DESIGN AND CONSTRUCTION OF A TOUCH-ACTIVATED ELECTRONIC SWITCH

BY

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A Project report submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering (B.Eng.) Degree in the Department of Electrical and Computer Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Nigeria.

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CERTIFICATION

This is to certify that this thesis "Design and Construction of Touch-Activated Electronic Switch" is the original work of Emmanuel John 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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The completion of my degree wouldn't have been possible and successful without the idance and leadership of God Almighty. It was neither by power nor by might but by God's irit that I attain the level I am now. Thank you Lord.

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Thank you all for making my dreams comes true. May our good God reward you all. Amen.

DEDICATION

This project is dedicated to God the Father, God the Son and God the Holy Spirit.

And also to my parents: Emmanuel and Lydia.

ABSTRACT

This project work is on the design and construction of a touch-activated electronic switch. The project was intended to produce a switch which is more reliable, efficient and durable than mechanical switches. They can, thus, be used in applications where mechanical switches are not suitable. The design of this project is in such a way that when a touch pad is touched a load can be switched "on" or "off". It employs a D flip-flop, for the latching. Thus a single touch pad is used for "ONing" and "OFFing" of the load which is connected to the output of a relay.

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Chapter One

Introduction

The field of power electronics has paved the way for a complete new technology in the world of electronics. Technological advancement in microelectronics has led to the development of semiconductor devices. This breakthrough in the field of electronics has made industrial and domestic processes much easier. This, in turn, has affected every aspect of human life.

Almost every electrical or electronic device (appliance) uses one form of switch or the other, for the purpose of control. A switch is a device with only two conditions: open or close ("ON" or "OFF"). The simplest switching device is the switch itself. A mechanical switch is a switch with moving parts. Examples of mechanical switches are toggle switches, flip switches, push buttons e.t.c.

Electronic switches are switches that are activated by non-electrical quantities such as sound light touch pressure e.t.c. These non-electrical quantities are converted into electrical signals by appropriate transducers. It is this electrical signal that *is used in* switching the device.

A touch-activated electronic switch is a switch that is turned "ON" or "OFF" by touching a metal contact, instead of flickering a lever like in regular switch. Touch-activated electronic switches have no mechanical parts. They operate by measuring the capacitance change between the metal touch button and an earth ground (i.e. difference in capacitance between the human body and ground when the metal plate is touched). The touch-activated electronic switch works by capacitative pickup of the mains (AC) hum. These switch circuits used a sensitive high impedance circuit to detect the small AC power line signals, picked up by the human body from nearby appliances. AC hum switches rely on the fact that the "hot" side of the power line is always referenced to earth ground. The human finger touching a metal button transferred the power line signal to the sensing circuit and triggered the switch. When the contact is touched body capacitance picking up general RF in the air is enough to short the plate to ground. Because the touch plate uses mains hum as it method of shorting the gate to ground a mains connected power supply must be used to supply power to the switch. A battery will not work. The skin of the human finger is thin and the human blood under the skin makes a nice electrical conductor. The outside surface area of the human body is also large. The act of touching a human finger to a metal button will therefore form an electrical interface that will produce a sizable capacitance change, if there are any metal objects nearby that are connected to earth ground.

The touch-activated electron switch is made up of three stages:

1. The regulated power supply
2. The touch activated circuit
3. The switching and relaying circuit

1.1 Aims and Objectives of the Project

Mechanical switches are in various forms. In spite of their diversity, all have some common features when it comes to performance. These kinds of switches are not reliable and cannot be used in all applications. This is because they have moving parts which are prone to wear. This leads to decrease in reliability and durability and, consequently, to possible failure. They are also slow because of the time taken for the moving part to move from "OFF" to "ON" position.

The aim of this project, therefore, is to design a switch that can eliminate this setback. Touch-activated electronic switch has no moving parts, and therefore they are more reliable, durable, faster and efficient [1].

1.2 Significance (Importance) Of the Project

Touch-activated electronic switches last longer than regular switches. They can be used in places where regular switches would not last, such as wet or very dusty areas. They also do not require pressure for activation. So, a person with disability who can not operate a mechanical switch consistently can operate a touch-activated electronic switch for this reason. Touch-activated electronic switches find applications in areas such as:

1. Control of light and intercoms within jail cells: - they are ideal for such hostile environments, since indestructible carriage bolts, mounted in thick cement walls, could be used as touch buttons.
2. in museums, interactive display, schools and hospital for switching.
3. for wheel chairs or for the handicapped.
4. As object sensors when the circuit is modified.
5. As lighting control and touch activated dimmers.
6. Detecting human feet from beneath a floor.
7. Security alarms and human motion detection when the system is modified [2].

1.3 Scope of The Project

This project has been undertaken to design and build a touch-activated electronic switch. The design of this project is in such a way that it can switch any electrical or electronic device (appliance). But a 60/100W bulb shall be used for testing.

Chapter Two

Literature Review

2.1 Introduction

There have been a lot of innovations and inventions in the field of electronics. Switches also have undergone such evolutions-from mechanical switches to the most sophisticated electronic switches. The background of electronic switching system can be linked to the development of solid-state devices and semiconductors devices. Almost all electronic switches consist of semiconductor devices or integrated circuit (IC) in one stage or more.

The discovery of solid-state devices in the mid 19^{th} century led to the construction of a practical diode by J. A. Fleming. The diode tube is used as a switch among other uses. It was used as a switch because it can permit current to flow or to be shut off [3].

Semiconductor diodes were also used for switching. The need for substitute to mechanical switches led to the modification of the p-n diode. The result of this modification was a transistor (i.e. transfer - resistance). The transistor was invented in 1948 by J.Bardeen, W. Brattain and W. Shockley [3].

Electronic switches are switches made from one or more of the devices mentioned above. The design of the electronic switch is in such a way that its efficiency, reliability and speed are high.

2.2 Overview of Electronic Switches

Electronic switches operate by the principle of conversion of non-electrical quantity into electrical signal by the use of a transducer. They employ a timing or a latching circuit which controls the duration of the "on" and "off" states of the switch. It uses a switching transistor and a relay.

2.2.1 Sound-Operated Electronic switch

This type of electronic switch operates on the principle of conversion of sound energy into electrical signals. The sound (from a clap, voice etc.) is converted to electrical signal by the use of a microphone. It has a pre-amplifier stage and an amplifier stage. These stages amplify the electrical signal. The rectifier stage converts the audio signal into dc. The dc voltage is filtered and then applied to the switching transistor which drives the relay.

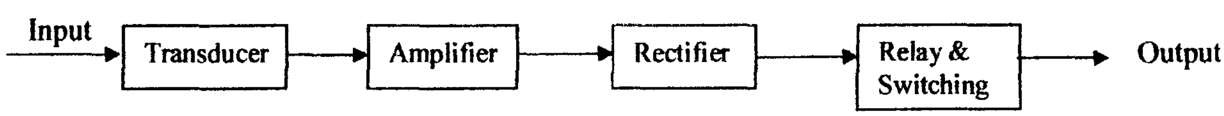


Fig.2.1: Block diagram of sound operated electronic switch.

In the design of the sound operated electronic switch, there was no provision for latching circuit. The relay operates momentarily in response to audio peaks. So; its operation can be affected by background noise.

Aliyu (2003) designed and constructed sound operated electronic switch. He made use of a microphone as the transducer. A 741 IC was used to amplify the audio signal. The rectified signal was used to drive a 555 timer which form the timing circuit. The output of the 555 timer drives a switching transistor which triggers a relay connected to its output. Olajide (2000) designed and constructed a sound activated electronic switch. He made use of a microphone as the transducer. An amplifier was used to amplify the weak signal. A 555 timer was used as timing circuit .the timing depends on the value of the resistor and capacitor connected to the timer circuit. A relay and a switching transistor form the final stage. Danlami (2003) designed and constructed a sound operated electronic switch. In the design, there was no provision for a timing circuit.

2.2.2 Touch- activated electronic switch

This kind of switch operates on the principle of change in capacitance between the human body and the ground when the metal contact of the switch is touched. Normally the capacitance of the touch plate to ground is very small. When the touch plate is touched, the human body acts like a large capacitance to ground allowing a small ac current to flow from the mains through the small parasitic capacitance of the mains transformer and the rectifier of the dc supply. This kind of touch activated electronic switch employs two Schmitt trigger inverters, two resistors, a diode and a capacitor. It has the advantage of using only one contact plate which is used for "ONning" and "OFFing".

Another type of touch activated electronic switch is the one that employs two touch plates- one for on and the other for off. It uses a 555 timer as the timing circuit.

The "OFF" and "ON' plates are connected to the trigger and reset of the 555 timer. The output of the 555 timer drives the switching and relaying circuit.

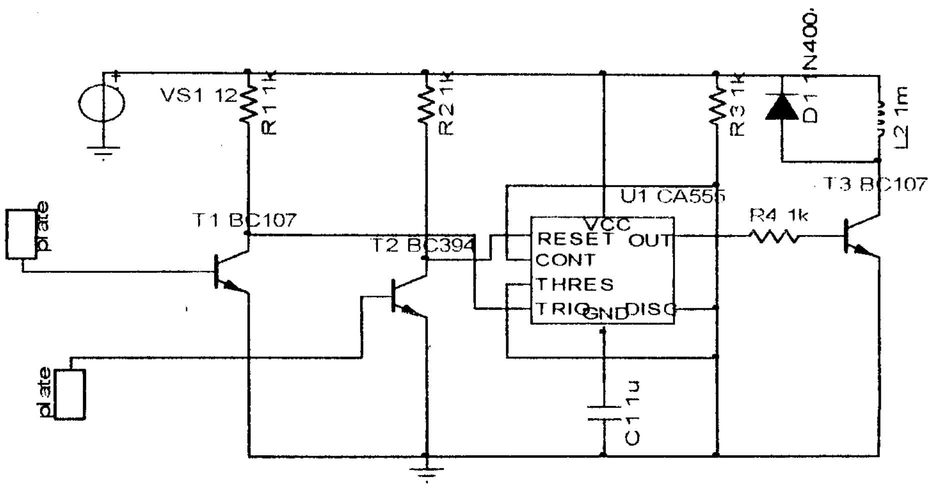


Fig.2.2: Schematic diagram of a touch activated Switch [4].

The circuit in fig. 2.2 is based around NMOS 555 timer IC. This is usually NE555 or LM555. It is used as a pulse generator, monostable multivibrator. That is, it produces one pulse only when it is triggered.

In my design of electronic switch, only one touch plate was used. And the 555 timer is replaced by a latching circuit. The latching circuit is made of a flip-flop which stays in one state until it is being triggered. That is, it stays in "ON" state or "OFF" state until signals are applied to its input. The duration of the switching is not controlled by a capacitor and/or a resistor as in the case where a 555 timer is used.

Chapter Three

Circuit Design and Analysis

3.1 Introduction

Semiconductor devices and integrated circuits (ICs) are not ideal. So, they impose significant limitations on design. For a design, therefore, to be successful, there must be a good understanding of the characteristics of these basic practical components.

Also in the selection of a particular component for a specific purpose, the principle of operation of each component must be considered. Then various devices and components that would suit different circuit are selected.

3.2 Design Analysis:

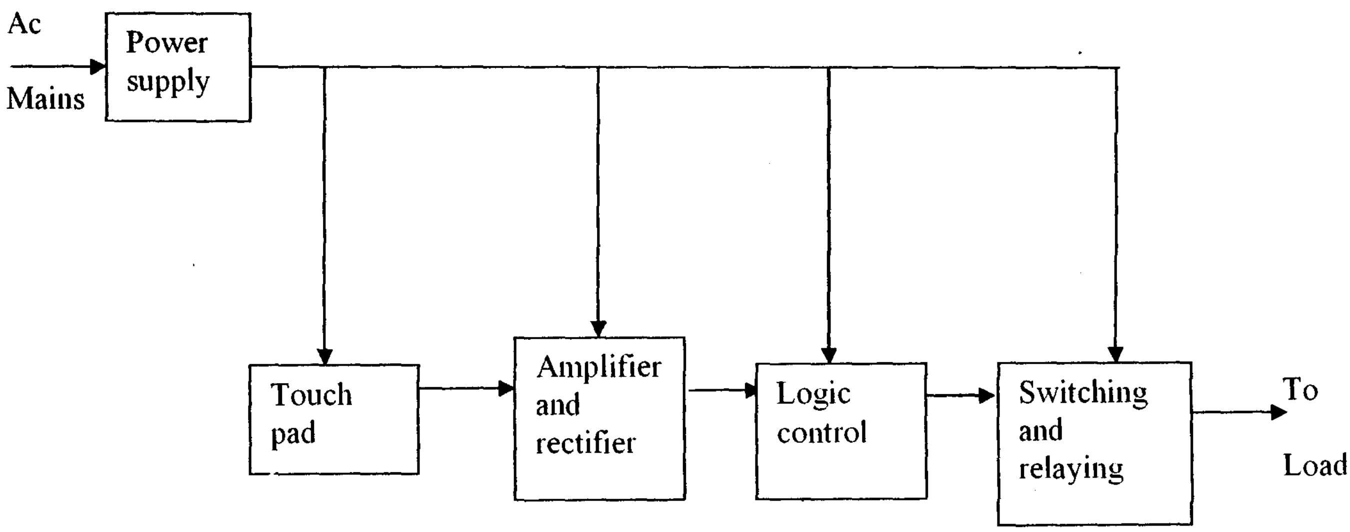


Fig. 3.1: Simplified Block Diagram Of Touch -Activated Electronic Switch.

The touch - activated electronic switch is made up of four basic stages. This part contains the record of how the design parameters were calculated and how the components were selected. The block diagram of the touch –activated electronic switch is shown in fig 3.1.

3.2.1 Power Supply Stage

Most electronic devices and circuits require a dc source for their operation. Since the most convenient and economical source of power is the domestic ac supply. It is advantageous to convert this alternating voltage (usually 220v) to de voltage. This process of converting ac to dc voltage is called rectification. Rectification is achieved by using diodes. The rectified voltage has some sinusoidal components known as ripple. To eliminate the ripple filtering circuits are used [8].

The power supply used in this project work consists of a 240/12 volts transformer, a bridge rectifier and a shunt filtering capacitor (5500μF).

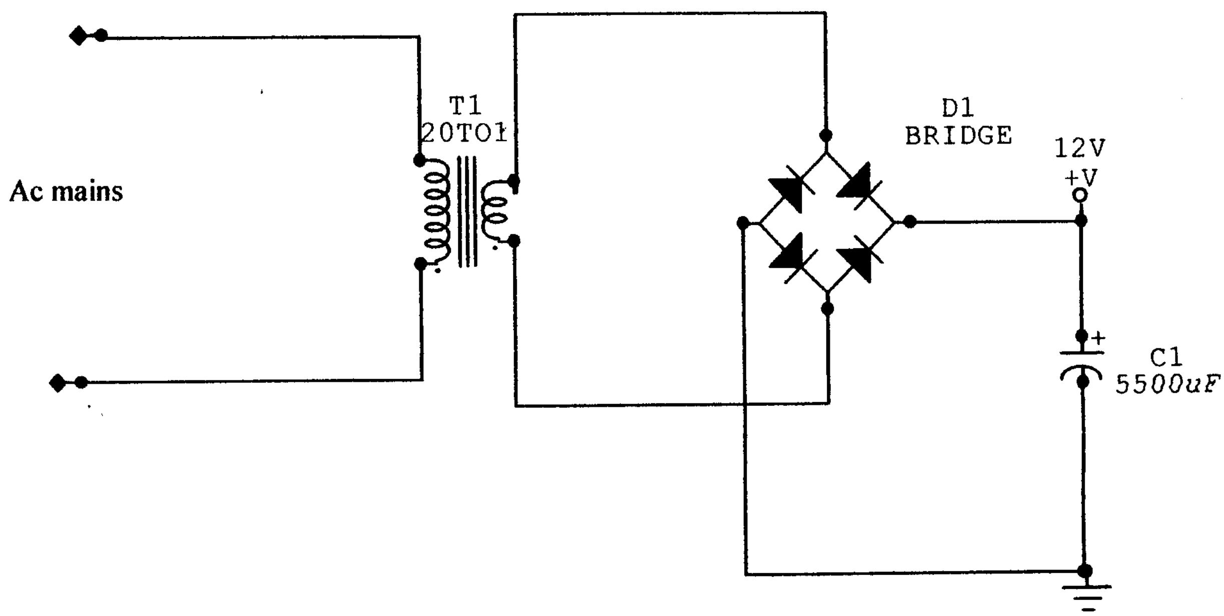


Fig. 3.2: Circuit Diagram of Power Supply

The transformer used in this project has a turn ratio of 20:1 (i.e. Np: Ns = 20:1) where Np =number of turns in primary winding; Ns = number of turns in secondary winding.

Assuming the ac mains voltage is 240 V

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

where V_s = Secondary winding voltage

V_p = Primary winding voltage

$$V_s = \frac{N_S}{N_P} \times V$$

$$= \langle\frac{1}{20}\rangle \times 240$$

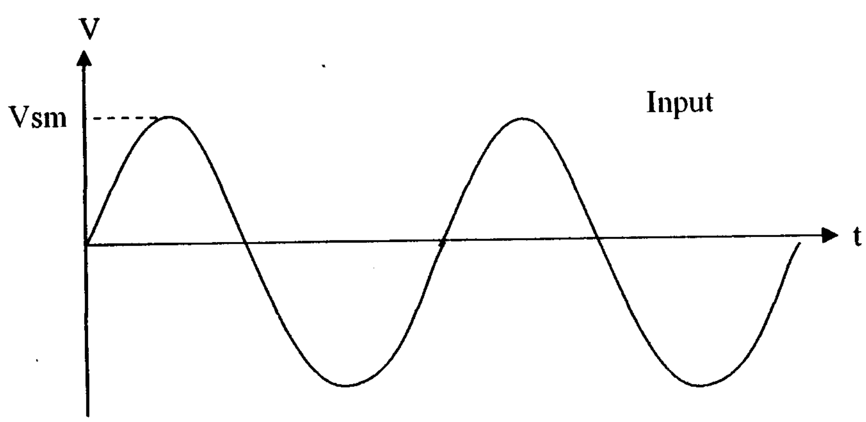
$$= 12V$$

Therefore, the voltage across the bridge rectifier is 12V (i.e. V_S)

But $V_s = V_{rms} = 12V$

Peak voltage, $V_{sm} = \sqrt{2} \times 12$

$= 16.97V$



(a)

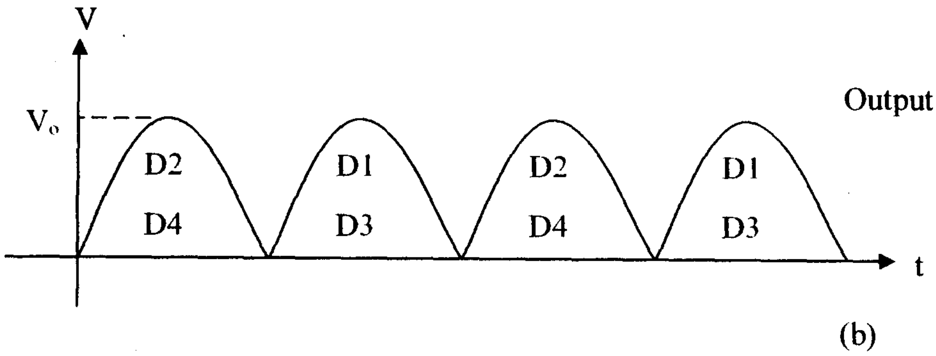


Fig 3.3 waveform of full-wave bridge rectifier

As seen from fig 3.2, during the positive half-cycle, secondary terminal M is positive while N is negative. Diodes D2 and D4 become forward – biased (ON) whereas D1 and D3 are reverse – biased (OFF). Hence, current flows through D2 and D4.

During the negative input half-cycle, secondary terminal N becomes positive and M negative now, D1 and D3 are forward-biased. Hence current flows through diodes D1 and D3.

Barrier potential, $V_B = 0.7v$ for silicon diode

:. Output voltage, $V_O = V_{S.} - V_B - V_B$

$= V_{S.} - 2V_B$

:. $V_O = 15.56 - 2x0.7$

$= 15.56 - 1.4 = 14.16V$

As seen from the output waveform (fig. 3.3 (b), the output is not a steady dc. It is a pulsating dc wave with a ripple frequency. That is, he rectified output consist of a dc component and components.

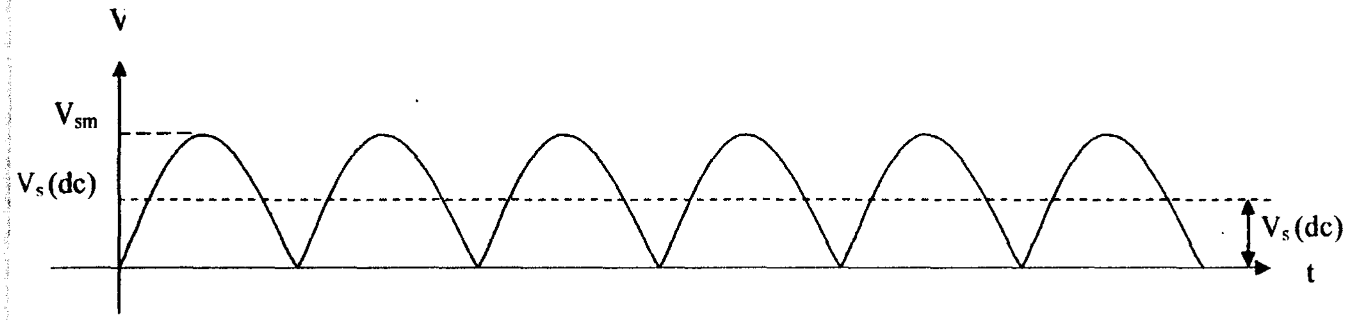


Fig.3.4 dc component

The dc component, Barrier potential, $V_B = 0.7v$ for silicon diode

$$V_s(dc) = \frac{2 \times V_s}{\pi} = 0.636V_s$$

$$Vs(dc) = 0.636x15.56V$$

$$= 9.896V$$

Filtering

A shunt capacitor filter is used to smoothen out or filter the pulsations (ripples) in the rectified voltage.

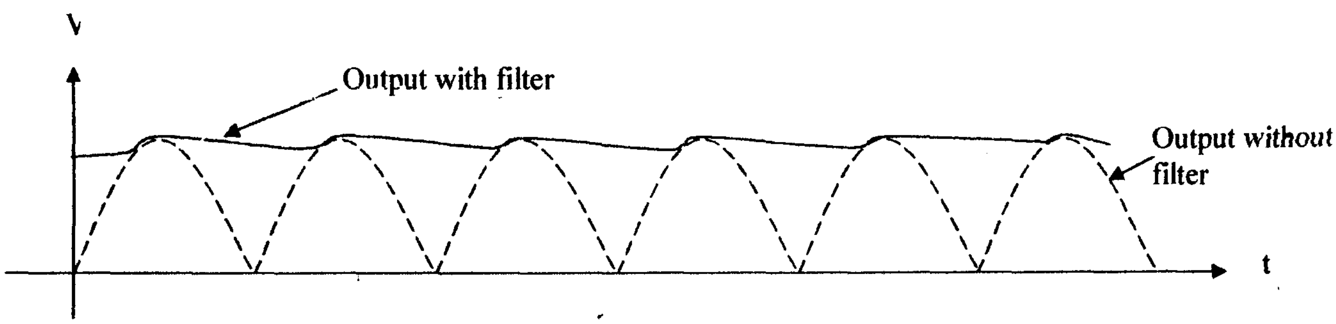


Fig. 3.5: filter action

The output from the filter is not totally ripple free the filter circuit only reduces the ripple voltage to a tolerable level

3.2.2 Amplifier and Rectifier Stage

3.2.2.1 Amplifier Stage

In this stage the induced ac signal which is weak is amplified by a 741 OP-Amp. The Op-Amp was connected in inverting amplifier configuration.

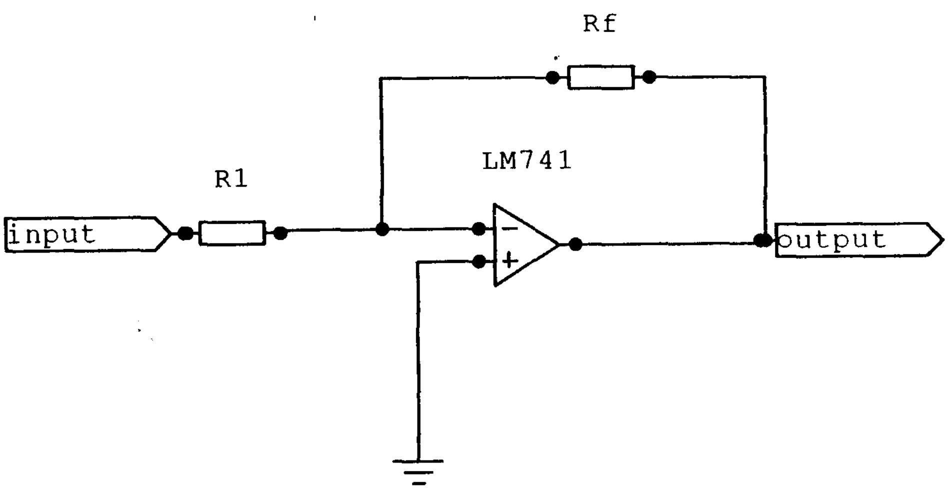


Fig 3.6: Inverting Op-Amp

It was required that the weak signal be amplified to 330 times its original value. That is, the amplification, Av = - 330; and choosing Rf to be 330 kΩ, R can be calculated as thus:

$$\text{Amplifier gain, } A_v = \frac{\text{Output Voltage}}{\text{Input Voltage}} = \frac{V_{out}}{V_{in}}$$

$$A_v = \frac{Vout}{V_{in}} = \frac{-R_f}{R_1}$$

$$\rightarrow -330 = \frac{-330}{R_1}$$

$$R_1 = \frac{-330}{-330} = 1k\Omega$$

3.2.2.2 Rectifier Stage

In this stage the amplified ac voltage is rectified using a half-wave rectifier circuit.The rectified voltage is filtered by a 10μF capacitor.

3.2.3 Logic Control Stage

This stage consists of a push-pull transistor and a D flip-flop. The transistor combination behaves like an npn transistor with large beta. The transistors are npn and pnp connected with collector of the npn feeding the base of the pnp. The output of this combination is used to clock the D flip-flop.

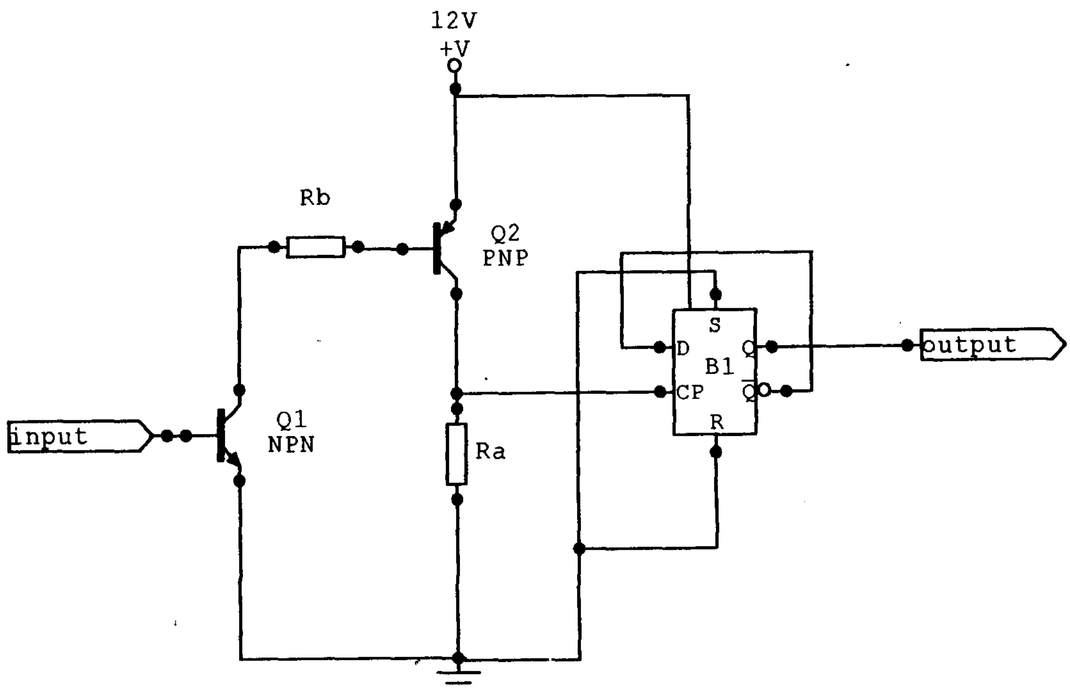


Fig 3.7: Logic Control Stage

Design:

For transistor Q2, Ic (max) -= 750 mA, Hfe =150 (from manufacturers data sheet) and Vbe = 0.7V

$$I_b = \frac{V_{cc} - V_{be}}{Rb}$$

Assuming the value of 12V

$$Rb = \frac{V_{cc} - V_{be}}{I_b}$$

$$I_c = h_{FE} \times I_b$$

$$I_b = I_c/h_{FE}$$

$$I_b = \frac{750mA}{150} = 5mA$$

$$R_b = \frac{V_{cc} - V_{be}}{I_b}$$

$$= \frac{12 - 0.7}{5 \times 10^{-3}} = \frac{11.3}{5x10^{-3}}$$

$$= 2.26 \times 10^3$$

$$Rb = 2.26k\Omega$$

The value of Ra is chosen in such a way that the clocking terminal of the D flip-flop would be maintained at ground potential before the arrival of the output of transistor Q2. So, Ra must be a resistance of large value; and hence 100kΩ is chosen. That is, Ra = 100kΩ

This stage is designed in such a way that, for every clock pulse the output of the flip-flop will assume one of two states (low or high). That is its state changes from either low to high or vice versa when a clock pulse is applied to the 'CLK' terminal. The other input of the D flip-flop (D) is connected to the inverse of the output (Q).

3.2.4 Switching and Relaying Stage

This stage employs the principle of the transistor as a switch and the use of a relay to control a load.

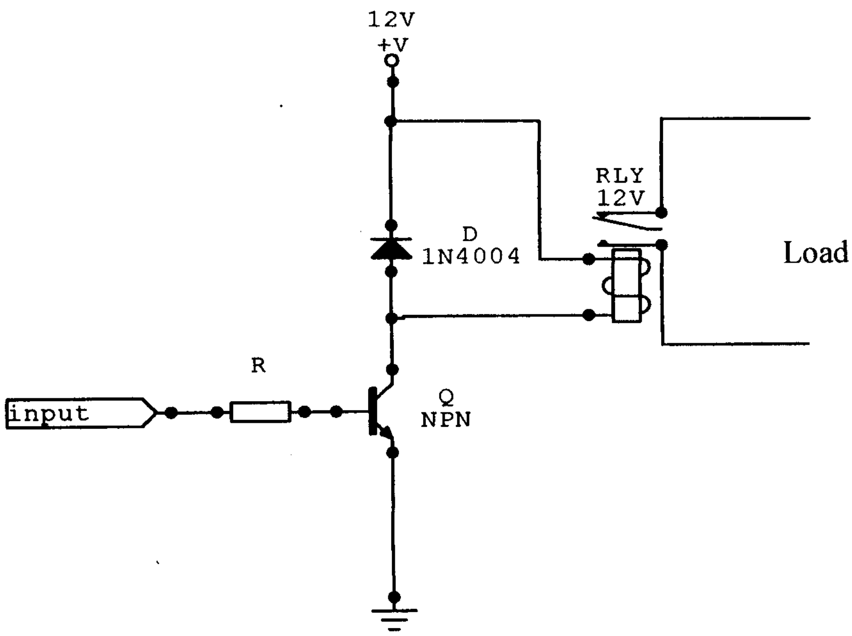


Fig. 3.8: Switching and Relaying Circuit

For Q, Ic (max) = 800 Am. HFE = 150 and (from the manufacturers data sheet) and

Vbe = 0.7v

$$I_b = \frac{V_{cc} - V_{be}}{Rb}$$

Assuming the value of 12V for Vcc,

$$Rb = \frac{V_{cc} - V_{be}}{I_b}$$

$$I_c = h_{FE} \times I_b$$

$$I_b = I_c/h_{FE}$$

$$I_b = \frac{800mA}{150} = 5.33mA$$

$$R_b = \frac{V_{cc} - V_{be}}{I_b}$$

$$= \frac{12 - 0.7}{5.33 \times 10^{-3}} = \frac{11.3}{5.33 \times 10^{-3}}$$

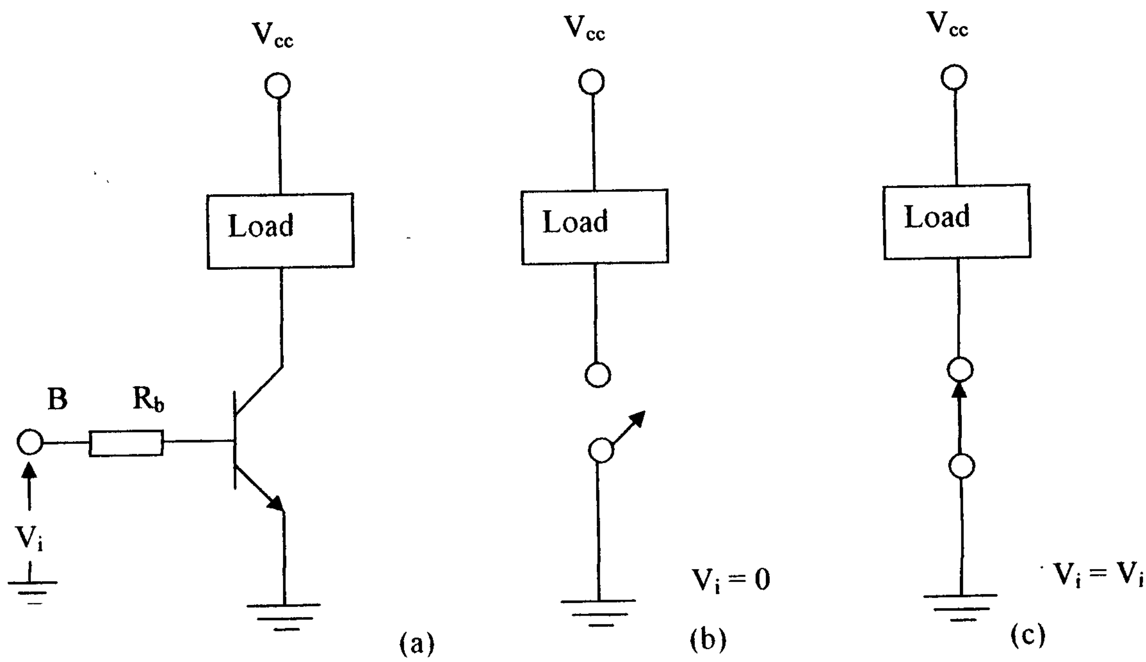
$$= 2.12 \times 10^3$$

$$Rb = 2.12k\Omega$$

3.2.4.1 Switching Action of a Transistor

When a transistor is used as a switch it is either biased to be non-conducting (OFF), or it is biased to conduct the maximum possible current (ON). When the base current is zero the transistor is held in its OFF condition and voltage across the transistor output is equal to the collector supply voltage, Vcc. When the transistor is driven into saturation it is in its ON state and the voltage across the transistor is its saturation voltage (Vce (sat)).

The transistor can, therefore, turn a given load ON or OFF by one appearing at the output of a digital logic even a microprocessor. The power level of the control signal is usually small, and hence, it is incapable of switching the load directly. However, such a control signal is certainly capable of providing enough base drive to switch a transistor ON or OFF, and hence, the transistor is made to switch the load [8].



Fig, 3.9 Transistor as a switch

When using a transistor as a switch, usually two levels of control signals are employed. The two levels are:

1. Saturation region, 2. cut-off region.

In the saturation region, both the base-emitter and base-collector junctions are forward-biased. That is, there is perfect short – circuit for both base-emitter and base –collector diodes. Hence, the transistor terminals are connected together, thereby acquiring equal potential. So, the potential of collector-emitter junction is zero (Vce =0). This condition is shown in fig 3.9 (a)and fig.3.9 (c).

In the cut-off region both the base-emitter and base-collector junction are reversed-biased. That is, both diodes act like open circuit under these condition as shown in fig. 3.9 (b). The transistor terminals are uncoupled from each other, neglecting the reverse leakage current, the potential of collector –emitter terminal is equal to Vce. That is Vce = Vcc. As seen, where the control signal Vi is zero (Vi = 0), the transistor acts as an open switch (fig. 3.9 (b)) [8].

3.2.4.2 Inductive Load and Diode Protection

In a circuit where an inductive load (like a relay) is connected to a semiconductor device that can easily damage, a damper diode must be connected across the relay, so that the semiconductor device (like transistor) can be protected when the load is switched off. If the diode were not included, the relay would induce a large voltage across the transistor when the load is switched off. This voltage could damage the transistor. Typical diodes used are IN 4001, IN 4002 or IN4004 [9].

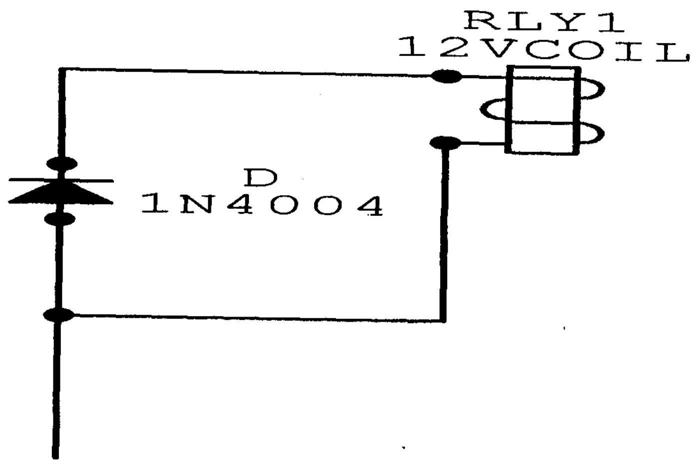


Fig. 3.10: Diode Protection

3.3 Circuit Operation

The operation of the electronic switch is such that when the touch pad is touched, an ac is induced. The induced ac signal has a very low level. This signal is coupled to the amplifier stage by capacitor C1. The amplifier amplifies the ac signal. Diode D5 is used to clamp the voltage level at the anode of diode D6, so that D6 will be biased into conduction. This takes care of the barrier potential of diode D6. Diode D6 rectifies the ac signal. The rectified voltage is applied to the push-pull transistor combination (Q1and Q2). The combination of Q1 and Q2 gives a high beta (β), and, therefore, gives a high collector current. The output of transistor Q2 is the clocking pulse for the D flip-flop. The data input (D) to the flip-flop is the same as the inverse of the output (Q). The output of the flip-flop depends on the two inputs (CLK and D).

Assuming the load is switched off, that is output Q is low (logic 0), when the touch pad is touched. The pulse from the 'touch' causes the clocking pulse to change and the data input (Q =1) will be transferred to the output Q; that is, output Q is high (Q =1). The load will then be switched on.

On touching the pad again, the change in the clocking pulse causes the data input to be transferred to the output. That is the input (D=0) will be transferred. This switches the load off. The combination of transistor and relay do the switching effectively.

List of components used:

C1, C2, C3, C4 = 10 μF

C5 = 5500 μF

R2 , R3, R7, R10, R11 = 10kΩ

R1, R5, R6, R8 = 1kΩ

R4 = 330k Ω

R9 = 100kΩ

IC1 = LM741

D4 BRIDGE, D1 = 1N4001

D2 = 1N4148

D3 = 1N4004

Q1, Q3 = 2SC1815GR

Q2 = 2SA1015GR

B1 = CD4013 E

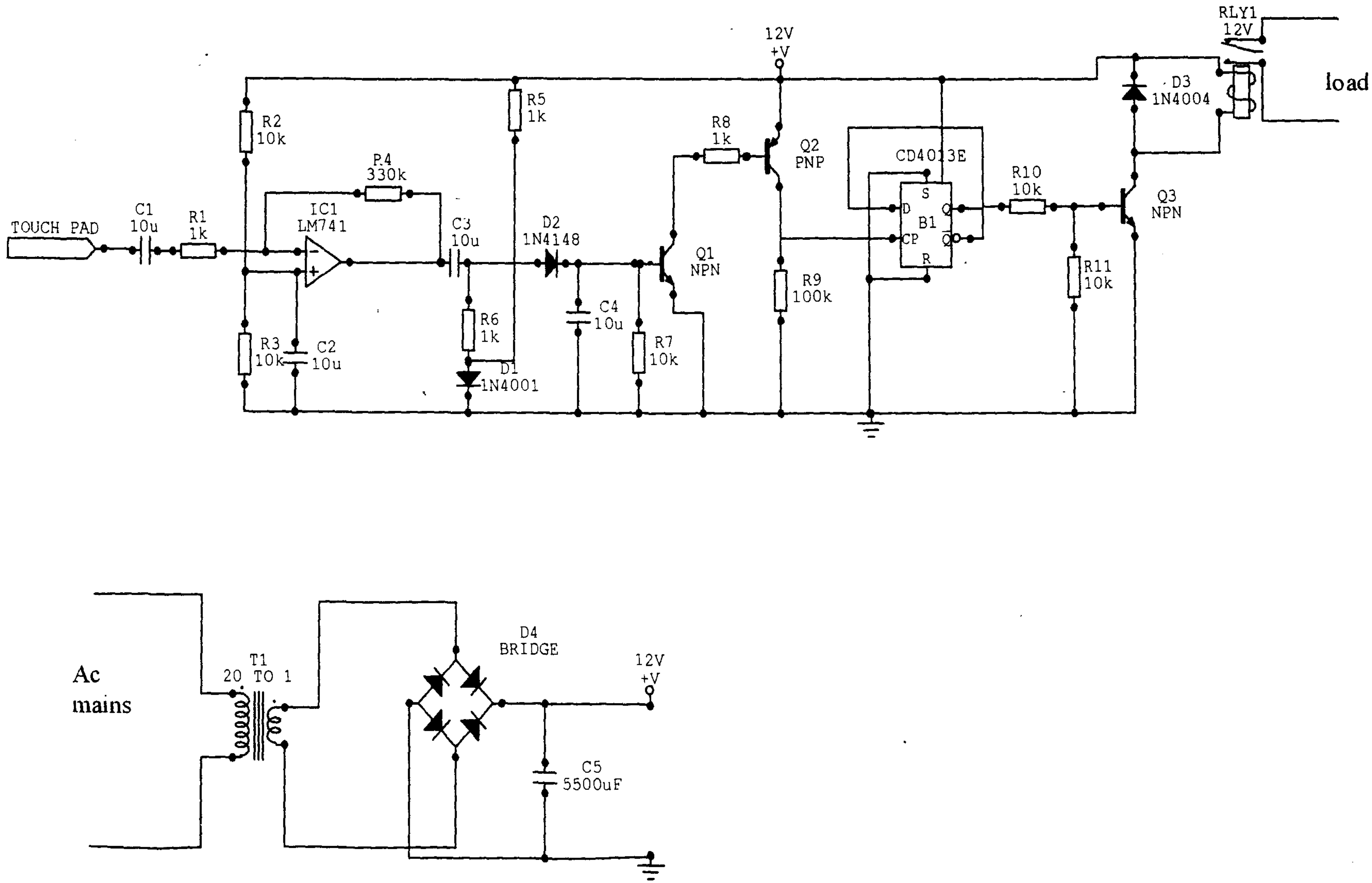


Fig 3.11 Circuit Diagram of Touch-Activated Electronic Switch

Chapter Four

Construction

4.1 Construction

This chapter gives the detailed explanation of how the circuit was constructed and also the testing of the operation of the circuit. The construction was done in accordance with the specifications in design. In some instances, some of the parameters calculated were adjusted and/or modified to make the circuit work properly. The following are the steps taken in the construction:

- The components were first fixed on the Vero board to ensure that the circuit works properly as designed before transferring it to the bread board
- A layout plan of the component position on the bread board was made. Also unnecessary spacing between components was avoided to reduce the length of wires used thereby making the construction less cumbersome and the package very portable.
- The circuit was then transferred to the bread board and adjustments and /or modifications were made on any observed error
- The components were soldered on to the board. The copper strips on the board were disconnected by using razor blade to cut-off unwanted connections appropriately
- Connections of the installed components to one another was achieved by using jumpers (wire) in accordance with the design
- The ICs were connected to their sockets and also soldered to the board. The whole circuit was fixed to the casing in order to reduce vibration which can make the circuit not function properly.

4.2 Testing

The circuit must be tested to make sure that the results are in accordance with those needed. Each of the stages in the circuit was tested separately before testing the circuit as a whole. The testing was done in the following steps:

- The operation of all the stages was tested one after the other
- The power stage was tested first. The circuit was checked for short circuit o r open circuit. The voltage across the output of the filtering capacitor was measured using a multimeter. The power supply is connected to the rest of the circuits
- The output of the amplifier, flip-flop, switching transistor and relay was measured and compared with the expected values.
- The voltage across the relay terminals was measured and it was in the range of 180-220 V depending on the ac mains.

Casing:

The casing was made from a plastic. This is because the touch pad is fixed on the casing and so it has to be insulated from the casing. If the casing were a metal it will affect the proper functioning of the circuit. Thus, an insulator material is chosen for the casing. And also the plastic casing is more durable than a wooden one. The dimensions of the casing are:

Length = 15cm; breadth = 9cm and height = 5cm.

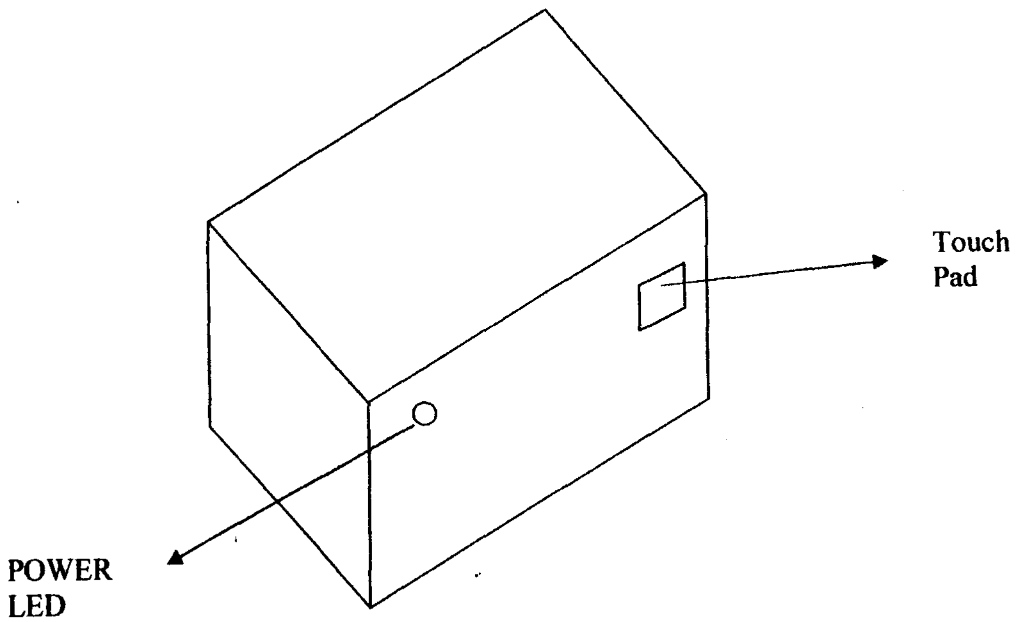


Fig. 5.1: Casing

Chapter Five

Conclusion

5.1 Conclusions

The project, which was intended to design and construct a touch – activated electronic switch, was designed to make use of a touch plate, amplifier, D flip-flop, switching transistor and a relay. It also includes other components such as resistors and diodes.

The design and construction of the project was successfully done, in that. the purpose for which the project was designed have been achieved .

The switch produced can be used to control any load takes 220 V as its supply voltage.

5.2 Recommendations

The department should standardize the practical taken by the students in 300 and 400 levels. That will go a long way in exposing the students to the methodologies of design and construction of simple circuits. It will therefore make the students ready to face the challenges posed by project design and construction.

The project (touch activated electronic switch) can be modified with additional circuitry to form a touch-activated burglar alarm.

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