DESIGN AND CONSTRUCTION OF AUTOMATIC FLUID QUANTITY CONTROL SYSTEM

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2001/12126EE

A Thesis Submitted to the Department of Electrical and Computer Engineering, Federal University of Technology, Minna, Niger State

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DEDICATION

This project is dedicated to Almighty God for His guidance and protection and all who in one way or the other contributed immensely to my degree programme. And to the upcoming Nigerians, who are ready to learn, think and work hard to acquire knowledge to take our nation to greater height.

DECLARATION

I Liman Suleiman, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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ABSTRACT

The project is aimed at the design and construction of an electronic device meant to control the flow of liquid in a vessel. As an improvement to previous works in this line, this project employs the use of double sensors to aid the reliability of the device.

The device is essentially made of two units; one of which is a trigger circuit unit built around a 555 timer. On the other hand, is a photo sensing unit built around a differential amplifier which triggers when the photo resistor perceive darkness.

On completion, the device was tested with its probes immersed in a container, which liquid content was meant to be maintained at a predefined level. The result was satisfactory as the liquid pump switched OFF immediately the liquid raised to the predefined level.

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CHAPTER ONE

INTRODUCTION

In most houses, water is first stored in an underground tank and from there it is pumped up to the overhead tank located on the roof. People generally switch "ON" the pump when their taps go dry and switch "OFF" the pump when the overhead tank starts overflowing. This results in the unnecessary wastage and sometimes non-availability of water in the case of emergency. [1]

In the industrial sector, where there are many continuous manufacturing processes, which requires great consumption of water, it is very important to maintain a certain quantity of water. This certain quantity of water acts as a reserve of water, which helps to take care of any erratic form of supply from the mains.

Also in the hydro electrical power stations, where the power station requires a great quantity of water to be able to generate electrical power. It is very important, a certain quantity of water is maintained at a particular level in the reservoir, which in this case is the dam, so as to avoid water overflow and to take care of it during dry periods.

Fluids can not be maintained to a particular level at a given point in time or an intermediate capacity without a form of measurement and control techniques. There are usually two question asked when maintaining a liquid to a predefined level.

1. What is its level measurement?
2. How can that level be maintained or controlled?

The answers to these questions are to simply define the terms;

1. Level measurement is the determination of the distance from the upper surface of a fluid or loose material in a reservoir to a predefined level located above or

below the surface. In this case we choose the predefined level that is required for the equipment we are using.

2. Level control is the process of maintain the quantity of fluid in the reservoir by the means of either a mechanical device or electrical device or a combination of both.

A particular level of a fluid in a reservoir is of great importance in processing operations. A level, which is too high, may cause damage to the equipment or result in overflow of valuable or hazardous materials. On the other hand, a level, which is too low, may equally cause damages, which could cause failure in continuous processing due to insufficient supply from the reservoir.

In other to avoid stoppages in continuous processing and the safety in operation, there is need for a sensitive and accurate level control. This project, which is an "Automatic Fluid Quantity Control System", involves the following process

- Taking the fluid level for the equipment.
- Assigning a predefined level (i.e. maximum and minimum level).
- Using sensors for the predefined level
- Creating a form of trigger circuit to "ON" and "OFF" the flow of the fluid.

A simple block diagram of this process is summarized in the Fig.1.0.

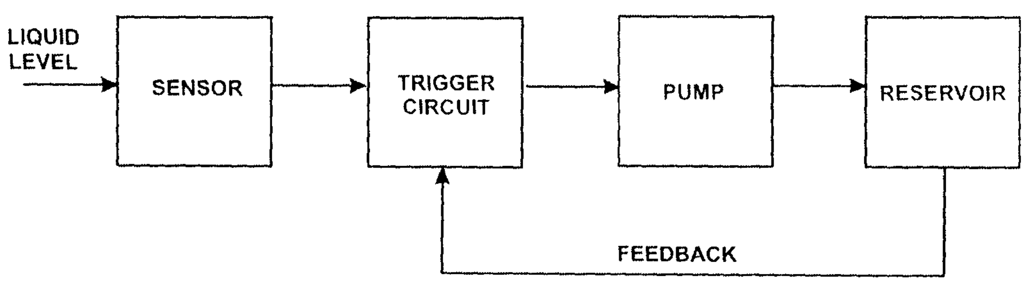


Fig. 1.0 A block diagram of a liquid controlled system

The projected presented here makes this system automatic, i.e. it switches "ON" the pump when the fluid level in the overhead tank goes low and switches it "OFF" as soon as the fluid level reaches a pre-determined level. It also means that, when the pump is pumping fluid, it should continue pumping the fluid until the vessel is filled to the predefined level (maximum limit), before going "OFF" and it should remain "OFF" till the fluid falls below the other predefined level (minimum level) before coming "ON" This project finds it uses in the following:

i. Hydro electric power station.

ii. Overhead tanks for storage of water.

iii. Bottling companies, in the filling of liquid content in the bottle.

iv. Petrol chemical industries, where a certain level has to be reached before mixture of the liquids can commence.

Note that these are just few places where this project finds its uses.

1.1 AIMS AND OBJECTIVES

1. To design and construct an electrical device that will be able to control the flow of a fluid in a vessel (container).
2. To practically understand the principles of applied mechanics and fluid mechanics that was been taught in class.

1.2 METHODOLOGY

The types of component used in this project were all specifically selected, and where further grouped into stages, so as to give us the final product, which is an

"Automatic Fluid Quantity Control System". Those various stages include; level sensors, switches or triggers, relays and AC to DC converter.

1.3 SCOPE OF WORK

1. A DC power supply unit.
2. Two electrical level sensor
    a. Liquid Sensor
    b. Phot Sensor
3. Trigger or Switch circuit

CHAPTER TWO

LITERATURE REVIEW

The "Automatic Fluid Quantity Control System" is an automatic feedback control system, which simply switches "ON" the pump when it reaches its minimum level and switches it "OFF" when it reaches it maximum level [2].

In an automatic control system, the variable to be controlled is first measured, secondly compared against a reference value and at least the difference applied to the system input, in order to influence the system in a desired manner [3,4].

The oldest automatic control system dates back to the Hellenistic era. The oldest application are flow rate control in water clock. The system was created by Ctesibus of Alexandria around the third centaury B.C, which regulates the water level in a vessel. The purpose of this system was to keep in a clock the flow of water in the container at a constant rate independent of level and pressure deviation, by using a floated valave. Although, Ctesibus left no written documents, a reconstruction of his work is possible through the accounts of the Roman engineer Vitruvius [5].

Philo of Byzantium, a generation younger than Ctesibius (ca 200 B.C), in his work titled "Pnenumatica" gives example of automatic oil level control system in oil candles. It is interesting, that today pnenumatica is known only through its Arabic translation, now finding in the Sulemaniye library [5].

The third important name in the history of automatic control is Heron of Alexandria, who lived in the first century B.C. In his work pneumatica, Heron described automatic control system as well as automata in the modern sense. These automata were designed to amuse, to arouse interest in the ancient temples or to water supply the bathhouse, attracted the attention of various circles and especially of the Islamic scholars in the following centuries [5].

The torch of scientific advancement was lit by three brothers. Muhammed, Hassan and Ahmad know as Benu Musa or sons of Musa bin Shakin of Khurasan, were very famous in the history of this technology. The advancement of this technology continued into the period of Islam and reached its height with al-Jazari, who served in the Artukid Capital Amid (Diyarbakir) as court engineer (1200 -1222). He is famous for his book "Kitab al-Hiyal (Book of Ingenious Devices), where he explained the design, construction and principles of fifty different systems of practical use and aesthetic value, such as water clocks, automata, water jets, vessels for blood collecting, water raising devices and ciphered keys [6,7].

When Baghdad fell to the Mongols in 1258 all creative thought along these lines came to an end. Moreover, the invention of the mechanical clock in the 14th century made the water clock and its feedback control system obsolete. (The mechanical clock is not a feedback control system.) The float regulator does not appear again until its use in the Industrial Revolution [6,7].

The Industrial Revolution in Europe followed the introduction of prime movers, or self-driven machines. It was marked by the invention of advanced grain mills, furnaces, boilers, and the steam engine. These devices could not be adequately regulated by hand, and so arose a new requirement for automatic control systems. A variety of control devices was invented, including float regulators, temperature regulators, pressure regulators, and speed control devices. [6,7]

J. Watt invented his steam engine in 1769, and this date marks the accepted beginning of the Industrial Revolution. However, the roots of the Industrial Revolution can be traced back to the 1600's or earlier with the development of grain mills and the furnace. The early steam engines were inefficient and regulated by hand, making them less suited to industrial use. It is extremely important to realize that the Industrial Revolution did not start until the invention of improved engines and automatic control systems to regulate them [8,9,10,11,12].

The millwrights of Britain developed a variety of feedback control devices. The fantail, invented in 1745 by British blacksmith E. Lee, consisted of a small fan mounted at right angles to the main wheel of a windmill. Its function was to point the windmill continuously into the wind. The mill-hopper was a device which regulated the flow of grain in a mill depending on the speed of rotation of the millstone. It was in use in a fairly refined form by about 1588[8,9,10,11,12].

Cornelis Drebbel of Holland spent some time in England and a brief period with the Holy Roman Emperor Rudolf II in Prague, together with his contemporary J. Kepler. Around 1624 he developed an automatic temperature control system for a furnace, motivated by his belief that base metals could be turned to gold by holding them at a precise constant temperature for long periods of time. He also used this temperature regulator in an incubator for hatching chickens[8,9,10,11,12].

Temperature regulators were studied by J.J. Becher in 1680, and used again in an incubator by the Prince de Conti and R.-A.F. de Réaumur in 1754. The "sentinel register" was developed in America by W. Henry around 1771, who suggested its use in chemical furnaces, in the manufacture of steel and porcelain, and in the temperature control of a hospital. It was not until 1777, however, that a temperature regulator suitable for industrial use was developed by Bonnemain, who used it for an incubator. His device was later installed on the furnace of a hot-water heating plant [8,9,10,11,12].

Regulation of the level of a liquid was needed in two main areas in the late 1700's: in the boiler of a steam engine and in domestic water distribution systems. Therefore, the float regulator received new interest, especially in Britain. In his book of 1746, W. Salmon quoted prices for ball-and-cock float regulators used for maintaining the level of house water reservoirs. This regulator was used in the first patents for the flush toilet around 1775. The flush toilet was further refined by Thomas Crapper, a London plumber, who was knighted by Queen Victoria for his inventions [8,9,10,11,12].

The earliest known use of a float valve regulator in a steam boiler is described in a patent issued to J. Brindley in 1758. He used the regulator in a steam engine for pumping water. S.T. Wood used a float regulator for a steam engine in his brewery in 1784. In Russian Siberia, the coal miner I.I. Polzunov developed in 1765 a float regulator for a steam engine that drove fans for blast furnaces [8,9,10,11,12].

By 1791, when it was adopted by the firm of Boulton and Watt, the float regulator was in common use in steam engines.

2.1 LEVEL SENSOR

There are many physical and application variables that affect the selection of the optimal level monitoring solution for industrial and / or commercial processes. The selection criteria include the physical: state (liquid, solid or slurry), temperature, pressure or vacuum, chemistry, dielectric constant of medium, density or specific gravity of medium, agitation, acoustical or electrical noise, vibration, mechanical shock, tank or bin size and shape; and the application constraints: price, accuracy, appearance, response rate, ease of calibration or programming, physical size and mounting of the instrument, monitoring or control of continuous or discrete (point) levels [13].

2.1.1 Magnetic and Mechanical Float Level Sensors

The principle behind magnetic, mechanical, cable, and other float level sensors involves the opening or closing of a mechanical switch, either through direct contact with the switch, or magnetic operation of a reed. With magnetically actuated float sensors, switching occurs when a permanent magnet sealed inside a float rises or falls to the actuation level. With a mechanically actuated float, switching occurs as a result of the movement of a float against a miniature (micro) switch. For both magnetic and mechanical float level sensors, chemical compatibility, temperature, specific gravity (density), buoyancy, and viscosity affect the selection of the stem and the float. For example, larger floats may be used with liquids with specific gravities as low as 0.5 while still maintaining buoyancy. The choice of float material is also influenced by temperature-induced changes in specific gravity and viscosity - changes that directly affect buoyancy [13].

2.1.2 Pneumatic Level Sensors

Pneumatic level sensors are indicated where hazardous conditions exist, where there is no electric power or its use is restricted, and in applications involving heavy sludge or slurry. As the compression of a column of air against a diaphragm is used to actuate a switch, no process liquid contacts the sensor's moving parts. These sensors are suitable for use with highly viscous liquids such as grease, as well as water-based and corrosive liquids. It has the additional benefit of being a relatively low cost technique for point level monitoring [13].

2.1.3 Conductive (Electrode-Based) Level Sensors

Conductive level sensors are ideal for the point level detection of a wide range of conductive liquids such as water, and is especially well suited for highly corrosive liquids such as caustic soda, hydrochloric acid, nitric acid, ferric chloride, and similar liquids. For those conductive liquids that are corrosive, the sensor's electrodes need to be constructed from titanium, Hastelloy B or C, or 316 stainless steel and insulated with spacers, separators or holders of ceramic, polyethylene and Teflon-based materials. Depending on their design, multiple electrodes of differing lengths can be used with one holder. Since corrosive liquids become more aggressive as temperature and pressure increase, these extreme conditions need to be considered when specifying these sensors [13].

2.1.4 Optical Interface Point Level Sensors

Optical sensors are used for point level sensing of sediments, liquids with suspended solids, and liquid-liquid interfaces. These sensors sense the decrease or change in transmission of infrared light emitted from an infrared diode (LED). With the proper choice of construction materials and mounting location, these sensors can be used with aqueous, organic, and corrosive liquids [13].

A common application of economical infrared-based optical interface point level sensors is detecting the sludge/water interface in settling ponds. By using pulse modulation techniques and a high power infrared diode, one can eliminate interference from ambient light, operate the LED at a higher gain, and lessen the effects of build-up on the probe [13].

An alternate approach for continuous optical level sensing involves the use of a laser. Laser light is more concentrated and therefore is more capable of penetrating dusty or steamy environments. Laser will reflect off most solid, liquid surfaces. The time of flight can be measured with precise timing circuitry, to determine the range or distance of the surface from the sensor. Lasers remain limited in use in industrial applications due to cost, and concern for maintenance. The optics must be frequently cleaned to maintain performance [13].

2.2 TRANSISTOR

A transistor is a semiconductor device, commonly used as an amplifier or an electrically controlled switch. The transistor is the fundamental building block of the circuitry that governs the operation of computers, cellular phones, and all other modern electronic devices.

Because of its fast response and accuracy, the transistor may be used in a wide variety of digital and analog functions, including amplification, switching, voltage regulation, signal modulation, and oscillators. Transistors may be packaged individually or as part of an integrated circuit, which may hold a billion or more transistors in a very small area [14].

Modern transistors are divided into two main categories: bipolar junction transistors (BJTs) and field effect transistors (FETs). Application of current in BJTs and voltage in FETs between the input and common terminals increases the conductivity between the common and output terminals, thereby controlling current flow between them. The transistor characteristics depend on their type. But in this project we will be focusing on the BJT type [14].

Bipolar transistor can be made to conduct by light, since absorption of photons in the base region generates a photocurrent that acts as a base current; the collector current is approximately beta times the photocurrent. Devices design for this purpose have a transparent window in the package and are called phototransistors [15].

When a transistor is used as a switch it must be either OFF or fully ON. In the fully ON state the voltage V_{CE} across the transistor is almost zero and the transistor is said to be saturated because it cannot pass any more collector current I_C. The output device switched by the transistor is usually called the 'load'.

The power developed in a switching transistor is very small:

In the OFF state: power = I_C x V_{CE}, but $I_C = 0$, so the power is zero

In the full ON state: power = I_C x V_{CE}, but $V_{CE} = 0$ (almost), so the power is very small.

This means that the transistor should not become hot in use and you do not need to consider its maximum power rating. The important rating in switching circuits are the maximum collector current $I_{C(max)}$ and the minimum current gain $h_{FE(min)}$. The transistor's voltage ratings may be ignored unless you are using a supply voltage of more than about 15V.

If the load is a motor, relay or solenoid (or any other device with a coil) a diode must be connected across the load to protect the transistor (and chip) from damage when the load is switched off. The diagram shows how this is connected 'backwards' so that it will normally NOT conduct. Conduction only occurs when the load is switched OFF, at this moment current tries to continue flowing through the coil and it is harmlessly diverted through the diode. Without the diode no current could flow and the coil would produce a damaging high voltage 'spike' in its attempt to keep the current flowing [15].

2.3 RELAY SWITCH

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It was invented by Joseph Henry in 1835. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of an electrical amplifier [16,17].

When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched off, the armature is returned by a force approximately half as strong as the magnetic force to its relaxed position. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing [16,17].

If the coil is energized with DC, a diode is frequently installed across the coil, to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a spike of voltage and might cause damage to circuit components. Some automotive relays already include that diode inside the relay case. Alternatively a contact protection network, consisting of a capacitor and resistor in series, may absorb the surge. If the coil is designed to be energized with AC, a small copper ring can be crimped to the end of the solenoid. This "shading ring" creates a small out-of-phase current, which increases the minimum pull on the armature during the AC cycle [18].

By analogy with the functions of the original electromagnetic device, a solid-state relay is made with a thyristor or other solid-state switching device. To achieve electrical isolation an optocoupler can be used which is a light-emitting diode (LED) coupled with a photo transistor [16,17].

Since relays are switches, the terminology applied to switches is also applied to relays. A relay will switch one or more poles, each of whose contacts can be thrown by energizing the coil in one of three ways: [16,17]

1. Normally-open (NO) contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive. It is also called a Form A contact or "make" contact.
2. Normally-closed (NC) contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive. It is also called a Form B contact or "break" contact.
3. Change-over, or double-throw, contacts control two circuits: one normally-open contact and one normally-closed contact with a common terminal. It is also called a Form C contact or "transfer" contact.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

The "Automatic Fluid Quantity Control System" consists of the following

1. Power supply unit
2. Liquid sensing circuit
3. Photo sensing circuit

The power supply unit is made up of a 15volts step-down transformer, a bridge rectifier with filter and an IC positive voltage regulator (7812).

The transformer steps down the AC mains supply from 240V to 15V, which is fed into the bridge rectifier for rectification of 15V AC to 15V DC. A 2200μF at 25V is used for filtering the AC component in the DC. A 12V regulator (7812) is used to stabilize the 15V Dc output of the filter to 12V, which is finally supplied to the main circuit.

The liquid sensing circuit is built around a 555timer, which operates in a mono-stable mode. It senses the liquid and activates the relay, which in turn switches ON/OFF the pump connected to the output power supply jack.

On the other hand, the photo sensing circuit is built around an operational amplifier (LM741), which operates as a voltage comparator. The voltage level at the amplifier is used to switch ON or CUT-OFF the transistor (BC547) that activates the relay connected to the output power supply jack. The complete circuit is illustrated below using a block diagram.

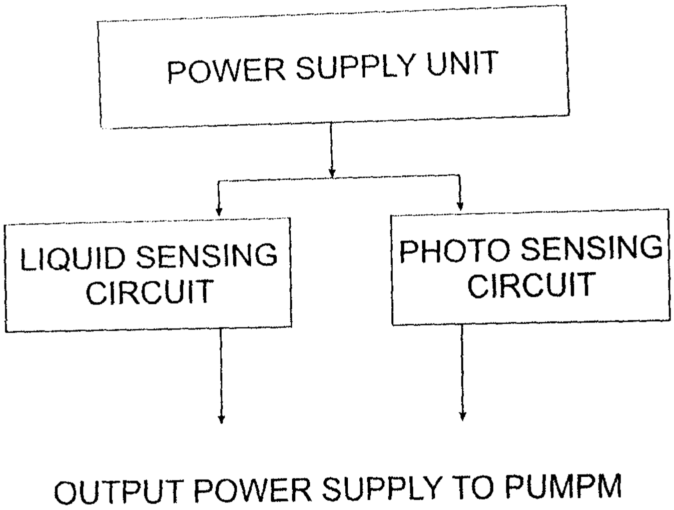


Fig.3.1 Block diagram of Automatic Fluid Quantity Control System

3.1 POWER SUPPLY UNIT

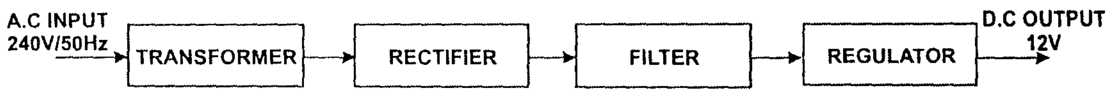


Fig. 3.2 Block diagram of the power supply unit

For an electronic device to function, it is required to be powered with the appropriate voltage and current. In this design the circuit is powered with a 12V and up to 1A required power supply.

A 240V/15V transformer step down the AC mains voltage to about 15 volts, which is required by the four diodes (D_1 – D_4) connected in bridge form and acting as a full wave rectifier. The rectifier voltage is filtered by C_1 to reduce the AC ripple to a minimal value. The filtered voltage is fed into IC_1, which is a 12V positive voltage regulator that gives a constant 12V output irrespective of the function of the AC mains voltage. LED_1 is a light emitting diode, acting as the power supply indicator, while R_1 limits the current through LED_1 to a safe value [19,20,21,22].

3.1.1 THE TRANSFORMER CIRCUIT

The first stage of the power supply unit design involves the stepping down of the 240V A.C mains to about 15 volts A.C, with the aid or 240V/15V, 1A transformer whose current capacity is enough to device the entire circuit. The transformer is an electrical device that provides physical isolation between the mains and the rest part of the circuit, the only link is by means of magnetic flux, thus eliminating the risk of electric shock [19,20].

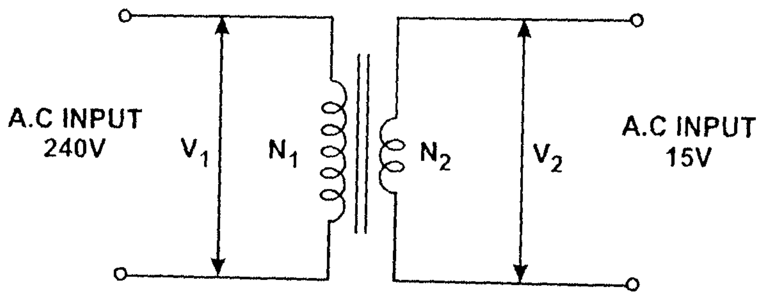


Fig. 3.3 Transformer circuit symbol

It consist of two coils, the primary winding and secondary winding. The ratio of the primary voltage V_1 to the secondary voltage V_2 is equal to the turns ratio of primary winding N_1 to that of secondary winding N_2.

i.e. $$\frac{V_1}{V_2} = \frac{N_1}{N_2} \qquad (3.1)$$

From the transformer data V_1 = 240V, V_2 = 15V, I_2 = 1A, and the frequency of A.C mains supply is 50Hz. For ideal transformer

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{240}{15} = 16$$

Hence the turn ratio $N_1:N_2 = 16:1$

The magnetic motive force (mmf) = NI

$$N_1 I_1 = N_2 I_2 \qquad (3.2)$$

$$\frac{N_1}{N_2} = \frac{I_2}{I_1} = 16$$

$I_2 = 1A$

$$\frac{I_2}{I_1} = 16$$

$$\frac{I_2}{I_1} = 16$$

$$I_2 = 16I_1$$

$$I_1 = \frac{I_2}{16} = \frac{1}{16} = 0.0625A$$

Power input = Power output

$P_1 = P_2$

$$I_1V_1 = I_2V_2 \tag{3.3}$$

0.0625x 240 = 1x 15 = 15W

3.1.2 THE RECTIFICATION CIRCUIT

The rectifier converts the 15V A.C voltage from the secondary of the transformer into pulsating 15V D.C. A full wave bridge rectifier circuit consists of four 1N4007 diodes arranged as shown in Fig. 3.4 below.

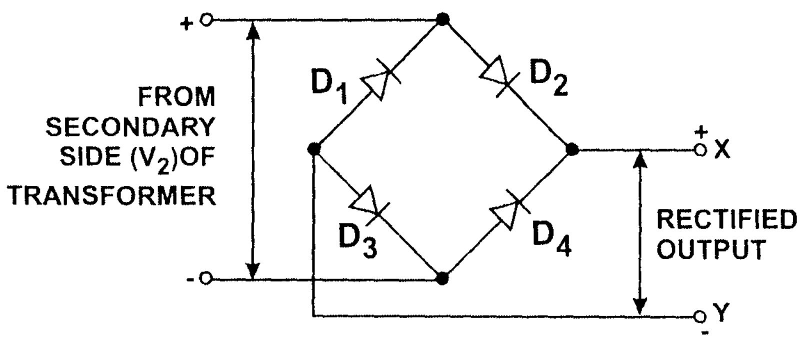


Fig. 3.4 Full wave bridge rectifier circuit

During the positive half cycle of the voltage, diodes D_2 and D_4 are forward biased, therefore the load voltage has the negative polarity on the left and the positive polarity on the right. During the negative half cycle diodes D_1 and D_3 are forward biased, the same result is achieved since the load current is in the same direction, no matter which diodes are conducting [19,20].

The output voltage of the transformer secondary winding $V_2 = 15$ volts

$$V_2(peak) = V_2\sqrt{2} = 15 \times \sqrt{2} = 21.21V$$

The average DC voltage V_{DC} across terminal XY is given as

$$V_{DC} = \frac{2}{\pi} V_{2(peak)} \qquad (3.4)$$

$$V_{DC} = \frac{2}{\pi}(21.21) = 0.636 \times 21.21 = 13.49V$$

3.1.3 THE FILTER CIRCUIT

The 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 in value. A filter capacitor is used to convert the full-wave rectifier signal into a constant DC voltage.

Capacitive filtering is adopted in this design where a large electrolytic capacitor is connected across the rectifier output. The capacitor charges during the diode conduction period to the peak value and the rectifier voltage falls below this value the capacitor discharges through the load, so that the load receives steady DC voltage [19,20].

For a 15 volts output from the transformer secondary terminal.

$$V_{2(peak)} = V_{rms}\sqrt{2} \qquad (3.5)$$

Where $V_{rms} = 15V$

$$V_{2(peak)} = 15\sqrt{2} = 21.21V$$

Let the ripple voltage be about 15% of this value

$$dV = \frac{15}{100} \times 21.21 = 3.18V$$

$$\frac{1}{C} = \frac{dV}{dt} \qquad \text{(Where dt = 5ms)} \qquad (3.6)$$

$$C = \frac{5ms}{3.18V} = \frac{5 \times 10^{-3}}{3.18} = 1572.3\mu F$$

However, it follows that the larger the capacitance the smaller the ripple component, in this design a preferred standard value of 2200μF/25 volts was used. The arrangement is shown below.

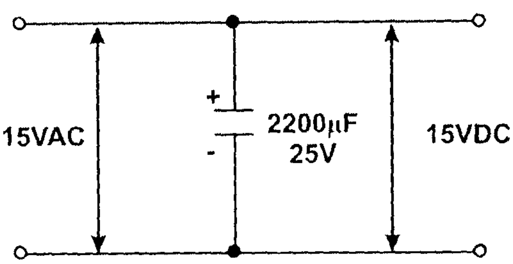


Fig. 3.5 A filter circuit diagram

3.1.4 THE REGULATOR

The output of the filter capacitor varies as the load current or output voltage varies, which is not desirable to most electronic circuits. The voltage regulator is used to reduce these variations to minimum possible value. This regulator maintains output voltage constant, regardless of the change in input voltage or change in load impedance. A 7812 voltage regulator is used to supply steady 12V to the liquid sensing circuit and the photo sensing circuit respectively.

A complete circuit diagram of power supply unit is shown below.

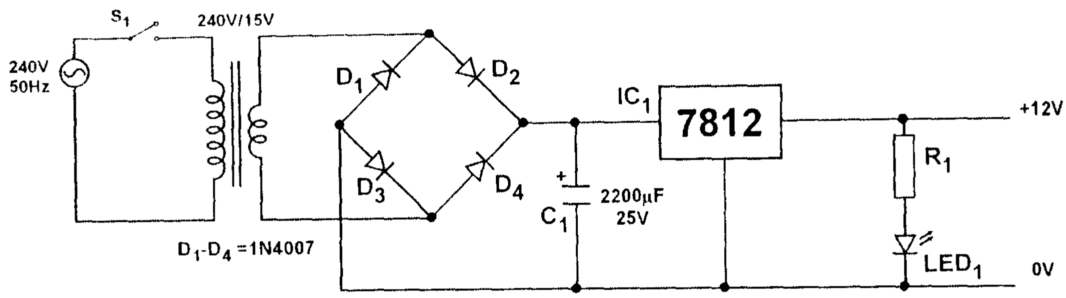


Fig.3.6 A 12V power supply unit

3.2 LIQUID SENSING CIRCUIT

The heat of the liquid (water) actuating circuit is built around the 555 timer IC. It is configured to operate in the mono-stable mode. In this mode, the 555 timer gives a high output, which will last for a calculated time, before returning to low (zero) whenever it is triggered.

This IC is triggered whenever the voltage at PIN 2 goes low below 1/3 the supply voltage as shown below

$$\frac{1}{3}\times 12 = 4V$$

In this design water acting as a conductor, connects PIN 2 to ground (0V), which is far below 4 volts. This happens when water comes in contact with the probes connected between PIN 2 of the IC and ground.

R_2, R_3 and C_2 determines the time period of the mono-stable circuit and is given by the formula in equation (3.1)

$$T = 1.1RC \tag{3.7}$$

Where $R = R_2 + R_3$ and $C = C_2$

Therefore, for $R_2 = 1K\Omega$, $R_3 = 10K\Omega$

We wish to make the delay time very small about 12miliseconds, so that false triggering due to turbulent water splashes can be eliminated.

T = 12 milliseconds

R = 1000 + 10000 = 11000Ω

$$C = \frac{12 \times 10^{-3}}{1.1 \times 11000} = 9.9 \times 10^{-7} F = 0.99 \times 10^{-6} F \approx 1 \mu F$$

A low at the base of TR_1 would reverse bias it as soon as PIN 3 of the 555 timer goes high TR_1 is switched ON, collector current flows. The voltage drop across the relay coil activates the relay and opens the normally closed contacts; power supplied to the device outlet 1 is stopped. This switches OFF the pump connected to outlet 1 and LED_2 goes OFF.

3.2.1 INTEGRATED CIRCUIT 555 TIMER

The liquid sensing circuit is built around this IC, which receives appropriate signals from the level to be controlled. To determine the signal to be sent to the out, a relay is connected to the output (PIN3) of the 555 timer via an NPN transistor. Signals from the liquid level sensor reaching PIN2 (trigger) of the 555 timer makes it to see zero volts less than one-third of the supply voltage (V_{CC}), this will cause PIN3 (output) to go high.

The PIN arrangement of IC 555 timer is shown below [19,22]

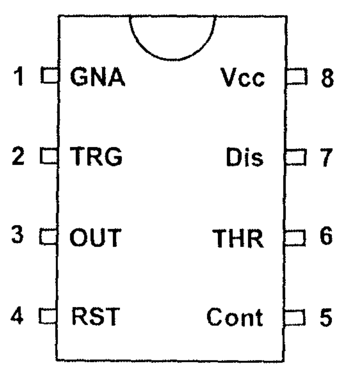


Fig. 3.7 IC 555 timer PIN identification

The complete liquid sensing circuit is shown in Fig. 3.8 below.

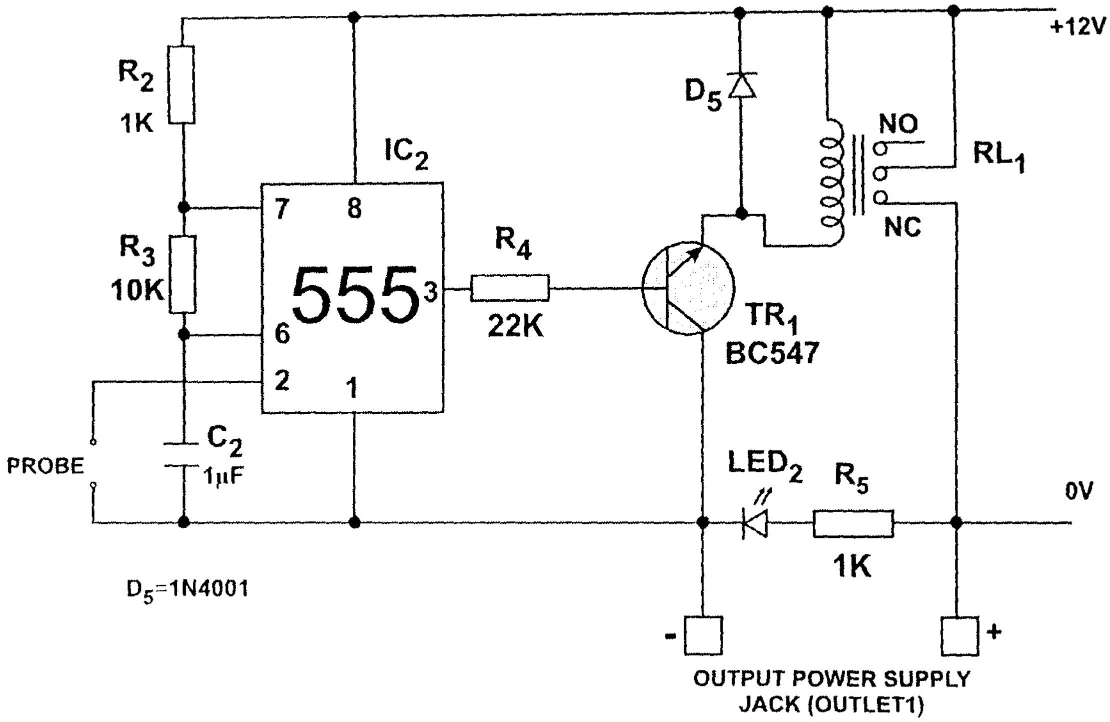


Fig. 3.8 Liquid sensing circuit

3.2.2 SWITCHING CIRCUIT FOR LIQUID SENSING CIRCUIT

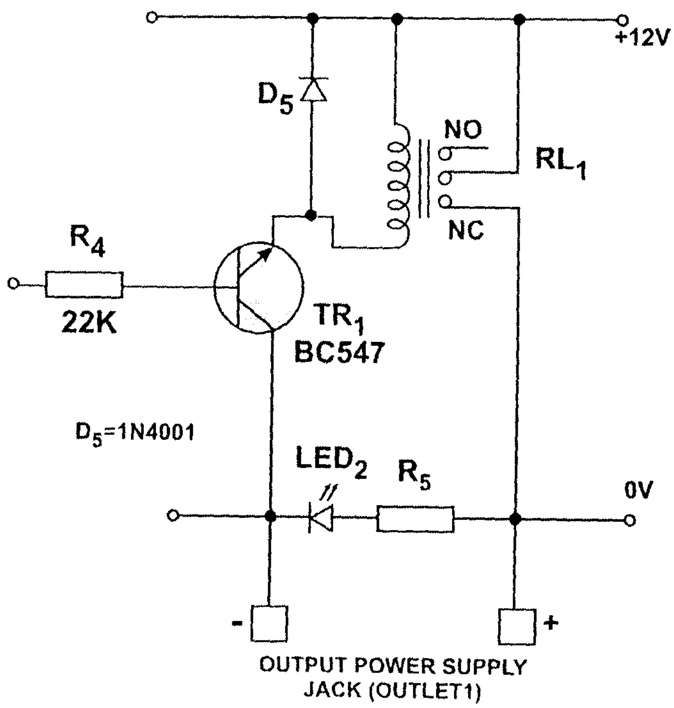


Fig. 3.9 Switching circuit for liquid sensing circuit

The relay has a coil resistance of about 400Ω, therefore the required saturation collector current for TR2 is given as

$$I_{C(SAT)} = \frac{V_{CC}}{R_C} = \frac{12}{400} = 30mA \tag{3.8}$$

For a transistor β of 200, the required base current is

$$I_B = \frac{I_C}{\beta} = \frac{30\times10^{-3}}{200} = 150\mu A \tag{3.9}$$

$$R_B = \frac{V_{cc} - V_{BE}}{I_B} = \frac{12-0.6}{150\times10^{-6}} = 76000\Omega = 76K\Omega \tag{3.10}$$

When operating a transistor as a switch, it must be driven into saturation to ensure that it dissipate minimal power. To take care of this, the base current was overdriven by thrice the required amount, in case of a lesser β, since the calculation makes use of

$R_B = \frac{76000}{3} = 25.3K\Omega$, but the nearest standard value is 22KΩ.

D_5 is a free wheeling diode that prevents damage to TR_1 as a result of back EMF from the relay coil. The value of D_5 is not critical, almost any rectifier diode would do. The value 1N4007 was used in this design.

R_5 is a current limiting resistor to LED_2. Suppose the voltage dropped across the LED is 1.2 V, then a 1KΩ resistor will limit the current to

$$\frac{12-1.2}{1000} = \frac{10.8}{1000} = 10.8\times10^{-3} = 10.8mA$$

This is a safe value for LED since it falls below the LEDs maximum rated value of 45mA. The data sheet for TR_1 which is an NPN BC547 is summarized in the table below.

Table 3.1 Data sheet specification of TR_1 and TR_2 BC547

Type	NPN -Si
V_{CB}	75V
V_{CE}	40V
V_{GD}	6V
I_C	0.6A
F_T	300MHz
pd_{Max}	0.5w

3.3 PHOTO SENSING CIRCUIT

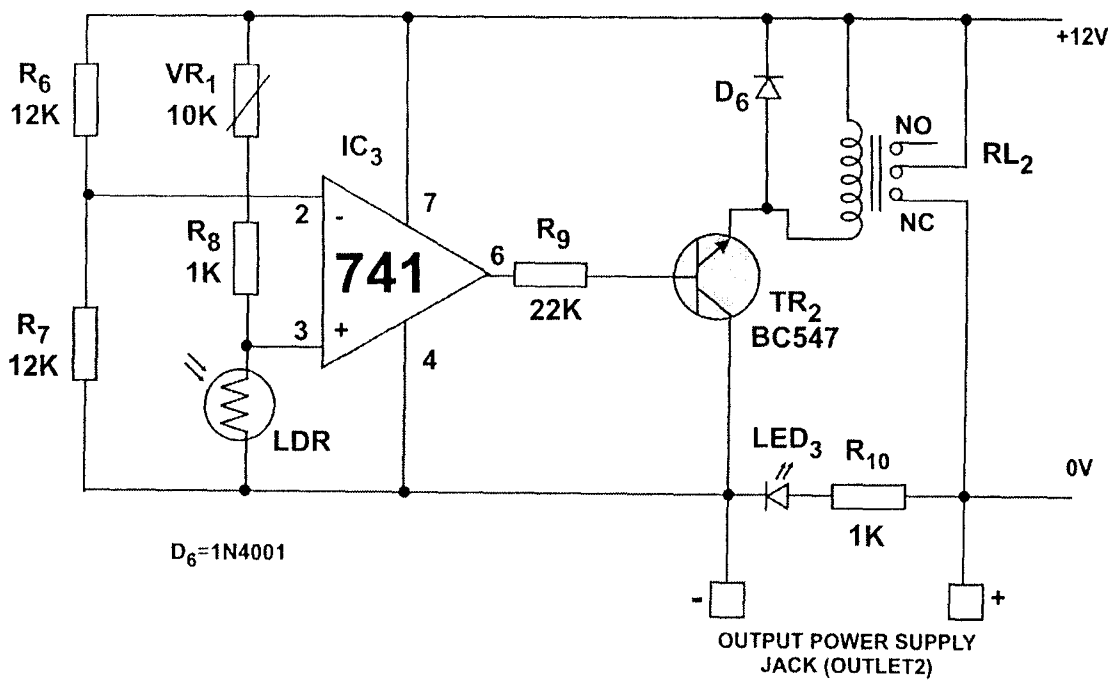


Fig. 3.10 Photo sensing circuit

The operational amplifier Op.741 is connected as a comparator. Its output at PIN 6 would go high whenever the voltage at the non-inverting terminal (PIN3) is higher than the voltage at the inverting terminal (PIN2) and vise versa. R_6 and R_5 are chosen of the same value of 12KΩ to form a stiff voltage divider of 6volts at PIN 2. Another voltage divider is formed by the series connection of VR_1 with R_8 and LDR (light dependant resistor). This voltage divider network is not stiff, and is varied depending on the intensity of inside light of the LDR. The LDR has a resistance that can be varied from 0 in bright light to about 100KΩ in full dark.

This circuit is designed to measure correctly the packing of bottles with drinks and other transparent containers. Light from one side of the container passes through the transparent surface to the other side and incidents on the LDR. The incident light reduces the resistance of the LDR, such that the voltage drop across the LDR is just below 6V. A pump connected to outlet 2 pumps its content into the container. As the contents fill the container to the desired level, it cuts the incident light preventing it from reaching the LDR. The LDR resistance increases, the voltage drop across the LDR rises above 6V. The output at PIN 6 goes high to switch on transistor TR_2. Relay RL_2 is activated so that normally closed contact is open to deactivate the pump.

3.3.1 SWITCHING CIRCUIT FOR PHOTO SENSING CIRCUIT

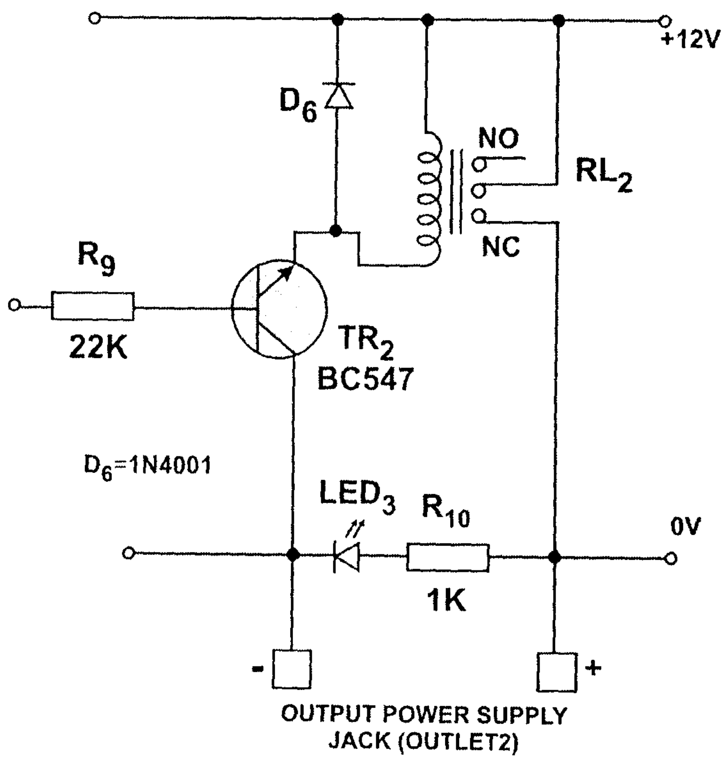


Fig. 3.11 switching circuit for photo sensing circuit

The relay coil represents the collector resistance of about 400Ω. A transistor operated as a switch must be driven into saturation so that it can dissipate minimal power, while delivering the required power to the load (Relay).

$$I_{C(SAT)} = \frac{V_{CC}}{R_C} = \frac{12}{400} = 30mA$$

For a transistor β of 200, the required base current is

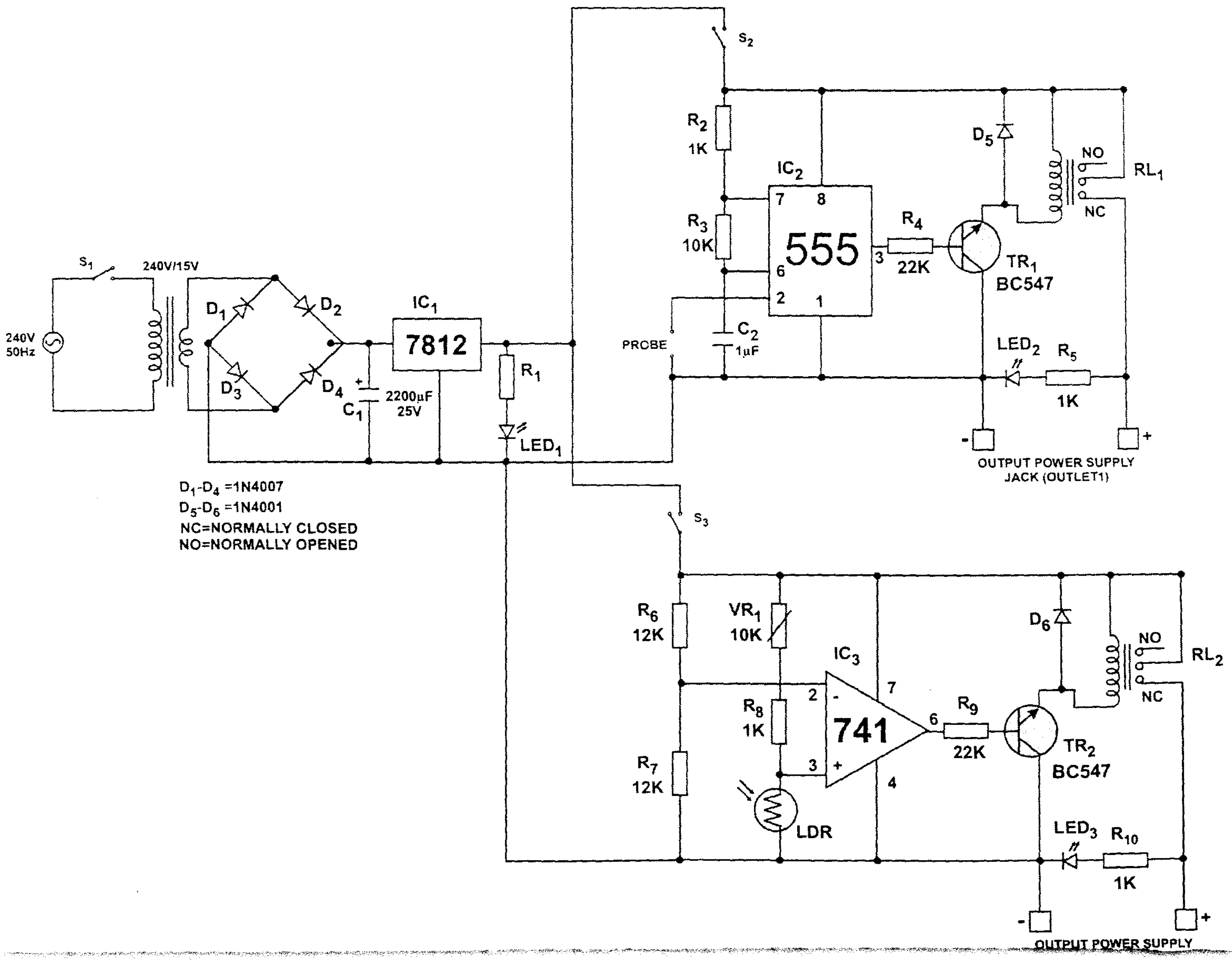
$$I_B = \frac{I_C}{\beta} = \frac{30 \times 10^{-3}}{200} = 150\mu A$$

$$R_B = \frac{V_{cc} - V_{BE}}{I_B} = \frac{12 - 0.6}{150 \times 10^{-6}} = 76000\Omega = 76K\Omega$$

But to guarantee saturation, the base current has been over driven by a factor 3 to take care of any β tolerance, therefore

$R_B = \frac{76000}{3} = 25.3K\Omega$, but the nearest standard value is 22KΩ.

Where $R_B = R_9$


S1
240V/15V
240V
50Hz
D1
D2
D3
D4
IC1
7812
C1
2200µF
25V
R1
LED1
S2
R2
1K
R3
10K
IC2
555
7
8
6
2
1
3
C2
1µF
PROBE
R4
22K
TR1
BC547
D5
NO
NC
RL1
LED2
R5
1K
OUTPUT POWER SUPPLY
JACK (OUTLET1)
D1-D4 =1N4007
D5-D6 =1N4001
NC=NORMALLY CLOSED
NO=NORMALLY OPENED
S3
R6
12K
VR1
10K
IC3
741
R7
12K
R8
1K
LDR
R9
22K
TR2
BC547
D6
NO
NC
RL2
LED3
R10
1K
OUTPUT POWER SUPPLY

CHAPTER FOUR

TESTING OF RESULTS

4.1 CONSTRUCTION TOOLS AND MATERIALS

The tools and materials as well as instrument used during the construction of this project are briefly described below

- Simulation: The circuit diagram was tested on the computer using the circuit maker software. The result obtained for each unit of the circuit was satisfactory.
- The breadboard: Board which temporary connection were made to ascertain the workability in accordance with the design.
- Vero board: This is a perforated board on which electronic component are inserted and soldered permanently.
- Digital multimeter: Instrument use for measuring electrical quantities such as resistance, voltage, current, etc. It is also used for checking continuity of the circuit.
- IC socket: Device used to hold ICs in position. The IC socket is first soldered on the board, before the IC chip is fixed on it. The purpose of the IC socket is to prevent the heat of the soldering iron from destroying the IC, which is very sensitive to heat.
- Lead sucker: This is used to suck up excess molten lead from the Vero board to prevent bridging.
- Soldering lead: This is a metal (lead) wire of low melting point, it is used to electrically connect components and wires in fixed position on the Vero board.
- Soldering iron: This is a low power heating element, needed to melt the lead. It is usually connected to the AC mains.

Other tools are cutters, scissors, hammer, nails, screws, drilling machine and gum.

4.2 TESTING AND RESULTS

The entire system was setup by connecting the power supply cable to ACC mains source. Measuring the output voltage after regulation to test the power supply unit. The reading was found to be 10.2V, which is acceptable and LEDs 1, 2 and 3 came ON, indicating that there is flow of current in the whole circuit.

At liquid sensing unit, the probes were inserted into a container and liquid (water) was gradually pumped into the container with the aid of a liquid pump. The volume of the liquid increases until it reaches the predefined level (probe position), then the power supply to the unit trips OFF, which in turn automatically switches OFF the liquid pump.

Also at the photo sensing unit, it's sensing and control ability was tested by simply blocking the incident light falling on the photo resistor (LDR). The unit power goes OFF, thereby cutting the power supply to the pump. The results gotten were as expected from the design. Great care had to be taken in setting the variable resistor of the photo sensor for the lightest sensitivity for a given light intensity.

4.3 LIMITATIONS

- The difficulty in getting the exact components, which lead to the use of its equivalent.
- Non-availability of the right equipment for testing. Most especially in the photo sensing unit, this causes delay in completion of the work.

4.4 PROBLEMS ENCOUNTERED

i. When the project work was first tested, the response from the system was not satisfactory. On checking, I noticed the base terminal of the transistor was cut, which was then replaced immediately. On testing again, a satisfactory result was obtained with the LED_2 and LED_3 coming ON as expected from the design.

ii. The initial stage of soldering on the Vero board was characterized by some minor mistakes, such as overflow of melting lead, which during the course of the wotk was overcome.

CHAPTER FIVE

CONCLUSION

From the result of the test carried out the project worked as expected by design. The Automatic Fluid Quantity Control system was able to control liquid to the desired level in the container. All that is required is for the user to set the probes or the photo sensor to the desired level.

The implementation of this design exposed students to the practical applications of the theoretical knowledge acquired in the course of study and as such, the confident and effective handling of the basic electrical components by the student is raised.

The liquid pump will respond when it receives signal from the control unit (liquid sensing unit and photo sensing unit) either high or low as the case may be, there by turning ON or cutting OFF the switching transistor, which will in turn energize or de-energize the relay.

Finally, the aims and objectives of the project have been achieved. The device can be used in our homes for filling of water tanks, in dam site of hydro stations, refineries in the filling of product tanks to a particular level and for filling bottles in bottling companies.

RECOMMENDATION

This project can only find use in small scale, which can be improved for large scale applications by connecting the relay to the A.C mains of the power supply unit. Also interfacing the device with computer with good programming will be a step ahead, this will display whether the device is working or not.

Further more, the design does not have any means of communication to a far distance, this can also be improved by using extention wires of connectors from the device to the point of consideration.

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APPENDIX

LIST OF COMPONENTS AND PRICES

S/N	COMPONENTS/MATERIALS DESCRIPTION	QUANTITY	RATE ₦	AMOUNT ₦
1	Transformer 240/15V, 1A	1	500	500
2	Diodes 1N4007	6	20	120
3	Capacitor 2200μF, 25V	1	120	120
4	Voltage Regulator (7812)	1	110	110
5	Resistor 1KΩ	5	20	100
6	Resistor 10KΩ	1	20	20
7	Variable Resistor 10KΩ	1	20	20
8	Resistor 12KΩ	2	20	40
9	Resistor 22KΩ	2	20	40
10	Light Emitting Diode 1.2V	3	20	60
11	IC 555 Timer	1	70	70
12	Capacitor 1μF	1	110	110
13	Transistor (BC547)	2	40	80
14	Operational Amplifier (LM741)	1	100	100
15	Relay 400Ω	2	100	200
16	Light Dependant Resistor (0-100)KΩ	1	400	400
17	DC Motor	1	250	250
18	Conductor Wire (Yard)	4	50	200
19	Switches	3	50	150
20	Output Power Supply Jack	2	100	200
21	Power Plug	1	100	100
22	Ply Wood 100x100cm	1	200	200
23	Vero Board	1	150	150
24	Screw Nuts 20Kg	1	20	20
25	Nails 20Kg	1	20	20
			TOTAL	**₦3,380**