DESIGN AND CONSTRUCTION OF AN OVER VOLTAGE AND UNDERVOLTAGE CUT-OFF SYSTEM.

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(2004/18868EE)

A THESIS SUBMITTED TO THE DEPARTMENT OF
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DECEMBER, 2009.

DECLARATION

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

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ACKNOWLEDGEMENT

I would like to give thanks to the Almighty God for His grace in helping me to commence and to complete my undergraduate studies. He has been my help throughout my period of schooling. It was not so easy, but God kept me. I am so hopeful and have this assurance that He would yet keep me and grant me success throughout my life.

I would also use this medium to show my deep and profound gratitude to my wonderful mother, Mrs. J. M. Saliu, for her contributions to my success. I also want to thank my siblings Okeka, Itiafa, Gbenga and Mosi, all my uncles and aunts, cousins and friends for their wonderful encouragements in the course of my studies. It is my prayer that God would bless you and continue to guide you and meet you all at your various points of needs, Amen.

Finally, I want to appreciate my project supervisor, Mr. A. M. B. Zungeru, for his kindness and patience in the course of my project. May God bless you and help you always in the course of your career, Amen.

ABSTRACT

This project is designed as an improvement over the traditional fuse system used in electrical installations today. The input is obtained from the power supply company and then stepped down to 24V. The stepped down voltage is then converted to direct current (DC) and then divided into two equal halves. One of the halves is regulated to remain at 12V before it is being sent to the comparator stage while the other is not regulated before it is sent to the comparator stage. Three scenarios occur at the comparator stage. First, as long as the input is not less than 180V or greater than 240V, the regulated voltage would always give an output in the comparator stage while the unregulated voltage would not give an output in the comparator stage. In this stage, there would be an output from the comparator stage to drive the load. Secondly, if the input voltage is greater than 240V, both the regulated and the unregulated voltage would give outputs in the comparator stage. In this case there would be no output from the comparator stage to drive the load. Finally, if there is no input voltage or the input voltage is less than 180V, there would be no output from the comparator stage neither would there be any output voltage to drive the load. The project is designed with the following objectives in mind:

- First objective is to put to use all that I have learnt in my undergraduate years to solve one of Nigeria's major problem.
- Secondly, inline with the purpose of the use of a fuse, this project serves as a protective means to all electrical installations and devices.
- Finally, this project is not a complete replacement to the conventional fuse system used today in electrical installations and devices, but it serves to create a redundant system for safety.

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CHAPTER ONE

GENERAL INTRODUCTION

1.1. INTRODUCTION

No doubt, we all know that among the major factors that contribute to the development of a country's economy; power supply, plays a prominent role. The federal ministry of power and steel has adopted the IEE regulation that allows the variation in consumer's voltage by +/-6% and the frequency by +/-1.5% [1]. Thus for a 415/240V supply at 50Hz, consumer voltages and frequency must be of the following:

$$390.1 \leq V \leq 439.9 \qquad (1.1)$$

$$225.6 \leq V \leq 254.4 \qquad (1.2)$$

$$49.25 \leq F \leq 50.75 \qquad (1.3)$$

However, today, power supply voltage in Nigeria has been found to be as high as 280V and as low as 110V, causing excessive damage to electrical installations and appliances. This has necessitated the use of automatic voltage regulators (AVR) and uninterrupted power supplies (UPS). Variation in frequency has led to inefficiency in production process and companies now are either folding or increasing the price of their goods. This however has led to the stunted growth in the economy of the Nation.

This project is focused on addressing the problem of over voltage and under voltage. Any voltage variation above 255V is considered over voltage. Over voltages in short durations are known as power surges. These are power line disturbances which are caused due to lightening strike on power lines or sudden under-loading. Under voltages are voltage variations which are less than 225V. They are usually caused by the over loading of electrical supply. Over voltage problems are primarily solved with the use of conventional fuses. A conventional fuse is a safety device for cutting off the electric circuit by means of a wire which is so designed that it burns out when current exceeding the admissible passes through it [2]. These are of two types: rewirable fuses and cartridge fuses. This project however meets the solution to over voltage and under voltage.

1.2. OBJECTIVES

The 2008 world's richest man Bill Gates, stated some years ago that "*knowledge is useless except it is used in the development of mankind*". This implies that all that is acquired during one's undergraduate studies is useless except it brings about creativity that is needed to solve national and global problems. Hence my first objective is to put to use all that I have learnt in my undergraduate years to solve one of Nigeria's major problem.

Secondly, inline with the purpose of the use of a fuse, this project serves as a protective means to all electrical installations and devices.

Finally, this project is not a complete replacement to the conventional fuse system used today in electrical installations and devices, but it serves to create a redundant system for safety.

1.3. METHODOLOGY

This project is designed as an improvement over the traditional fuse system used in electrical installations today. The input is obtained from the power supply company and then stepped down to 24V. The stepped down voltage is then converted to direct current (DC) and then divided into two equal halves. One of the halves is regulated to remain at 12V before it is being sent to the comparator stage while the other is not regulated before it is sent to the comparator stage.

Three scenarios occur at the comparator stage. First, as long as the input is not less than 180V or greater than 240V, the regulated voltage would always give an output in the comparator stage while the unregulated voltage would not give an output in the comparator stage. In this stage, there would be an output from the comparator stage to drive the load. Secondly, if the input voltage is greater than 240V, both the regulated and the unregulated voltage would give outputs in the comparator stage. In this case there would be no output from the comparator stage to drive the load. Finally, if there is no input voltage or the input voltage is less than 180V, there would be no output from the comparator stage neither would there be any output voltage to drive the load.

1.4. SCOPE OF WORK

This work is divided into five chapters. The first chapter focuses on the introduction of the whole project. It gives information on the method involved in carrying out the project, the reason for the project as well as the scope of work. In chapter two, a brief historical background as well as the theoretical foundation for the work is looked at. Chapter three illustrates the implementation of the theoretical basics explained in chapter two for the design of the project. In chapter four, various tests carried out on the project work are analyzed as well as the construction for the model. Chapter five focuses on the summary of the work and the recommendations for further improvement of the work.

CHAPTER TWO

LITERATURE REVIEW

2.1. LITERATURE REVIEW

Electricity is of two types: Static electricity and Current electricity. Electricity which accumulates and stays in a substance is described as static electricity. The discovery of electricity can be dated to as early as 600BC when a Greek Philosopher, named *Thales* first experimented on static electricity [1]. Centuries later, *William Gilbert,* a court physician, showed that many substances such as glass, ebonite, resin, and sulphur also acquired attractive properties when rubbed with suitable materials [2]. *Gilbert* named this force *electricity* after the word *electron* which is the Greek name for *amber*. The study of voltage generation began around the late eighteenth century when *Luigi Galvani*, an Italian scientist, detected muscular contractions in frog legs when they were hung by brass hooks on iron railings. The contractions occurred whenever the suspended legs came in contact with iron railings. *Galvani* was under impression that the frogs muscles and nerves acted as a source of electricity and that a discharge took place when both wires were joined to form a conductive path. However, his friend, *Allessandro Volta (1745 - 1827)*, had a totally different explanation. He proposed that the main cause of the twitch was due to the presence of the two dissimilar metals, with the liquid material in the frog's legs between them. He later conducted so many tests to prove his point and this led to the invention of the voltaic cell which could maintain an electric current in a circuit when it's terminals are joined by a piece of wire [3]. The unit of electrical pressure is the *volt*, after *Allessandro Volta* who built the first battery in 1799 [4].

Modern generation of electricity is based on the principle discovered in 1831 by *Michael Faraday* (1791 - 1867). This principle states that *the induced emf in a circuit is equal to the rate at which the magnetic flux through that circuit is changing with time.* By observing your socket slots, you'll see copper wires that may snake out of your house and over the countryside for hundreds of miles. If you follow them you would most certainly find yourself at an electric generator, in which a potential difference is established between the wires by Faraday's law. On your way from the wall plug to the generator, you would have to portage around several transformers, in which Faraday's law is at work, stepping up or down the potential difference between the wires [5].

2.2. THEORETICAL BACKGROUND

The theoretical foundation which supports this project is explained in this section. Some electrical components were used to do this work. These components are listed below:

- Transformer
- Diodes
- Capacitors
- Resistors
- Operational amplifiers (Opamps)
- Transistors and
- Relay.

2.2.1. Transformers: These are electrical devices which transfer electrical energy from one circuit to another through magnetic means [6]. These circuits through which there is a transfer of electrical energy are not connected via electrical means. The electrical energy is transferred without a change in frequency and power but there may be changes in the magnitudes of quantities such as voltage and current. A transformer is represented below as consisting of two electrical circuits linked by a common ferromagnetic core. One coil is termed the *primary winding* which is connected to the supply of electricity, and the other the *secondary winding,* which may be connected to a load. A circuit diagram symbol for a transformer is also shown below.

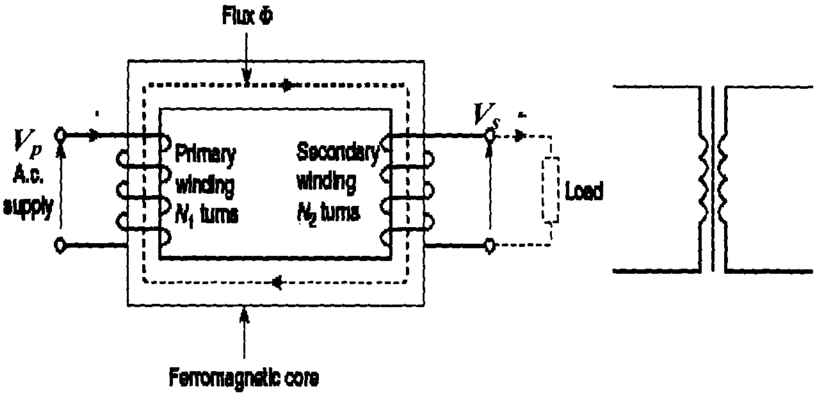


Fig 2.0. (a) A transformer. (b) Circuit symbol.

According to Faraday's law, the voltage at the primary windings is given as

$$V_p = N_p\,(d\varphi_p/dt) \qquad (2.1)$$

Similarly, the voltage at the secondary windings is given as

$$V_s = N_s\,(d\varphi_s/dt) \qquad (2.2)$$

With perfect flux coupling, $\varphi_p = \varphi_s$, and if we divide 2.5 by 2.6, we get

$$(V_p/V_s) = (N_p/N_s) = k_p \qquad (2.3)$$

Where k is the transformation ratio of the transformer, N is the number of turns of any of the sides (primary p or secondary s). The magneto-magnetic force (MMF) will produce a net flux in the core which is equal to

$$E_{net} = N_pI_p - N_sI_s = 0 \qquad (2.4)$$

With the core saturated,

$$N_pI_p = N_sI_s$$

$$(I_p/I_s) = (N_p/N_s) = (1/k) \qquad (2.5)$$

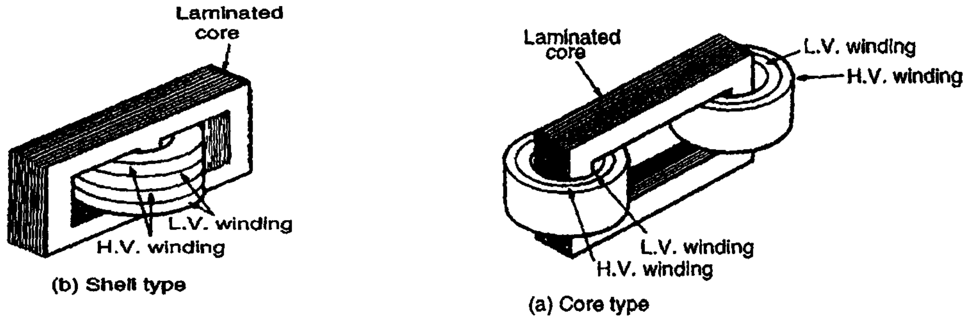
Since power at the primary winding is the same as power at the secondary winding,

$V_pI_p = V_sI_s$ or

$$(I_p/I_s) = (V_s/V_p) \qquad (2.6)$$

V_p/V_s is called the voltage ratio and N_p/N_s the *turns ratio*, or the *transformation ratio* of the transformer. If N_s is less than N_p then V_s is less than V_p and the device is termed a *step-down transformer*. If N_s is greater then N_p then V_s is greater than V_p and the device is termed a *step-up transformer*.

There are various types of transformers. They are power transformers, audio frequency transformers, radio frequency transformers, instrumentation transformers, auto transformers, et.c. The diagrams below reveal the common transformers found everywhere which are useful in electronic projects [7].



(b) Shell type

(a) Core type

Fig 2.1. Common Transformers.

2.2.2. Diodes: Materials may be classified as conductors, semiconductors or insulators. The classification depends on the value of resistivity of the material. Good conductors are usually metals and have resistivities in the order of 10^{-7} to $10^{-8}\Omega$m, semiconductors have resistivities in the order of 10^{-3} to $3 \times 10^{3}\Omega$m, and the resistivities of insulators are in the order of 10^{4} to $10^{14}\Omega$m [8]. Diodes, transistors and integrated circuits (IC) are all devices formed from semiconductors.

Diodes are two terminal devices consisting of a *PN* junction formed by either silicon (Si) or Germanium (Ge). They are one way devices that offers low resistance when forward biased and a very high resistance when reverse biased. A *PN* junction is a region where the *P* type layer joins the *N* type layer [9]. The process of obtaining unidirectional currents and voltages from alternating currents and voltages is called *rectification*. Semiconductor diodes are commonly used to convert alternating current (a.c.) to direct current (d.c.), in which case they are referred to as *rectifiers*. The simplest form of rectifier circuit makes use of a single diode and, since it operates on only either positive or negative half-cycles of the supply, it is known as a *half wave rectifier*. Four diodes are connected as a *bridge rectifier* and are often used as a *full-wave rectifier*. Note that in both cases, automatic switching of the current is carried out by the diode(s).

When a junction is formed between p-type and n-type semiconductor materials, the resulting device is called a *semiconductor diode*. This component offers an extremely low resistance to current flow in one direction and an extremely high resistance to current flow in the other. This property allows diodes to be used in applications that require a circuit to behave differently according to the direction of current flowing in it. Various different types of diode are available for different applications. A semiconductor diode is an encapsulated p-n junction fitted with connecting leads or tags for connection to external circuitry. Where an appreciable current is present (as is the case with many rectifier circuits) the diode may be mounted in a metal package designed to conduct heat away from the junction. The connection to the p-type material is referred to as the *anode* while that to the n-type material is called the *cathode*. Below are the circuit symbols for various types of diodes.

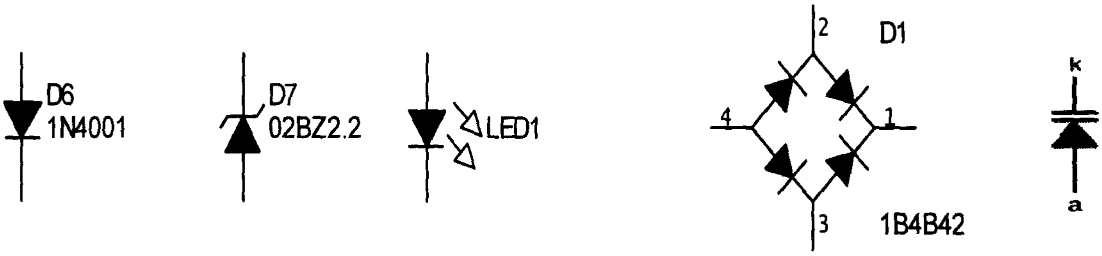


Fig 2.2. Symbols for (a) Diode. (b) Zener Diode (c) Light Emitting Diode. (d) Diodes used as bridge rectifier (e) Veractor Diode.

Light emitting diodes (LED) can be used as general purpose indicators and, compared with conventional filament lamps, operate from significantly smaller voltages and currents. LEDs are also very much more reliable than filament lamps. Most LEDs will provide a reasonable level of light output when a forward current of between 5mA and 20mA is applied. Light emitting diodes are available in various formats with the round types being most popular.

Zener diodes are heavily doped silicon diodes that, unlike normal diodes, exhibit an abrupt reverse breakdown at relatively low voltages (typically less than 6V). A similar effect, called *avalanche breakdown*, occurs in less heavily doped diodes. These avalanche diodes also exhibit a rapid breakdown with negligible current flowing below the avalanche voltage and a relatively large current flowing once the avalanche voltage has been reached. For avalanche diodes, this breakdown voltage usually occurs at voltages above 6 V. In practice, however, both types of diode are referred to as *Zener diodes*. Whereas reverse breakdown is a highly undesirable effect in circuits that use conventional diodes, it can be extremely useful in the case of Zener diodes where the breakdown voltage is precisely known. When a diode is undergoing reverse breakdown and provided its maximum ratings are not exceeded, the voltage appearing across it will remain substantially constant (equal to the nominal Zener voltage) regardless of the current flowing. This property makes the Zener diode ideal for use as a *voltage regulator*.

2.2.3. Capacitors: A capacitor is an electrical device that is used to store electrical energy. A capacitor consists of two conducting plates facing each other with an insulating material called dielectric separating them. Common dielectric materials include air, paper, mica, e.t.c. The capacitance *(C)* of a capacitor is the ability of a capacitor to store charge [10]. Next to the resistor, the capacitor is the most commonly encountered component in electrical circuits. Capacitors are used extensively in electrical and electronic circuits. For example, capacitors are used to smooth rectified a.c. outputs, they are used in telecommunication equipment – such as radio receivers – for tuning to the required frequency, they are used in time delay circuits, in electrical filters, in oscillator circuits, and in magnetic resonance imaging (MRI) in medical body scanners.

The capacitance of a capacitor is related to the stored quantity of charge *(Q)*, and the potential difference across its terminals as shown below.

$$Q = C\,V \qquad (2.7)$$

Q is measured in *Coulombs* while C is measured in *Farads (F), Pico farads (pF), Micro farads (µF)* et.c. The quantity of charge Q is also related to the current flow I as shown below.

$$Q = I\,t \tag{2.8}$$

t is measured in seconds *(s)*. The above two equations can be combined to have

$$Q = C\,V = I\,t \tag{2.9}$$

The diagrams below show the circuit representation of capacitors.

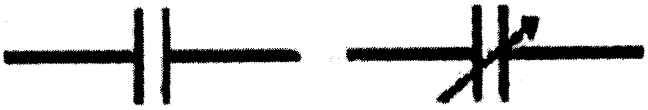


Fig 2.3. (a) Fixed Capacitor. (b) Variable Capacitor.

2.2.4. Resistors: The property of a body which limits the flow of current is called its resistance [11]. This property is a major factor which determines the electrical nature of any given substance. A resistor is a component which is designed to produce a known amount of resistance in a circuit. Resistors are of two kinds. The first classes which are standard resistors are resistors with fixed values while the second classes are resistors whose resistances can be varied. They are known as variable resistors or *rheostats*. The value of the resistance *(R)* of a resistor in a circuit can be determined by the ratio of the potential difference *(V)* across its terminals to the current flow *(I)* through it as provided by *Ohm's* law as shown below.

$$R = V / I \tag{2.10}$$

The resistance R is measured in *ohms (Ω)*, the potential difference V is measured in *volts (v)* while the current flow I is measured in *Amperes (A)*. The diagram below shows the representation of resistors.

Fig 2.4. Symbols for (a) A Fixed Resistor and (b) A Variable Resistor.

The table below shows the color code employed for resistors.

Table 2.0. Fixed Resistor Color Code.

Color	**Significant Figures**	**Multiplier**	**Tolerance**
Silver	-	10^{-2}	±10%
Gold	-	10^{-1}	±5%
Black	0	1	-
Brown	1	10	±1%
Red	2	10^{2}	±2%
Orange	3	10^{3}	-
Yellow	4	10^{4}	-
Green	5	10^{5}	±0.5%
Blue	6	10^{6}	±0.25%
Violet	7	10^{7}	±0.2%
Grey	8	10^{8}	-
White	9	10^{9}	-
None	-	-	±20%

Therefore,

(i) For a *four-band fixed resistor* (i.e. resistance values with two significant figures): yellow-violet-orange-red indicates 47kΩ with a tolerance of ±2% (Note that the first band is the one nearest the end of the resistor).

(ii) For a *five-band fixed resistor* (i.e. resistance values with three significant figures): red-yellow-white-orange-brown indicates 249kΩ with a tolerance of ±1% (Note that the fifth band is 1.5 to 2 times wider than the other bands).

Resistor values can also be represented in letters and digit codes as shown in the table below [12].

Table 2.1. Letter and Digit Code for Resistors.

Resistive value.	**Marked as.**
0.47Ω	R47
1 Ω	1R0
4.7 Ω	4R7
47 Ω	47R
100 Ω	100R
1k Ω	1K0
10k Ω	10K
10M Ω	10M

The tolerance is indicated as follows: *F*=±1%, *G*=±2%, *J* =±5%, *K* =±10% and *M* =±20%.

Thus, for example,

R33M = 0.3Ω ± 20%

4R7K = 4.7 Ω ± 10%

390RJ = 390 Ω ± 5%.

2.2.5. Operational Amplifier: An operational amplifier (op-amp) is defined as a high gain, high input resistance directly coupled negative feedback amplifier which can amplify signals having frequency ranges from 0Hz to a little beyond 1MHz [13]. Operational Amplifiers are usually called *op amps* because they were originally made from discrete components, being designed to solve mathematical equations electronically, by performing operations such as addition and division in analogue computers [14]. The diagram below shows the circuit model of an operational amplifier.

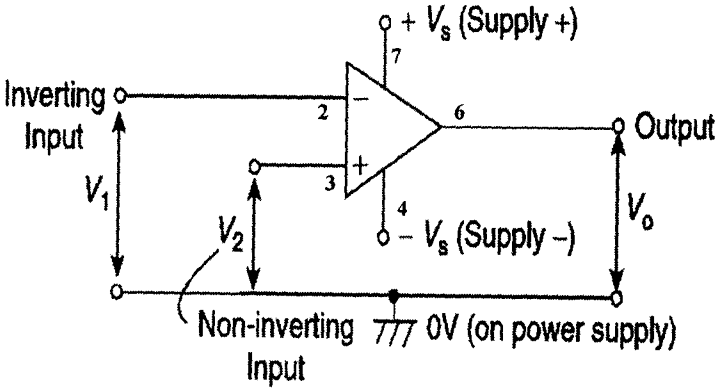


Fig 2.5. Circuit symbol of an Operational Amplifier.

An op amp is basically a differential voltage amplifier, i.e. it amplifies the difference between input voltages V_1 and V_2. Three situations are possible:

(i) if $V_2 > V_1$, V_o is positive

(ii) if $V_2 < V_1$, V_o is negative

(iii) if $V_2 = V_1$, V_o is zero

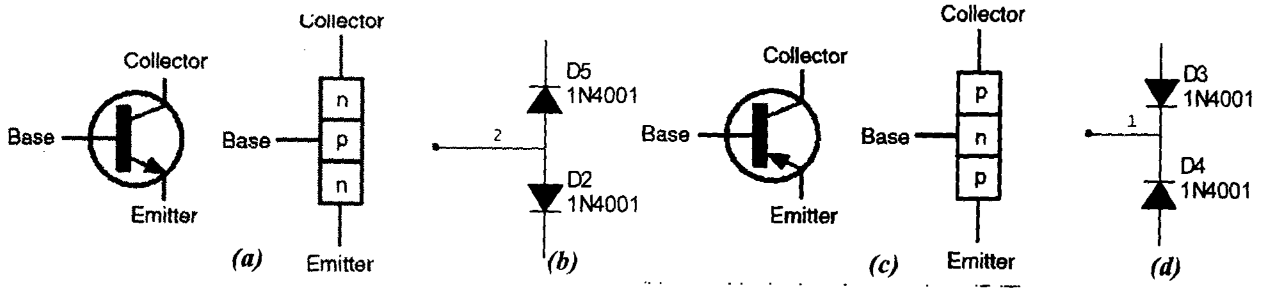
In general, $V_o = A_o (V_2 - V_1)$ (2.11) or $A_o = V_o/(V_2 - V_1)$ (2.12)

where Ao is the open-loop voltage gain [15].

2.2.6. Transistors: Transistors fall into two main classes – *bipolar junction transistors (BJT)* and *field effect transistors (FET)* [16]. They are also classified according to the semiconductor material employed – silicon or germanium, and to their field of application (for example, general purpose, switching, high frequency, and so on). Transistors are also classified according to the application that they are designed for:

1. Low-frequency Transistors designed specifically for audio low-frequency applications (below 100 kHz),
2. High-frequency Transistors designed specifically for high radio-frequency applications (100 kHz and above),
3. Switching Transistors designed for switching applications,
4. Low-noise Transistors that have low-noise characteristics and which are intended primarily for the amplification of low-amplitude signals,
5. High-voltage Transistors designed specifically to handle high voltages,
6. Driver Transistors that operate at medium power and voltage levels and which are often used to precede a final (power) stage which operates at an appreciable power level,
7. Small-signal Transistors designed for amplifying small voltages in amplifiers and radio receivers and
8. Power Transistor designed to handle high currents and voltages.

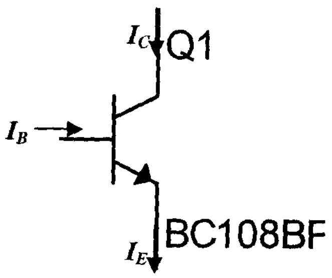
A BJT consists of two back to back *PN* junctions manufactured in a single piece of semiconductor material [17]. These junctions give rise to three regions called *emitter*, *base* and *collector*. The emitter is heavily doped since it is to supply majority charge carriers to the base which is lightly doped and at the middle section of the transistor. The collector is physically larger than the emitter because it has to dissipate more power. The transistor is operated by forward biasing the emitter – base junction and reverse biasing the collector – base junction. Based on this thesis, our focus would be on BJT. It is because they make use of both types of charge carriers (holes and electrons) that they are called *bipolar* and since the transistor also comprises two p-n junctions and for this reason it is a *junction transistor*; hence the name – *bipolar junction transistor* [18]. The diagrams below show the representations of a transistor.



(a) *(b)* *(c)* *(d)*

Fig 2.6. (a) *NPN* transistor (b) Equivalent pair of diodes (c) *PNP* transistor and (d) It's equivalent pair of diodes.

A transistor is known as a current regulated switch. This is shown through the load line equations shown below:



The currents flowing in a transistor are related thus:

$I_E = I_C + I_B$ (2.13)

The direct current gain, $h_{FE} = (I_C/I_B) = \beta$ (2.14)

Transistors are also known as amplifiers. They are current controlled switches used to drive relays. From the diagram,

$V_{CC} - I_C R_C - V_{CE} = 0$, therefore

$I_C R_C = V_{CC} - V_{CE}$ and

$I_C = -(1/R_C)\,V_{CE} + (1/R_C)\,V_{CC}$ (2.15)

The above equation is used to plot a graph of I_C against V_{CE}. The graph is known as the *DC load line* for the transistor. The graph has a negative slope which is equal to the reciprocal of the load resistor. The graph below explains this.

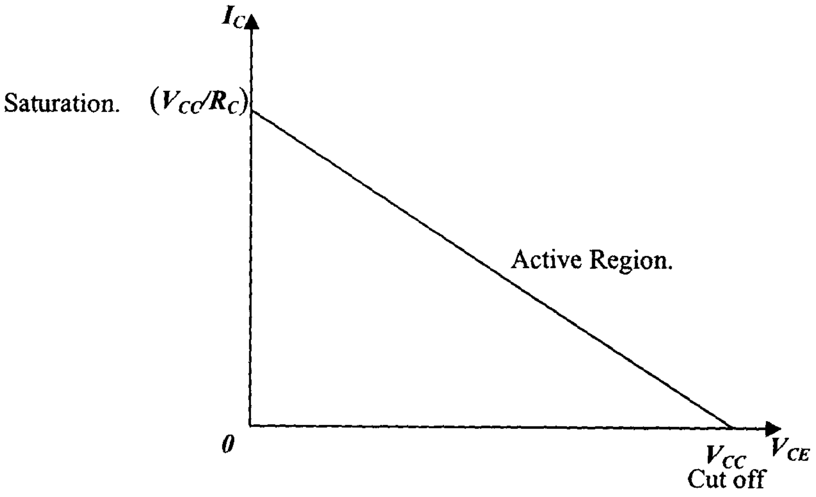


Fig 2.7. DC load line for a transistor.

The y- intercept and x- intercept are respectively obtained by making V_{CE} and I_C equal to zero.

2.2.7. Relays: These are built based on principles of electromagnets. A relay is similar to an electric bell except that contacts are opened or closed by operation instead of a gong being struck. It consists of a coil wound on a soft iron core. When the coil is energized the hinged soft iron armature is attracted to the electromagnet and pushes against two fixed contacts so that they are connected together, thus closing some other electrical circuit.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.1. INTRODUCTION

This project is designed to be able to solve the problem of over voltage and under voltage that is disturbing our power system in Nigeria. In order for this to be achieved, it is necessary that the input from the power company should be converted to dc and then compared to some set standards. If the inputted supply meets this standard, it can then be allowed to power any electronic appliance or else the model should cut off the supply to the load. The block diagram below explains the stages involved in the achievement of this project.

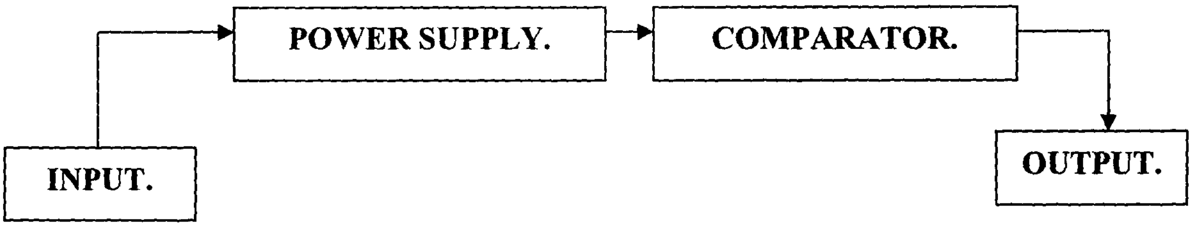


Fig 3.0. Block Diagram of the over voltage under voltage cutoff system.

3.2. INPUT STAGE

The input is the direct supply from the power holding company of Nigeria. It is a single phase supply. Generation, transmission and distribution of electricity via the National Grid system is accomplished by three phase alternating currents. The voltage induced by a single coil when rotated in a uniform magnetic field is known as a *single-phase voltage*. Most consumers are fed by means of a single-phase a.c. supply. Two wires are used; one called the live conductor (usually coloured red) and the other is called the neutral conductor (usually coloured black). The neutral is usually connected via protective gear to earth, the earth wire being coloured green. The standard voltage for a single phase a.c. supply is 240V. The majority of single-phase supplies are obtained by connection to a three-phase supply. *A three-phase supply* is generated when three coils are placed 120° apart and the whole rotated in a uniform magnetic field as shown below. The result is three independent supplies of equal voltages which are each displaced by 120° from each other [19] as shown below.

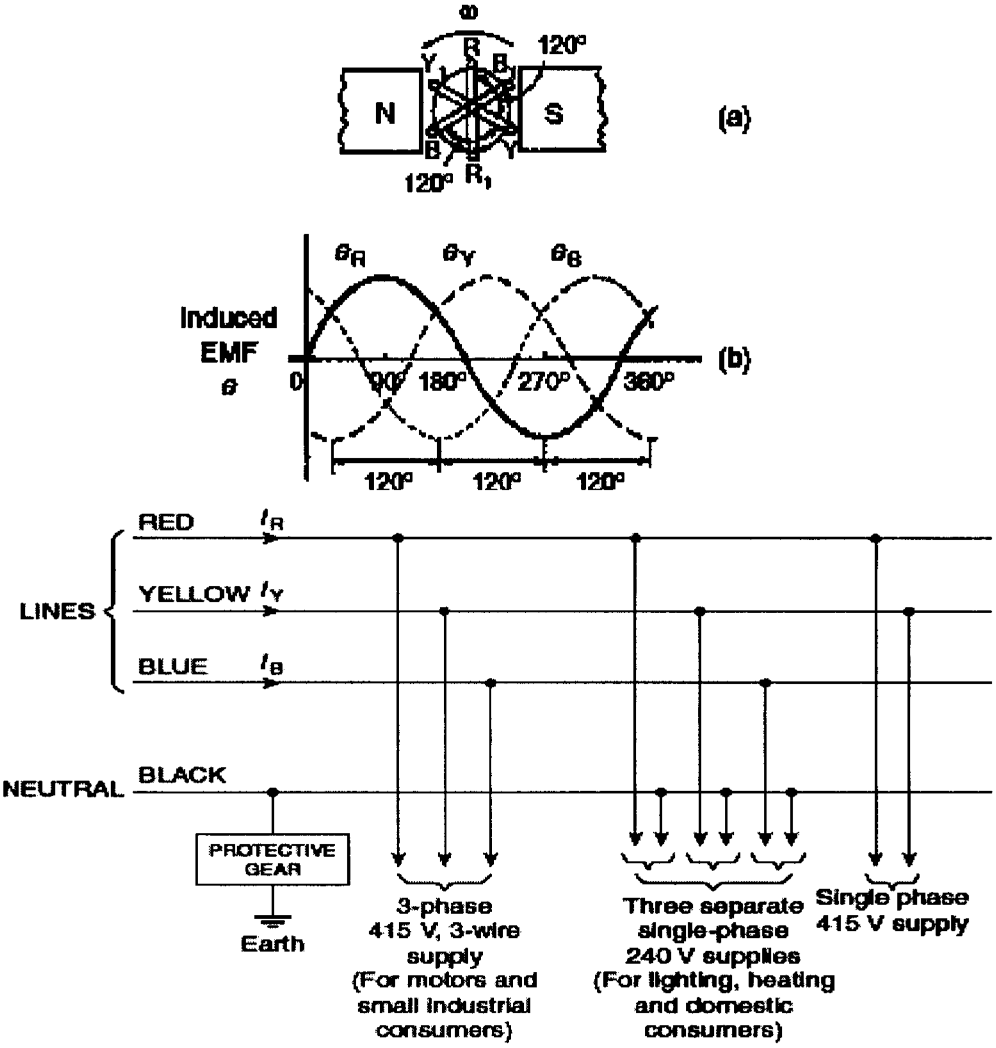


Fig 3.1. Three Phase Generation and Distribution.

A three-phase a.c. supply is carried by three conductors, called *lines* which are coloured red, yellow and blue. The currents in these conductors are known as *line currents* (I_L) and the p.d.'s between them are known as *line voltages* (V_L). A fourth conductor, called the *neutral* (coloured black, and connected through protective devices to earth) is often used with a three-phase supply. The voltages, V_R, V_Y and V_B are called *phase voltages* or line to neutral voltages. Phase voltages are generally denoted by V_φ. The voltages, V_{RY}, V_{YB} and V_{BR} are called *line voltages*. Generally,

$$V_L = V_\varphi\sqrt{3} \tag{3.1}$$

Therefore, if $V_L = 415\text{V}$, then

$$V_\varphi = 415 / \sqrt{3} = 239.6004V \approx 240V.$$

3.3. POWER SUPPLY STAGE.

A power supply converts ac input to dc. There are two types of power supplies. They are the unregulated power supply and the regulated power supply. The difference between the two of them is the presence of a regulator circuit. Based on this thesis, the regulated power supply will be on focus. The block diagram below shows the stages involved in a power supply.

Fig 3.2. Block Diagram of Power Supply Stage

The transformer used is a 240V/24V step down transformer having a step down current of 500mA. The stepped down voltage is then rectified using a bridge rectifier and then filtered with an electrolytic capacitor. The value to be used is obtained thus:

From 2.9,

$Q = CV = It$,

$I = 500mA$ according to the current rating of the transformer and $t = 1/2f$.

In Nigeria, $f = 50Hz$,

hence $t = 1/2(50) = 0.01s$.

In the power supply, $V = dV$ which is also known as the ripple voltage. It is 15% of the peak value of the output voltage.

$Peak\ Voltage = 24\sqrt{2} = 33.94V$,

Therefore $dV = 15(33.94)/100 = 5.0912V$ and

$C = It/dV$

$= 0.5(0.01)/5.0912$

$= 982.09\mu F \approx 1000\mu F$.

A $1000\mu F$ capacitor was used to filter the rectified stepped down voltage. Regulators are useful in order to keep the voltage constant irrespective of the fluctuations in the power supplied by the power supply company (PHCN). The output from the filter is regulated to 12V with the help of a 12V regulator IC. The diagram below shows the 12V regulator IC which is 7812 as well as its equivalent circuit using a transistor current amplifier and a Zener diode.

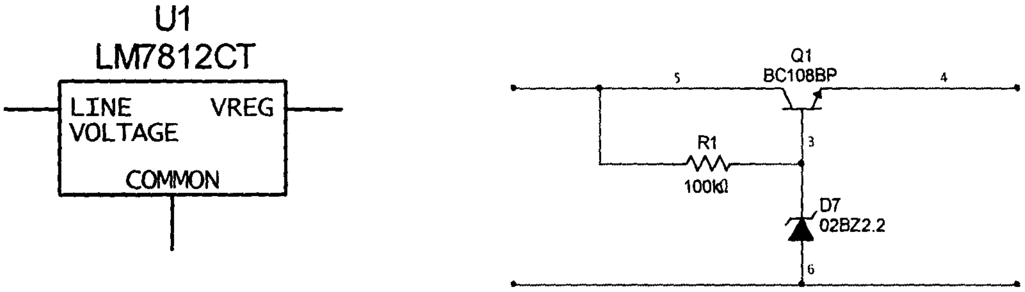


Fig 3.3. 12V Regulator.

An LED indicator is placed after the regulator in order to indicate the presence of power from the power supply company. The value of the limiting resistor used is obtained as follows:

V_{LED} lies between $1.5V$ and $3.3V$ [20]. Most LEDs will provide a reasonable level of light output when a forward current of between 5mA and 20mA is applied.

Using $V_{LED} = 1.7V$, and forward current $I_{LED} = 20mA$, the value of the limiting resistor is obtained according to Kirchooff's voltage law,

$12 - 0.02R_l - 1.7 = 0.$

$R_l = (12 - 1.7)/0.02 = 515\Omega$

$R_l \approx 500\Omega.$

A 500Ω resistor was used as the limiting resistor to the LED indicator. The diagram below shows the circuit for the power supply stage.

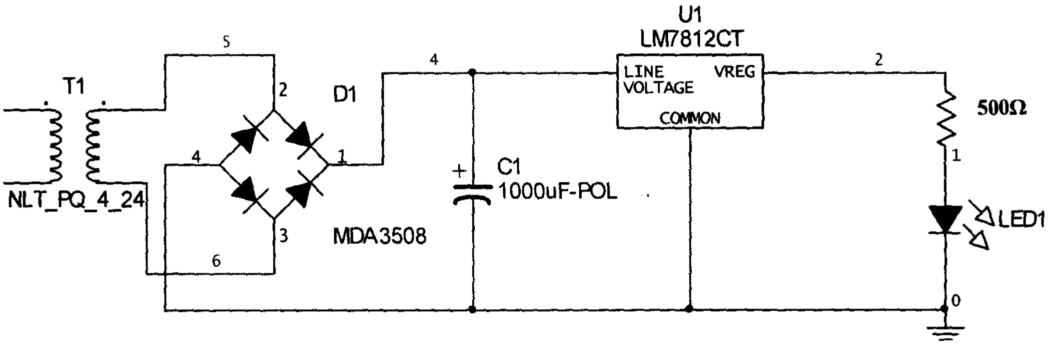


Fig 3.4. Circuit Diagram of Power Supply Stage.

3.4. COMPARATOR STAGE

It is at this stage that the fuse action is carried out. Operational amplifiers are good voltage comparators. Three operational amplifiers are used to achieve this. One of the op-amps is used to check under voltage, the other is used to check over voltage while the third op-amp compares the output of the two op-amps. An op-amp comparator can only bring an output if the voltage to the non inverting input is greater than or at least equal to one-third of the supply voltage to the op-amp (V_{CC}).

The under voltage comparator, compares the supplied voltage from PHCN to a referenced 9V. The supplied voltage is tapped from a potential divider network which is placed between the filter capacitor and the voltage regulator IC in the power supply stage. The voltage is divided into two equal halves via a 100KΩ variable resistor. 100K was chosen as the value so as to allow for more scale in voltage. The reference 9V is obtained by tapping the regulated 12V output from the power supply stage and regulating it to 9V via a Zener diode. If the supply voltage from the power supply company is less than 180V, the output voltage from the potential divider network would be less than 12V and the input to the under voltage comparator would be less than one-third of the supply voltage to the op-amp. Hence the under voltage comparator would generate no output. The under voltage comparator only generates an output when the supplied voltage is greater than or equal to 180V. The diagram below shows the circuit of the under voltage comparator.

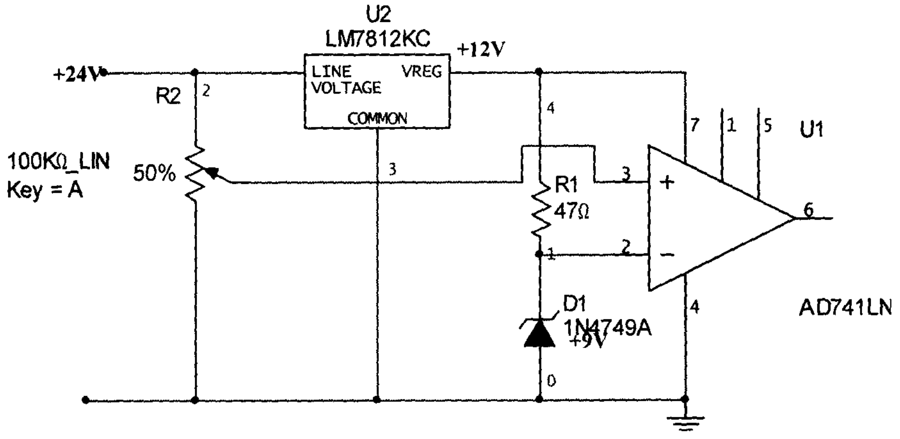


Fig 3.5. Low Voltage Comparator.

The reference voltage chosen for the over voltage comparator is the regulated 12V tapped from the output of the power supply stage. The voltage to be checked is tapped from the potential divider network and connected to the non inverting input. When the supply voltage is less than or at most equal to 240V, the input voltage to the non inverting input of the over voltage comparator would be at most equal to the reference voltage hence making both inverting and non inverting inputs to be equal. Once this is so, the over voltage comparator would yield no output. For the over voltage comparator to yield an output, the supply must be greater than 240V. The diagram below shows the circuit of the over voltage comparator.

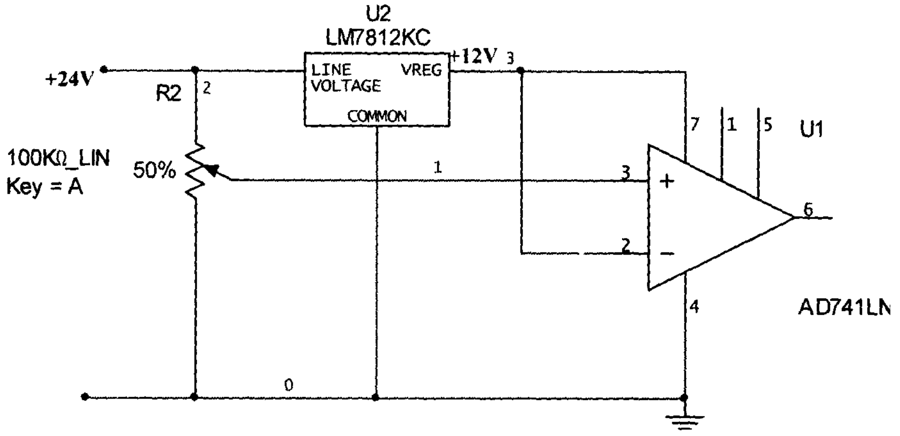


Fig 3.6. Over Voltage Comparator.

The mode of work of the third comparator is summarized in the table below.

Table 3.0. The workings of the third comparator.

Supplied Voltage.	**Under voltage comparator.**	**Over voltage comparator.**	**Final comparator.**
< 180V	No Output.	No Output.	No Output.
≥ 180V but < 240V	Output.	No Output.	Output.
≥ 240V	Output.	Output.	No Output.

The table shows that the only allowed voltage to power the load must lie between 180V and 240V. The diagram below shows the circuit of the comparator stage.

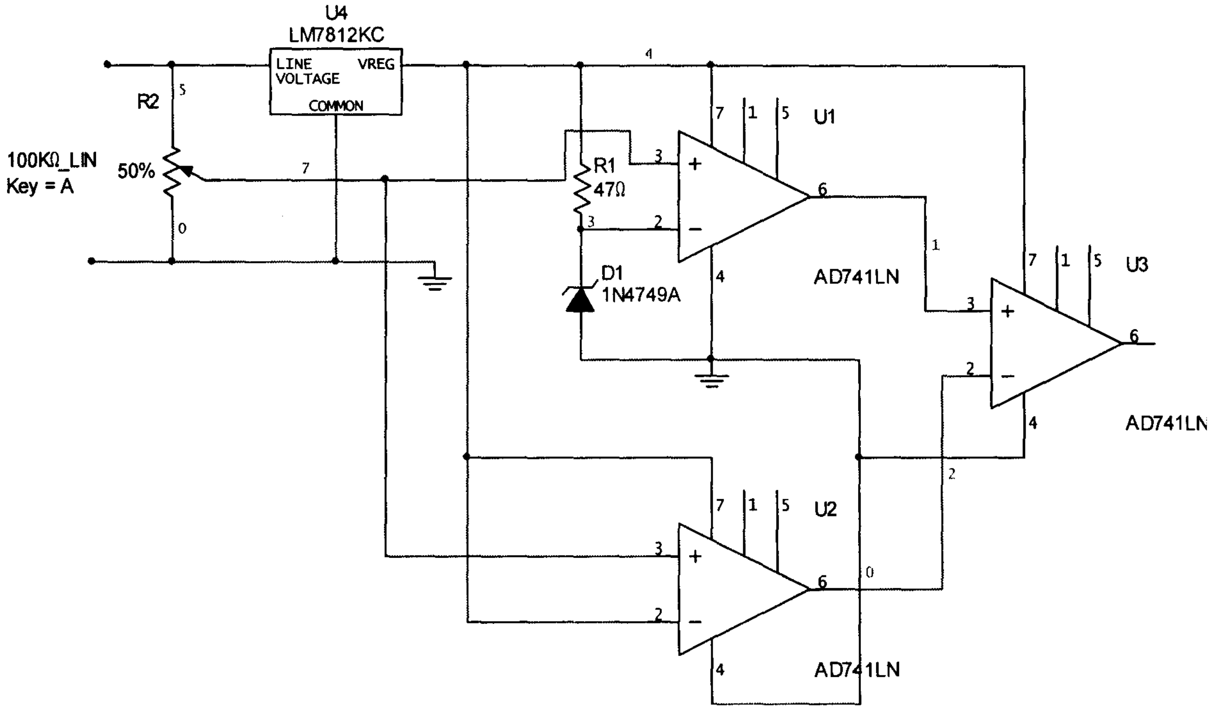


Fig 3.7. Comparator Stage.

3.5. OUTPUT STAGE.

The output stage comprises of a driver transistor switch and a relay. The transistor driver is operated as a switch. The base resistance is obtained thus:

From 2.15,

$I_C = -(1/R_C)\,V_{CE} + (1/R_C)\,V_{CC}$

When $V_{CE} = 0$,

$|\,I_C\,| = (1/R_C)\,V_{CC.}$

With R_C as the relay resistance which is equal to 400Ω, and $V_{CC} = 12$V.

$I_C = (1/400)\,12$

$I_C = 30mA.$

From 2.14,

$h_{FE} = (I_C/I_B) = \beta$

with $\beta = 250$,

$I_B = I_C/\beta = 0.03/250$

$I_B = 0.12mA$.

For a transistor, from Kirchhoff's voltage law,

$$V_{BB} - I_B R_B = 0 \tag{3.2}$$

With $V_{BB} = 12V$,

$R_B = (1 / I_B)\ V_{BB}$

$= 12/0.00012 = 100000\Omega = 100k\Omega$.

A diode was attached to the relay in order to prevent back emf from damaging the relay. The diagram below shows circuit diagram of the output stage.

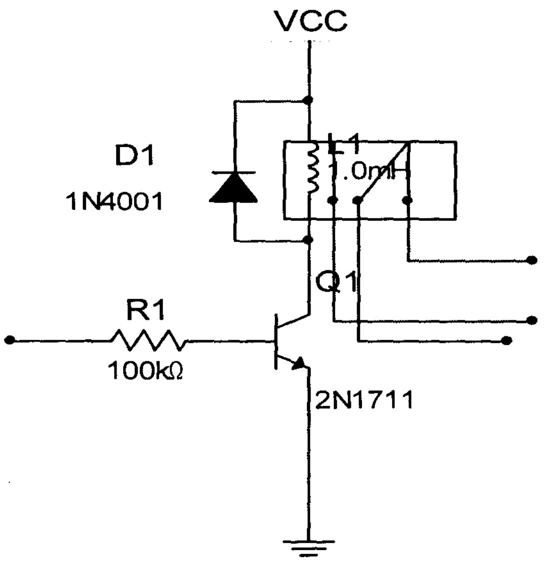


Fig 3.8. Output Stage.

The general circuit diagram is shown in the next page.

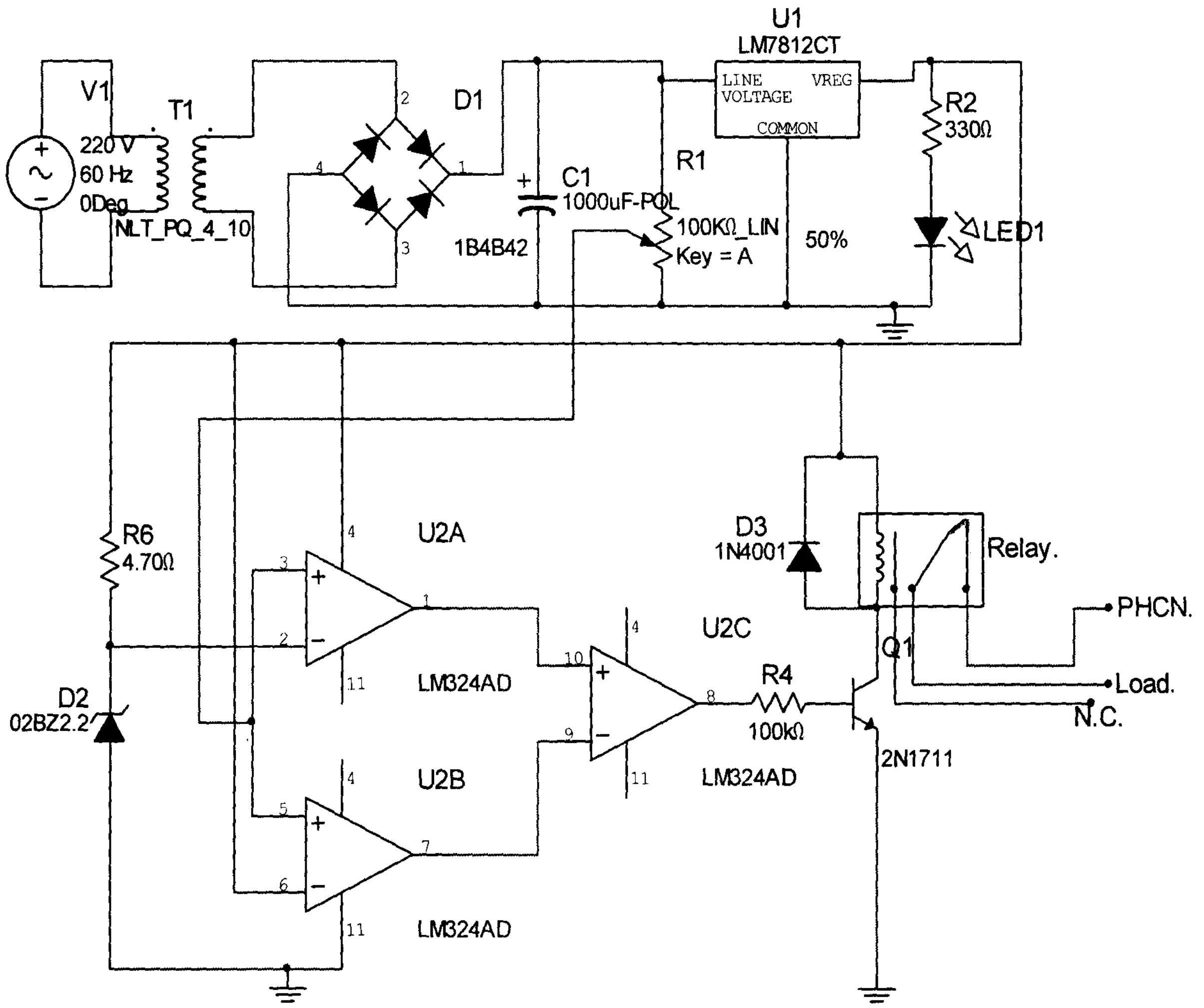


Fig 3.9. General Circuit Diagram.

CHAPTER FOUR

CONSTRUCTION AND TESTING

4.1. CONSTRUCTION AND CASING

The circuit was first carried out on a breadboard stage by stage with each stage properly tested to check the practical workability of each stage. As soon as all was seen to be working, the whole work was then transferred on a $10cm \times 13cm$ veroboard and tests were carried out on it. When it was discovered that the whole project was working in a good condition, every thing was then cased with chipboard designed with slots for proper ventilation for the circuit. The casing is$13cm \times 13cm \times 6cm$.

4.2. TESTS

Adequate tests were carried out on each stage of the project so as to see to the proper working condition of the project. The table below reveals the summary of the results of the tests carried out on the project.

Table 4.0. Results of Tests Carried Out on the Project.

PHCN INPUT (V)	TRANSFORMER OUTPUT (V).	RECTIFICATION OUTPUT (V).	OUTPUT FROM POTENTIOMETER (V).	REGULATOR OUTPUT (V).	COMPARATOR OUTPUT (V).
< 180	< 17.9	< 16.5	8.9	11.8	0.1
180 - 240	17.9 – 23.9	16.5 – 22.5	9 – 11.9	11.8	10.1
> 240	> 23.9	> 22.5	11.9	11.8	0.1

4.3. PRECAUTIONS

Proper and neat soldering was carried out to avoid unnecessary short circuiting on the board. Components soldered on the veroboard were spaced from each other to avoid complications. The project was tested to determine its reliability and durability.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSION

This project is designed as a form of electronic fuse which saves household appliances and buildings from electrical hazards that could come as a result of the poor power supply to buildings. This project works in such a way that it can only permit an acceptable voltage range into any appliance and building. Any power supplied with voltage outside this range is not allowed into the building or the appliance. The project was tested and found working.

5.2. RECOMMENDATIONS

The optimum performance of this project can be made possible *if* power supply is at least close to ideal. I recommend that in the production of every appliance, this project should be added along with the power supply stage. This would enhance the safety of these appliances. I also recommend that this project should be added to household electrical installations after the cut out fuse. This would prevent voltages in the range outside the accepted range from entering the house. This could prevent electrical hazard in the house.

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