should have a high current rating because of the high voltage drawn when relays switch on.

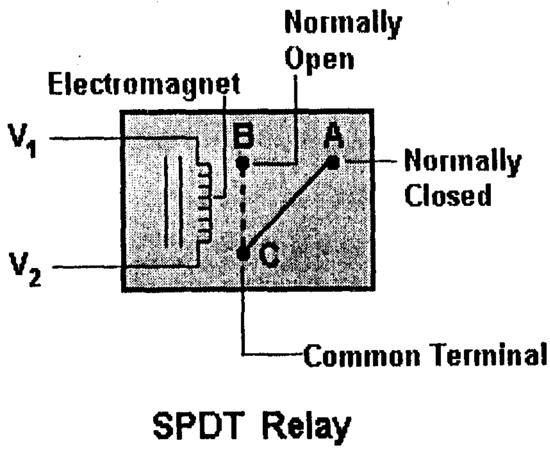


Figure 12: Diagram of the internal structure of a relay.

A simple electromagnetic relay is an adaptation of an electromagnet. It consists of a coil of wire surrounding a soft iron core, an iron yoke, which provides a low reluctance path for magnetic flux, a movable iron armature, and a set, or sets of contacts. The armature is hinged to the yoke and mechanically linked to a moving contact or contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay shown in figure 11 is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the Printed Circuit Board (PCB) via the yoke, which is soldered to the PCB.

When an electric current is passed through the coil, the resulting magnetic field attracts the armature and the consequent movement of the movable contact or contacts either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing.

If the coil is energized with DC, a diode is frequently installed across the coil, to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to circuit components. Some automotive relays have diode inside the relay case. Alternatively a contact protection network, consisting of a capacitor and resistor in series, may absorb the surge. If the coil is designed to be energized with AC, a small copper ring can be crimped to the end of the solenoid. This "shading ring" creates a small out-of-phase current, which increases the minimum pull on the armature during the AC cycle [14].

3.5 The Alarm Unit

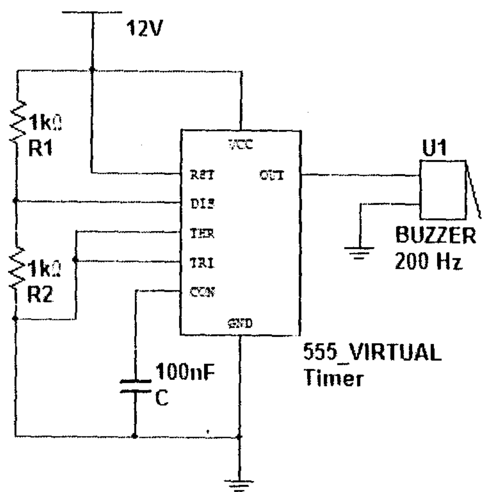


Figure 13: Diagram of the alarm unit.

The alarm unit is made up of a buzzer and a 555 timer. The buzzer produces the sound output from the pulse generated by the 555 timer. The "555" integrated circuit is a general-purpose timer used for various functions. In this experiment, we explore its use as an astable multivibrator, or oscillator. Connected to a capacitor and two resistors, it will oscillate freely, driving the LEDs on and off with a square-wave output voltage. This circuit works on the principle of alternately charging and discharging a capacitor. The 555 timer begins to discharge the capacitor by grounding the discharge terminal when the voltage detected by the threshold terminal exceeds 2/3 the power supply voltage (V_{cc}). It stops discharging the capacitor when the voltage detected by the trigger terminal falls below 1/3 the power supply voltage. Thus, when both threshold and trigger terminals are connected to the capacitor's positive terminal, the capacitor voltage will cycle between 1/3 and 2/3 power supply voltage in a "saw tooth" pattern. As soon as the discharge terminal on the 555 timer goes to ground potential, a transistor inside the 555 timer connected between that terminal and ground turns on, (the capacitor's discharging current only has to go through the 1k- resistor). The result is an RC time constant that is much longer for charging than for discharging, leading to a charging time greatly exceeding the discharging time.

The 555 timer output terminal produces a square-wave voltage signal that is "high" (nearly V_{cc}) when the capacitor is charging, and "low" (nearly 0 volts) when the capacitor is discharging. This alternating high/low voltage signal drives the two LEDs in opposite modes: when one is on, the other will be off. Because the capacitor's charging and discharging times are unequal, the "high" and "low" times of the output square-wave form will be unequal as well. This can be seen in the relative brightness of the two LEDs: one will be much brighter than the other, because it is on for a longer period of time during each cycle. The equality or inequality between "high" and "low" times of a square wave is expressed as the wave's duty cycle. A square wave with a 50% duty cycle is perfectly symmetrical, (i.e. its "high" time is precisely equal to its "low" time). A square wave that is "high" 10% of the time and "low" 90% of the time is said to have a 10% duty cycle. In this circuit, the output waveform has a "high" time exceeding the "low" time, resulting in a duty cycle greater than 50%. The audio detector (or an oscilloscope) is used to evaluate the different voltage waveforms produced by this circuit. The output frequency or charge/discharge times are explained by different resistor values and capacitor values [15]. A 555 timer in asynchronous form is connected as shown below:

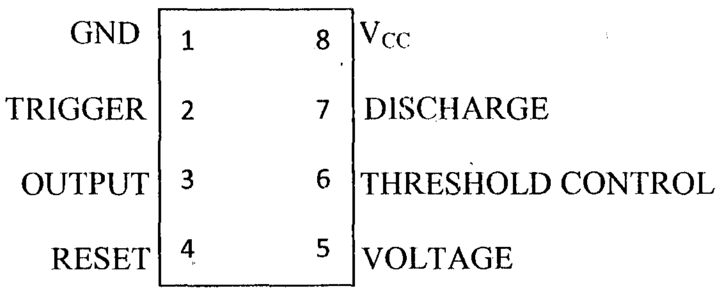


Figure 14: Pin configuration of a 555 timer.

Astable multivibrator using a 555 timer is connected as shown below:

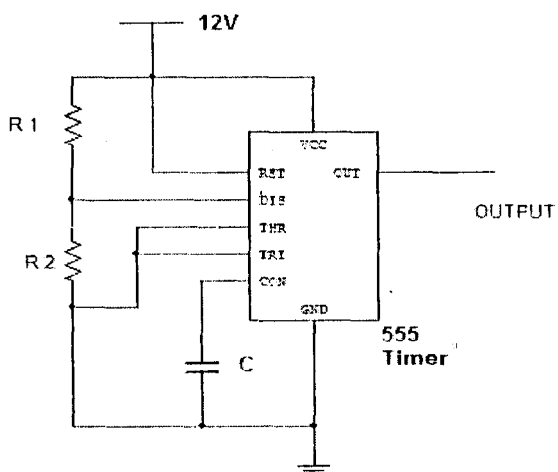


Figure 15: Internal diagram of a 555 timer.

FOR TIMER 1,

Time taken to charge from $\frac{1}{3}$ to $\frac{2}{3}$ $V_{cc} = T_{on} = 0 \cdot 693RC$ [16]

$$T_{on} = 0 \cdot 693(R_1 + R_2)C \text{ -------------------------------- } (12)$$

$$= 0 \cdot 693(1000 + 470) \times 0 \cdot 1\mu F$$

$$= 0 \cdot 00010187 \sec$$

Time taken to discharge from $\frac{2}{3}$ to $\frac{1}{3}$ $V_{cc} = T_{off} = 0 \cdot 693RC$

$$T_{off} = 0 \cdot 693 \times 1000 \times 0 \cdot 1\mu F \text{ -------------------------------- } (13)$$

$$= 0 \cdot 693 \times 1000 \times 0 \cdot 1\mu F$$

$$= 0 \cdot 0000693 \sec$$

$$F = \frac{1}{T} \text{ -------------------------------- } (14)$$

$$T = T_{on} + T_{off} = (0 \cdot 00010187 + 0 \cdot 0000693) = 0 \cdot 00017117 \sec$$

$$F = \frac{1}{0 \cdot 00017117} = 5842.14524Hz$$

$$F = 5.84214524KHz.$$

FOR TIMER 2,

Time taken to charge from $\frac{1}{3}$ to $\frac{2}{3}$ $V_{cc} = T_{on} = 0.693RC$

$$T_{on} = 0.693(R_1 + R_2)C$$

$$= 0.693(1000 + 1000) \times 0.1\mu F$$

$$= 0.0000693 \sec$$

Time taken to discharge from $\frac{2}{3}$ to $\frac{1}{3}$ $V_{cc} = T_{off} = 0.693RC$

$$T_{off} = 0.693 R_1 C$$

$$= 0.693 \times 1000 \times 0.1 \mu F$$

$$= 0.0000693 \sec$$

$$F = \frac{1}{T}$$

$$T = T_{on} + T_{off} = (0.0001386 + 0.0000693) = 0.0002079 \sec$$

$$F = \frac{1}{0.0002079} = 4810.00481 Hz$$

$$F = 4.81000481 KHz$$

Duty cycle $\frac{T_{on}}{T} = \frac{0.0001386}{0.0002079} = 0.667$

3.6 The Output Unit

The output terminal is made up of the LEDs and the tap control. Light emitting diodes, commonly called LEDs, are just tiny light bulbs that fit easily into an electrical circuit. They do dozens of different jobs and are found in all kinds of devices. Among other things, they form the numbers on digital clocks, transmit information from remote controls light up watches and tell you when your appliances are turned on. Collected together, they can form images on a jumbo television screen or illuminate a traffic light. But unlike ordinary incandescent bulbs, they don't have a filament that will burn out, and do not get hot. They are illuminated solely by the movement of electrons in a semiconductor material, and they last just as long as a standard transistor. The calculation for the LED resistance is given below:

V_{supply} = 9volts

$V_{LED} = 2volts$

$I_{LED} = 20mA$

$$R = \frac{V}{I} \quad \text{--} \quad (15)$$

$V = V_{supply} - V_{LED}$

$V = (9 - 2)$ volts $= 7$ volts

$$R = \frac{7}{0 \cdot 02} = 350\Omega$$

A smaller value was not used because it will allow greater current to pass through the LED, thereby, causing damage to it. The water in the water tank serves as the base resistance.

A buzzer or beeper is a signaling device, usually electronic, typically used in automobiles, household appliances such as microwave ovens, or game shows. It consists of a number of switches or sensors connected to a control unit that determines which button was pushed or a preset time has lapsed, and usually illuminates a light on the appropriate button or control panel, and sounds a warning in the form of a continuous or intermittent buzzing or beeping sound.

Initially, this device was based on an electromechanical system which was identical to an electric bell without the metal gong (which makes the ringing noise). Often these units were anchored to a wall or ceiling and used the ceiling or wall as a sounding board. Nowadays, it is more popular to use a ceramic-based piezoelectric sounder which makes a high-pitched tone. Usually these were hooked up to "driver" circuits which varied the pitch of the sound or pulsed the sound on and off.

The word "buzzer" comes from the rasping noise that buzzers made when they were electromechanical devices, operated from stepped-down AC line voltage at 50 or 60 cycles.

Other sounds commonly used to indicate that a button has been pressed are a ring or a beep [17]. A buzzer was used because of its sensitivity and high quality of sound it produces.

The tap in this project is represented by an electric motor. This was done due to the difficulty in constructing a mechanical tap using gears and the control of the tap such that, no water flows as it is switched off. The tap action (off and on) is controlled by the relay switches, which monitors the water level and refills the tank appropriately.

The circuit diagram, containing all the various units combined is as shown below:

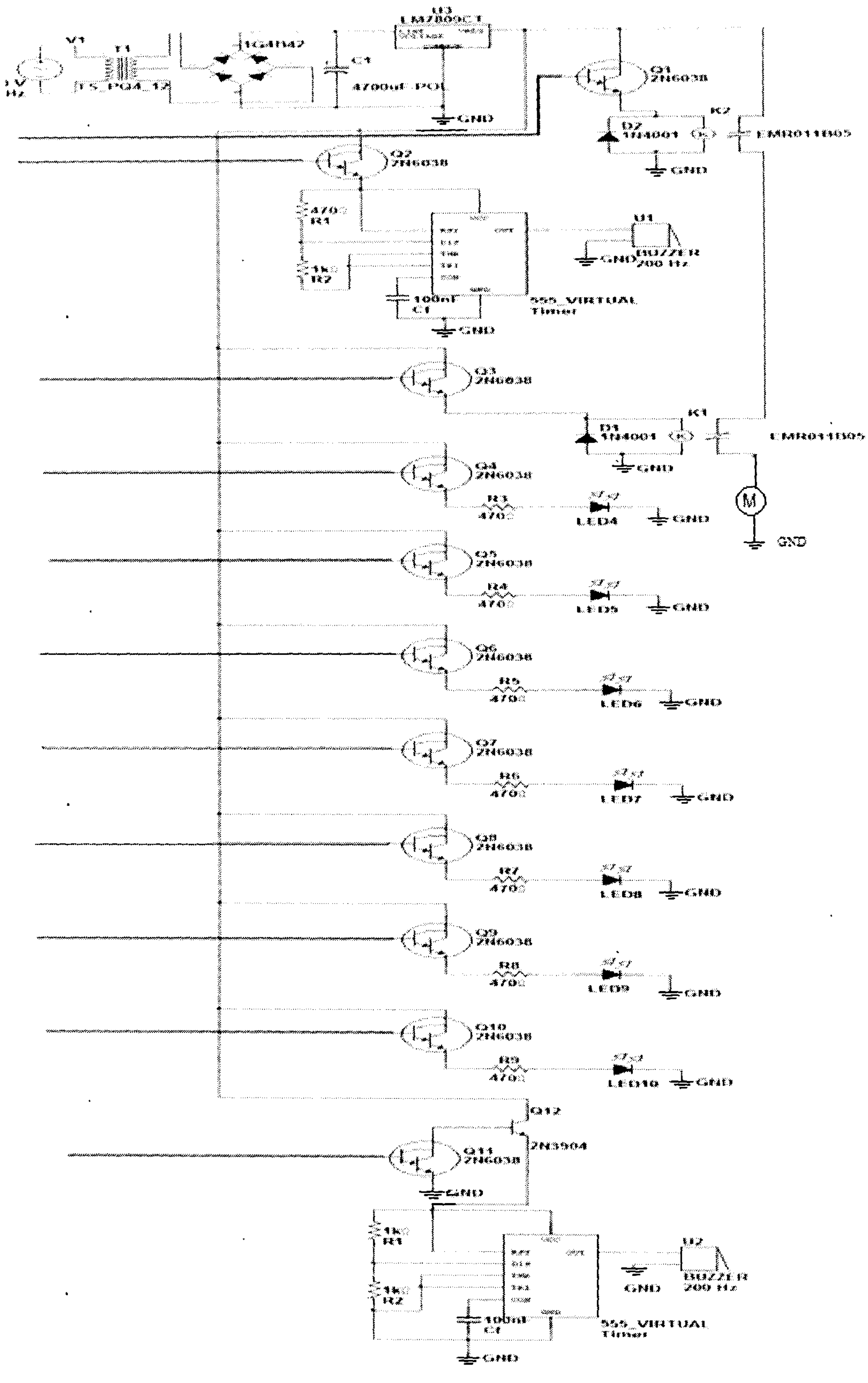


Figure 16: Circuit diagram.

CHAPTER FOUR

CONSTRUCTION, TESTING AND RESULT.

4.1 Circuit Construction

The circuit diagram was drawn from the block diagram, unit by unit first, before it was drawn as a single unit. As it was combined, there were some problems in the arrangement of the relays and the various resistances to use for the 555 timer. In all, the major problem was to draw the circuit to standard.

The various units were constructed and tested on the bread board, after which the whole circuit was then constructed and tested. The power unit was first connected and was used to test all other units as it provided the power needed in the circuit. Corrections were made on the circuit to put the circuit in the best operating conditions and to ensure they do not over-heat due to excessive voltage.

The circuit components were scraped to remove impurities so as to be firmly soldered. Thereafter, it was soldered on a Vero board. The scraping encouraged smooth and neat soldering of the components on the board.

To test the circuit, a tap would have been used. To make a mechanically controlled tap posed great problem in construction because it uses gears. So an electrical motor is used to represent a tap in this project.

The tank always refills when the water level falls below the minimum water level. This is to ensure constant water supply as water supply is not constant in this country. An electric motor was used to represent a pumping machine.

4.2 Tank Construction

In constructing the tank, the major problem was that of leakages. In this project, a plastic bowl was used to represent the tank to counter this problem. A tap head was firmly fixed for water outlet.

4.3 Casing

The casing for the circuit was made of an acrylic. The circuit was first mounted on a wood, which was then screwed to the acrylic casing. The choice was due to the neat appearance acrylic casings display and it is easy to use.

4.4 Testing

After testing, V_{LED} was 1.9volts. This is due to the transistors used, which acts as loads. They are responsible for the 0.1volt drop. The I_{LED} was 18.6mA.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION.

5.1 Conclusion

The project was able to solve the problem of water shortage, by refilling automatically and showing the water levels in the tank. It was able to sound an alarm in case of refilling failure and had a control backup in case of refilling errors.

The project made use of cheap components, which made the over-all project cheaper than many previous works done on similar projects and made use of a Darlington pair, which made it more reliable.

5.2 Recommendation

1. The circuit can be designed using a microcontroller.
2. A three-stage or more stage Darlington pair can be used to increase the sensitivity of the circuit.
3. The project can be interfaced with a computer system for monitoring and control.
4. More control back-ups and error minimizing techniques can be applied.
5. A printed circuit board can be used in place of a vero board to reduce the circuit complexity and enhance easy understanding of the circuit.
6. A power back-up can be used to ensure continuity of power as power supply is not constant.

5.3 Precautions

1. Before soldering, the components were scraped first to remove impurities, which might hinder a firm soldering on the Vero board.
2. Enough soldering lead was applied to each soldered component.
3. It was ensured that when soldering, the soldering iron was not placed on the components for a long time to avoid over-heating of the components.
4. It was ensured that the voltage rating of the components was not exceeded.
5. It was ensured that all connections made and the casing were neatly done.

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APPENDIX

The data sheet is shown below consisting of all the various components used.

For 3904

Database Name	: Master Database
Family Group	: Transistors
Family	: BJT_NPN
Name	: 2N3904
Description	: V_{ceo}=40
	: V_{cbo}=60
	: I_c(max)=0.2
	: hFE(min)=30
	: hFE(max)=300
	: Ft=300
	: Pd=0.625
	: Package=TO-92
Thermal resistance junction	: 200.00
Thermal resistance case	: 83.30
Power dissipation	: 0.62
Min Operating Temp	: -55.00
Max Operating Temp	: 150.00

For 9014

Database Name : Master Database

Family Group : Transistors

Family : MOS_3TEP

Name : IRFD9014

Date : July 22, 1998

Description : V_{dss}=60

: I_d=1.1

Thermal resistance junction : 120.00

Power dissipation : 1.30

Min Operating Temp : -55.00

Max Operating Temp : 175.00

For IN4001

Database Name : Master Database

Family Group : Diodes

Family : DIODE

Name : 1N4001

Description : V_{rrm}=50

: I_{rrm}=50

: trr=30.0

Thermal resistance junction : 50.00

Min Operating Temp : -50.00

Max Operating Temp : 175.00

'or 6Volts Relay

base Name : Master Database

Group : Basic

: RELAY

: EMR021B06

: Coil_Vmax=7.2

: Coil_Vpull=3.8

: Coil Vdrop=0.8

: Coil R=500

: Contact Imax=0.5

np : -10.00

p : 60.00

orkbench (Multisim 09).