DESIGN AND CONSTRUCTION OF A DIGITAL WATER-LEVEL ACTUATOR

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ATTESTATION

This is to certify that this project was carried out by Ako Msugh Barnabas with registration number 2000/9794EE under the supervision of Associate Professor Y.A. Adediran and submitted to the Electrical and Computer Engineering Department, Federal University of Technology, Minna.

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DEDICATION

This piece of work is dedicated to God Almighty for His invaluable love, favour, guidance and protection which He granted to me and to my Mum, Mrs Adeyam Ako, Barr John Ako of blessed memory, Mummy Assistant Comptroller–General (Mrs) Rhoda Ako, Uncle Robert Ako and my siblings for their concerted efforts towards my successful completion of this project.

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ABSTRACT

Digital Water-Level Actuator is a micro-motor designed for monitoring water levels in a reservoir. It involves the use of five water sensing probes, each of such sensors placed at a specific level in the water tank under consideration. A particular light indicator (light emitting diode) is switched on whenever the water level submerges a corresponding sensor. The design incorporates input (with amplifiers), logic control, alarm and pumping units which work as a closed system. The audio alarm circuit indicates critical situations in the tank. The leading alarm is triggered on whenever the water level is at the brim (when completely filled up) and when the water level is very close to empty tank (far below one-quarter level). More interestingly, the two points are notified with distinct audio alarm sounds. The pump switches ON/OFF when the tank is below one-quarter and up to the brim respectively. The device finds application in water boards and home water tanks.

CHAPTER ONE

GENERAL INTRODUCTION

1.6 Introduction

The project is all about Digital Water Reservoir Actuator. It's merely a control device for monitoring and pumping water into a tank. It operates with limited number of electronic or logic devices. The device is attributed to five water sensors at different significant levels in the concerned reservoir. The sensors are connected to the input of the device. The five sensors monitor the full, three-quarter, half, one-quarter and almost empty levels of water in the tank. The main results of the combined signals from the sensors are both visual indications of the water levels through Light Emitting Diodes' (LEDs) Panel and Water Pumping Control to the reservoir.

In addition, an alarm is incorporated into the system to define both the full and the almost empty water level situations. It is quite obvious through related feedback from the sensors that the whole motor works in an automatic cycle of operation. Another evident fact is that the system is quite digital for reasons of operational flexibility and optimal performance. Such water level reservoir actuators are quite significant for wide range of purposes. It's used for domestic water tanks, industrial water storage facilities, laboratory experiments and lots more.

Moreover, the project involves a model set-up for showing the operation of the involved water actuator system. Although there are a number of limitations the significance of the project is sincerely defined.

1.2 Aims and Objectives

The design and construction of the Digital Water-Level Actuator is aimed at achieving the following goals:

(i) Introducing the student to the practical application of the theoretical courses taught in classroom; such courses are: Analogue, Digital and Power Electronics , Microcomputer Hardware Technology and Programming, Circuit Theory, Laboratory Practicals among others.

(ii) Reducing waste of resources arising from the forgetfulness of putting OFF the water pump when the tank is filled up.

(iii) Reducing the labour cost for employers and monotony for operators both in industrial and home applications.

1.3 Methodology

The project involves basic electronic principles coupled with the electrical conductivity of water. The input of the system or water sensors work according to the conductivity of water. Each sensor consists of two parallel- spaced conductors. This allows the two to be electrically connected due to the ionization of the water. Positive ions called cations (H^+ or H_3O^+) and negative ions called anions (OH^-) are released into the water which induces current. The initial electrically- free conductor receives the little electric current from the other through contact with water. The limited electric current requires amplification for reasonable digital use. A control unit is incorporated in the design to manipulate the signal from the input for specific output functions.

The output involves light indicators to show the level of water in the reservoir, the triggering ON of the two distinct alarms for both full and almost empty water level conditions in the reservoir and the pumping effect of water in the tank when it's going empty and switching OFF further supply of water into the tank when level is at full position. The output is attributed to an alarm-oscillator circuit, a motor switching unit, light emitting diode (LED) panel and other relevant circuits.

The project is executed through the following units:

(i) **Input Unit-** It involves five water probes or sensors.

(ii) **Input Amplifiers-** For strengthening the signals from the input.

(iii) **Logic control Unit-** For manipulating the input signals into usable control.

(iv) **Alarm Unit-** For responding to full load and almost empty water level conditions.

(v) **Pumping Unit-** For connecting water to the reservoir.

1.4 The Scope of the Work

The project is limited to five water sensors working based on conductivity of water for indicating water levels in a reservoir at around full, three-quarter, half, one-quarter and almost empty situations. Five Light Emitting Diodes (LEDs) provide a visual output of the level of water in a particular storage tank. Two different sounds from the alarm unit are incorporated into the design to define the full and almost empty conditions of water in the tank. A direct current (dc) electric motor pump is used for getting water into a particular storage facility. The design involves mostly Complementary Metallic-Oxide Semiconductor (CMOS) Integrated Circuit for reasonable circuit flexibility, low cost and low power consumption. Transistor- Transistor Logic (TTL) Integrated Circuits are not involved due to their attributed high power consumption and low logic function availability. The project is aimed at high economic enhancement through the use of limited number of electronic components.

1.5 Problems and Limitations

The project is attributed to quite a number of limitations as follows:

(i) The use of only five water levels in the tank specifies some degree of assumptions to the amount of water available for storage.

(ii) The level of water in the tank is assumed within two specific water probes (full and below one-quarter).

(iii) System low flexibility. This is because the device may not effectively adapt to other fluids (e.g. petrol) due to their electrical conductivities. This greatly limits its wide applications.

(iv) Absence of computer interfacing and programming may reduce the importance of the project.

Despite the fact that the project is a mere model, it embodies numerous merits. It is designed with limited number of components for reasonable simplicity and low cost. It is attributed to low power consumption with the use of CMOS ICs. The system is simply configured to show its importance to the monitoring water in storage facility.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Background

Essential to all automatic-control mechanisms is the feedback principle, which enables a designer to endow a machine with the capacity for self-control. A feedback loop is a mechanical, pneumatic or electronic device that senses or measures a physical quantity such as temperature, position, speed, position or size, compares it with a pre-established value and akes whatever pre-programmed action necessary to maintain the measured quantity within he limits of the acceptable standard. An outstanding early example is the Flyball Governor nvented in 1788 by the Scottish Engineer, James Watt, to control the speed of steam engine.

Polzunov I, a Russian, in 1765 was the first person to invent a historical feedback system or water-level control [1]. It consisted of a float attached to a lever which, in turn, controlled value. The system was used in a boiler where the float detects the water inlet in the boiler.

Since then, several other approaches to controlling water flow in a container have been eveloped. One of such is the float switch used to operate a motor that pumps water into a nk. Float switches are generally designed with two sets of contacts:

(i) Normally Open (NO)

(ii) Normally Closed (NC)

ince the pair of Normally Open and Normally Closed contacts of the float switch can her open or close contacts with changes in liquid level, variations in the applications of the ntrol device are possible. For example, when normally closed contacts are used, the pump motor continues to pump water until the water level rises high enough to cause contacts to open and switch OFF the pump. The installation of such systems are however clumsy.

In other to separate the control equipment from the pump motor, magnetic control could also be used in some places. Despite the fact that this approach is quite sensitive, it's more expensive than the float contact switch, it is neater and satisfies certain industrial and commercial installation requirements (i.e. certain electrical control equipment should be located in one area away from the load device). Simple electromagnetic devices like solenoids, magnetic motor starters and contactors are used to effect the controlling process.

2.2 Principle of Operation of a Typical Water-Level Actuator

It is quite evident that the old related projects used unsuitable design components especially Transistor-Transistor Logic (TTL) ICs (7400 series) and relays unlike CMOS ICs (4000 series) used in this project. CMOS ICs usually exhibit relatively lower power consumption, higher compatibility, wider voltage supply range, more encouraging logic function availability, lower cost as compared to TTLs' and relays'. The use of the 4000 series CMOS ICs in this project also provides more reasonable simplicity and flexibility.

An IC like 555-Timer (a TTL device) is attributed to a single frequency output. But in respect to just frequency conduction, 4060B (a CMOS device) generates ten frequencies at once fir its output terminals. Therefore, in a circuit involving say six frequencies, can be taken care of by a single CMOS IC (4060B) and six 555-Timer. This clearly implies that low cost and high compatibility are associated with CMOS devices as compared with TTLs as the overall power consumption of the set-up is more reduced owing to limited number of involved components.

Apart from the ICs used, the project involves the monitoring of the lowest and the highest levels of water through different alarms. It implies that an alarm is triggered ON for the lowest water level and another different alarm goes for the highest water level in the tank. This feature allows users to know at a distance the water level conditions.

The more interesting feature of the project is the water actuation process with respect to a storage tank. Through the placement of water detectors at the lowest and highest levels, water is automatically pumped into the tank.

Digital Water-Level Actuator will have more applications if computer interfacing chips are incorporated and a program coded in any of the powerful object-oriented programming languages (e.g. Java or C++) to run the water-level monitoring process. This is very expensive to establish but more logical in the present Cyber World hence high skills are also involved.

3.1.1 Power Supply Unit

All electronic devices require a direct current (dc) voltage source to operate. Very often, a circuit that converts the readily available alternating current (ac) supply to dc voltages is used. This system uses one of such circuits to provide the required voltages for operation. Fig 3.2 shows a block diagram of the power supply unit and the waveform of each stage.

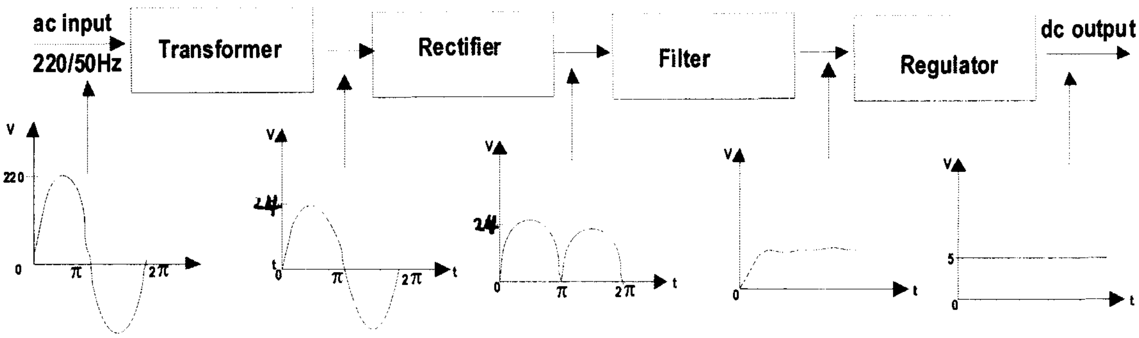


Fig 3.2 Power supply block diagram and waveforms

The Transformer

The first stage of the power supply design involves the stepping down of the 220V ac from the mains to about 24V ac with the aid of 220V/24V, 500mA transformer whose current capacity is enough to drive the entire circuit. The transformer is an electrical device that provides physical isolation between the 220V ac mains and the rest of the hardware. The magnetic flux eliminates the risk of shock of the transformer. It consists of two coils- the primary (input) winding and secondary (output) winding. Fig 3.3 shows the circuit symbol of a transformer. The ratio of the primary voltage, V_1 to the secondary V_2 is equal to the ratio of the number of turns in primary winding, N_1 to that in the secondary winding, N_2.

$$\frac{V_1}{V_2}=\frac{N_1}{N_2} \quad \text{.......................} \quad (2.1)$$

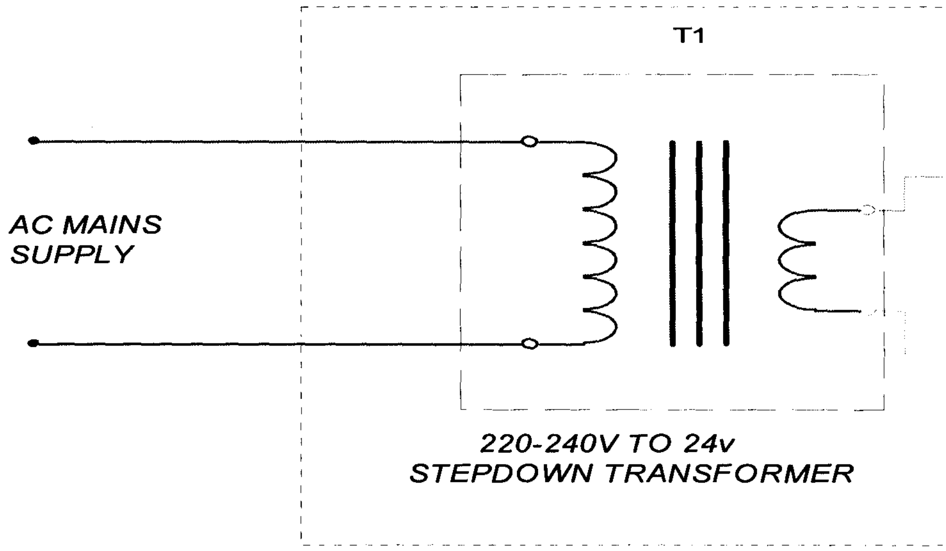


Fig 3.3 Transformer circuit symbol

The step-down transformer is rated 24V, 500mA.

The Rectifier

The rectifier converts the 9V ac voltage from the transformer into a pulsating dc voltage and the process is called Rectification.

A full-wave bridge rectifier is used for the rectification. It consists of four IN4001 diodes as shown below in the arrangement in fig. 3.4.

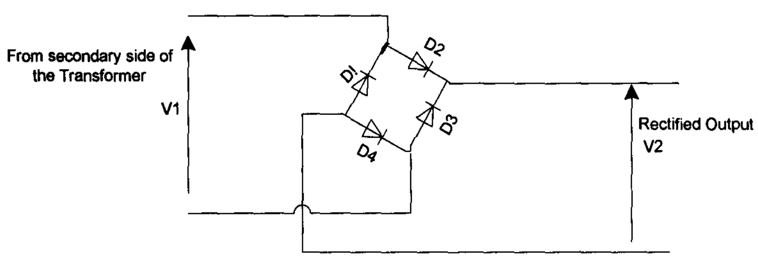


Fig 3.4 Full-wave bridge rectifier

During the positive half cycle, diodes D2 and D3 are forward biased and current flows through any load connected at terminals AB. In the negative half cycle, diodes D1 and D4 are forward biased. Since the load current is in the same direction in both half cycles, the full-wave rectified signal appears across the load. The average dc voltage, V_{dc} across AB is:

$$V_{dc} = \frac{2V_{2(peak)}}{\pi} = \frac{2\sqrt{2}V_{rms}}{\pi} = \frac{2\sqrt{2}x9}{\pi} = 8.10V$$

Where $V_{2\,(peak)}$ and V_{rms} are the peak output and the root mean square voltages of the secondary winding in the transformer respectively.

The diodes were so chosen such that their Peak Inverse Voltage (PIV) rating is greater than $V_{2(peak)}$, so that they do not break down when reverse biased.

The Filter

The pulsating dc voltage from the rectifier is only suitable for limited applications such as charging batteries and running dc motors. Most electronic circuits require dc voltage that is constant value. A filter is used to convert the full-wave rectified signal into a constant dc voltage.

A capacitive filtering is adopted in this design where a large electrolytic capacitor is connected across the rectifier output. The capacitor charges up during the diode conduction period to the peak value, and when the rectifier voltage falls below this value, the capacitor discharges through the load, so that the load receives almost steady dc voltage. The discharge time constant, which is the time taken for the capacitor to drop to 33% of the peak value is given as:

$\tau_d = R_L C$ .... (3.2) where R_L is the load resistance, C is the capacitance.

Since R_L is a constant for any given circuit (usually 3.6kΩ), it follows that the larger the value of C, the smaller the ripple voltage. A 2200μF, 35V capacitor was chosen for this circuit, which is large enough for the intended purpose.

The Regulator

The output of the filter capacitor varies when load current or the input voltage varies. This effect is also undesirable.

Two positive monolithic voltage regulator IC chips: 7809 and 7805 were used to supply steady 9V and 5V to drive the switching unit and energize the rest of the circuit respectively. These regulator chips supply rated voltage with a wide range of voltage input (7V to 35V) and variations in the load current. Lower value capacitors (47μF, 16V) are connected at their outputs to filter- off any ripples left on the supply line. Each of the regulator chips falls under the 78xx series positive voltage regulator with maximum voltage and current ratings of the 40Vand 1A.

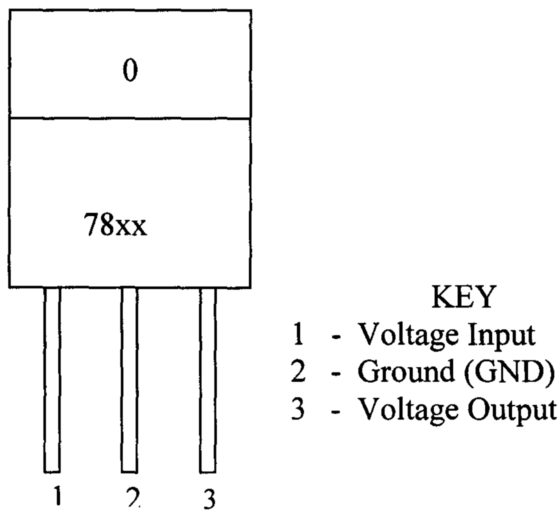


Fig 3.5 Pin assignment of the 78xx voltage regulator series

Electrolytic capacitors are usually connected to the output of the regulators for enhancing smooth electric current flow in the circuit [2].

A power switch allows opening and closing of the complete circuit. A power indicator shows the presence of electric power in the circuit. This circuit holds a resistor of 1kΩ in series with a light emitting diode (LED). The resistor allows a particular suitable voltage across the light indicator which is normally related to 2.7V and 3mA.

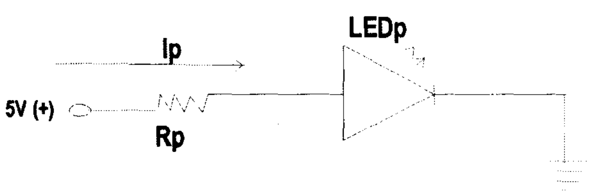


Fig 3.6 The power indicator circuit

$$R_P = \frac{V_{CC} - V_{LED_P}}{I_P}$$

$$R_P = \frac{5 - 2.7}{3 \times 10^{-3}}$$

R_P = 766.67 Ω

Where V_{LEDP} = voltage rating of the LED

N.B: 1K resistor was used in the circuit.

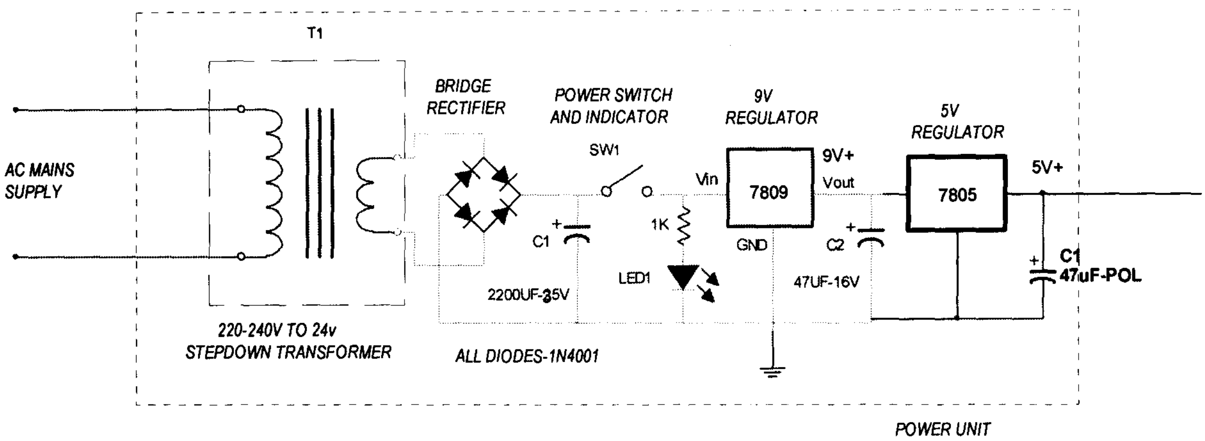


Fig 3.7 Power supply unit circuit diagram

3.1.2 Water Detector/Sensor Unit

The Digital Water-Level Actuator uses electrical transducers to convert water level the tank into electrical signals. The electric signals in this case are dc voltage levels (LOW and HIGH). The transducers used are probes which are merely conductors lowered into the tank at desired levels, with the sensor 5 at almost the bottom (below ¼) of the tank. They operate based on the conductivity of water.

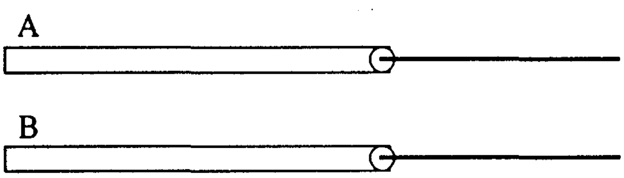
All aqueous solutions conduct electricity to various degrees. The conductivities of liquids vary with temperature, volume, and separation height of the measuring probes. Tap water for instance, has a conductivity of about 50μS/cm at 25°C (equivalent to 20kΩ/cm). Table 3.1 lists typical conductivities for various solutions at 25°C.

Table 3.1 Typical conductivities of solutions at 25°C [3].

Solution	**Conductivity(μS/cm)**	**Solution**	**Conductivity(μS/cm)**
Ultra pure water	0.055	Ground water	20,000
Boiled water	1.0	1.0M KCl	111.342
Tap water	50	10% NaOH	355,000
Sea water	50,000 C.	10% Sulphiric Acid	432,000

Five probes are used in the arrangement shown in Fig 3.11. The two most important probes in the circuit are the LOW (sensor 5) placed below ¼ of the tank and the HIGH (sensor 1) placed at the maximum desired water level in the tank while sensors 2, 3 and 4 are evenly and linearly placed between LOW and HIGH. The HIGH/FULL/OVERFLOW probe is placed at a level that will indicate possibility of water spillage from the tank.

Each sensor is made of two mere closely placed metallic conductors. The design is aimed at bridging the two conductors through water. One of the conductors is connected to the positive side of the power supply.



KEY:
A and B are two metallic conductors

Fig 3.8 A water sensor

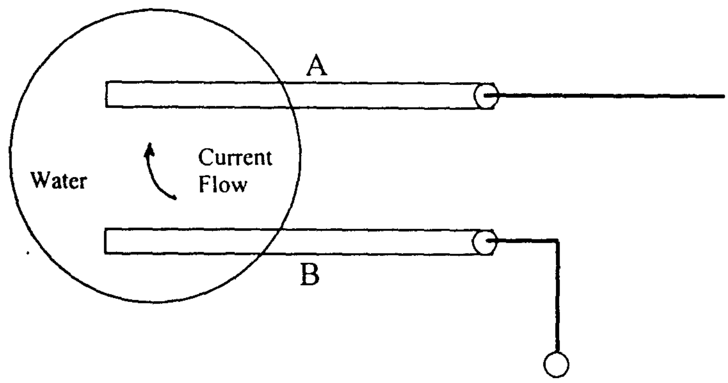


Fig 3.9 An illustration of the mode of operation of water sensor

It's quite evident that water is slightly electrically conductive. But the flow of electricity through water is not through electrons but ions. Such conduction is attributed to reasonable resistance as compared to normal conductors.

In Fig 3.9, electric current flows from terminal B, which is positive to A through water contact of the two. The corresponding electric current at A is slightly weaker. It is not directly suitable for any major amplification. Therefore, the terminal A of the water sensor is connected to an amplifying device, normally a transistor. In this circuit, a CMOS inverter is used for that purpose.

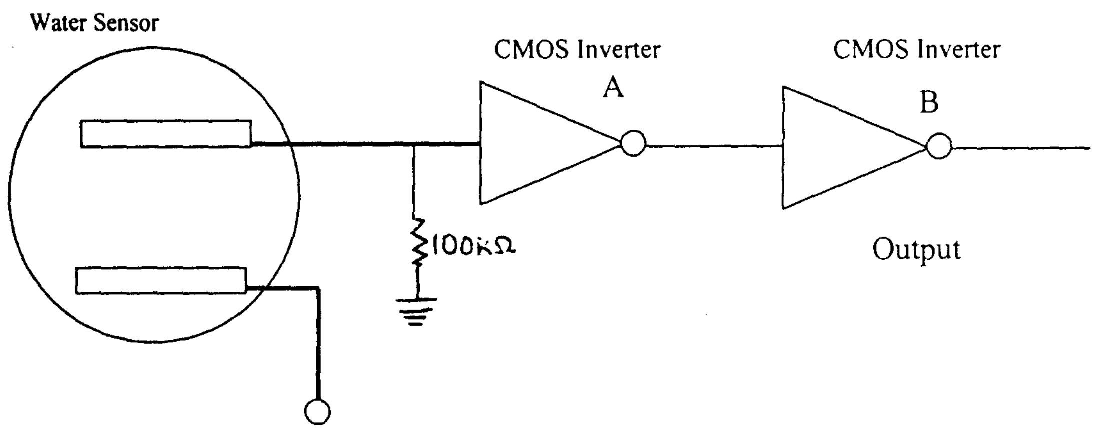


Fig 3.10 The water sensor/input amplifier

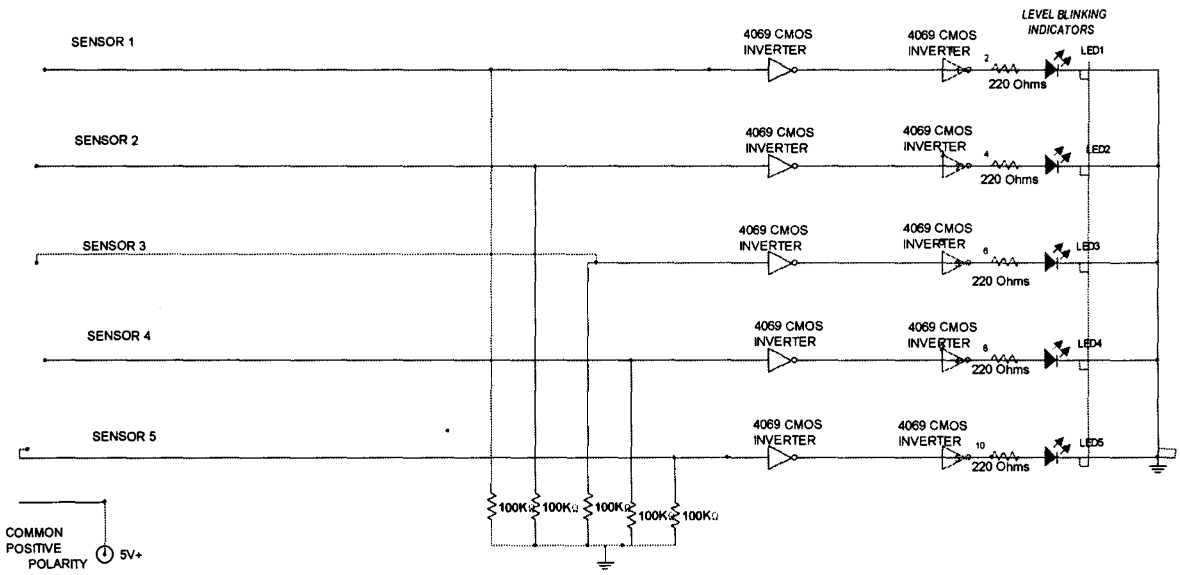


Fig 3.11 The water sensor circuit

The five water sensors have a common positive terminal. Therefore, four water sensors involve a single metallic conductor member. The other one possesses two, including a common positive terminal. The whole sensors are designed to monitor water levels in a tank. This is the limitation of the five levels.

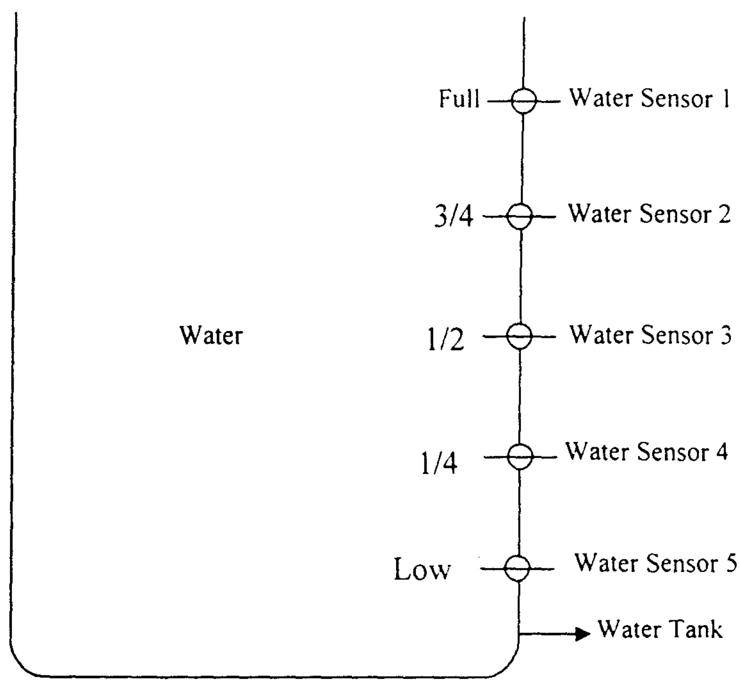


Fig 3.12 An illustration of water sensors at different levels of the tank.

Water sensor is always placed at the lowest level because it carries the common positive terminal.

Two inverters (NOT gates) are cascaded linking each probe with a resistor across the input of the first NOT gate to achieve the intended purpose. When water rises in the tank and touches any probe, the input to which the sensor is connected is effectively linked through water. This conduction sends logic 1(Vcc = +5V) to the first NOT gate outputting a LOW (logic 0) and the same inputed logic at the final output of the second NOT gate. This implies that any activated line send s the same signal to the assigned sensor of the level. The LED at this level now comes ON indicating the presence of water. On the other hand, when water goes below a probe, a logic 0 is sent to the cascaded NOT gates outputting the same result. The LOW (logic 0) result makes the LED to go OFF, indicating absence of water. Every input of the first NOT gate is grounded and connected to a 100kΩ resistor for protection against excessive voltage (greater than 5V).

In reality, the 100kΩ resistor of each input and the resistance of water between the probe in question constitute a Voltage Divider across the input to the NOT gate; thus V_{IL} gives the voltage at the input pin when the probe is in water:

$$V_{1L} = \frac{R_w}{R_w + 100k\Omega} x(V_{CC}) \text{ .... (3)} \quad (+V_{CC} = +5V) \qquad [4]$$

where R_W is the resistance of the resistance of the water between the probes. As earlier stated, the resistance of water, R_W depends on the distance of separation of the probes, hence there is an upper limit to the separation height between each probe.

3.1.3 Input/Output Buffer

A buffer is any logic circuit designed to have a greater output current and/or voltage capability than an ordinary logic circuit. They give electrical protection to any device in the event of current or voltage surge.

Buffers could be inverting or non-inverting with active low or active high enable input.

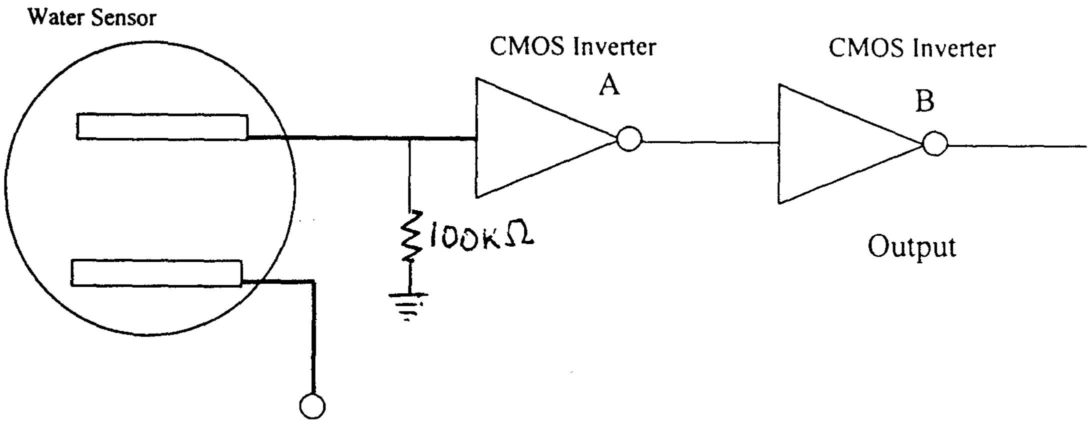


Fig 3.13 The water sensor/input amplifier

The circuit in fig 3.13 with buffers is used for water detection. It consists of two CMOS inverters. This means that the device holds six independent inverters or NOT gates. It can operate within 3 -18V power (dc) supply. The choice of this component deals with its Metallic Oxide Semiconductor (MOS) nature. Such devices are attributed to reasonable compatibility with high impedance inputs such as the one for water sensors.

The figure 3.14 shows the internal structure and pin assignment of the IC.

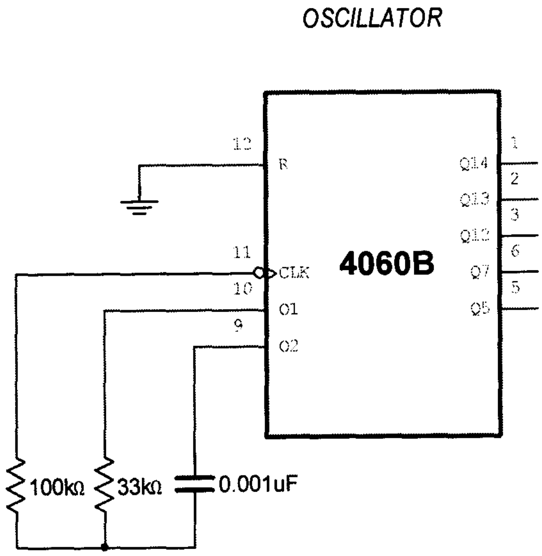


Fig 3.14 Pin assignment of the 40690B

In fig 3.14, the input of inverter A is connected to a 100kΩ resistor and grounded. It is used to initially set the input of the CMOS device to logic 0 due to its high impedance nature. The output of the inverter A is initially at logic 1 and that of inverter B at logic 0.

When the corresponding water sensor is in contact with water, the input of the inverter A is slightly positive and the output changes from logic 1 to 0. This is the basic detection of water by the sensor. Inverter B now behaves as a buffer between the first inverter and the preceding circuit.

3.1.4 Switching Unit

The switching unit, also called "Pump Control Unit", is all about SR (S-Set, R-Reset) latch made up of a 4013B IC. A latch is a bit memory storage device. It operates a high current MOSFET that the dc motor. The 4013B is a package that involves two independent D-type flip-flop with SR feature. The device possesses active high inputs [5].

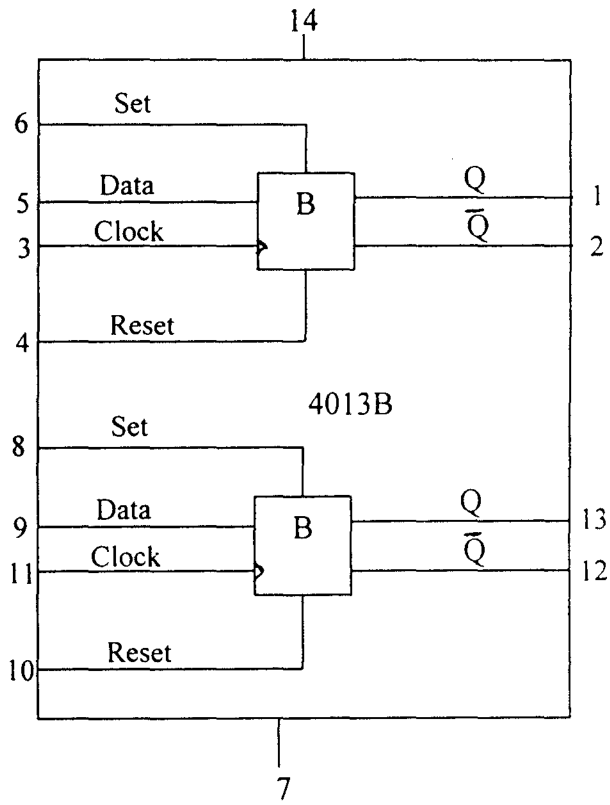


Fig 3.15 The functional diagram of the 4013B

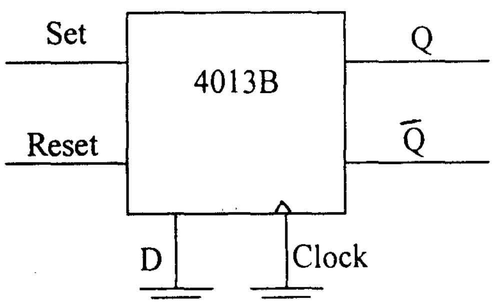


Fig. 3.16: The 4013B at JR Mode

Table 3.2 Simple truth table of an SR Flip-Flop Latch

S	R	Q	$\bar{Q}$
0	1	0	1
1	0	1	0

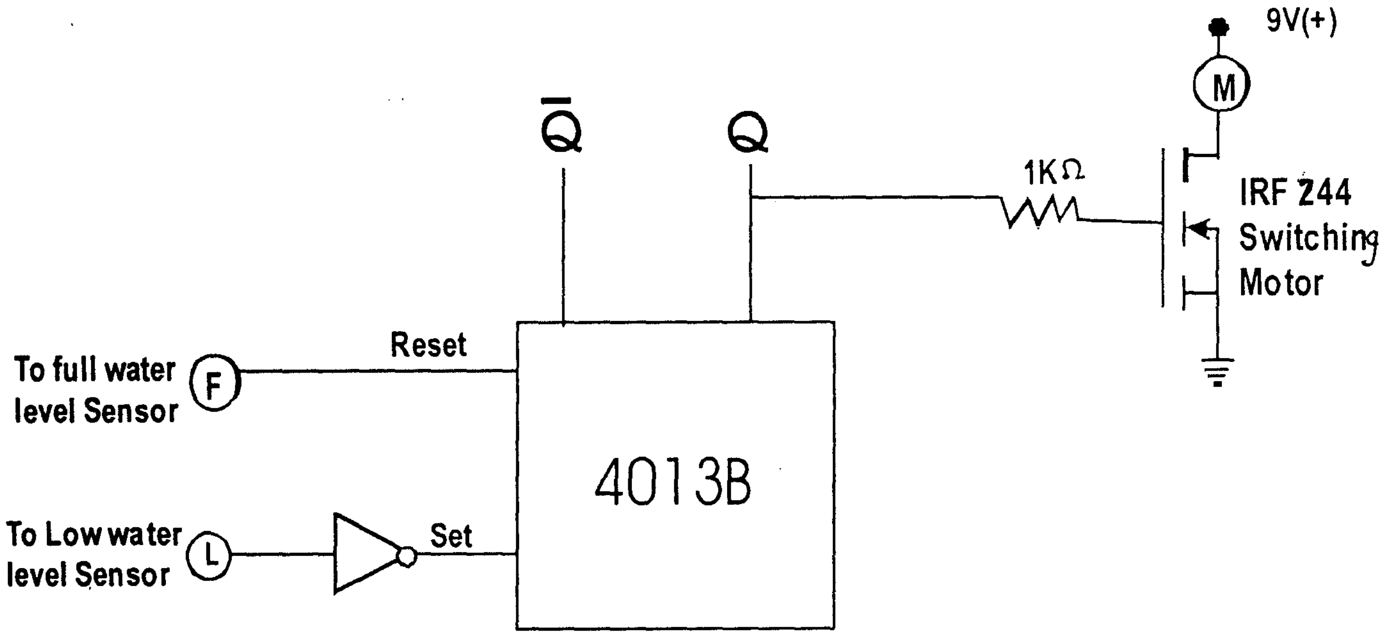


Fig 3.17 The Pump Control Unit

As water touches the lowest sensor, terminal L changes from logic 0 to 1.Therefore, Set terminal of the flip-flop is put at low logic level. When water level gets to the highest sensor (FULL), the flip-flop or the latch is set. Therefore, the Q output of the device changes from logic 1 to 0 to switch OFF the pump. More interestingly, when the water pump drops beyond the lowest water sensor in the reservoir, the same responses are automatically carried out [4].

In summary, the automatic operation of the pump makes water to be pumped into the reservoir when level is below ¼ and stops the pump when water rises to the FULL sensor.

3.1.5 LED Display Unit

The unit shows the relative level of water in the tank. It consists of five Light Emitting Diodes (LEDs) – all red in colour. Every red LED is switched ON when water rises to its FULL level and vice versa. This implies that at FULL tank, all the five LEDs are switched ON in red colour and OFF when level is below ¼ of the tank(all LEDs go OFF). Bur hence automatic in operation, immediately water goes below the lowest probe (sensor 5), the pump turns ON and the monitoring process continues in that order.

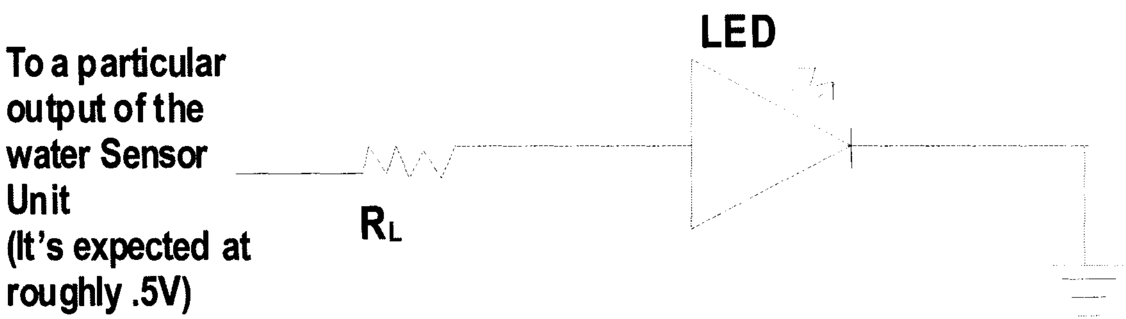


Fig. 3.17: A single light indicator's circuit

R_L is required to cause a suitable voltage drop across the LED. A voltage and current of 2.7V and 10mA are required for the LED respectively.

Therefore,

$$R_L = \frac{voltage\ across\ the\ resistor}{electric\ current\ through\ the\ resistor}$$

$$R_L = \frac{5-2.7}{10\times10^{-3}}$$

$$R_L = 230\Omega$$

$$\text{Error} = (230-220)\,\Omega = 10\Omega$$

$$\%\ \text{error} = \frac{10\Omega}{220\Omega} x100$$

$$\%\ \text{error} = 45.45\%$$

Five of the circuits in fig 3.17 are required for the complete light indicator unit. A particular light indicator comes ON whenever its corresponding water sensor is in contact with water. The involved LEDs are red in colour.

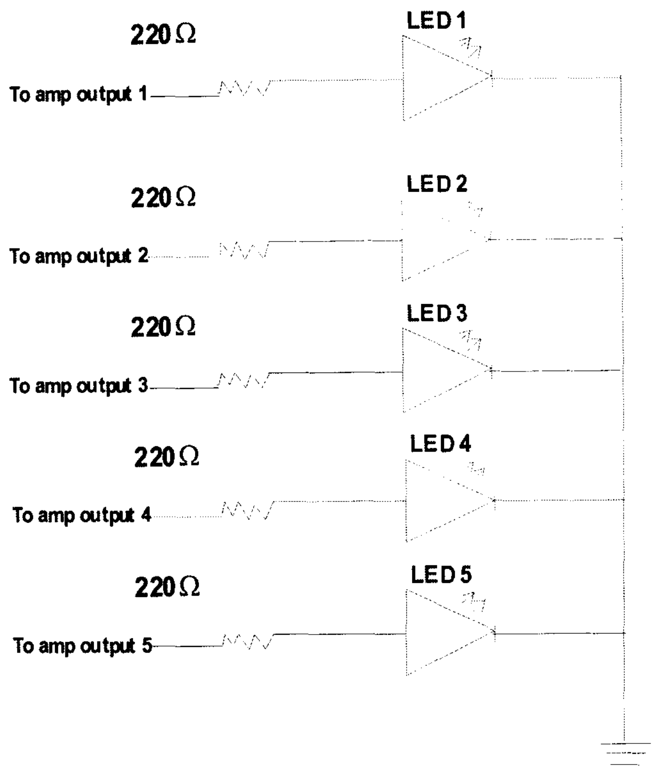


Fig 3.18 The complete light indicator unit

3.1.6 Alarm Unit

This is designed to give an audible tone for both FULL and LOW water levels in the tank. A particular alarm comes ON for each state (FULL or below one-quarter) and is disabled automatically if not at these two distinct water levels.

The central component in this unit is the 4060B CMOS oscillator/divider. It generates ten frequencies at once. This feature makes it preferable to the common 555-Timer chip. In fact, ten 555- Timers only meet a frequency generation task for only one 4060B CMOS chip. The device is attributed to high level of compatibility.

The 4060B can be configured in both RC (resistor-capacitor) and crystal modes. The RC mode is quite common. It involves an external capacitor and two resistors to the device. It has 14-stage dividers that breakdown a main frequency into smaller units [2].

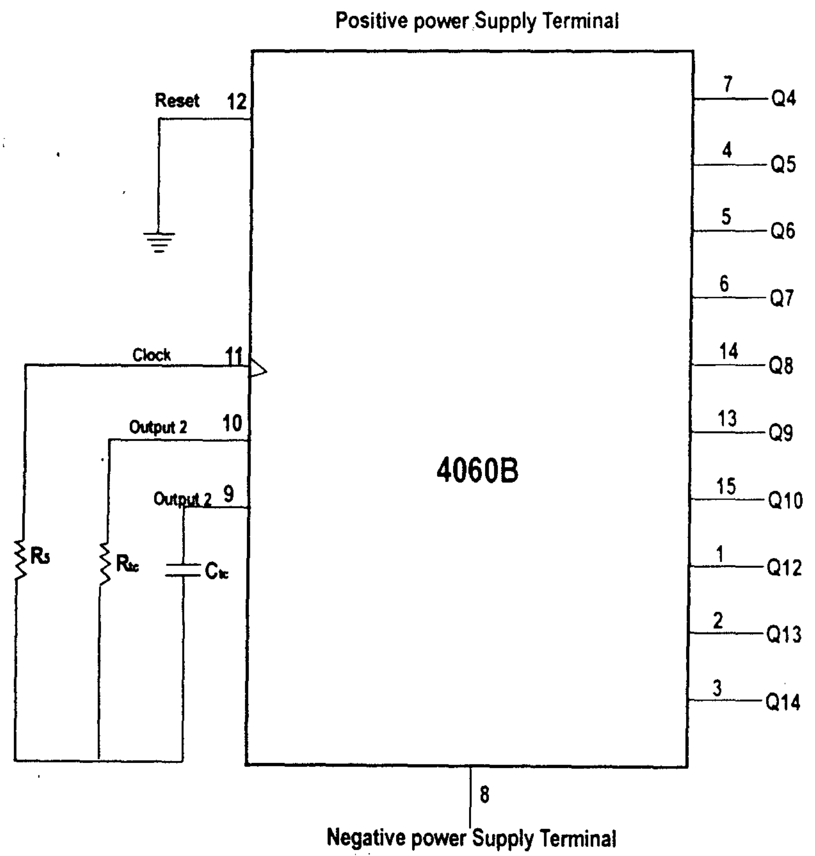


Fig 3.19 The functional diagram of a 4060B

4060B has the following relationships:

Main frequency:

$$f_m = \frac{1}{2.3R_{tc}C_{tc}}$$

where R_{tc} and C_{tc} are 4060B resistance and capacitance respectively.

$$10R_{tc} \geq R_5 \geq 2C_{tc}$$

The frequency output from a particular output terminal is given as:

$$f_{Qx} = \frac{f_m}{2^x}$$

x is the value of a particular Q output.

For this circuit, $R_{tc} = 33K\Omega$, R5 = 100 kΩ and $C_{tc} = 0.001\mu F$

Therefore,

$$f_m = \frac{1}{2.3x33x10^3x0.001x10^{-6}}$$

$f_m = 13.2KHz$

A 4060B IC is involved in the circuit. It consists of three output frequencies. Their values are computed as follows:

Frequency associated with pin 6 = $\frac{f_m}{2^7} = \frac{13.2x10^3}{2^7} = 103.125Hz$

Frequency associated with pin 7 = $\frac{f_m}{2^4} = \frac{13.2x10^3}{2^4} = 825Hz$

Frequency associated with pin 3 = $\frac{f_m}{2^{14}} = \frac{13.2x10^3}{2^{14}} = 0.806$ Hz

The first two frequencies are audio in nature. They are used in switching ON the alarm through the combination of the other very low frequency from pin 3.

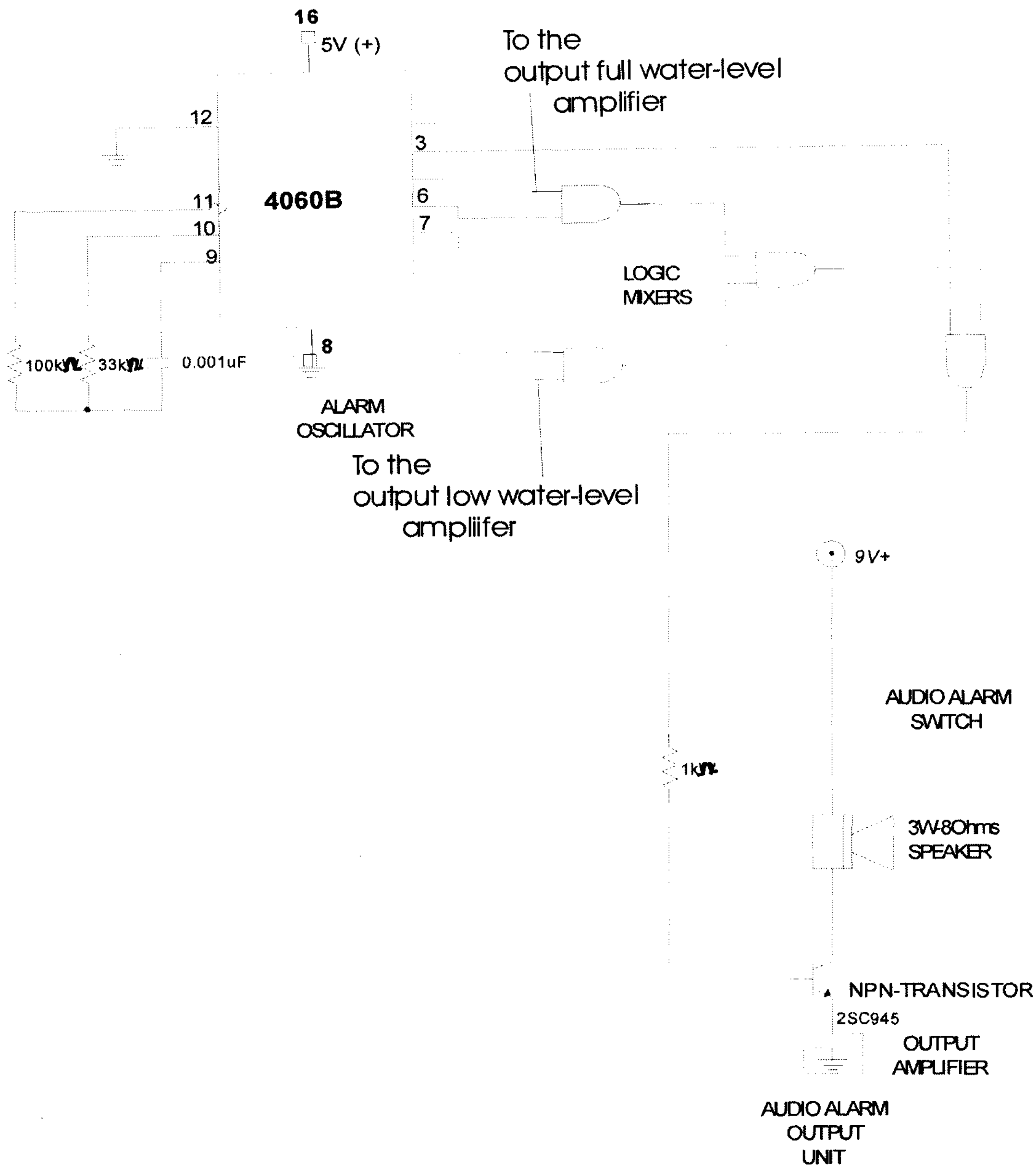


Fig 3.20 The Alarm Unit

The alarm unit consists of three AND gates. The logic unit that is connected to the 4060B, allows the signals from the first and last water sensors to select a particular audio alarm. The design gives a high tone alarm to the state the low water level condition in the tank while a low tone alarm goes for the full-water level condition.

The AND gates are derived from the 4018B IC which consists of four AND gates.

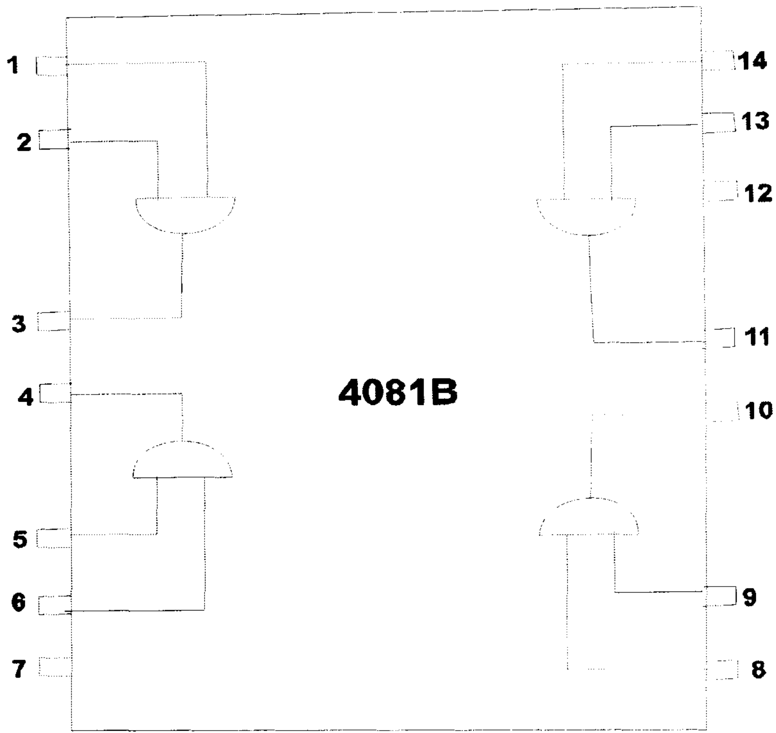


Fig 3.21 Pin configuration of the 4081B

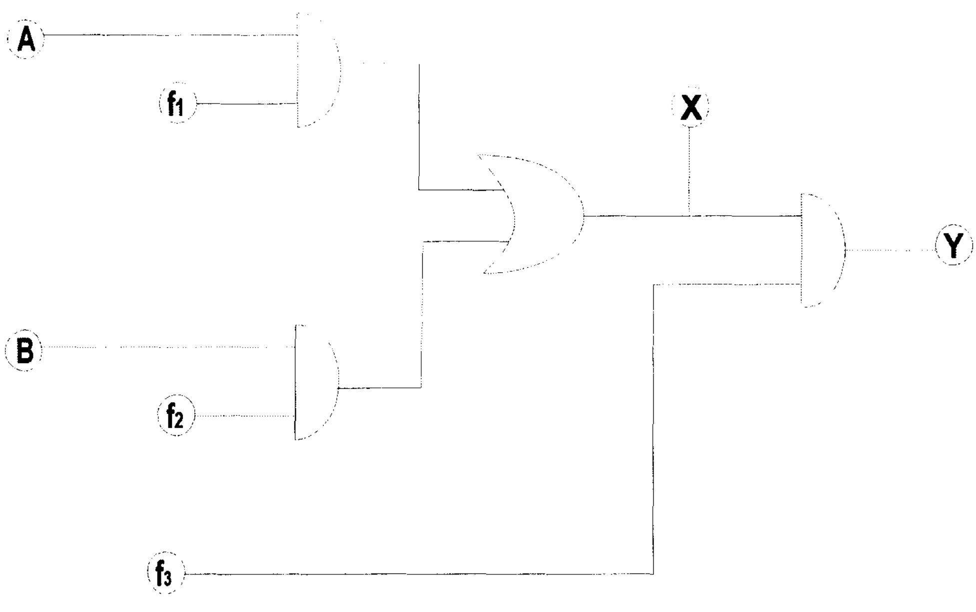


Fig 3.22 The selector in the alarm unit

The selector works in the manner that is stated in the truth table in table 3.3:

Table 3.3 The truth table of the selector

A	B	X
0	0	0
1	0	f_1
0	1	f_2
1	1	f_1, f_2

Signals at X and f_3 undergo an AND function for Y. f_3 is relatively low frequency. It breaks signal X. The operation is illustrated in fig 3.23

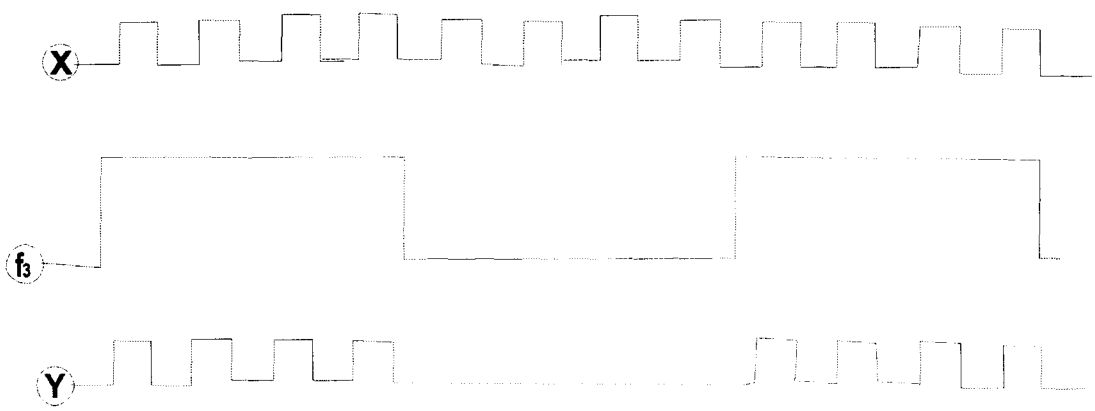


Fig 3.23 An illustration of the AND gates operation between signals X and f_3 [6].

The result is an alarm breaking switch. The output circuit allows signal Y to reach a reasonable level to power the speaker.

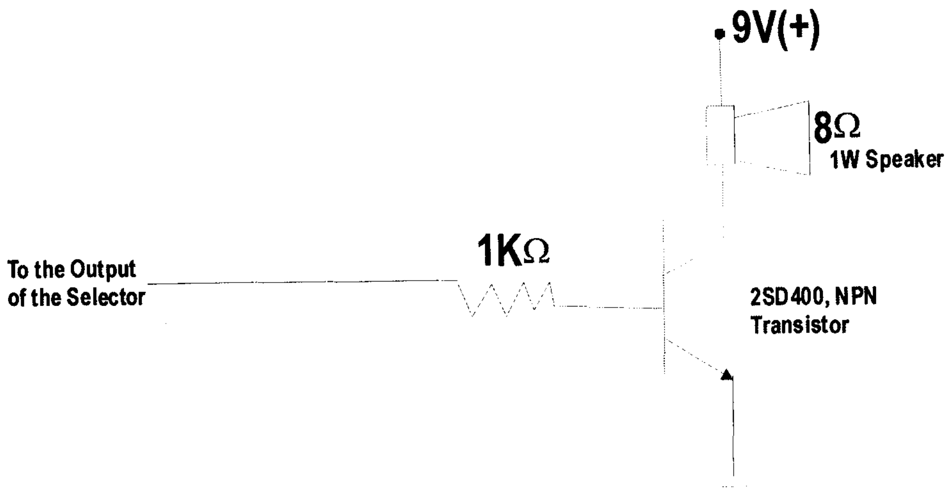


Fig 3.24 Output amplifier/Switch

2SD400 NPN transistor voltage and current ratings are 25V and 1A respectively. Its typical current gain, h_{FE} is 100.

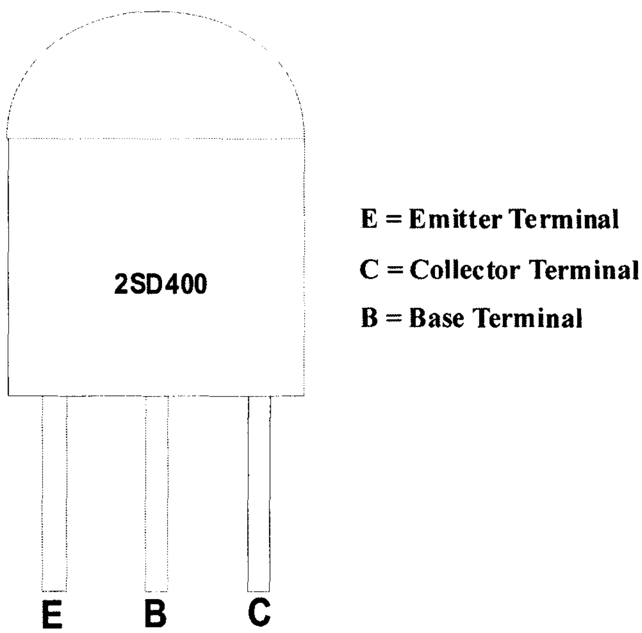


Fig 3.25 pin assignment of the 2SD400 NPN transistor

Using the 1kΩ base resistor, R_b in the transistor's circuit implies, Base current, $I_b = \dfrac{V_c - 0.6}{R_b}$

$I_b = 4.4mA$

Collector current, $Ic = I_b \times h_{FE}$

$Ic = 4.4 \times 10^{-3} \times 100$ $(h_{FE} = 100)$

$Ic = 0.44A$

The output of the amplifier is expected to be related to electric current of approximately 0.44A [7].

CHAPTER FOUR

CONSTRUCTION AND TESTING

4.1 Tools and Materials

During the construction of Digital Water-Level Actuator, some tools and materials were used. Some of them are briefly discussed below:

(i) **Breadboard-** This is a board on which a circuit is set up temporarily to ascertain that it is working properly before it is transferred to a veroboard.

(ii) **Veroboard-** This is a perforated plastic, overlaid with strips of metal conductors. It is used for permanent construction of the project prototype.

(iii) **Lead-** This is a metal with low melting point. It is used to hold components and connecting wires in place on the veroboard.

(iv) **Soldering Iron-** It provides the heat needed to melt the lead onto the veroboard when connected to ac mains.

(v) **Lead Suckers-** This is used to suck-up molten lead from the veroboard when de-soldering a connection.

(vi) **Digital Multimeter-** This is a multifunction electronic measuring instrument employed in the measurement of voltages, resistances, transistor current gain (h_{FE}) and check for continuity.

Others are connecting wires, pliers, glue, razor blade, cutting knife, drilling machine, file, chisel, scissors hammer and bending machine.

4.2 Hardware Construction

Careful planning of the circuit layout and simple wiring minimized errors and mad troubleshooting easier. All ICs used in the design were aligned in the same direction for a logical signal flow and this made it easy to keep track of pin numbers during soldering and troubleshooting.

To ensure that each unit was working properly, it was soldered independently and tested. All the units were then interconnected together as specified in the design. All the connections to the device are detachable by pins at the front panel of the system casing. This makes the device to be portable.

4.3 Project Casing

Plastic was used to case the project. The front panel was cut at convenient portions for the power and pump switches, a power and five power level indicator LEDs and perforated around the speaker position to allow passage of sound alarm. The cover has holes drilled on its sides for ventilation. The front panel also has a pin socket for the pump and five other pins' sockets for the probes.

The back panel has provision for the pin 2-pin power supply cable. Each component on the front and back panel is labeled for easy identification.

4.4 System Coupling and Photographs

The transformer was mounted, using screws at the centre of the casing so as to balance its weight. The circuit board was then mounted in a vertical position so as to create reasonable space inside the device for interconnecting wires. The pins' sockets, switches and the speaker were firmly screwed to the casing. The LEDs were fixed to the casing using gum.


Fig 4.1 Photographs of the device (interior view and testing set-up)

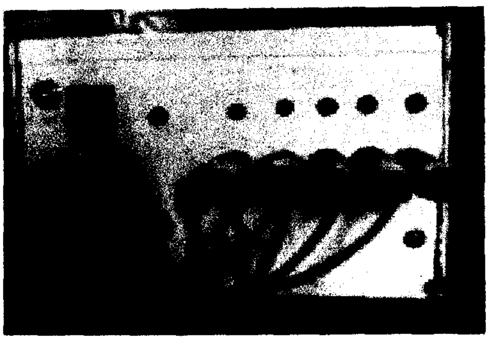



Fig 4.2 Photographs of the device (front and back views)

4.5 Construction Precautions

(i) All soldered joints were tested for continuity so as to avoid open circuits.

(ii) All excessive lead was removed to avoid bridges (short circuits) on the board.

(iii) Polarities if electrolytic capacitors and pin configurations of transistors and ICs were checked properly before soldering.

(iv) ICs were mounted on IC sockets to avoid over-heating them and for easier troubleshooting.

(v) Excessive heating of the components was avoided so that they do not burn-out.

4.6 Testing and Result

The system was set-up by connecting the pump power cable, supply cable and the five water sensing probes to their respective connecting points/ports at the front of the device. The five sensors panel was then lowered inside the bowl (tank) with the FULL (sensor 1) going below the brim. The bowl acting as tank provided was meant for storing water.

The device was then switched ON after which the pump was triggered ON from its power switch on the front panel of the device. In the automatic water pump control mode, when the water had reached any sensor, its corresponding LED will come ON. Immediately the sensor 1 would come ON, the pump will automatically switch OFF with the alarm triggering to notify the water level. This implies that all the five LEDs come ON at this stage (FULL). As water was being ran-out from the tap, the LEDs started going OFF whenever water goes below its corresponding sensor in the tank.

But immediately water just got below the lowest sensor (below one-quarter of the tank), a different audible alarm triggers and the pump switched ON to start pumping water into tank.

The automatic process continued until power supply was switched OFF.

4.7 Problems Encountered

During testing period, it was discovered at some points that the system was no longer responding to changes in the water level. Most of the LEDs were not coming ON when water reached their corresponding sensors. Again the pump was stopping without completing the task. They were checked and the system functioned normally thereafter.

The alarm was discovered not responding when got to sensor 1 (FULL) and below one-quarter (below sensor 5). This was checked and rectified too with the two distinct alarm sounds being heard audibly.

Drilling and cutting out of the plastic parts for the casing to desired shapes and filing the edges wasn't an easy task at all, particularly in the absence of precision machines.

4.8 Bill of Engineering Measurement and Evaluation (BEME)

S/N	Description	Qty	Unit Cost-(₦)	Total Cost(₦)
1	Power Unit (Step-down transformer)	1	250.00	250.00
2	4060B Alarm Oscillator	1	150.00	150.00
3	N-Channel MOSFET (IRFZ44)	1	140.00	140.00
4	Pump Control Latch (4013B)	1	30.00	30.00
5	NPN Transistor (2SD400)	1	80.00	80.00
6	8Ω, 1W Speaker	1	200.00	200.00
7	Pump	1	150.00	150.00
8	105mm x 92mm Veroboard	1	70.00	70.00
9	AND Gates	3	5.00	15.00
10	OR Gates	1	5.00	5.00
11	NOT Gates	11	20.00	20.00
12	LEDs	6	5.00	30.00
13	Power Switches	2	40.00	80.00
14	220Ω Resistors	5	4.00	20.00
15	Voltage Regulators (7809 and 7805)	2	40.00	80.00
16	220μF Capacitors	1	10.00	10.00
17	47μF Capacitors	2	5.00	10.00
18	10KΩ Resistors	5	2.00	10.00
19	100KΩ Resistors	1	5.00	5.00
20	1KΩ Resistors	3	5.00	15.00
21	33KΩ Resistors	1	5.00	5.00
22	0.001μF Capacitors	1	10.00	10.00
23	Tap	1	150.00	150.00
24	Gum	1	40.00	40.00
25	152.5cm Long Transparent Pipe	1	50.00	50.00
26	Transparent Plastic Containers	3	70.00	210.00
27	130cm White Plastic Sheet	1	200.00	200.00
28	Screws	12	2.50	30.00
29	Connecting Wires for Probes	5	5.00	25.00
30	Bare Copper Wires for Sensors	5	30.00	150.00
31	Black Sello-tape	1	20.00	20.00
32	White Maskin Tape	1	40.00	40.00
33	Super Glue	1	20.00	20.00
				GRAND TOTAL =₦2,290.00

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the results of the tests carried out, the Digital Water-Level Actuator performed its expected functions satisfactorily. The components used in constructing the device are expensive and commonly available. The device will be highly useful in homes, industries, hospitals, schools, etc to make water available at reduced cost and minimum energy input. The practical implementation of the design made the student to become more familiar with electronic components and improve the student's skills and techniques in handling construction tools.

In summary, the aims and objectives of the project have been achieved, though with little problems that were encountered but logically resolved.

5.2 Recommendations

In the design, the water level was measured at discrete points only. This can be improved by using differential approach like varying resistance with liquid level.

Interfacing the device with a computer and coding a program (e.g. in C++ or Java) will make it possible to know the exact liquid level in the container at any point in time and communicate to the user using appropriate displays on the computer screen.

The device will have more applications if interfaced with a computer and a program run to respond to a wide span of fluids' conductivities not limiting it to water alone.

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Appendix: The Complete Circuit Diagram of a Digital Water-Level Actuator