DESIGN AND CONSTRUCTION OF A WATER LEVEL INDICATOR

BY

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(2000/10657EE)

A PROJECT SUBMITTED

TO

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

SCHOOL OF ENGINEERING & ENGINEERING TECHNOLOGY

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING DEGREE IN ELECTRICAL AND COMPUTER ENGINEERING

NOVEMBER, 2005

DECLARATION

I, IKE CHIDI BASIL (2000/10657EE) hereby declare that this project was carried out by me in the department of Electrical / Computer Engineering under the supervision of Dr. Y. A. Adediran.

All information utilized and their sources have been duly acknowledged.

.... 07/12/2005 ....

IKE CHIDI BASIL DATE

CERTIFICATION

This is to certify that this thesis "Design and Construction of a Water Level Indicator" is the original work of Ike Chidi Basil carried out under the supervision of Dr Y. A. Adediran for the award of Bachelor of Engineering (B. Eng) degree in Electrical and Computer Engineering of F U T., Minna.

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ACKNOWLEDGEMENTS

The successful completion of this work would not have been realized without assistance from great and distinguished personalities, to whom I shall forever remain grateful.

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DEDICATION

To my dad and mum for your love, prayers and support.

ABSTRACT

The design and construction of a water level indicator is described in this project. The project is intended to display six LED's (output) accordingly in a bar graph mode to show the level of water (input) in a tank. One of the LED's is red and indicates the critical level (very low water level) of the tank while the others are green and are used to show the variations of water level as it increases or decreases in the tank. The project comprises the sensing unit in the tank, the driver unit and the power supply unit.

CONTENTS

CHAPTER ONE

1.1 INTRODUCTION

The importance of liquid level control for domestic and industrial purposes cannot be over-emphasized. In Nigeria, pipe-borne water supply can be anything but satisfactory. This obvious inefficiency in water supply has resulted in storage of water in water tanks for use when supply from public water mains become erratic. The storage of water in water tanks can come from different sources of water available like rain, bore-hole, pipe –borne water from public mains, e.t.c.

Water storage is a critical aspect of obtaining water security, so that water can be made available at all times. This is because the unavailability of water will cause discomfort in life, obstruction of industrial processes and several unpleasant experience.

In the agricultural sector, where a large quality of water is needed for irrigation purposes, it is necessary to maintain certain reserve of water in the reservoir by controlling the flow of water either into the reservoir or out of the reservoir. In industrial sector, it is necessary to maintain certain reserve of water in intermediate capacities (vessels). To take care of erratic supplies from public mains where many continuous manufacturing processes require the consumption of great quantity of water so as to avoid a sudden disruption of manufacturing processes. The idea of water level of reservoir is also important in hydro power stations where water is used for power generation purposes. Also at home or buildings, a knowledge of water level is necessary so as to regulate water usage especially in areas where water supply is not very constant.

The water level indicator is designed to indicate the level of water in a tank or other water storage vessels. It indicates if the water is at a very low level, at different levels of the water containing vessel by the appropriate light emitting diodes {LEDs} illuminating. The water level indicator operates on the principle that the conductivity of water increases as the separation distance of the measuring probes is increased, by supplying a reference voltage to the reference probe and placing the other probes horizontally at some distances apart from each other and also from the reference probe.

The knowledge of the water level in a tank is necessary to prevent the incidence of being taken unaware when the tank or reservoir is empty, as well as when the tank is full during the filling process. A large volume of purified water is wasted due to the over filling of tanks as a result of the inability to know when the tank is full or any indication of the level of water in the tank especially if the tank or reservoir is placed very high {over head tank}, underground or is opaque {i.e. when the level of water cannot be seen}.

Earlier on, there were several traditional ways for finding the level of water in a tank. Like tapping down the side of the tank until the sound suddenly changes or removing the tank cover and dipping in a measuring stick. These methods are mostly unreliable and can be awkward and time consuming, especially when the tank is placed high or is underground. Therefore, the need for a water level indicator arises since nobody will always want to clamber up on top of a tank or go inside it each time he or she want to find out the level of water in it.

1.2 PROJECT AIMS AND OBJECTIVES

The design and construction of the water level indicator is aimed at achieving the following goals:

1) To design and construct an electronic device that will indicate the level of water in a tank or reservoir, thereby allowing a user to control and regulate the usage of water in various places like homes, building, industries, farms etc.
2) To put into practice, the various theories learnt in the school. Such courses include analogue electronics, digital electronics, power electronics, and laboratory practical at various levels, circuit theory and advance circuit theory, among others.
3) To ease the stress encountered by a person wishing to know the level of water in a tank especially in places where someone is employed to monitor and control water level in a tank.

1.3 PROJECT OUTLINE

Chapter one: This chapter gives a general introduction to the project. Aims and objectives are also contained in this chapter.

Chapter two: This chapter covers the literature review that highlights pervious work of the subject and also the level measurement techniques.

Chapter three: This chapter contains the principle of operations and the detailed circuit design and the analysis of the projects, which also shows an in-depth look at various components and sub circuits that make up the system.

Chapter four: This chapter covers all the details of the construction and testing procedures employed to achieve the final product. It spans simulation of the circuit diagram on the computer, bread boarding and soldering of the components on the vero board, casing construction, testing precautions taken, troubleshooting and results obtained, as well as the difficulties encountered, in the course of the construction and testing.

Chapter five: This chapter contains the conclusion drawn from the results of the testing, with reference to the objectives and goals of the project. The chapter also contains the recommendations for further work on the project topic in future.

1.4 METHODOLOGY

The method employed in the design and construction of a water level indicator is based on the conductivity property of water.

Multiple point (discrete) sensing technique and a driver unit (circuit) is used for the level indicator sensing and output (LEDs) respectively.

CHAPTER TWO

2.1 LITERATURE REVIEW

In order to obtain the level of a liquid, various methods have been employed in the time past starting from the ancient "eye level" measurement where the liquid is placed in a transparent container and the eye is placed at the line of the best horizontality and at that point, the measurement is taken as the level]of the liquid. This is however prone to a lot of errors mostly arising from the observer. The need for a more reliable method of detecting the level of liquid in a tank or reservoir arises.

The earliest record of water level measurement (indicator) was the use of the float regulator mechanism in Greece in the period 300BC to 1BC using feedback control concepts. The water clock invented by kleisibios used a float regulator to measure the level of water in a container on which a scale attached is used to take the reading of time. Russian PULZUNOV. I in 1765 invented the first historical feedback system for level indicator and control [1]. It consists of a water level float regulator using feed back system; the float detects the water level and controls the valve that covers the water inlet in the boiler.

The past 100 years have witnessed the emergence of various methods of water level indicator as a result of the improvement in technology witnessed within this period. The ordinary dipstick is a simple device used for measuring liquid level. It consists of a metal bar, on which a scale is etched, and fixed at a known position in the liquid – containing vessel; removing the instrument from the vessel makes a level measurement and reading how far up the scale the liquid has wetted [2].

Several other approaches towards controlling liquid flow and measuring the liquid level in a tank have since been developed. Measuring the level the level of float on the surface of a liquid by means of a suitable transducer is another method of liquid level indication; the system used in potentiometer is very common and well known for monitoring the level of oil in motor vehicle fuel tanks. An alternate system is the float and tape gauge, where a tape is attached to a pulley situated vertically above the float and its other end a counter weight or a negative – rate counter spring is attached. The amount of rotation of the pulley measured by either a synchro or a potentiometer is proportional to the liquid level.

Pressure measuring devices used for water level measurements, utilize the principle that the hydrostatic pressure due to a liquid is directly proportional to its depth and hence the level of its surface.

In open topped vessels or covered ones that are vented to the atmosphere, the level of liquid is measured using an appropriate pressure transducer inserted at the bottom of the vessel. The liquid level is then related to the measured pressure according to $h = P/\rho g$, where ρ = density of the liquid, g = acceleration due to gravity, and P = pressure [2]. Capacitive devices are used for measuring level in such applications as for measuring level in liquid metals (high temperature), corrosive liquids (acids, etc), and high pressure devices. The radiation method of water level measurement utilizes a radiation source and system located in a liquid tank or reservoir.

The ultrasonic level gauge principle uses energy from an ultrasonic source above the liquid reflected back from the liquid surface into an ultrasonic energy detector; measurement of the time of flight allows the liquid level to be inferred. The Stevens ultrasonic level transmitter is a non – contact, solid state device for sensing water level in channels, lakes or steams for input to a data logger or other monitoring unit; analogue output can be configured normal or inversely proportional to the distance from the target of water surface [3].

The principle of vibrating level sensor consists of two piezoelectric oscillators fixed to the inside of a hollow tube, which generates flexural vibrations in the tube at its resonant frequency (which varies according to the depth of its immersion in the liquid)

A phase locked loop (PLL) circuit is used to track the changes in resonant frequency and adjust the excitation frequency applied to the tube by the piezoelectric oscillator. Liquid level measurement (indication) is, therefore, obtained in terms of the output frequency of the oscillator when the tube is resonating [2].

The Stevens submersible depth transmitter is a sensing device designed for water level measurement applications. Higher range units are used for ground water, storage tanks or other applications. Low range units are ideal for open – channel flow applications; a stainless steel pressure transducer is used as the primary sensing element, and it measures the depth of water by pressure above the unit.

The improvement in technology in the semiconductor industry, led to the development of the operational amplifiers, transistors, integrated circuits IC (which contain several electrical components, like resistors, capacitors, etc), etc. This led to newer water level measuring techniques like the water level and TDS (Total Dissolved Solids) sensor which can be built using an older style telephone handset with all components (except the probe) included in the handset. The circuit works by sensing the resistance of the probe which is inserted inside the tank or reservoir (e.g. Well). If the probe is open (not touching water), the circuit will produce an audio frequency around 400Hz. When the probe touches quality water, the frequency doubles (approximately), increasing the tone by about one octave. If the water has dissolved solids in solution, the tone will quickly go higher giving the person measuring an approximation of the mineral quality of the water [3].

This project makes use of different electrical components like resistors, capacitors, integrated circuits, etc and is used only to indicate the level of water in a tank or reservoir at six different levels.

2.2 LEVEL MEASUREMENT TECHNIQUES

There are several level measurement techniques which can be employed nowadays. One of such techniques, is the electronic level controller (ELC) which is a device used in monitoring and controlling the level of media in a vessel. It can be used for predetermine level indication with ON – OFF control and for continuous level measurement in a wide variety of process medium applications.

Some types of water level measurement techniques are listed below:-

- Gauge glasses, which are of two kinds; low-pressure type and high-pressure type.
- Float-operated hydraulic level gauge, with dual opposed hydraulic system.
- Gamma-ray level gauge, used for difficult applications.
- Capacitance probe-type level system for conducting liquid.
- Capacitance probe-type system for dielectric liquid.
- Gas gauge system for level measurement in a tank.

- Mercury manometer with two liquid seals at different levels in a tank.
- Force balance diaphragm-type transmitter for level measurement.
- Trapped-gas system using diaphragm box, to minimize lead-line errors and venting [2].

Water level instrument has ultimate utilization with the advent of water tank and bid reservoir in the industries or public society of water distribution using hook gauge, tape gauge, float gauge, etc. But the recent advanced techniques on water level measurement lead to the electronic system performing the task. By the introduction of microprocessors system in science and technology, large parts of systems mechanism, and large number of components can be integrated together. Nowadays, with low cost integrated and logic circuits, water level indicator can be constructed.

CHAPTER THREE

3.1 CIRCUIT DESIGN AND ANALYSIS

The circuit design and analysis consists of the different stages namely; the power supply unit, the sensing unit and the output unit. These various steps are analyzed extensively.

3.1.1 POWER SUPPLY UNIT

All electronic devices utilize a direct current (DC) voltage source for operation. The mains electricity supply is an alternating current (AC) at a voltage of 220V-240V and have to be converted to D.C supply of the required value.

The use of batteries is an alternative power supply to the rectification process. However, it has some disadvantages which include; limited life span – this result from the manner in which the internal resistance increases with age thereby deteriorating the battery. It cannot satisfy the amount of current drawn by most electronic devices for a long time as the battery is quickly drained and this becomes inefficient, hence an AC to DC conversion is done by the power supply unit to avoid these inadequacies of the battery.

The power supply unit consists of the transformer, a bridge rectifier, a filter and a voltage regulator which all function together to transform the AC voltage supply from the mains into a regulated DC supply as the output of the power supply unit .The block diagram of the power supply unit is shown in figure 3.1.

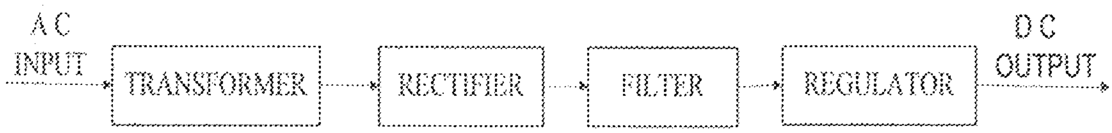


Fig 3.1 Block diagram of the power supply unit

The input ac supply voltage is a single phase voltage obtained from the mains supply of PHCN with a value of 220V, 50Hz.

3.1.1.1 THE TRANSFORMER SPECIFICATIONS

This is the stage of the power supply unit that involves the reduction of the AC voltage value to a lower value of 12V AC with the aid of 240V/12V transformer. The current rating is about 500mA which is enough to drive the entire circuit .A transformer is an electrical device that provides physical relation between the 240V A.C main and the rest part of the circuit. The only link is by means of magnetic flux, thus eliminating the risk of electric shock.

There are basically two types of transformer, namely; step-up and step-down transformer. The step-down transformer is used and consists of two windings (coils), the primary winding and the secondary winding. Figure 3.2 shows the circuit symbol of a transformer.

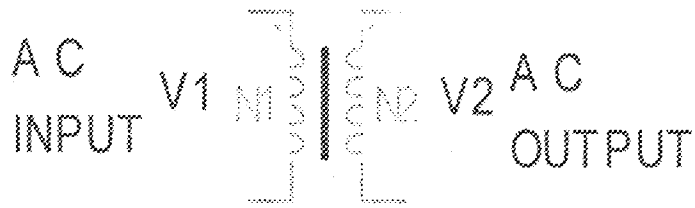


Figure 3.2 Transformer circuit symbol

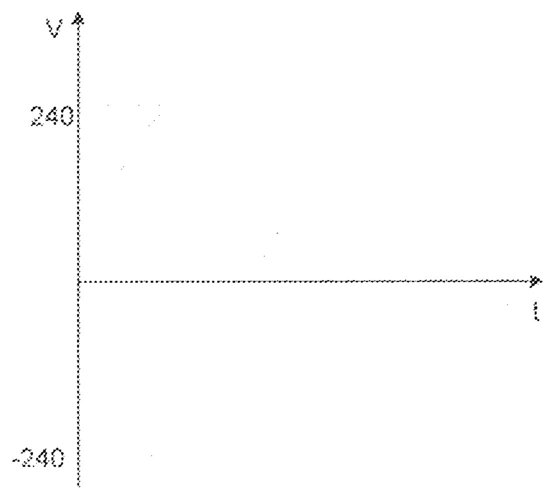


Figure 3.3 (a) input signal (b) output signal

Figure 3.3 a and 3.3 b shows the waveforms associated with the input and out put of the transformer.

The transformer data is given as V_1 (input) =240V, V_2 (output) =12V, I_2 =500mA=0.5A, frequency f =50Hz.

The ratio of the primary voltage V_1 to the secondary voltage V_2 is equal to the turns ratio or number of turns of the primary winding N_1 to that of the secondary winding N_2 of the transformer.

The primary and the secondary voltages of an ideal transformer are related as follows.

$V_1/V_2 = N_1/N_2$

$= 240V/12V = 20$

Turns ratio $N_1:N_2 = 20:1$

Magneto motive force (mmf) = NI

$N_1 \times I_1 = N_2 \times I_2$

$N_1/N_2 = I_2/I_1 = 20$

$I_2 = 500mA = 0.5A$

$I_1 = I_2/20 = 0.5/20 = 25mA$

Also, power input = power output

$P_1 = P_2$

$I_1 \times V_1 = I_2 \times V_2$

$25mA \times 240 = 6W$

3.1.1.2 THE RECTIFIER SPECIFICATIONS

The output of the transformer (secondary terminal) which is an AC signal is converted to DC signal with the aid of a rectifier circuit but the full wave bridge rectifier circuit is used for this project. It consists of four 1N 4001 diodes arranged as shown in figure 3.4 below.

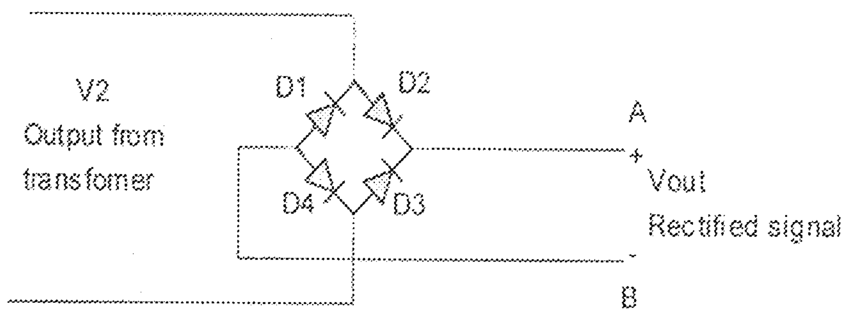


Fig 3.4 Full-wave rectifier circuit diagram

During the positive half cycle of the secondary voltage, diodes D_2 and D_4 are forward biased, current flow through diode D_2, terminal A, terminal B,(through a load connected at the output terminals),diode D_4 During the negative half cycle of the input voltage V2, diodes D1 and D_3 are forward biased and therefore, conducts current flowing through a load connected across the terminals AB in the same direction as above (i.e. from point A to B)

This circuit achieves the aim of making current flow in one direction only (DC) irrespective of the positive and negative half-cycles of the input signal. The associated waveforms (input and output) are shown in figure 3.5 below.

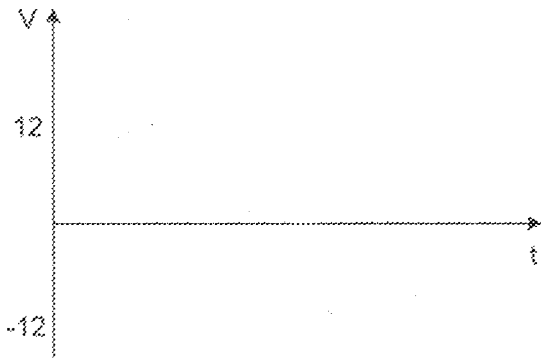
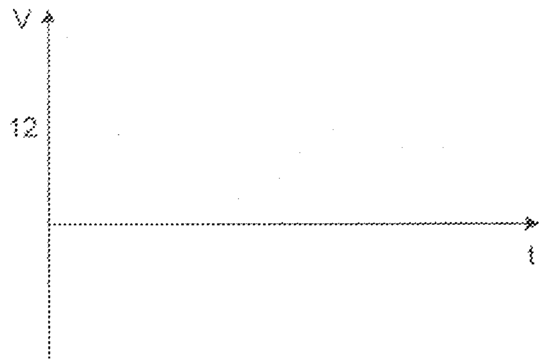


Fig 3.5 (a) input signal V2



(b) Output Rectified signal

The peak secondary voltage of transformer $V_{ps} = \sqrt{2}\, V_{rms}$

$V_{rms} = 12V$

$V_{ps} = 12\sqrt{2} = 16.97V$

The average DC voltage V_{dc} across terminal AB

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

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

$= 10.8V$

By standard, the acceptable PIV (Peak inverse voltage) = $4 \times V_{ps}$ for a full wave bridge rectifier.

$4 \times V_{ps} = 4 \times 16.97V = 67.88V$

Thus, the diode IN4004 with PIV greater than 67.88V is chosen.

3.1.1.3 THE FILTER SPECIFICATIONS

The filter circuit forms a part of the power supply unit so as to minimize the ripple content of the rectifier output. The output voltage waveform of a rectifier is pulsating because it has both DC component and some AC components called ripple and this type of output signal is not suitable for driving electronic circuits. The filter circuits receives DC signal as input and filters out or smoothens out the pulsations in the input.

There are various types of filtering circuits but the simple capacitive filtering is adopted in the design; where a large electrolytic capacitor (100µF) is connected to the rectifier output. The shunt capacitor "bypasses" AC signal present (ripples) and this effect makes the output to almost assume a pure DC level. The capacitor charges during the diode connection period to the peak value and when the input voltage falls below the value, the capacitor discharges through the load so that the load receives almost steady voltage. The rectified and filtered output waveforms are shown in figure 3.6 a & b

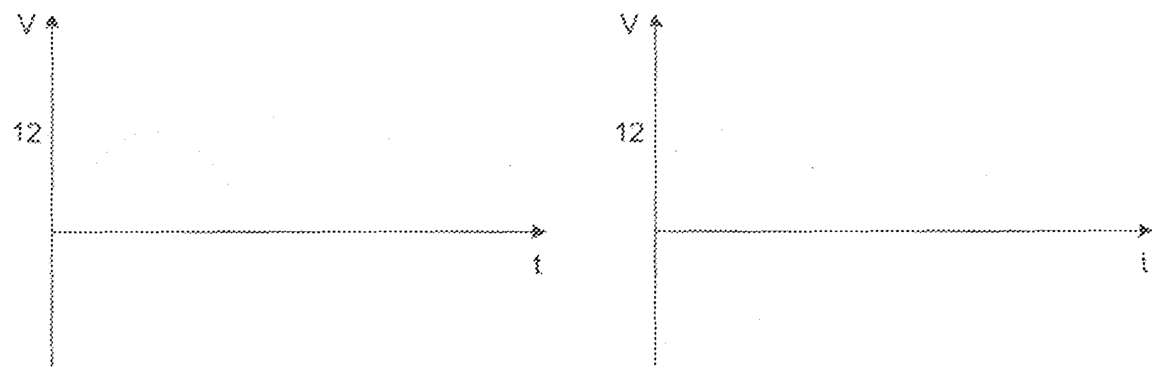


Fig 3.6 (a) Rectified signal waveform (b) Filtered signal waveform

3.1.1.4 THE VOLTAGE REGULATOR

The introduction of voltage regulator in the power supply unit is necessary to maintain a constant voltage supply of 12V regardless of the varying voltage of input or load change which can cause irregular supply. In other words, a voltage regulator is a circuit that holds an output voltage at a predetermined value regardless of the change in normal input or changes in load impedance.

Voltage regulators mostly come in a three terminal package; one input terminal, one output terminal, and a ground terminal. The monolithic voltage regulator IC chip 78L12 is used to supply steady 12V DC to drive the system circuit. The 78L12 chip supply the rated voltage 12V with a wide range of voltage input and variations in load current. A 10μF capacitor is connected at the output terminal of the regulator to filter of any ripple left on the supply line. Figure 3.7a, b & c shows the filter / regulator circuit, input and output waveforms respectively.

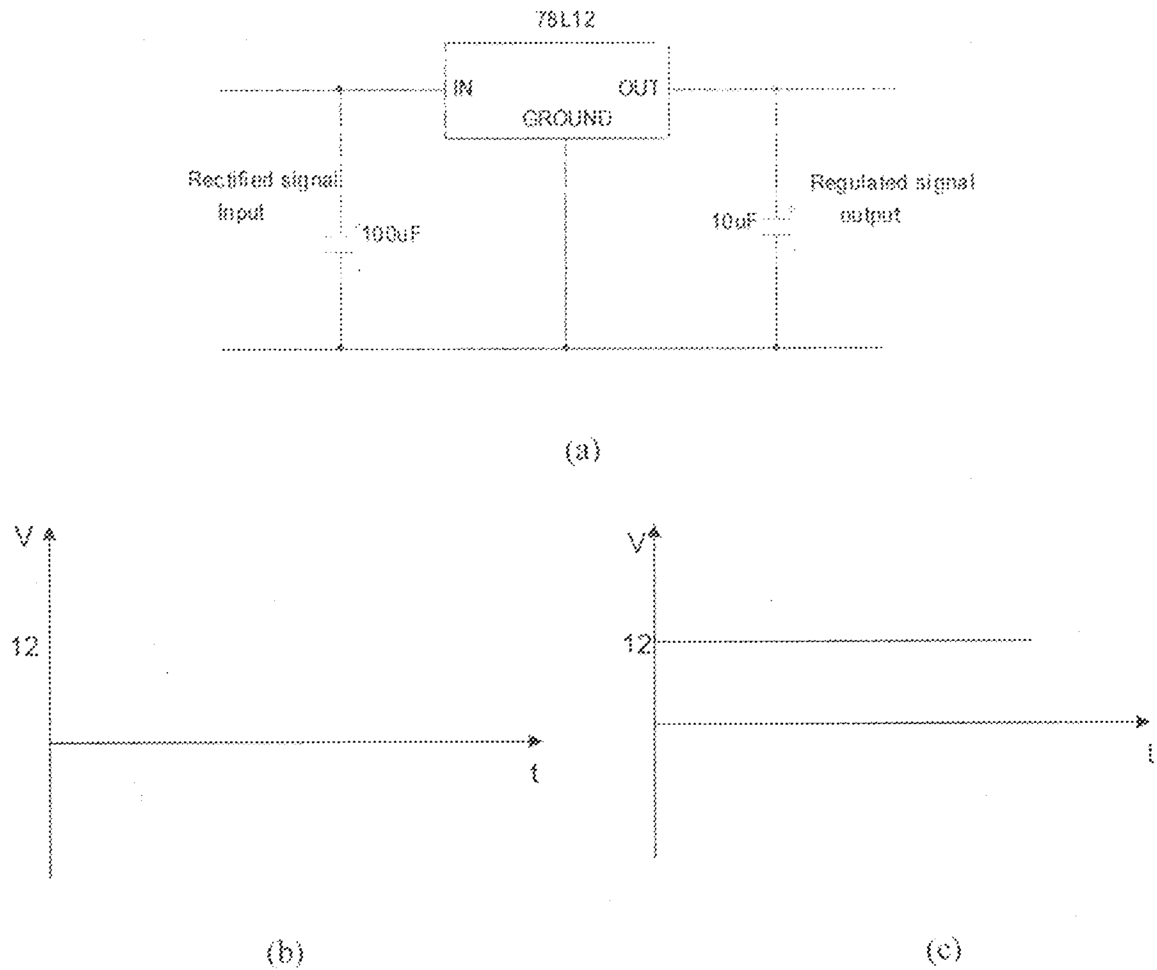


Fig 3.7 (a) Filter/regulator circuit

(b) Input signal

c) Output signal (regulated) [4, 6]

3.1.2 SENSING REGION

The sensing region consists of the tank and the sensing points in the tank which produces the required DC signal that drives the various LEDS (output).

3.1.2.1 THE SENSORS ARRANGEMENT

The water sensor unit uses copper conductors as the probe to convert the water level into electrical signal (DC). The required signal produced from the sensor is based on the principle that the conductivity of water increases with the increase in separation distance of the sensors (with appropriate values of resistor connected to form the biasing network with the PNP transistor of the main circuit).

The resistors of the sensors are connected in parallel to each other and as they are switched in (when water level passes them), forms a part of the circuit.

The probes are equally spaced on a tube which is supported at the two ends to remain firm in the water. The conductors connecting the probes through their various resistors are passed inside the tube. A hole is made on the tube so as to make contact to the sensors with their separate conductors. The sensors arrangement is shown in figure 3.8.

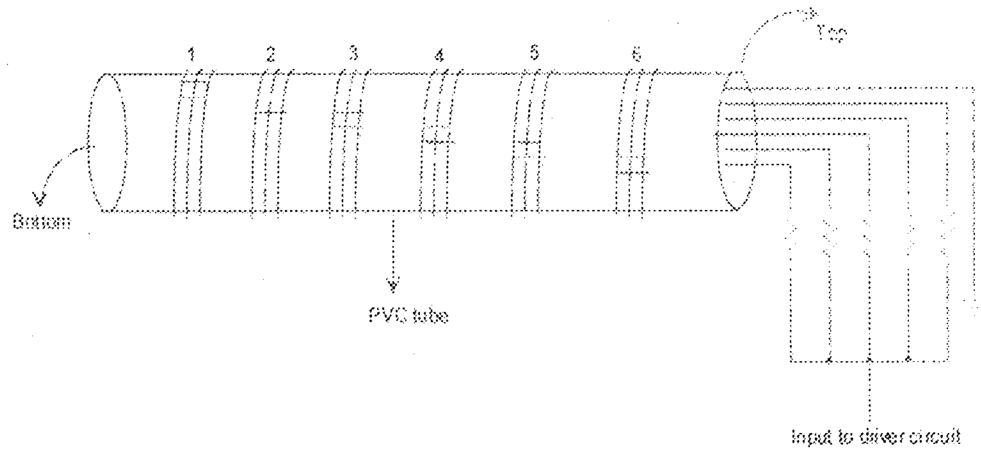


Figure 3.8 Sensors arrangement in a tube.

3.1.2.2 TANK/RESERVOIR

The tank reservoir can either be made of metal or plastic. When using a metal tank, the sensors are placed so as not to touch the tank. The bottom of the sensors arrangement is supported at the bottom of the tank and the top at the top of the tank [8]

3.1.3 THE DRIVER CIRCUIT/ OUTPUT UNIT

The driver circuit consists of several components which is powered by the power supply unit. The major IC's are the LM3914 and the IC555 timer. It also has one PNP transistor, six light emitting diodes LED's, resistors of various values (including a variable resistor) and capacitors.

3.1.3.1 THE LM3914 DOT/BAR DISPLAY DRIVER

The LM3914 is a monolithic integrated circuit that senses analogue voltage levels and drives 10 outputs (LEDS), providing a linear analog display. A single pin changes the display from a moving dot to a bar graph. Current drive to the LEDS is regulated and programmable, eliminating the need for resistors. The feature allows operation of the whole LM3914 system from less than 3V.

The LM3914 circuit contains its own adjustable reference and accurate 10- step voltage divider. The low bias current input buffer accepts signal down to ground V^- , yet needs no protection against input of 35V above or below ground. The buffer drives 10 individual comparators referenced to the precision divider. The LM3914 has so many applications in electronics and includes the purpose for which it is used in this project (to display five output LEDS).

The input to the IC LM3914 is provided by the resistor ladder network via the transistor connected to 12V so that different voltage level is obtainable at the inputs. Since the IC has an internal reference voltage of about 1.25 V maintained between two pins (7 and 8), it is used as a comparator for the various voltage values it receives as input. The connection of the LM3914 (IC1) is shown in the figure 3.9.

Pins 1, 10-18 are the output pins while pin 5 receives the input signal (voltage signal). Power of the transistor is to pin 3(+12V) and pin 2 is connected to ground. Pin 9 is the mode selector (when connected to +12V, it displays in bar mode and displays in dot mode when compared to ground.

From LM3914 data sheet (Appendix), maximum LED current =10mA

Supply voltage = 12V

LED voltage = 2V

Value of limiting resistor = (12V – 2V)/10mA

=1KΩ

Thus, a 1KΩ resistor was chosen as the limiting resistor for each LED.

3.1.3.2 THE IC 555 TIMER

The IC555 timer is one of the most popular and useful integrated circuits of all time. It is used for several applications e.g. to generate a single pulse, generate a time delay, generate a voltage which rises linearly, e.t.c. The IC555 timer can also be used as a transducer and that is why it is employed in this project.

A transducer is a subsystem which converts energy from one form into another, where one of the forms is electrical. In an output transducer, for example, electrical energy can be converted into light, sound or movement. The output of a 555 timer can deliver more than 100mA of current. This means that output transducers including buzzers, filament lamps, loudspeakers, and small motors can be used in electronic circuit to turn ON and OFF.

From the circuit diagram,(figure 3.9), the IC555 timer (IC2)drives LED 6 (output) to provide a warning when the water level falls below the lowest sensing point .

In a "Schmitt" trigger circuit, there are two different switching thresholds. if V_{in} (input voltage to the IC2) is slowly increased starting from 0V, the output voltage snaps from high to low when V_{in} reaches a level equal to 0.667 of the power supply voltage. Once this level has been exceeded, decreasing V_{in} does not affect the output until V_{in} drops below 0.33 of the power supply voltage. If a led (L6) is connected between the positive supply rail and the output, current flows through the LED when the output voltage is low. In other words, the LED lights when the input voltage is high.

With the connection of IC2 correctly done as shown in figure 3.9,pins 6 and 2 provide the threshold and trigger inputs and the signal at this inputs causes the output pin 3 to switch low or high. When LED 5 is on, its anode is about 2V and pins 6 and 2 of

IC2 are pulled low via the 100kΩ resistor, so that they sit below the lower threshold voltage. As a result, pin 3 of IC2 is high and LED 6 is off. However, if LED 5 is off as a result of low water level, the anode of led 5 goes to 12V. This voltage exceeds the upper threshold voltage of IC2 and so pin 3 switches low and LED 6 turns ON.

The control pin (pin 5) of IC2 is tied to the positive rail supply voltage via a 1kΩ resistor. This causes IC2 to switch at threshold s of $0.46V_{cc}$ and $0.667V_{cc}$. This is necessary to ensure that IC2 switches correctly to control LED6.

A 2.2KΩ resistor is used as the limiting resistor at the output of the IC555timer.

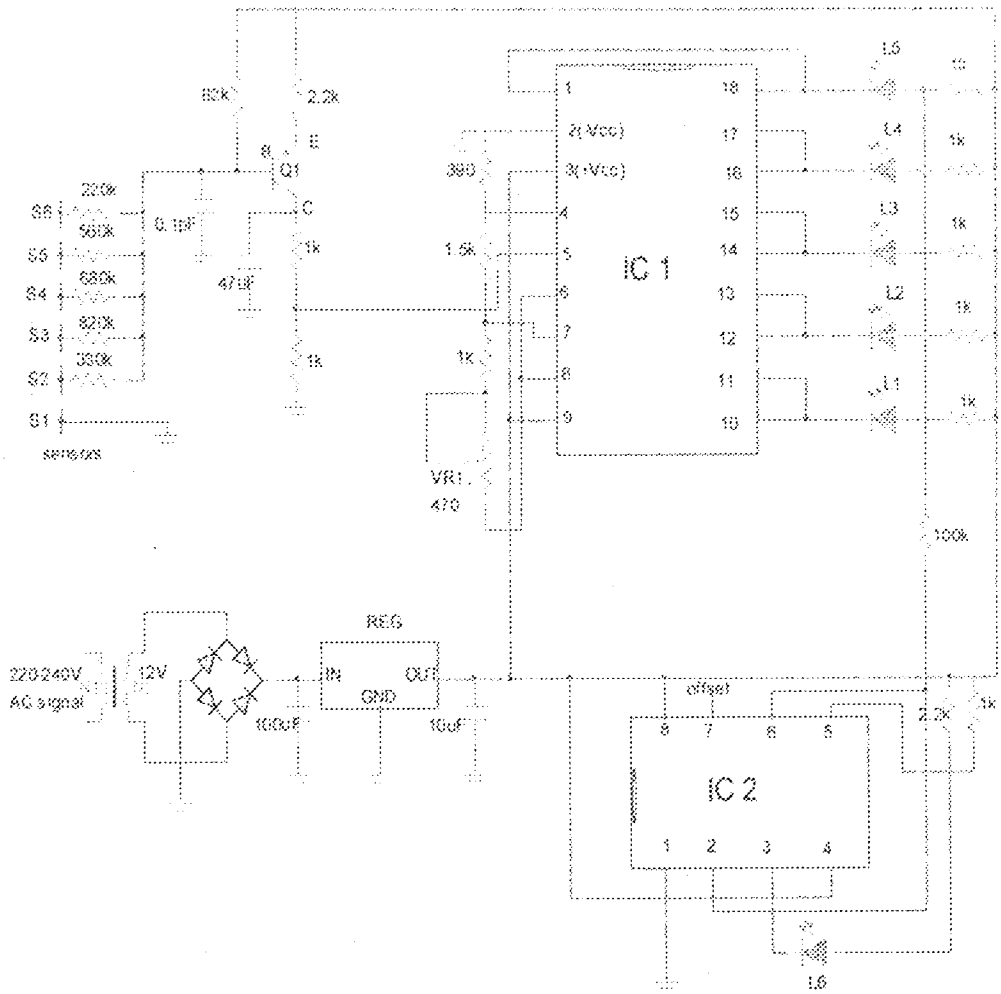
3.1.3.3 THE PNP TRANSISTOR

The PNP transistor used in the project functions as an inverting buffer stage which is biased using the potential divider biasing method. As shown in figure 3.9, the PNP transistor is connected in the common emitter configuration. The transistor Q_1 is also necessary to provide a reasonably low impedance drive into pin 5 of IC1, while keeping the current through the water sensors below the level at which electrolysis becomes a problem [3, 4, 5, 6, 7, 8, 9].

3.2 CIRCUIT DIAGRAM AND DESCRIPTION

Figure 3.9 shows the circuit details and the description is as follows. It is based on an LM3914 Linear LED dot bar display driver (IC1) which drives five green LEDs (LEDs 1-5).In order to obtain a bar graph mode of the LM 3914 so that the height of the green LED column indicates the level of the water in the tank, pin 9 of the IC1 (LM 3914) is tied high (when low, the IC1 is in dot mode).

The full scale range of the bar graph depends on the voltage on pin 6.This voltage can be varied using the variable resistor VR1 from about 1.6V to 2.3V.After taking into account the voltage across the 390Ω resistor on pin 4, this gives a full range scale that can be varied (using VR 1) between about 1.1V (VR1 set to 0Ω) and 2V (VR1 set to 470Ω). This is possible because the IC1 has an internal voltage reference that maintains 1.25V between pins 7 and 8.



IC1 – LM3914

IC2 – IC555 Timer

Figure 3.9 Circuit diagram of water level indicator

IC1's output directly drives LEDS 1-5 via the 1kΩ current limiting resistors. However, an LM 3914 has 10 comparator outputs but only five steps are needed for this application. Five outputs from IC1 is achieved by wiring the outputs of successive comparator pairs in parallel i.e. pins 1 and 18 are wired together, pins 16 and 17, pins 14 and 15 and so on.

The input signal for IC1 is provided by an assembly consisting of six sensors located in the water tank and connected to the indicator unit. The sensor assembly relies on the fact that there is a fairly low (and constant) resistance between a pair of electrodes in a tank of water, regardless of the distance between them.

As shown in figure 3.9, sensor 1 is connected to ground while sensors 2-6 are connected in parallel to the base of PNP transistor Q1 via resistors R1-R5.Q1 functions as an inverting buffer stage and it's collector voltage varies according to how many sensor resistors are in circuit (i.e. how many sensor resistors are in the circuit (i.e. how many sensors are covered by water).

When the water level is below sensor 2. resistors R5-R1 are out of circuit and so Q1's base is pulled high by an 82kΩ resistor. As a result, Q1 is off and no signal is applied to IC1 (i.e. LEDS 1-5 are off). However, if the water covers sensor 2, the sensor end of resistor is essentially connected to ground. This resistor and the 82kΩ resistor now form a voltage divider and so about 9.6V is applied to Q1's base and so Q1's emitter is now at about 10.2V which means that 0.8mA of current flows through the 2.2kΩ emitter resistor. The same current flows through the 1kΩ collector load resistors, and about 0.8V is applied to pin 5 of IC1.This causes pins 1 and 18 of IC1 to switch low and so the first green LED(L5) in the bar graph lights.

As each successive sensor is covered by water, additional resistors are switched in parallel with R5 and Q1's base is pulled lower and lower. As a result, Q1 turns on" harder" with each step (i.e. its collector increases) and so the signal voltage on pin 5 of IC1 increases accordingly.IC1 thus switches more outputs low to light additional LEDS.

Q1 is necessary to provide a reasonably low impedance drive into pin 5 of IC1, while keeping the current through the water sensors below the level at which electrolysis becomes a problem.

3.2.1 CRITICAL LEVEL INDICATION

IC2 is a 555timer IC and it drives LED6 (red) to provide a warning when the water level falls below the lowest sensing point (sensor 2), i.e. when all the green LEDs are extinguished. However, IC2 is not used as a timer. Instead it is wired as a threshold detector and simply switches its output at pin 3 high or low in response to a signal on its threshold and trigger inputs (pins 6 and 2)

When there is water in the tank, LED 5 is on and its anode is about 2V. This "low" voltage pulls pins 6 and 2 of IC2 low via a 100kΩ resistor, so that these two pins sit below the lower threshold voltage. As a result, the pin 3 output of IC2 is high and LED 6 is off.

However if the water falls below sensor 2, LED5 turns off and the anode of LED 5 "jumps" to +12V.This voltage exceeds the upper threshold voltage of IC2 and so pin 3 switches low and LED 6 turns on to give the critical low-level warning [5,8,9].

3.3 PRINCIPLE OF OPERATION

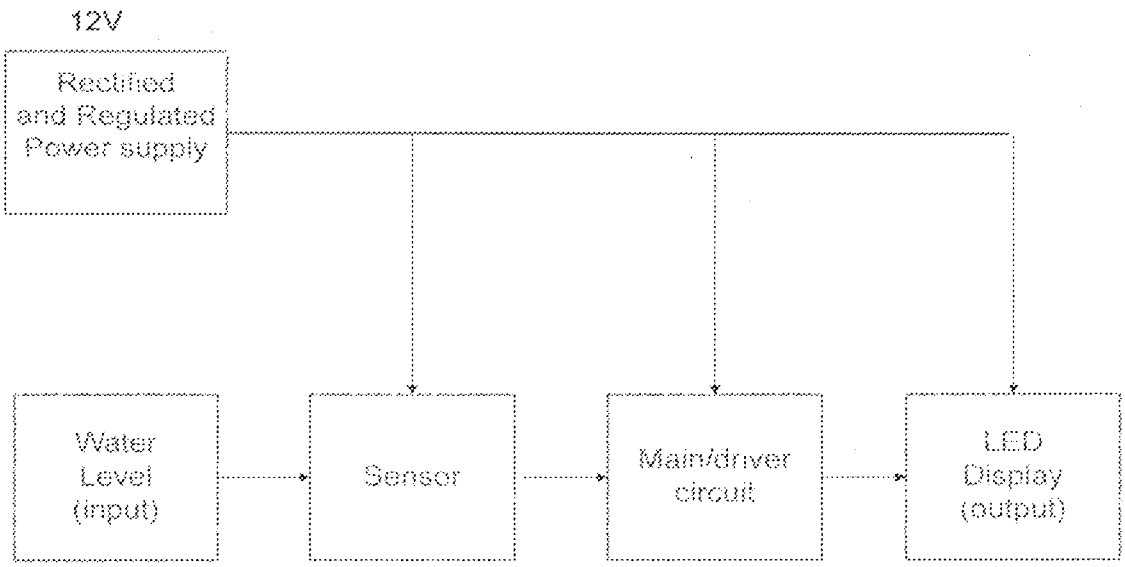


Figure 3.10 Block diagram of the water level indicator design.

The block diagram of the water level indicator is shown in figure 3.10 and the output is based on light display of light emitting diodes LEDS (6) according to the level of water in the tank, which is the input. Sensors are placed in the tank at different levels and equally spaced using a plastic tube which is supported at the bottom of the tank. If the water level is below the second lowest sensor (critical level), one LED (red) is driven with the remaining five LEDs (green) extinguished.

When the water level reaches the second lowest sensor in the water, the critical level indicator (red LED) is extinguished and one LED (green) is driven (LED 1).When the water level increases and is just above the next sensor, another LED (green) is driven and so on until all the five LEDS (green) are driven when the water level is just above the topmost sensor in the tank to signify that the tank is full.

CHAPTER FOUR

4.1 CONSTRUCTION

In the course of the construction of this water level indicator, some tools and materials were used .These include:

i. Breadboard: This is a board with connectivity along its horizontal lines and vertical lines (In some cases). It was used primarily for temporal setting up of the design and to ascertain its working condition and hence further modification.

ii. Vero board: This is a perforated plastic board where the working circuit was finally mounted and soldered permanently.

iii. Soldering lead: This is a metal with low melting point. It was used to hold components and connecting wires in place in the vero board.

iv. Soldering iron: This is a low power heating element typically 40 watts. It provides the heat needed to melt the lead, so that it can be used for the connection of the components permanently on the vero board. It is usually connected to the AC mains.

v. Lead sucker: This used to suck up excess molten lead from the vero board to prevent short circuiting (bridging) or undesirable electrical connections.

vi. Multimeter: This is a multi-functional device used for testing of continuity and measurement of voltages, currents and resistances in the course of the construction.

vii. Wires and connections: Wires were used during the testing stage of the project on the breadboard to connect the component together as well as during the soldering of the components on the Vero board. Aluminum wires were used.

viii. Wire cutters/strippers: These tools were used to cut the wires to the desired size required before use, as well as to strip off insulation of the wire in other to expose the conductor for proper and neat soldering.

The circuit was first laid- out on the bread-board to observe its operational response and ensure that it is in line with the required objectives. Then it was dismantled.

The circuit was finally constructed on the vero board starting with the power supply unit. The components were inserted into the holes on the board properly to ensure that it is out on the other side where the copper tracks are. All components and jumpers (connecting wires) were inserted in place before soldering. This was to permit better judgment on connection linkages between the components. The connection between the components on different horizontal lines (potential) was carried out with the use of aluminum wires and a hole was made to break the horizontal lines continuity where it was needed or necessary.

To obtain a good soldering joint which is very important, it was ensured that the tip of the wire was in contact with the copper track, the wire to be soldered and the soldering lead. This soldering operation was carried out for a period of five seconds or less to prevent the components from getting overheated thereby damaging the components. The integrated circuits are very sensitive to this heat, so they were protected by the use of IC sockets. These sockets were soldered to the board while the ICs were inserted into place.

The entire circuit board and the transformer were housed in a wooden casing. This type of casing was chosen because of its poor conductivity, readily available and relatively cheaper. The appropriate holes for the LEDs, sensors wires and power cable were drilled at various positions. Holes were also drilled to allow air flow for ventilation.

The sensor probes were wound on PVC tube and the connecting wires passed inside the tube with the resistors of each wire connected. A plastic container is used as the tank where the sensors are placed.

Various precautions were taken during the constroction which includes—

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

ii. All the excess leads were removed to avoid "short circuits" on the boards.

iii. Polarities of the electrolytic capacitors and LEDS were properly checked to be correctly positioned before soldering on the vero board.

iv. IC sockets were used for the IC s to avoid overheating caused by soldering.

4.2 TESTING AND RESULTS

After all the components were arranged on the breadboard, they were tested to ensure the required output. The components and connecting wires which were soldered were tested for continuity using the continuity alarm tester of the multi-meter. The soldering joints were properly checked and errors detected were corrected by appropriate soldering and de-soldering actions.

At the end of the soldering operation, each unit was tested at every stage and the results obtained were adequate.

The device was set up by placing the water level sensors in the tank and connecting the power supply appropriately. A bowl of water was also provided. With the power supply connected, and no water in the tank, the red LED (L6) is turned on. When water was poured into the tank to reach the sensor 2, one green LED (L1) was turned on and L6 was extinguished. As the water increased to sensor 3, another green LED (L2) was also turned on. The water level was increased up to the highest level (sensor 6) and at that time, all the five green LEDs (L5—L1) were on. Table 4.1 shows a summary of the water level test.

At the initial testing stage, some problems were encountered because the response was not satisfactory. These problems were as a result of overflow of molten lead during soldering which were later corrected.

TABLE 4.1 Water level test and result.

INPUT (WATER LEVEL)	OUTPUT					
	GREEN LEDs					RED LED
	L5	L4	L3	L2	L1	L6
Below Sensor 2	OFF	OFF	OFF	OFF	OFF	ON
Above Sensor 2	ON	OFF	OFF	OFF	OFF	OFF
Above Sensor 3	ON	ON	OFF	OFF	OFF	OFF
Above Sensor 4	ON	ON	ON	OFF	OFF	OFF
Above Sensor 5	ON	ON	ON	ON	OFF	OFF
Above Sensor 6	ON	ON	ON	ON	ON	OFF

CHAPTER FIVE

5.1 CONCLUSION

From the results of the tests carried out after the construction of the project, the water level indicator was able to detect when the water in a tank or reservoir is at different levels up to the top of the tank. Hence the aim of the project has been achieved. The components used in constructing the device are readily available. The device constructed will be useful in our homes, in the industries, hospitals, schools, e.t.c to provide knowledge of the water quantity available for use

5.2 RECOMMENDATION

In the construction of the project, the output unit consists of six (6) LEDs to indicate the level of water in the tank or storage level. This can be improved on by incorporating a display unit to display the volume of water in the tank on a seven segment display if the dimensions of the tank are known.

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APPENDIX

LIST OF COMPONENTS

LM3914 linear dot, bar driver [1]

NE555 timer [1]

BC558 PNP transistor [1]

78L12 12V regulator [1]

IN4004 Diodes [4]

5mm Green LEDs [5]

5mm Red LED [1]

Capacitors:

- 100µF 35ww PC electrolytic
- 47µF 16ww PC electrolytic
- 10µF 16ww PC electrolytic
- 0.1µF Green cap

Resistors (0.25ww, 1%)

- 820 KΩ [1]
- 82 KΩ [1]
- 680 KΩ [1]
- 2.2 KΩ [2]
- 560 KΩ [1]
- 1.5 KΩ [1]
- 330 KΩ [1]
- 1 KΩ [9]
- 220 KΩ [1]
- 390Ω [1]
- 100 KΩ [1]
- 470Ω Trim port [1]

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Dissipation (Note 6)	
Molded DIP (N)	1365 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 4)	±35V
Divider Voltage	−100 mV to V⁺
Reference Load Current	10 mA
Storage Temperature Range	−55°C to +150°C
Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260°C
Plastic Chip Carrier Package	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 2, 4)

Parameter	Conditions (Note 2)		Min	Typ	Max	Units
COMPARATOR						
Offset Voltage, Buffer and First Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA			3	10	mV
Offset Voltage, Buffer and Any Other Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA			3	15	mV
Gain ($\Delta I_{LED}/\Delta V_{IN}$)	$I_{L(REF)} = 2$ mA, $I_{LED} = 10$ mA		3	8		mA/mV
Input Bias Current (at Pin 5)	$0V \le V_{IN} \le V^+ - 1.5V$			25	100	nA
Input Signal Overvoltage	No Change in Display		−35		35	V
VOLTAGE-DIVIDER						
Divider Resistance	Total, Pin 6 to 4		8	12	17	kΩ
Accuracy	(Note 3)			0.5	2	%
VOLTAGE REFERENCE						
Output Voltage	$0.1\text{ mA} \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$		1.2	1.28	1.34	V
Line Regulation	$3V \le V^+ \le 18V$			0.01	0.03	%/V
Load Regulation	$0.1\text{ mA} \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$			0.4	2	%
Output Voltage Change with Temperature	$0°C \le T_A \le +70°C$, $I_{L(REF)} = 1$ mA, $V^+ = 5V$			1		%
Adjust Pin Current				75	120	µA
OUTPUT DRIVERS						
LED Current	$V^+ = V_{LED} = 5V$, $I_{L(REF)} = 1$ mA		7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	$V_{LED} = 5V$	$I_{LED} = 2$ mA		0.12	0.4	mA
		$I_{LED} = 20$ mA		1.2	3	
LED Current Regulation	$2V \le V_{LED} \le 17V$	$I_{LED} = 2$ mA		0.1	0.25	mA
		$I_{LED} = 20$ mA		1	3	
Dropout Voltage	$I_{LED(ON)} = 20$ mA, $V_{LED} = 5V$, $\Delta I_{LED} = 2$ mA				1.5	V
Saturation Voltage	$I_{LED} = 2.0$ mA, $I_{L(REF)} = 0.4$ mA			0.15	0.4	V
Output Leakage, Each Collector	(Bar Mode) (Note 5)			0.1	10	µA
Output Leakage	(Dot Mode) (Note 5)	Pins 10–18		0.1	10	µA
		Pin 1	60	150	450	µA
SUPPLY CURRENT						
Standby Supply Current (All Outputs Off)	$V^+ = 5V$, $I_{L(REF)} = 0.2$ mA			2.4	4.2	mA
	$V^+ = 20V$, $I_{L(REF)} = 1.0$ mA			6.1	9.2	mA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Electrical Characteristics (Notes 2, 4) (Continued)

Note 2: Unless otherwise stated, all specifications apply with the following conditions:

$3\ V_{DC} \le V^+ \le 20\ V_{DC}$ $V_{REF}, V_{RHI}, V_{RLO} \le (V^+ - 1.5V)$

$3\ V_{DC} \le V_{LED} \le V^+$ $0V \le V_{IN} \le V^+ - 1.5V$

$-0.015V \le V_{RLO} \le 12\ V_{DC}$ $T_A = +25°C$, $I_{L(REF)} = 0.2$ mA, $V_{LED} = 3.0V$ pin 9 connected to pin 3 (Bar Mode).

$-0.015V \le V_{RHI} \le 12\ V_{DC}$

For higher power dissipations, pulse testing is used.

Note 3: Accuracy is measured referred to +10.000 V_{DC} at pin 6, with 0.000 V_{DC} at pin 4. At lower full-scale voltages, buffer and comparator offset voltage may add significant error.

Note 4: Pin 5 input current must be limited to ±3 mA. The addition of a 39k resistor in series with pin 5 allows ±100V signals without damage.

Note 5: Bar mode results when pin 9 is within 20 mV of V^+. Dot mode results when pin 9 is pulled at least 200 mV below V^+ or left open circuit. LED No. 10 (pin 10 output current) is disabled if pin 9 is pulled 0.9V or more below V_{LED}.

Note 6: The maximum junction temperature of the LM3914 is 100°C. Devices must be derated for operation at elevated temperatures. Junction to ambient thermal resistance is 55°C/W for the molded DIP (N package).

Definition of Terms

Accuracy: The difference between the observed threshold voltage and the ideal threshold voltage for each comparator. Specified and tested with 10V across the internal voltage divider so that resistor ratio matching error predominates over comparator offset voltage.

Adjust Pin Current: Current flowing out of the reference adjust pin when the reference amplifier is in the linear region.

Comparator Gain: The ratio of the change in output current (I_{LED}) to the change in input voltage (V_{IN}) required to produce it for a comparator in the linear region.

Dropout Voltage: The voltage measured at the current source outputs required to make the output current fall by 10%.

Input Bias Current: Current flowing out of the signal input when the input buffer is in the linear region.

LED Current Regulation: The change in output current over the specified range of LED supply voltage (V_{LED}) as measured at the current source outputs. As the forward voltage of an LED does not change significantly with a small change in forward current, this is equivalent to changing the voltage at the LED anodes by the same amount.

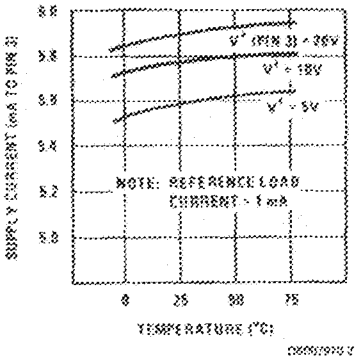
Line Regulation: The average change in reference output voltage over the specified range of supply voltage (V^+).

Load Regulation: The change in reference output voltage (V_{REF}) over the specified range of load current ($I_{L(REF)}$).

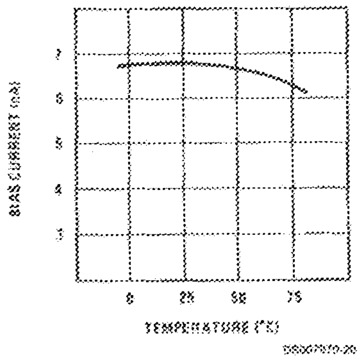
Offset Voltage: The differential input voltage which must be applied to each comparator to bias the output in the linear region. Most significant error when the voltage across the internal voltage divider is small. Specified and tested with pin 6 voltage (V_{RHI}) equal to pin 4 voltage (V_{RLO}).

Typical Performance Characteristics

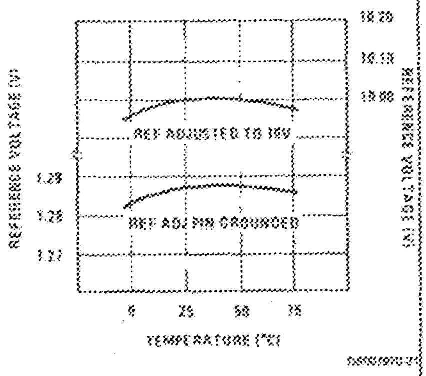
Supply Current vs Temperature



Operating Input Bias Current vs Temperature



Reference Voltage vs Temperature



DC AND AC ELECTRICAL CHARACTERISTICS

T_A = 25°C, V_{CC} = +5V to +15 unless otherwise specified.

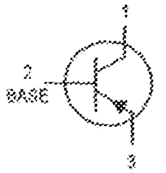
SYMBOL	PARAMETER	TEST CONDITIONS	SE555			NE555/SE555C			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{CC}	Supply voltage		4.5		18	4.5		16	V
I_{CC}	Supply current (low state)[1]	V_{CC}=5V, R_L=∞		3	5		3	6	mA
		V_{CC}=15V, R_L=∞		10	12		10	15	mA
	Timing error (monostable)	R_A=2kΩ to 100kΩ							
t_M	Initial accuracy[2]	C=0.1μF		0.5	2.0		1.0	3.0	%
$\Delta t_M/\Delta T$	Drift with temperature			30	100		50	150	ppm/°C
$\Delta t_M/\Delta V_S$	Drift with supply voltage			0.05	0.2		0.1	0.5	%/V
	Timing error (astable)	R_A, R_B=1kΩ to 100kΩ							
t_A	Initial accuracy[2]	C=0.1μF		4	6		5	13	%
$\Delta t_A/\Delta T$	Drift with temperature	V_{CC}=15V			500			500	ppm/°C
$\Delta t_A/\Delta V_S$	Drift with supply voltage			0.15	0.6		0.3	1	%/V
V_C	Control voltage level	V_{CC}=15V	9.6	10.0	10.4	9.0	10.0	11.0	V
		V_{CC}=5V	2.9	3.33	3.8	2.6	3.33	4.0	V
V_{TH}	Threshold voltage	V_{CC}=15V	9.4	10.0	10.6	8.8	10.0	11.2	V
		V_{CC}=5V	2.7	3.33	4.0	2.4	3.33	4.2	V
I_{TH}	Threshold current[3]			0.1	0.25		0.1	0.25	μA
V_{TRIG}	Trigger voltage	V_{CC}=15V	4.8	5.0	5.2	4.5	5.0	5.6	V
		V_{CC}=5V	1.45	1.67	1.9	1.1	1.67	2.2	V
I_{TRIG}	Trigger current	V_{TRIG}=0V		0.5	0.9		0.5	2.0	μA
V_{RESET}	Reset voltage[4]	V_{CC}=15V, V_{TH}=10.5V	0.3		1.0	0.3		1.0	V
I_{RESET}	Reset current	V_{RESET}=0.4V		0.1	0.4		0.1	0.4	mA
	Reset current	V_{RESET}=0V		0.4	1.0		0.4	1.5	mA
V_{OL}	Output voltage (low)	V_{CC}=15V							
		I_{SINK}=10mA		0.1	0.15		0.1	0.25	V
		I_{SINK}=50mA		0.4	0.5		0.4	0.75	V
		I_{SINK}=100mA		2.0	2.2		2.0	2.5	V
		I_{SINK}=200mA		2.5			2.5		V
		V_{CC}=5V							
		I_{SINK}=8mA		0.1	0.25		0.3	0.4	V
		I_{SINK}=5mA		0.05	0.2		0.25	0.35	V
V_{OH}	Output voltage (high)	V_{CC}=15V							
		I_{SOURCE}=200mA		12.5			12.5		V
		I_{SOURCE}=100mA	13.0	13.3		12.75	13.3		V
		V_{CC}=5V							
		I_{SOURCE}=100mA	3.0	3.3		2.75	3.3		V
t_{OFF}	Turn-off time[5]	V_{RESET}=V_{CC}		0.5	2.0		0.5	2.0	μs
t_R	Rise time of output			100	200		100	300	ns
t_F	Fall time of output			100	300		100	300	ns
	Discharge leakage current			20	100		20	100	nA

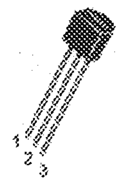
NOTES:
1. Supply current when output high typically 1mA less.
2. Tested at V_{CC}=5V and V_{CC}=15V.
3. This will determine the max value of R_A+R_B. for 15V operation, the max total R=10MΩ, and for 5V operation, the max. total R=3.4MΩ.
4. Specified with trigger input high.
5. Time measured from a positive going input pulse from 0 to 0.8×V_{CC} into the threshold to the drop from high to low of the output. Trigger is tied to threshold.

Amplifier Transistors

PNP Silicon

BC556,B
BC557A,B,C
BC558B





CASE 29–04, STYLE 17
TO–92 (TO–226AA)

MAXIMUM RATINGS

Rating	Symbol	BC 556	BC 557	BC 558	Unit
Collector–Emitter Voltage	V_{CEO}	–65	–45	–30	Vdc
Collector–Base Voltage	V_{CBO}	–80	–50	–30	Vdc
Emitter–Base Voltage	V_{EBO}	–5.0			Vdc
Collector Current — Continuous	I_C	–100			mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0			mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12			Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–55 to +150			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector–Emitter Breakdown Voltage (I_C = –2.0 mAdc, I_B = 0)	BC556	$V_{(BR)CEO}$	–65	—	—	V
	BC557		–45	—	—	
	BC558		–30	—	—	
Collector–Base Breakdown Voltage (I_C = –100 µAdc)	BC556	$V_{(BR)CBO}$	–80	—	—	V
	BC557		–50	—	—	
	BC558		–30	—	—	
Emitter–Base Breakdown Voltage (I_E = –100 µAdc, I_C = 0)	BC556	$V_{(BR)EBO}$	–5.0	—	—	V
	BC557		–5.0	—	—	
	BC558		–5.0	—	—	
Collector–Emitter Leakage Current (V_{CES} = –40 V)	BC556	I_{CES}	—	–2.0	–100	nA
(V_{CES} = –20 V)	BC557		—	–2.0	–100	
	BC558		—	–2.0	–100	
(V_{CES} = –20 V, T_A = 125°C)	BC556		—	—	–4.0	µA
	BC557		—	—	–4.0	
	BC558		—	—	–4.0	

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) (Continued)

Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				—
(I_C = –10 µAdc, V_{CE} = –5.0 V)	BC557A		—	90	—	
	BC556B/557B/558B		—	150	—	
	BC557C		—	270	—	
(I_C = –2.0 mAdc, V_{CE} = –5.0 V)	BC556		120	—	500	
	BC557		120	—	800	
	BC558		120	—	800	
	BC557A		120	170	220	
	BC556B/557B/558B		180	290	460	
	BC557C		420	500	800	
(I_C = –100 mAdc, V_{CE} = –5.0 V)	BC557A		—	120	—	
	BC556B/557B/558B		—	180	—	
	BC557C		—	300	—	
Collector–Emitter Saturation Voltage		$V_{CE(sat)}$				V
(I_C = –10 mAdc, I_B = –0.5 mAdc)			—	–0.075	–0.3	
(I_C = –10 mAdc, I_B = see Note 1)			—	–0.3	–0.6	
(I_C = –100 mAdc, I_B = –5.0 mAdc)			—	–0.25	–0.65	
Base–Emitter Saturation Voltage		$V_{BE(sat)}$				V
(I_C = –10 mAdc, I_B = –0.5 mAdc)			—	–0.7	—	
(I_C = –100 mAdc, I_B = –5.0 mAdc)			—	–1.0	—	
Base–Emitter On Voltage		$V_{BE(on)}$				V
(I_C = –2.0 mAdc, V_{CE} = –5.0 Vdc)			–0.55	–0.62	–0.7	
(I_C = –10 mAdc, V_{CE} = –5.0 Vdc)			—	–0.7	–0.82	
SMALL–SIGNAL CHARACTERISTICS						
Current–Gain — Bandwidth Product		f_T				MHz
(I_C = –10 mA, V_{CE} = –5.0 V, f = 100 MHz)	BC556		—	280	—	
	BC557		—	320	—	
	BC558		—	360	—	
Output Capacitance (V_{CB} = –10 V, I_C = 0, f = 1.0 MHz)		C_{ob}	—	3.0	6.0	pF
Noise Figure		NF				dB
(I_C = –0.2 mAdc, V_{CE} = –5.0 V,	BC556		—	2.0	10	
R_S = 2.0 kΩ, f = 1.0 kHz, Δf = 200 Hz)	BC557		—	2.0	10	
	BC558		—	2.0	10	
Small–Signal Current Gain		h_{fe}				—
(I_C = –2.0 mAdc, V_{CE} = –5.0 V, f = 1.0 kHz)	BC556		125	—	500	
	BC557/558		125	—	900	
	BC557A		125	220	260	
	BC556B/557B/558B		240	330	500	
	BC557C		450	600	900	

Note 1: I_C = –10 mAdc on the constant base current characteristics, which yields the point I_C = –11 mAdc, V_{CE} = –1.0 V.

Contek 78L12 ELECTRICAL CHARACTERISTICS

(Vi=19V,Io=40mA,0 C <Tj<125 C,C1=0.33uF,Co=0.1uF,unless otherwise specified)(Note 1)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	Vo	Tj=25 C	11.5	12	12.5	V
		14.5V<=Vi<=27V,Io=1mA-40mA	11.4		12.6	V
		14.5V<=Vi<=VMAX, Io=1mA-70mA	11.4		12.6	V (note 2)
Load Regulation	Vo	Tj=25 C,Io=1mA-100mA		25	150	mV
		Tj=25 C,Io=1mA-40mA		12	75	mV
Line regulation	Vo	14.5V<=Vi<=27V,Tj=25 C		25	300	mV
		16V<=Vi<=27V,Tj=25 C		20	250	mV
Quiescent Current	ΔIq	Vi=19V,Io=0mA,Tj=25 C		2.0	6.0	mA
Quiescent Current Change	ΔIq	16V<=Vi<=27V			1.5	mA
	ΔIq	1mA<=Vi<=40mA			0.1	mA
Output Noise Voltage	Vn	10Hz<=f<=100kHz		80		uV
Temperature coefficient of Vo	ΔVo/ΔT	Io=5mA		-1.0		mV/ C
Ripple Rejection	RR	15V<=Vi<=25V,f=120Hz,Tj=25 C	37	65		dB
Dropout Voltage	Vd	Tj=25 C		1.7		V

Contek 78L15 ELECTRICAL CHARACTERISTICS

(Vi=23V,Io=40mA,0 C <Tj<125 C,C1=0.33uF,Co=0.1uF,unless otherwise specified)(Note 1)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	Vo	Tj=25 C	14.4	15	15.6	V
		17.5V<=Vi<=30V,Io=1mA-40mA	14.25		15.75	V
		17.5V<=Vi<=VMAX, Io=1mA-70mA	14.25		15.75	V (note 2)
Load Regulation	Vo	Tj=25 C,Io=1mA-100mA		20	150	mV
		Tj=25 C,Io=1mA-70mA		25	150	mV
Line regulation	Vo	17.5V<=Vi<=30V,Tj=25 C		25	150	mV
		20V<=Vi<=30V,Tj=25 C		15	75	mV
Quiescent Current	ΔIq	Vi=23V,Io=0mA,Tj=25 C		2.2	5.5	mA
Quiescent Current Change	ΔIq	20V<=Vi<=30V			1.5	mA
	ΔIq	1mA<=Vi<=40mA			0.1	mA
Output Noise Voltage	Vn	10Hz<=f<=100kHz		90		uV
Temperature coefficient of Vo	ΔVo/ΔT	Io=5mA		-1.3		mV/ C
Ripple Rejection	RR	18.5V<=Vi<=28.5V,f=120Hz, Tj=25 C	34	63		dB
Dropout Voltage	Vd	Tj=25 C		1.7		V