DESIGN AND CONSTRUCTION OF AN OVERHEAD TANK WATER LEVEL INDICATOR AND PUMP ACTUATING DEVICE

BY

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CERTIFICATION

This is to certify that this project titled "Design and construction of an overhead tank water level indicator and pump actuating device" was carried out by Aweda P. Olatunbosun under the supervision of Engr. Nwohu and submitted to electrical computer Engineering Department, Federal University of Technology, Minna in partial fulfilment of the requirements for the award of Bachelor of Engineering (B.ENG) degree in electrical and computer Engineering.

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DEDICATION

I dedicate this project to Almighty God for granting me wisdom and understanding in carrying out the project.

And to my parents Revd. and Mrs. E.O. Aweda for their efforts and resources that were exploited in training me .

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TABLE OF CONTENTS

TABLE OF SYMBOL AND ABBREVIATION

ABSTRACT

The design and construction of an overhead tank water level indicator and pump actuating unit has been completed in its realization technique and operation. The device activates the pumping machine and continuously monitor the flow of water into the overhead tank at various discrete levels which are indicated by the level indicator and stops the pumping machine immediately the tank is filled.Otherwise, an alarm is sounded to alert human operator.

However, the activities of the water level indicator and pump actuating unit can be sub-divided into four categories ; the sensing unit, indicator unit, control unit and the alarm unit. The sensing probe detects the discrete level, send the signal to illuminate the appropriate LED and activates the pumping machine controlled by a thyristor.

Meanwhile, the design and construction of a water level indicator and pump actuating device is a project aimed at reducing manual repetitive work which is found in every human endeavour.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

Water is a necessity for living. Although water bodies occupy about two-third of the earth, the supply of water to most homes in many cities is in adequate. Thus, many buildings in urban areas have overhead storage tanks installed. At times, the pressure of the water supplied is low to an extent that water cannot rise up to fill the overhead tank. In order to alleviate this problem, surface or underground tank is installed to collect water from low pressure water supply and is pumped into the overhead tank. This requires continuous monitoring and control of the water pump.

Continuous operation over a long period causes boredom and fatigue in human operators with subsequent deterioration in performance. Thus, the stress in operation causes a reduction in efficiency since it is impossible to standardise the behaviour of human operators in handling manual control of water pump. Advances in the theory and practice of automatic control provide the means for attaining optional performance of dynamic systems, improving productivity and relieving the drudgery of many repetitive manual operations.

The idea of water level indicator and pump activating device is aimed at eliminating the burden of monitoring the overhead tank water level and the manual control of the water pump. The system has a probe inserted in the overhead tank. As water is pumped into this tank, the probe senses the water level at some pre-determined level which would be indicated by the level indicator. When the tank is filled up to the last discrete level, all the LED's would light up. Hence. the contacts of the relay open thereby switching off the pumping machine. Otherwise, an alarm would sound if the water is due for overflow.

Various techniques have been developed in the past to sense a liquid level in general. Some were based on the principles of floatation, radioactive sensing, ultrasonic sensing etc. But to design a water level sensing device and pump actuating unit is based on the conductivity of water only. The application of this device is also suitable for other liquids and could be used in the factories, hotels, residential building etc.

1.2 THE AIM AND OBJECTIVES

The aim of this project is to design and construct an automatic water level indicator with a pump activating device. It is the function of the system to start the pumping machine whenever the water level is below the required level and to stop the pumping machine whenever the required level of water in the tank is attained. Otherwise, the device should sound an alarm if the pump fails to stop so as to alert human operator and to prevent water wastage.

1.3 METHODOLOGY

The method employed in the design and construction of a water level indicator and pump actuating device is based on the conductivity property of water. Multiple point (discrete) sensing technique and a semi controllable switch is used for the level indicator and water pump control device respectively.

1.4 PROJECT OUTLINE

Chapter one deals with the general overview of the design and construction of a water level indicator and pump actuating device. It examines the need for the project, gives relevant information on various approaches used in the past to realise the device and ways of improving on it. It also states the method used in realising the physical model.

Chapter two gives the step-by-step approach on the design and is sub-divided into units namely; the power supply, indicator, control and alarm units. The principles employed in the design of each unit is explained in details.

Chapter three explains the actual construction of the physical model, the techniques used in the construction and the test carried on the device to determine its performance.

Chapter four summarises the work done so far from the theoretical principles to the physical realisation of the physical model. The chapter also gives recommendation on the areas the device can be improved.

1.5 LITERATURE REVIEW

A large variety of sensing approaches has been developed for the determination of the level of liquids in general. The knowledge of the liquid level is very important because other measurement can be inferred from the liquid level.

For example, the volume of the liquid can be determined if the geometry and dimension of the tank is known.

Liquid level can be sensed by taking some important physical parameter of the liquid in a vessel into consideration.

This include, temperature, pressure, weight and turbidity to mention a few. These have helped a long way to develop an appropriate transducer to suit a particular parameter chosen.

Generally, liquid level is sensed based on either obtaining a discrete indication when a predetermined level has been reached (otherwise 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 a discrete indication has to be obtained. Furthermore, if two or more discrete levels were to be established in a vessel, the use of two or more point sensors would be preferable to continuous system. Apparently, this is due to inconsistency in the accuracy of the measurement, using a continuous sensing technique [5].

Most commonly used water level sensing device is the float system. This consist of a level sensing float element which mechanically actuates a transduction element, usually a potentiometer or a magnetic reed switch.

Since the development of semiconductor technology, electronic water level sensing and pump activating device has replaced most of the early systems. This includes the use of moving coil indicator, light emitting diodes (LED) and digital indicator that includes liquid crystal display (LCD). While transistor and thyristor switches have replaced manual switches used as control device of the water pump. These semiconductor switches operate without arcing since there is no moving part in the switches hence, they do not wear away. Moreover, thyristor is preferable due to its high speed, switching capacity and reliability. Also, it is more definite in its action. Otherwise, an operational amplifier could be employed in a regenerative comparator circuit because of its high gain, occupies little space and is cheap. At this level of development, there are increase in sophistication, minimum maintainability and high reliability as a result of emergence of microelectronics.

In summary, the work carried out on the design and construction of a water level indicator and pump-actuating device has been systematically organised in the subsequent chapter for proper understanding.

CHAPTER TWO

THE DESIGN OF A WATER LEVEL INDICATOR AND PUMP ACTUATING DEVICE

2.1 POWER SUPPLY UNIT

The power supply unit is required to energize the circuit of the water level indicator and pump actuating device. However, it is necessary to process the alternating current supplied from the mains into a direct current of constant amplitude.

A step down transformer is used to change the ac line voltage from 240V to 12V which is the desired dc amplitude value to be used by the circuit. This is determined by the turns ratio of the primary winding with respect to the secondary machine.

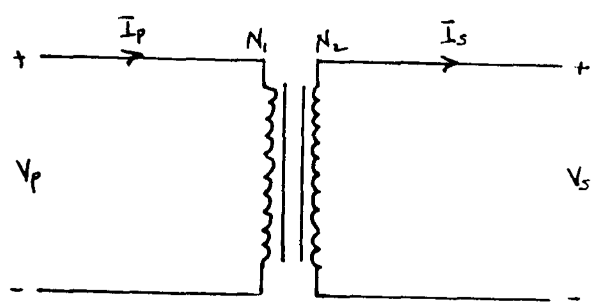


Fig 2.1 symbol for a laminated core transformer

A major characteristic of a semiconductor diode is its ability to allow current in one direction only. Thus, a diode which is capable of converting the 12V alternating voltage into a unidirectional voltage is employed. A full bridge rectifier is used to realise this as shown below.

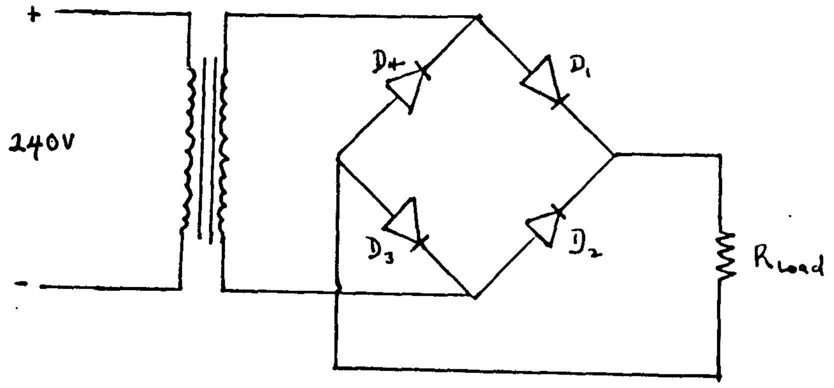


Fig 2.2 Full wave bridge rectifier

The bridge rectifier consist of two pairs of diode with a pair having its common anode terminals joined together while the other pair have its common cathode terminal joined in a similar way. Both pairs are connected together to the secondary terminal of the transformer as shown in fig 2.2.

Therefore, two diodes which are always in series with the input voltage conducts simultaneously. For instance, during the positive half cycle of the transformer output D_1 and D_3 conduct while D_2 and D_4 are reverse biased. Similarly, during the negative half cycle, D_2 and D_4 conduct while D_1 and D_3 reverse biased. Hence, current is sent into the load resistor through the same direction as long as a pair of diode conducts.

In selecting diodes for the rectifier circuit, it is necessary to know the peak inverse voltage of each diode. This is the voltage across a diode during the part of the cycle when the diode is reverse biased thus, the peak inverse voltage across each diode is twice the maximum transformer secondary voltage.

PIV RATING

$V_{dc} = \frac{2}{\pi} V_{max}$. (Full wave)

$V_{max} = \frac{\pi}{2} V_{dc}$

$= \frac{\pi}{2} \times 12$

$= 18.85$ V

PIV = V_{max}

$= 18.85$V

Diode rating (apply a safety factor of 2)

$= 18.85 \times 2$

$= 37.70$V

A diode with PIV rating of 40V is appropriate

The rectified voltage normally contains high percentage of ripple content which can be filtered out, leaving a smooth dc voltage. Thus a capacitor is required to provide the desired smoothing action. The capacitor is charged when the diode is forward biased and discharges into the load when it is reverse biased.

A filter capacitor with sufficiently large value is chosen to provide an acceptably low ripple voltage. The capacitor voltage decays only partially before it is recharged to its peak. The cyclic change in the output voltage otherwise termed ripple have its amplitude depending on the load current and capacitors value.

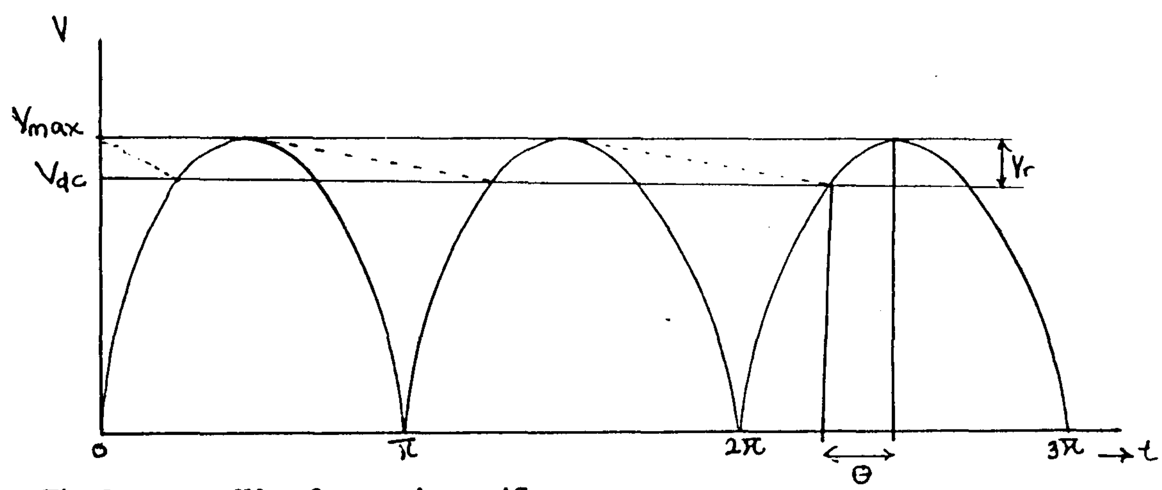


Fig. 2. 3 Waveform at the rectifier output

Although, it is difficult to accurately determine the ripple amplitude because of the exponential decay of the capacitor voltage. However, a capacitor with sufficiently large value, the ripple amplitude will be small relative to V_{max} and the capacitor discharges over the full cycle (i.e $\theta = 0$).

If the regulated dc supply is adequate, it is often necessary to make the supply voltage to be constant as well as having a very low ripple amplitude. Thus à Zener diode is used to produce a stable output voltage. However, the stabilisation efficiency is increased by connecting the diode's cathode terminal to the transistor base as shown in figure 2.4 This is done in order to reduce the magnitude of current flowing in the zener diode. Since the transistor is connected as an emitter follower, the voltage at its emitter is approximately equal to the base voltage. Meanwhile, the base voltage is specified by the zener diode hence, the output is held constant within limits determined by the diode characteristics [6] .

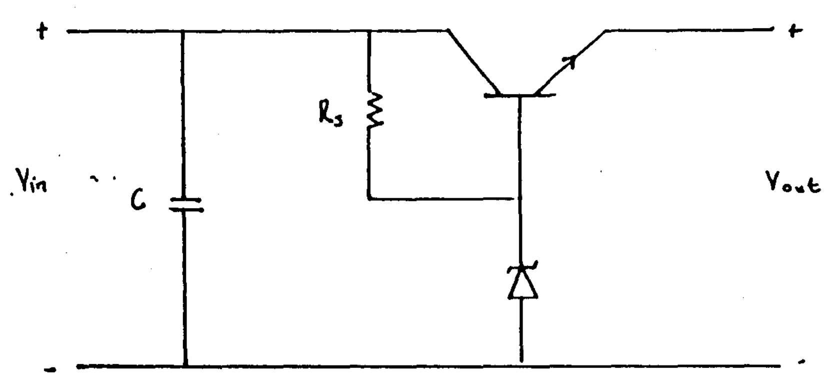


Fig. 2.4 Filtering and Voltage regulation circuit.

2.2 INDICATOR UNIT

The indicator unit consists of two main components namely, the transistor switch and the light emitting diodes (LED).

One of the most widespread uses of Bipolar junction Transistor is its application to switching circuits. Unlike an amplifier which usually aims at processing signals in analogue manner, without distorting waves shapes.

This transistor behaves like a switch when both junctions are forward biased in the saturated region and reverse biased in the cut-off region. Thus, the base-emitter threshold voltage (V_{BE}) determines the switching state of the transistor circuit. Any input less than the base-emitter voltage leaves the transistor in the cut-off region. When the switch is OFF, the circuit is opened no current flows and the full voltage is across the switch. As the input voltage increases, the transistor passes through its active region and eventually becomes saturated. This is the 'ON' state in which the circuit is closed, full current flows and there is no voltage drop across the switch.

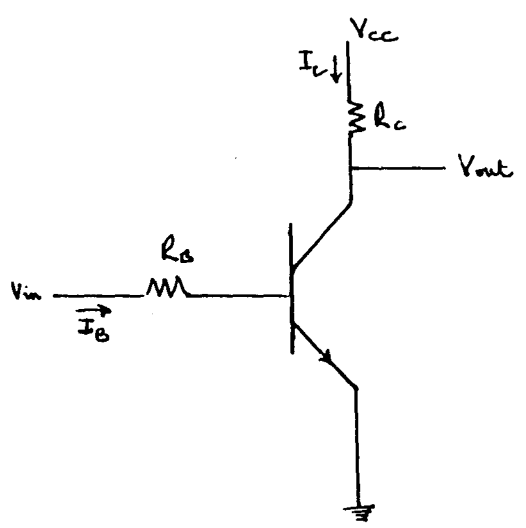


Fig. 2. 5 Transistor switch

Five identical NPN transistors are used in the switching circuit of the indicator unit as shown in figure 2.6

Application of positive voltage to the base of the transistor causes current to flow through the collector to the emitter and light up the LED. The magnitude of the collector current flowing is approximately equals V_{cc}/R_c as the transistor is in saturation and V_{CE} approximately equals to zero. [7].

It is necessary to determine the minimum value of base resistor R_B which will be enough for the transistor to operate in saturation over the full range of β.

However, it is noted that β varies for different specimen of a given type of transistor depending on the collector current, collector to emitter voltage and temperature. When β drops at low collector to base voltage, some extra base current is necessary to bring the transistor into full saturation. Hence the base resistor is conservatively selected to get plenty of excess base current at minimum value of β [1].

A BC238 transistor used as a switch has the following parameter,

$I_c = 0.8$ A, $V_{CE} = 0.4$, $\beta = 125$

$V_{CC} = 12$

Hence,

$I_B = I_c/\beta$

$= 0.8/125$

$= 6.4$mA.

$$R_B = \frac{12 - 0.7}{6.4}$$

$= 1875\Omega$

Thus, the total resistance to the base of each transistor should not exceed 1.9kΩ. However, 1 kΩ fixed resistor is selected since the tank and content has their own resistance that is necessary to be considered. The higher the value of β will not affect this value as there is enough base current to drive the transistor into saturation [7].

The transistors are connected in parallel with 1kΩ resistor as shown in figure 2.6

Thus water is used as a bridge that provides the bias voltage to the base of each transistor.

Base voltage, $V_B = 12V$

Base resistor, $R_B = 1K\Omega$

Therefore, Base current, $I_B = \dfrac{V_B - V_{BE}}{R_B}$

$= \dfrac{12 - 0.7}{1K\Omega}$

$= 11.3mA.$

$I_c = \dfrac{V_{CC} - V_{CE}}{R_C}$ since $V_{CC} >> V_{CE}$,

$I_c \cong \dfrac{V_{CC}}{R_C}$

$= 12/410$

$= 29.26mA.$

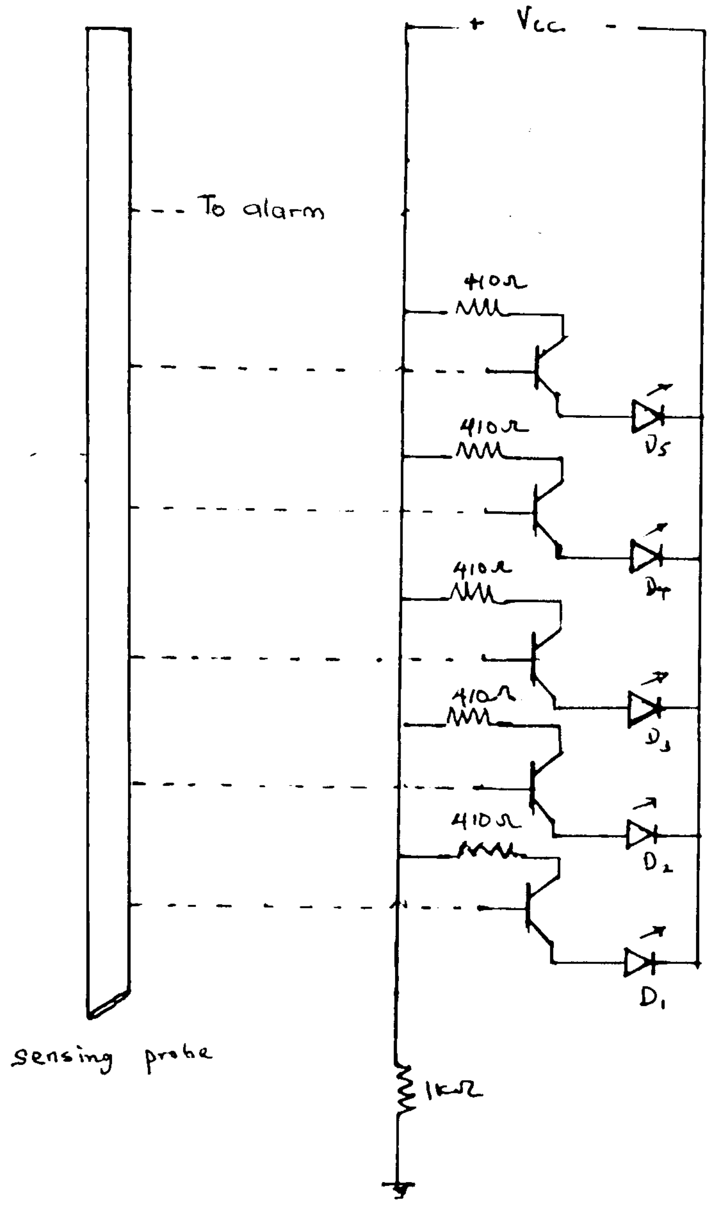


Fig 2.6 Indicator Circuit

The sensing probe consist of a perforated hallow plastic rod of 15mm long, each perforated hole is located at 2mm apart. The sensor for each transistor switch is fixed at each hole while the metal tank itself serve as a reference potential for all the switches. These switches are used to illuminate respective LED depending on its contact with water. Five LEDs are used in all, each one indicating a specific level. The LEDs indicate various levels in the tank as shown in table 1.

TABLE 1.0 LED water level representation

No	LED COLOUR	VOLUME REPRESENTATION
1	Red	Empty
2	Yellow	¼
3	Yellow	½
4	Yellow	¾
5	Yellow	Full

2.3 THE CONTROL UNIT

The control unit (otherwise called actuating unit) consist of silicon controlled Rectifier (Thyristor) and a Relay.

The thyristor is a three terminal, four junction semiconductor device. The device is used as a switch because of its high speed of operation, it does not produce arcing and is definite in its action. It is switched on by applying a low level positive signal to the gate when the device is forward biased. Once turned on, the thyristor will remain in conduction until the anode current falls to a low value (below the holding current).

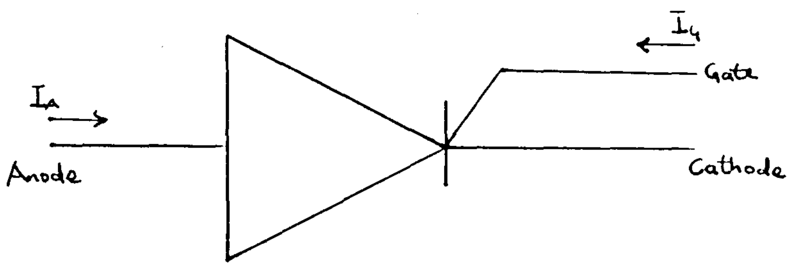


Fig. 2.7 Thyristor symbol

On the other hand, a relay is a magnetic switching device used to isolate a system from the high voltage required to operate the motor. It consists of a main coil and a number of contacts. The contacts are of two types; normally open and normally closed. A normally open contact is one which is opened when the relay is de-energized while a normally closed contact is one which is closed when the relay is de-energized. Thus, when the relay is energized, its contacts change state.

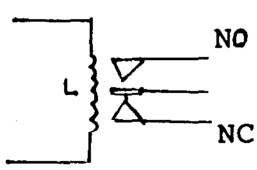


Fig. 2. 8 Symbol for relay

When a relay is de-energized, a voltage spike is produced which is dangerous to the thyristor.Thus, a diode is connected across the inductor in a reverse condition to protect the thyristor.

This thyristor and relay form a complementary switch. Hence when the thyristor is turned 'ON', the relay is deenergized and when the thyristor is 'OFF', the relay is energized.

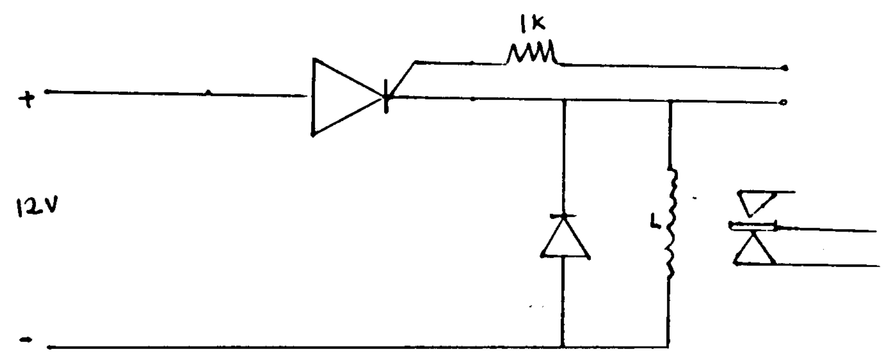
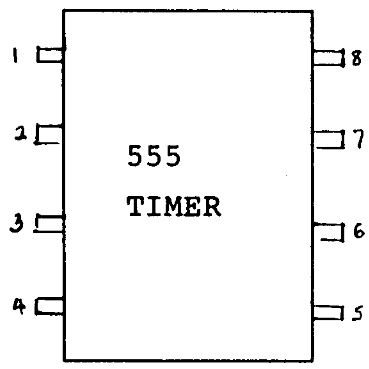


Fig 2. 9 Control Circuit

2.4 THE ALARM UNIT

The alarm unit consists of a thyristor switch, a pulse generator and the output transducer.

The pulse generator mainly comprises the 555 timer. This is operated in an astable mode. A typical 555 timer IC package has of 8 pins as shown in the figure below (fig. 2. 10).



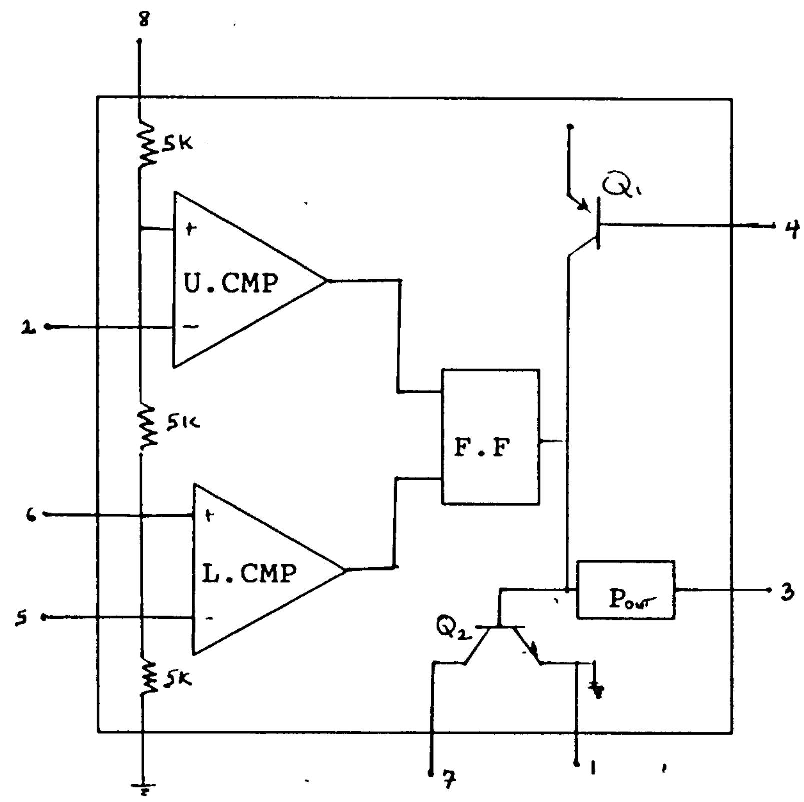


Fig 2.10a 555 timer

Fig. 2.10b functional diagram

From the function diagram of the 555 timer, the positive terminal (pin 8) is connected to the voltage supply (V_{cc}) while Pin 1 is grounded.

Two comparators are present in the circuit which are referred to as the upper comparator and the lower comparator. The three 5KΩ internal resistors act as voltage divider, providing bias voltage of 2/3Vcc to the upper comparator and 1/3Vcc to the lower comparator. Thus, the two voltages set the necessary comparator threshold voltage.

Pin 2 is the inverting input of the lower comparator and is called trigger terminal.

Pin 6 is the non-inverting input of the upper comparator otherwise called the threshold terminal.

Pin 4 is the reset terminal. This allows the 555 timer to be disabled by resetting the flip-flop.

Pin 5 is the control terminal. This is applicable when the timing internal is varied by varying the reference voltage of the comparator.

This terminal is by-passed to the ground with the aid of a capacitor since its function is not required.

The discharge terminal (Pin 7) is a function of the state that exist at the output. When the output is high, the discharge transistor is reverse biased. Thus, the discharge terminal appear essentially as an open circuit. When the output is low, the discharge transistor is forward biased and the discharge terminal appears like a short to ground.

The output of the 555 timer (Pin 3) goes HIGH when it receives a trigger input and stays there until a threshold input is applied. Consequently, the output becomes LOW.

2.4.1 ASTABLE OPERATION OF 555 TIMER

In order to operate the 555 timer in an astable mode, it is necessary to retrigger it continuously. This is done by connecting the trigger input (pin 2) and the threshold input (pin 6) together. In addition, the timing resistor is split into two sections R_A and R_B. The discharge terminal (Pin 7) which is connected to transistor Q_1 internally, is fixed to the junction of R_A and R_B.

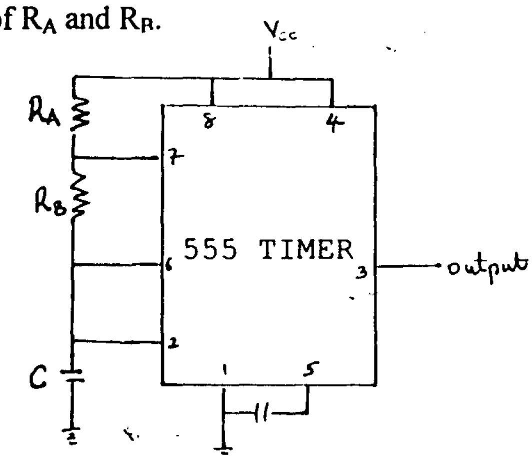


Fig 2.11 Astable configuration

When the power supply is connected, the external timing capacitor charges towards V_{cc} with a time constant $(R_A + R_B)C$. During this time, the output goes HIGH. When the capacitor voltage is a bit greater than 2/3Vcc, the capacitor discharges toward R_B and the discharging terminal (Pin 7) with a time constant R_BC until the capacitor voltage reduces to a bit less than $1/3V_{cc}$, then it starts charging. Hence the periodic discharging of the capacitor between 2/3 V_{cc} and 1/3 V_{cc} is internally controlled by the two comparators and the control flip-flop.

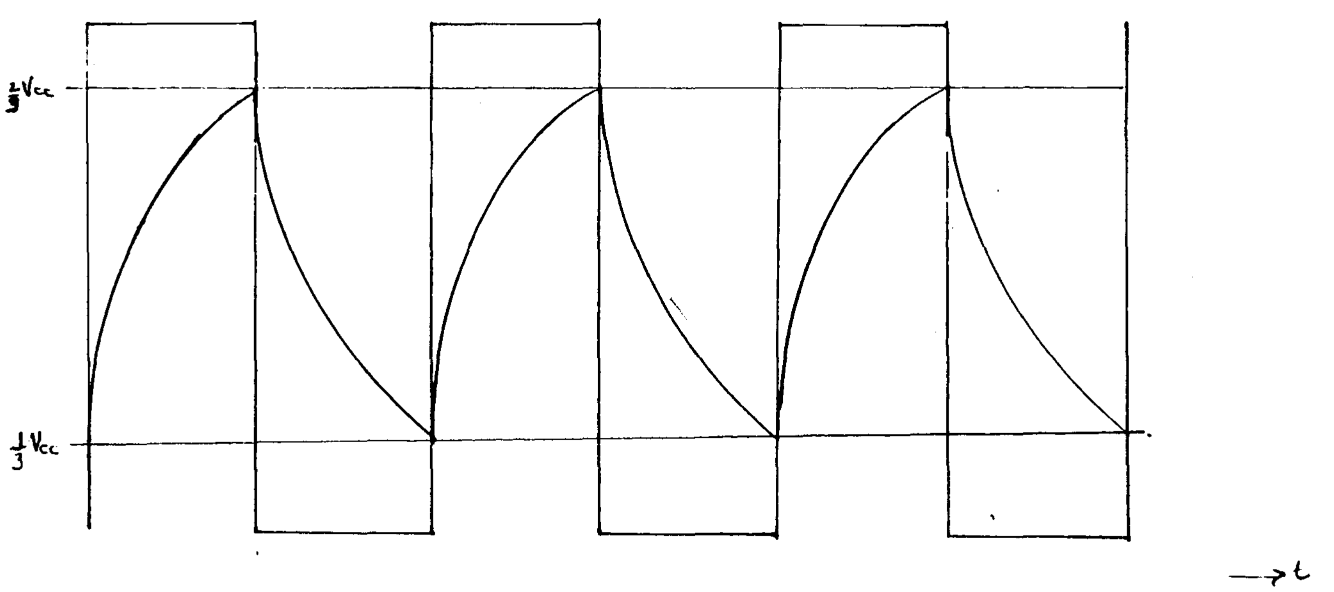


Fig 2.12 Timing sequence and capacitor voltage waveform.

2.4.2 DESIGN CALCULATION

Since current flows into the transistor Q_1 through the resistors R_A and R_B during the charging period, the resistor value must be large enough to limit the current and prevent damage to the discharge transistor Q_1. The maximum current that Q_1 can withstand is known to be 0.2A.

The time taken to charge from $1/3V_{cc}$ to $2/3V_{cc}$ is

$$t_H = 0.693RC$$

Since R_A and R_B are in the charge path, but only R_B is involved in the discharge path then

$$t_H = 0.693\,(R_A + R_B)C$$

$$= 0.693\,(10+10) \times 10^3 \times 0.1 \times 10^{-6}$$

$$= 1.386 \times 10^{-3}\text{s}$$

The time taken to discharge through R_B is

$$t_L = 0.693\,R_AC$$

$$= 0.693 \times 10^3 \times 10 \times 0.1 \times 10^{-6}$$

$$= 693 \times 10^{-4}\text{s}$$

The total time $T = t_H + t_L$

$$= 1.386 \times 10^{-3} + 6.93 \times 10^{-4}$$

$$= 2.079 \times 10^{-3}\text{s}$$

The frequency of oscillation is determined by finding the reciprocal of the total cycle time

$$f = \frac{1}{2.079 \times 10^{-3}\text{s}}$$

$$= 481\text{Hz}$$

Since the timing capacitor charges through R_A and R_B but discharges through R_B, the duty cycle D defined as the ratio of 'ON' time to the total time is

$$= \frac{R_B}{(R_A + 2R_B)C} \times 100$$

$$= \frac{10}{30} \times 100$$

$$= 33.3\%$$

Although the output signal may be fed directly into the output transducer (i.e loudspeaker), it is necessary to filter out the dc components of the signal and the spikes generated at the signal peaks. Hence, a capacitor (100 μF, 25V) is placed in series with the loudspeaker. The capacitor acts as high pass filter.

CHAPTER THREE

CONSTRUCTION TESTING AND RESULT

3.1 CONSTRUCTION

Every component of each design unit was mounted on a breadboard and tested. Necessary adjustments in the design configuration were made in order to achieve the desired performance. After obtaining the desired result on the breadboard, the circuit components were transferred on to a veroboard and permanent soldering was done. The components were mounted on the veroboard and have their terminals passed through the holes to the bottom in accordance with the circuit diagram, before they were carefully soldered.

The sensing probe was constructed by using a plastic hollow rod, 15mm long. Seven holes were drilled on it at regular interval of 2mm. Each wire lead from the base of each transistor was mounted on the last five holes while the wire leads from the cathode and gate of thyristor controlling the pumping machine and the alarm were mounted on the first two holes respectively.

The reference potential to provide biasing voltage to each transistor base was connected to the metal tank.

A metal case was constructed to house the vero board and transformer. The case has a length of 11.5mm, breath 7mm and height 6mm. (Fig. 3.0). Holes were drilled on the front side of the case to allow the passage of audio tone from the loudspeaker mounted to the side. Similarly, fine holes were vertically drilled beside the loudspeaker on which the five LEDs, were mounted.

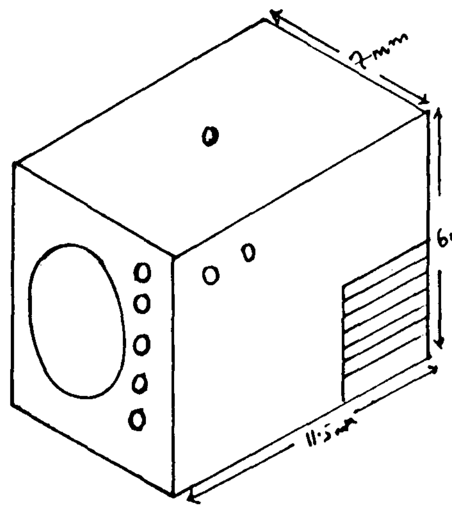


Fig. 3.0 Case

For ventilation purpose, both sides of the case close to the transformer location were perforated. Other holes were drilled by the side and back of the case for mounting the switches and allow the passage of wire leads respectively. Detail dimension on the constructed case is shown at appendix A.

In order to demonstrate the performance of the device, a motor was mounted at the top of the case.

3.1 TESTING AND RESULT

When the device was switched on, the motor was running. This show that water was being pumped into the overhead tank which was indicated by the illuminated LED to indicate the level of water. The five LEDs were illuminated when the tank was filled and the motor automatically stopped.

In case the control device develop a problem and the motor continues to run as demonstrated by adding more water to the tank, the alarm automatically comes on to alert human operator. Two switches were provided, first switch is used to put off the alarm and the second one is used to control the pump manually.

Table 2.0 Result of the Water level Indicator

LEVEL	ILLUMINATED LED	REMARK
0	1	EMPTY
¼	1&2	
½	1-3	HALF TANK
¾	1-4	
1	1-5	FULL TANK

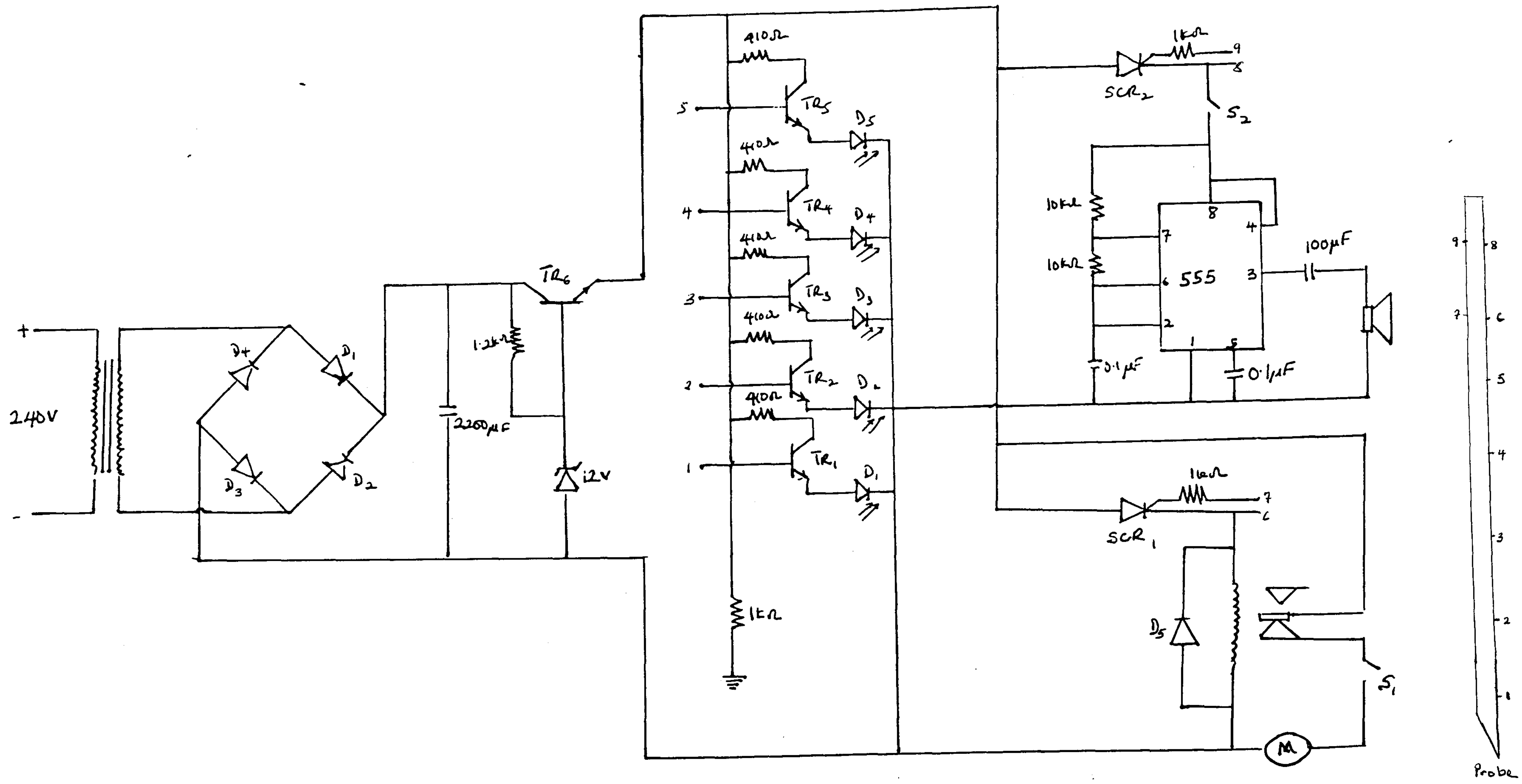


Fig. 3.1 Circuit diagram of water level indicator and pump actuating device.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

The ability of the device to indicate the water level and to activate the water pump meets an acceptable specification and can be compared with the existing ones. Moreso, the availability of materials used and the low cost incurred in the realization and construction of the device makes its production economically viable.

However, the project is opened to criticism and improvement by technologist, engineers, researchers, industrialist and investors.

4.2 RECOMMENDATION

Various characteristics of water were considered before embarking on this project. The major ones include viscousity, temperature, conductivity and other chemical properties of water (especially the pH). These often vary from one area to another depending on the source and chemical used in treating water.

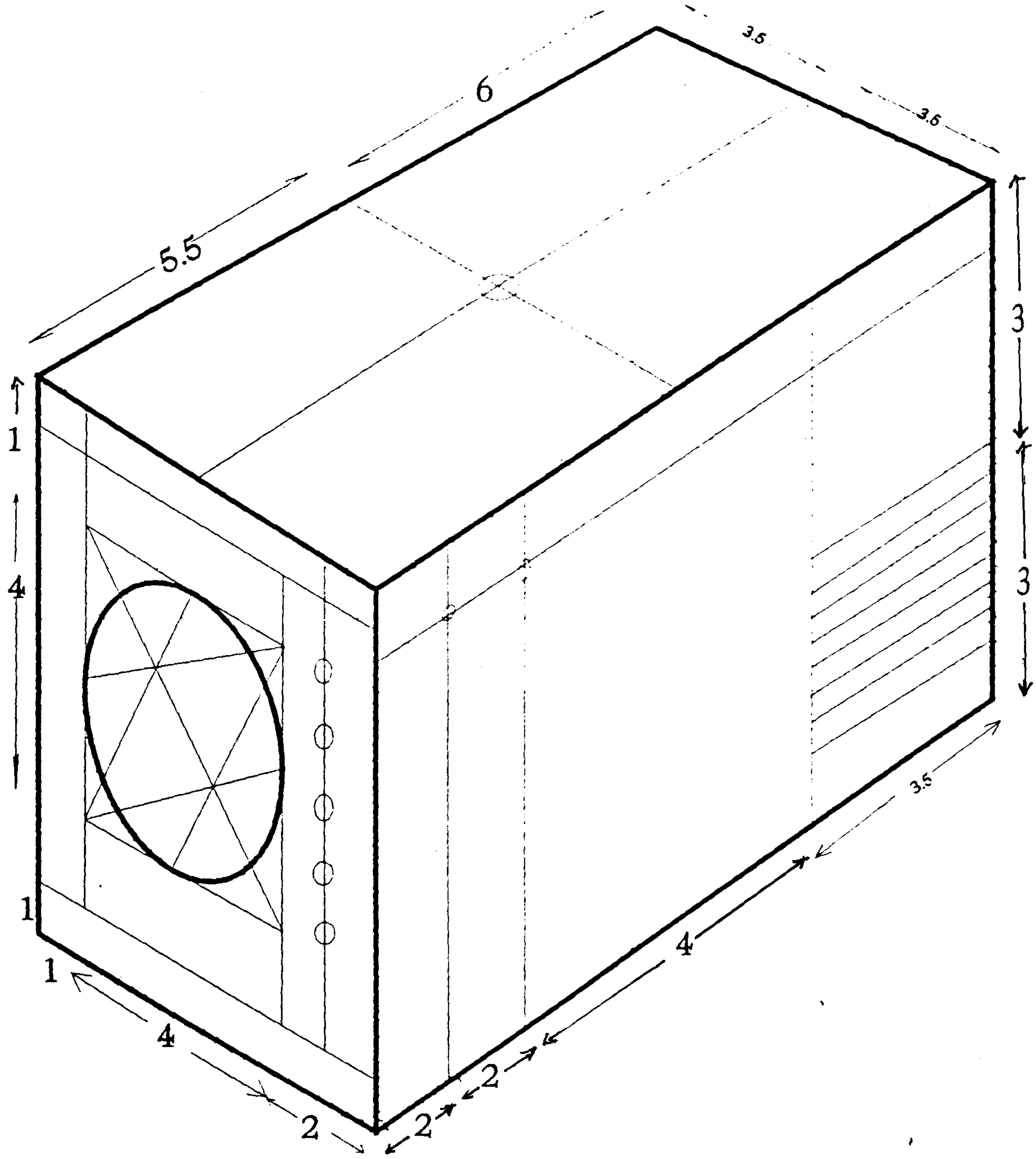
However, the device will perform excellently at any place irrespective of the variation in the above characteristics and could be used in factories, hotels, residential building and in the rural areas.

Furthermore, I wish to recommend a few areas of interest to anybody that is interested in improving on the device. They are the areas that could not be actualised due to time constraint and unavailability of the components. The areas are:-

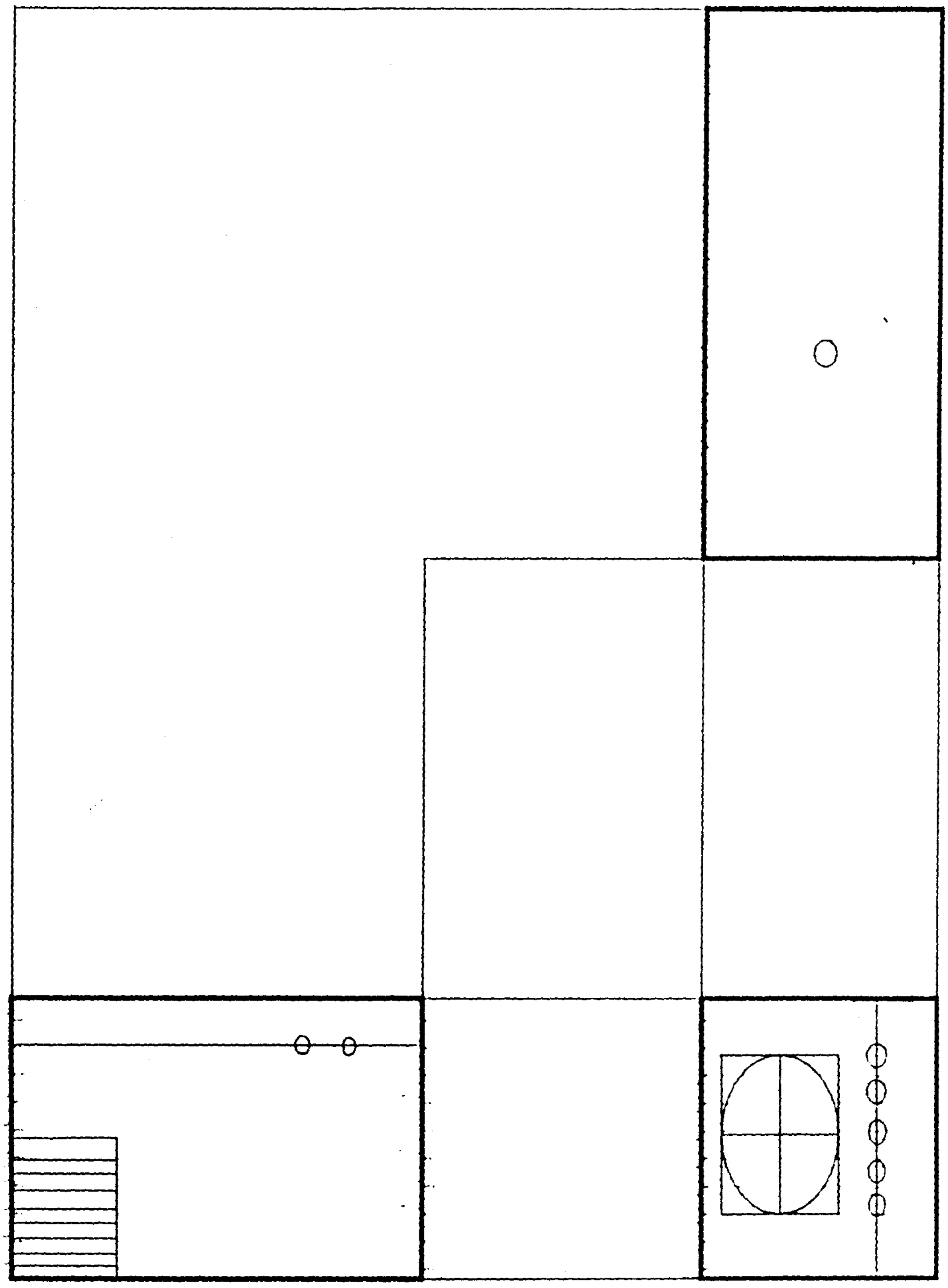
(a) Replacing the sensing device with a capacitive probe so that a fully continuous indication could be achieved.

(b) Reducing the components used for the indicator units by using a comparator circuit.

APPENDIX A.



ISOMETRIC DIAGRAM OF THE CASE



PLAN VIEW

SIDE VIEW

FRONT VIEW

HIRD ANGLE PROJECTION