DESIGN AND CONSTRUCTION OF AN OVER / UNDER VOLTAGE PROTECTION CIRCUIT WITH AN ALARM.

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Dedication

I dedicate this project to Almighty God for being my guide throughout my research that has finally culminated in this feasible piece of work, may His grace continue to be my Strength (Amen).

Declaration

I ESENE NICHOLAS A. declare that this work was done by me and has never been presented elsewhere for the Award of a degree. I hereby relinquish the copyright to the Federal University of Technology, Minna.

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Abstract

This project was carried out with the aim of designing and constructing an under/over voltage protection circuit which detects abnormal voltage conditions when they occur using the components that can be obtained locally in the market. The device would provide protection against power surge, over and under voltage conditions for small business and domestic equipments. It uses a voltage comparator in combination with a relay which has normally open contacts, and an accompanying control circuit which sets the normal operation of the relay within the range of 180V-240V, and alerting the user about the abnormal voltage conditions by tripping "ON" an alarm. Normal operation meaning that the relay contacts will remain closed within the range of mains power supply from Power Holding Company of Nigeria (PHCN).

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CHAPTER ONE

1.0 INTRODUCTION

In a world of rising inconsistencies, statistics shows that power supply transmission and distribution are steadily on the decrease in Nigeria[1], and voltage fluctuations (over/under voltage) are on the increase. Steady Power supply has become a cliché, and the importance of voltage protection for electrical appliances in cases of voltage fluctuations cannot be over emphasized. Electronics appliances are of utmost importance and have become an integral part of our society. This has directly affected its demand, which is on the increase. Due to this development, improvements in circuit protection devices to protect these systems cannot be avoided as technology advances.

There are various common power problems associated with distribution and transmission of electric power [2] (with typical examples of damage that might be caused):

- Power failure - Total loss of utility power: Causes electrical equipment to stop working.
- Under-voltage (brownout) - Low line voltage for an extended period of time: Causes overheating in motors.
- Switching transient - Instantaneous under voltage (notch) in the range of nanoseconds: May cause erratic behavior in some equipment, memory loss, data error, data loss and component stress.
- Voltage sag - Transient (short term) under-voltage: Causes flickering of lights.
- Over-voltage - Increased voltage for an extended period of time: Causes light bulbs to fail.
- Voltage spike - Transient (short term) over-voltage i.e. spike or peak: Causes wear or acute damage to electronic equipment.

Under voltage: The under voltage condition arises when a transmission or distribution system suffers a breakdown or fault like a fuse blowing on a lighting system, will drop system voltages below this for a few seconds before the fuse or circuit breaker opens. It also arises when demand for electricity reaches its peak.

This condition is dangerous to electrical/electronic appliances(such as television sets, fridges, air conditioners, video machines, refrigerators, etc.) as they will experience a voltage lower than normal due to a drop in voltage level. A sudden dip in voltage caused by engine starting or other heavy loads can also cause it [3]. This is one of the primary causes of memory loss in GPS navigation systems and crashes in mobile computer systems [4].

Overvoltage: is a sustained voltage that exceeds normal steady state limits. When the voltage in a circuit or part of it is raised above its upper design limit, this is known as **overvoltage**. The conditions may be hazardous. Depending on its duration, the overvoltage event can be permanent or transient, the latter case also being known as a voltage spike. Overvoltage is caused by malfunctioning alternators, voltage regulators, poorly adjusted 'fast charge' controllers, battery chargers and solar panels. A typical natural source of transient overvoltage events is lightning. Man-made sources are spikes usually caused by electromagnetic induction when switching on or off inductive loads (such as electric motors or electromagnets), or by switching heavy resistive AC loads when zero-crossing circuitry is not used - anywhere where a large change of current takes place[4].

Overvoltage protection devices : Arcing horns, Zener diode, Avalanche diode, Transil, Trisil, Spark gap, Gas filled tube, Metal Oxide, Varistor, SiBar, Thyristor[4].

The over/under voltage protection circuit can simply be described as a voltage protection system that protects appliances at the preset abnormal voltage levels (i.e. during under voltage and Overvoltage) by cutting off the power supply. It automatically restores power to appliances when the voltage condition is normal. The device protects electronic appliances against damage caused by voltage fluctuations whether low or high voltage by switching off the appliances connected to it automatically during over and under voltage conditions and triggering an alarm to alert the owner of the abnormal voltage conditions.

In this project; the power supply is achieved by using a step-down transformer, bridge rectifier and a capacitor filter to turn AC to DC voltage which is needed to power the circuit. The over/under voltage protection is achieved by comparator LM339 which is used as a comparator. It consists of four (4) voltage comparators, of which only two comparators are used. The unregulated power supply is connected to the series combination of resistors and potentiometer. The regulated power supply is also connected to the referenced voltage potentiometer through resistors. Preset potentiometer(VR4) is adjusted such that for normal power supply of 180V to 240V, the voltage of the non-inverting terminal(Pin7) of IC LM339 is less than reference voltage of the inverting terminal (Pin6), hence the output of the comparator is zero and the transistor(2N2222) which is connected to Pin(1) of the op-amp remains off. The relay which is connected to the collector of the transistor remains de-energized. As the AC supply to the electrical appliances is given through the normally closed (N/C) terminal of the relay, the supply is not disconnected during normal operation.

When the AC power supply goes above 240V, the voltage of the non-inverting terminal (Pin7) of the comparator increases above the reference voltage of the inverting terminal (Pin6), this drives the transistor to energize the relay, AC supply is disconnected and the electrical appliance turns off. When the line voltage is below 180V, the voltage at the inverting terminal (Pin7) is less than the voltage at the non-inverting terminal (Pin5), output of op-amp goes high and energizes the relay through the transistor, AC supply is disconnected and the electrical appliance turns off. Thus the appliances are protected against over/under voltage.

There are potentials in using this type of device in homes, companies, schools or anywhere where voltage fluctuations are experienced. The alarm can be used to alert the owner of the abnormal voltage conditions. Voltage protection devices are always a compromise between its cost, sensitivity level and ease of use. This is a protection circuit which balances the three variables to suit any individual requirements.

1.1 OBJECTIVES OF THE VOLTAGE PROTECTION CIRCUIT

The objectives of this project include:

- Means of automating the switching on and off of electrical appliances connected to it during voltage fluctuations.
- Provides fast protection against transient voltage spikes, transients that could cause damage to sensitive components
- Alerting the user of the abnormal voltage conditions.
- To achieve a low cost voltage protection system.

1.2 METHODOLOGY

The Construction of overvoltage/under voltage protection of electrical appliances with an alarm requires a Voltage Comparator IC LM339, which consists of four voltage comparators, a low Power audio amplifier, LM339, Transistors, Resistors of various values, Variable resistor and relays.

The IC LM339 in connections with the resistors and zener diodes energizes and de-energizes the relay during normal voltage and under/over voltage conditions.

The Circuit is also connected to an alarm which comprises of an IC LM386 which when connected with the various resistive and capacitive components produces an audible sound like a siren.

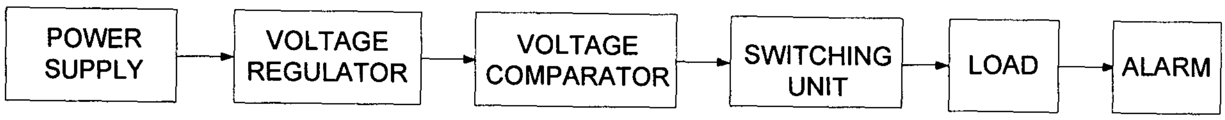

Fig. 1.0: Block Diagram of the Over/Under Voltage Protection Circuit.

1.3 SCOPE OF THE PROJECT

The concept and motivation behind this project is to design and construct an overvoltage/under voltage protection of electrical appliances with an alarm which will supply and maintain a steady DC (direct current) to electrical appliances during normal conditions and cutoff power supply during abnormal conditions. It senses an input voltage representing the voltage input of the power supply, generates a reference voltage, comparing the input voltage with the reference voltage, detecting the over/under-voltage condition when the reference voltage exceeds or is less than the input voltage, and disables the power supply when the over/under-voltage condition is detected.

1.4 SOURCES OF MATERIALS/CONSTRAINTS

Materials for this project were sourced from various websites from the internet and from consultation from friends. The components used were purchased from the market.

The major constraint encounter in this project was in setting the voltage level for the over/under voltage conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW/THEORETICAL BACKGROUND

2.1 BRIEF REVIEW/THEORETICAL BACKGROUND

Electricity was discovered by Michael faraday (1791 – 1867). Economy of scale and relative continuity all combined to provide the needed support of the central station electric service, which was the idea of Thomas Edison [5]. The problem of voltage fluctuations became more pronounced when the transmission and distribution stations were so distanced from the consumers. Voltage drop and the resultant loses in resistive parts of the low voltage DC distribution were the first timing factors encountered, and also the problem of voltage regulation and control. However, as a solution to these problems a remarkable landmark was made by George Westinghouse who introduced the AC transformer. Developments in AVR (automatic voltage regulators) began by making use of the motorized system controlled by an accompanying circuit to select tapping on the secondary of an autotransformer so as to step up when the input voltage is low or step down when the input voltage is high[6]. Early modifications in the AVR circuit, to convert them to switches were carried out by companies like General Electric and Asea Brown Boveri (ABB) [7, 9]. Some of the shortcomings are that it is bulky, costly and the mechanical parts easily wear off resulting in improper contacts between taps of the transformer.

Another approach taken to improve voltage stability was the use of Use of Series Compensation in Transmission Lines [8]. Series compensation is the use of capacitance in series on a transmission line. The addition of capacitance serves multiple purposes, the most important being the improvement in stability along the entire line. Another compensation method is shunt compensation [10] which is used to support voltage at a certain point on the line as opposed to the entire line. Series and Shunt compensation have been in use since the early part of the 20th century. The first application of shunt compensation was in 1914 and has been used ever since becoming the most common method of capacitive compensation. Series compensation was first used in the United States for NY Power & Light in 1928, but didn't become popular until the 1950's when the voltage levels that could be handled began increasing. By 1968, a 550kV application had been implemented and today there are applications approaching 800kV. Series compensation is used in numerous applications and locations around the world. There are currently approximately 500 series compensation installations worldwide. Series compensation is frequently found on long transmission lines used to improve voltage regulation. Due to the long transmission lines, voltage begins to decay as the line moves further from the source. Series compensation devices placed strategically on the line increase the voltage profile of the line to levels near 1.0 p.u.

Another application where series compensation is commonly used includes situations where improved power transfer capability is required. Series compensation is a valid solution to increasing power transfer capabilities mainly because it is a more cost effective method compared to other methods currently available. One less common method to increasing power transfer capabilities is to install additional lines to an existing system. Adding new lines presents many disadvantages when compared to using the alternative of series compensation. The main disadvantages posed when installing additional lines to a system include astronomical equipment and installation costs, long-term planning and approval periods that can exceed 3 years, as well as long-term installation periods. Series compensation is most well known for its use in improving system stability. Added stability greatly improves how the grid can handle a fault. When stability is questionable in certain areas, series compensation is a viable method used today to improve its stability. The applications previously mentioned are merely a select few of

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the uses that series compensation devices provide. These applications and others are used throughout the world to improve the system as a whole. One common location where series compensation devices are used heavily is on long transmission lines fed from hydroelectric generating plants. Many of the lines use the series compensation devices to improve voltage regulation because the main load area is commonly several hundred kilometers from the generating station, allowing for large voltage decay.

Disadvantages of series compensation include:

• High initial cost

• Heavy dependence on protection

• Past reinsertion problems following a disturbance

• Sub-synchronous resonance

The two main disadvantages of series compensation are the high initial costs and the sub synchronous resonance [11]. Advancements are being made to improve the protection of series compensation. As the components used to protect this implementation method become more reliable, they won't need to be replaced as often and the system will be operable for a longer time at the same overall cost. Sub-synchronous resonance is another major problem when dealing with series compensation system.

In 29th December, 2004 Lee, Chun-Yuan (Hsinchu, TW) invented an overvoltage protection circuit [12]. His invention relates to an IC package substrate with over voltage protection function, more particularly, to a single IC package substrate provided with a structure having multiple over voltage protection devices. In order to protect the IC device, several over voltage protection devices are subsequently proposed. However, those over voltage protection devices need to install individual protection devices on a printed circuit board according to the actual necessity after the IC device was manufactured and installed on the printed circuit board. Therefore, such design has the disadvantages of high design costs, wasting limited space, requires installing independent over voltage protection devices to prevent respective IC devices from damage by surge and providing incomplete protection to the IC device.

Other developments included the resonant circuit voltage regulators, and more recently the comparator types of voltage regulators in which the voltage regulator involves few components in the form of inductance of a transformer coupled with a parallel inductive and capacitive circuit. When the line voltage falls below he rated values, less current is drawn by the inductance and the parallel circuit combination becomes capacitive. The capacitive current drawn through the transformer raises the output voltage. If the line voltage rises above the rated value, the parallel circuit becomes less capacitive and the output voltage falls below the line voltage. However, voltage regulators do not disengage the device on critical voltage conditions. Its disadvantages are that it is bulky, heavy and frequency dependent.

Another approach is the use of Circuit Breakers. A Circuit Breaker is an electrical device that cuts off the electric current through a circuit under abnormal conditions [13]. The most familiar household circuit breakers protect circuits against overloading or overheating to prevent fire and electrical shock. Circuit breakers also provide protection against short circuits. A short circuit is caused by a contact between the neutral, or grounded, side of the electrical line and the live side of the line. Defective insulation or other parts can cause short circuits. Short circuits offer very low resistance to current, which allows large currents to flow through the circuit, sometimes melting the wires or causing a fire. Circuit breakers in the live side of the electrical line can stop short circuits by cutting the connection when the current gets too high. Common household circuit breakers are made up of a coil of wire called a solenoid and an iron plunger inserted partially inside the solenoid. When current flows through the solenoid, it produces a magnetic field just as a bar magnet would. The strength of the solenoid's magnetic field depends on the amount of current flowing through it. When the amount of current exceeds the amount that the circuit is designed to hold, the magnetic field in the solenoid is so strong that it pulls the iron plunger completely into the solenoid, breaking contact with the circuit at the end of the plunger and stopping the flow of current. In some circuits, especially those that carry large currents, simply breaking the circuit is not enough to stop the flow of current. The current in some circuits is strong enough to jump, or arc, across the gap in the circuit, even after the circuit breaker has been tripped. Circuit breakers that deal with high levels of current, especially direct current, have methods of getting rid of the energy in the arc and stopping the current. In oil breakers, the design of the circuit breaker forces the arc of broken circuit through a sealed container of oil or gas. The arc heats the oil around it. The hot oil begins to circulate in the tank, carrying heat and energy away from the arc. Air-blast circuit breakers send the arc through compressed air, which is immediately released to the outside, carrying the heat and energy of the arc with it. The disadvantages of using circuit breakers is that they do not offer effective fast switching protection of electronic appliances as they only offer protection in the invent of a short circuit and not over /under voltage condition.

The present technological dispensation has changed voltage stabilization and protection techniques greatly. It came up with another approach known as regulated DC inversion approach [14]. This uses the principle of switch mode power supplies. The regulated DC output from the power supply is inverted using push-pull inversion and stepped up to the required constant AC output voltage using a transformer. It uses zener diodes and potentiometers for voltage protection. The output of the system is a square wave AC voltage which could be filtered to obtain a pure sinusoid. This method produces good regulation and protection. The system is usually not heavy but very expensive to construct than other systems.

Phase controlled voltage regulator is one of the attempts towards realizing a good regulated voltage [15]. In this system, the load is connected in series with the voltage controlling device which is usually a SCR (Silicon Controlled Rectifier).

Voltage control is achieved by triggering the SCR at a phase angle determined by the control circuit in such a way that the voltage across the load connected to the output terminals is regulated to the desired value. This method is very fast in response to voltage fluctuations at the input. This system is not bulky and expensive but its disadvantage is that the output waveform is distorted.

Another method to be considered is that of voltage regulation by transistors [16], known as Transistorized voltage regulator. This approach is an improvement on motorized voltage regulation method. The pure mechanical tap change was replaced by miniature electromechanical relay. The major component of this approach is the autotransformer which the turn ratio (referred to as taps) can be varied to give the desired regulations. Most systems of this kind use two relays. In this case where large amount of power needs to be switched the relay is employed. Hence, the relay are cascaded so a small relay switches the power needed to drive a much larger relay and that second relay switches the power to drive the load, and also de-energizes the load via the first relay in abnormal conditions. These were applied for the automation of heavy duty rotating machines like industrial motors.

The positions of the relay contact on the taps of the transformer are dictated by the control circuit. The control circuit determines whether the low supply voltage is to be stepped up to the rated value or the high supply voltage is to be stepped down to the rated value of the output.

However, attempts to bring this technology to domestic and small business (low voltage users) were only recently started. In the 1990s, most of the circuits used operational amplifiers as their automatic voltage regulator parent, but the major shortcomings of this is that the operational amplifiers in the market are not ideal so it response are not sensitive enough especially for under voltage conditions.

Transistors as switches to drive the relay were found to be very competent and economical, a factor taken advantage of in this project. The development of integrated circuits has revolutionized the fields of communications, information handling, and computing. Integrated circuits reduce the size of devices and lower manufacturing and system costs, while at the same time providing high speed and increased reliability.

Today's research to increase the speed and capacity of computers concentrates mainly on the improvement of integrated circuit technology and the development of even faster switching components [17]. Very-large-scale integrated (VLSI) circuits that contain several hundred thousand components on a single chip have been developed.

The advances in fabrication of discrete electronic components have led to reduction in their costs and sizes which gave better switching performance than the electromechanical switches earlier considered. One of the latest developments is the use of overvoltage and under voltage protection circuit which uses discrete components to protect appliances from voltage surge or fluctuations.

The under voltage/overvoltage protection circuit with an alarm presented here is a low cost and reliable circuit for protecting domestic appliances refrigerators, televisions, etc. from damages posed by voltage fluctuations. It uses potentiometers to set the reference voltages for the over / under voltage condition, a comparator IC (integrated circuit) to compare the input voltage with a reference voltage, switches the transistor on/off and energizes/de-energizes the electromechanical relay in accordance with the voltage condition.

In real life, the value of the variable resistance is present for the under voltage or over voltage switching "ON" and switching "OFF" actions of the transistors (with the use of the autotransformer) but by varying the value of the resistance. The voltage supply to the transistor changes and the circuit interprets this as a drop or rise in supply voltage hence it operates the normally open relay contacts and either maintains or switches off power to the appliance it is protecting. The value of over voltage switch (transistor) rheostat resistance is reduced to simulate an over voltage condition and the value of the under voltage rheostat has been restored (to its original approximate value) to simulate the under voltage conditions.

Whenever the circuit is switch on and the electrical appliance is connected to it, it supply and maintains a steady DC (direct current) to the electrical appliances during normal conditions and cutoff power supply during abnormal conditions. It senses an input voltage representing the voltage input of the power supply, generates a reference voltage, compares the input voltage with the reference voltage, detects whether there is an over/under-voltage condition, that is when the reference voltage exceeds or is less than the input voltage, and disables the power supply from the appliance when the over/under-voltage condition is detected and triggers the alarm circuit. This circuit is not expensive and not bulky, it is easy to construct, has high switching speed and produces an alarm when the abnormal voltage condition is experienced.

CHAPTER THREE

3.0 DESIGN AND ANALYSIS OF CONSTRUCTION OF AN OVER/UNDER VOLTAGE PROTECTION CIRCUIT WITH AN ALARM.

3.1 INTRODUCTION

This chapter deals with the design methods and the analysis employed in the design of an over / under voltage protection circuit with an alarm. These analyses are required to make the correct choice of component values for effective performance.

The over/under voltage protection circuit with an alarm designed in this project can be divided in the following modules;

1. Power Supply Unit.
2. Voltage Regulation Unit.
3. Voltage Control (Comparing) Unit.
4. Switching Unit.
5. Alarm Unit.

3.2 THE POWER SUPPLY UNIT

The power supply unit comprises of;

- 12V Centre-Tap 500mA Step down transformer (rated 240V/12V-0-12V).
- A packaged full-wave bridge rectifier.
- 2200µf 35V, 470µf 25V and 2(two) 0.1µf Capacitors.
- 7812 and 7805 Voltage Regulators.

3.2.1 THE STEP DOWN TRANSFORMER

A transformer is a static (or stationary) piece of apparatus by means of which electric power in one circuit is transform into electric power of same frequency in another circuit. It can raise or lower the voltage in a circuit but with a corresponding decrease or increase in current. The physical basis of a transformer is mutual inductance between the two circuits linked by a common magnetic flux. In its simplest form, it consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance as shown in Fig. 3.1.

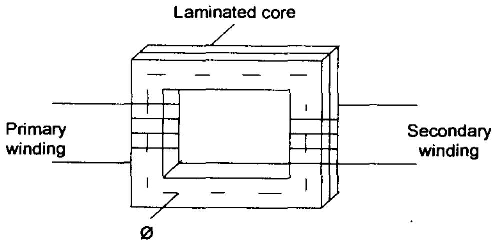

Fig. 3.1: Primary and Secondary Winding of a Transformer Linked by Magnetic Flux Ø

The two coil is connected to a source of alternating voltage, an alternating flux is set up in the laminated core most of which is linked with the other coil in which it produces mutual induced e.m.f (according to Faradays law of electromagnetic induction e = Mdl/dt). If the second coil circuit is closed, a current flows in it and so electric energy is transferred (entirely magnetically) from the first coil to the second coil. The first coil in which electric energy is fed from the A.C mains is called the **primary winding** and the other from which energy is drawn out, is called the **secondary winding.** Summarily, a transformer is a device that;

1. Transfer electric power from circuit to another
2. It does so without change in frequency
3. It accomplishes this by electromagnetic induction, and
4. Where the two electric circuits are mutual induction influence of each other.

3.2.2 FULL WAVE BRIDGE RECTIFICATION

The DC level obtained form a sinusoidal input can be improved 100% using a process called full wave rectification. A packaged full-wave bridge rectifier (D3SBA20) was used for this project but its internal structure which is the most familiar network for performing such a function appears in Fig. 3.2 with its four diodes in bridge configuration.

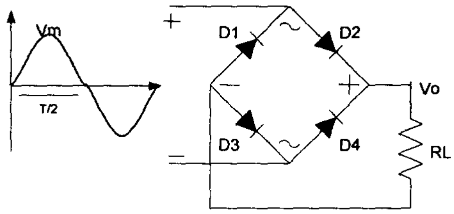

Fig. 3.2: Full-Wave Bridge Rectifier.

During the period T= 0 to T/2 the polarity of the input is shown in Fig. 3.2. The resulting polarities across the ideal diodes also showed in Fig. 3.3 to reveal that D2 and D3 are conducting while D1 and D4 in "off" state.

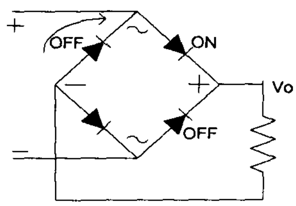

Fig. 3.3: Networks of Fig. 3.4 for the Period 0 to T/2 of the Input Voltage.

The net result is the configuration of Fig. 3.4, with its indicated current and polarity across R. Since the diodes are ideal the load voltage is Vo = Vi, as shown:

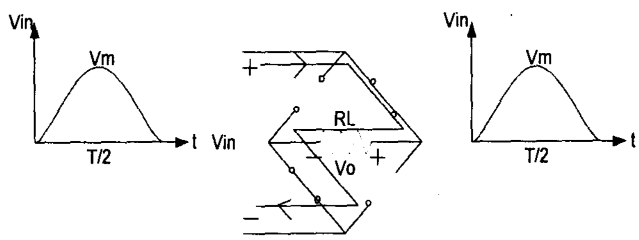

Fig. 3.4: Conduction Path for the Positive Region of Vi.

The input and output waveform is shown in Fig. 3.5 below:

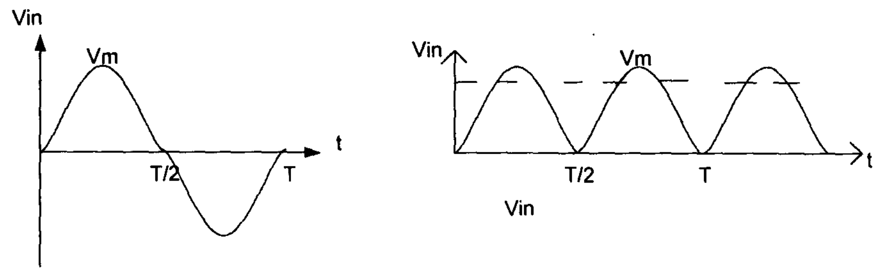

Fig. 3.5: Input and Output Waveforms for a Full Wave Rectifier.

Since the area above the axis for one full cycle is now twice that obtained for a half wave system, the d.c level has also doubled and,

$V_{d.c} = 2(0.318V_m) = 0.636V_m$ for a full wave.................... (3.1)

If silicon rather than ideal diodes are employed, an application of Kirckoff's voltage law around the conduction path would result in $V_{in} - V_t - V_o - V_t = 0$, and $V_o = V_{in} - 2V_t$.

The peak value of the output voltage V_o is therefore $V_{omax} = V_{in} - 2V_t$.

For situations where $V_{in} >> 2V_t$, equation 3.2 can be applied for the average value with a relatively high level of accuracy.

$V_{dc} = 0.636(V_{in} - 2V_t)$............................. (3.2).

Then again, if V_m is sufficiently greater than $2V_t$, the equation (3.1) is often applied as a first approximation for V_{dc}.

3.2.3 PIV (PEAK INVERSE VOLTAGE)

The required PIV of each diode (Ideal) can be determined four equation obtained at the peak of the positive region of the input signal. For the indicated loop the main voltage across R is V_m and the PIV rating is defined by

$PIV \geq V_m$ ....full wave bridge rectifier.

3.2.4 CAPACITOR FILTER

A very popular filer is the capacitor filter circuit. A capacitor is connected at the output, and a dc voltage is obtained across the capacitor.

Fig. 3.6 shows the block diagram of the circuit.

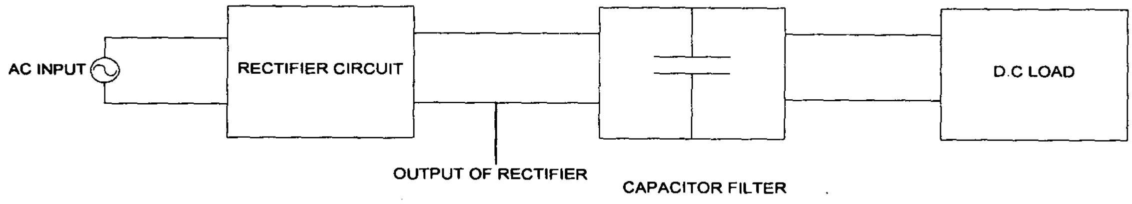

Fig. 3.6: Simple Capacitor Filters.

Fig. 3.7 shows the resulting wave form after the filter capacitor is connected at the rectifier output.

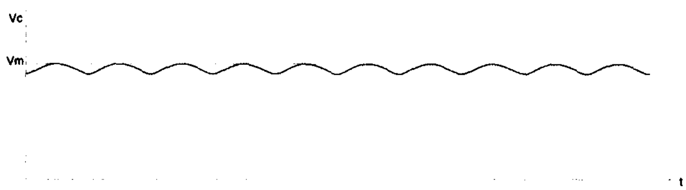

Fig. 3.7: The Output Wave Form after Connecting the Capacitor.

3.3 THE VOLTAGE REGULATOR UNIT

3.3.1 THE IC VOLTAGE REGULATOR

Voltage regulators comprise a class of widely used ICs. Regulator IC units contains the circuitry for reference source, comparators, control devices and overload protection all in a single IC. Although the internal construction of the IC is somewhat different from that of the discrete components circuits, the external operation is much the same.

In this project, the LM78XX (Series Voltage Regulators) was used.

General Description of the 78XX series

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment [18].

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features includes: Output current in excess of 1A, Internal thermal overload protection, No external components required, Output transistor safe area protection, Internal short circuit current limit and Available in the aluminum TO-3 package.

Voltage Range: LM7805C 5V, LM7812C 12V and LM7815C 15V

Fig. 3.8(a) and Fig. 3.8(b) show the schematic representation and the physical appearance of the 78xx positive regulator series.

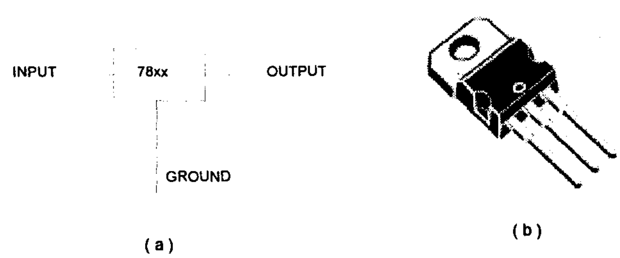

Fig. 3.8(a) and Fig. 3.8(b): Schematic Drawing and Package of the 78xx Positive Voltage Regulator Series.

Shown in Fig. 3.9 is the circuit diagram of a complete power supply unit.

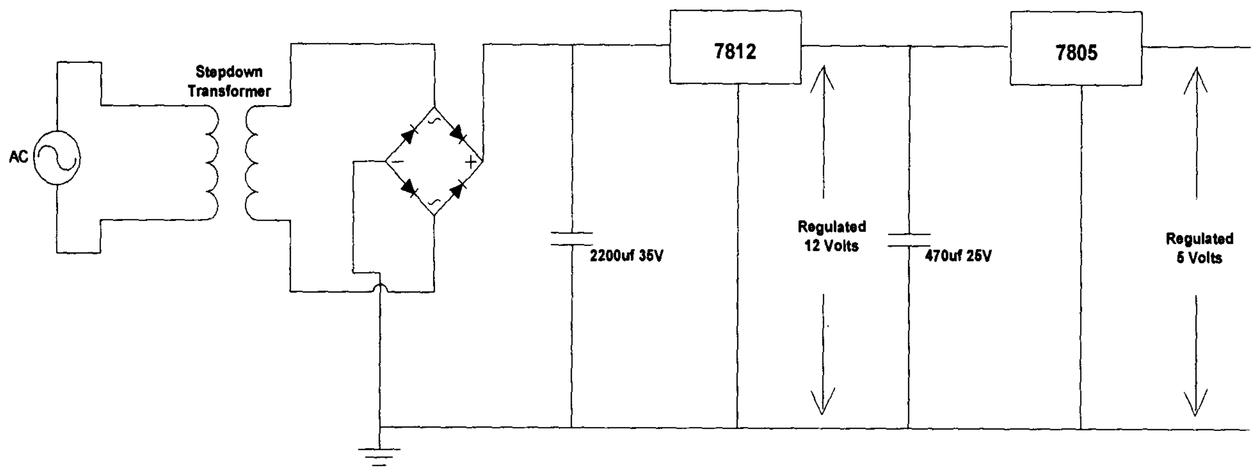

Fig. 3.9: Circuit Diagram of a Complete Power Supply Unit.

3.3.2 DESIGN OF THE POWER SUPPLY UNIT

The power supply unit is made up of a step down transformer which steps down the available mains voltage to a lower voltage value, a bridge rectifier circuit, a capacitor and a voltage regulator which keeps the output d.c voltage at a constant value.

3.3.3 D.C PARAMETERS OT THE CIRCUIT

For the design of the circuit, the following d.c parameters are required.

1. D.C current rating of the circuit = 500mA
2. D.C voltage rating of the circuit = 12v d.c
3. Ripple factor of the power supply unit =0 .08

3.3.4 CHOICE OF TRANSFORMER

Since the d.c voltage required for the circuit is 12v d.c and the current rating of the circuit is about 500mA, a transformer of 240Vr.ms/12Vr.m.s is selected for the design of the power supply circuit.

3.3.5 CHOICE OF BRIDGE RECTIFIER DIODE.

The bridge rectifier diode was selected based on their peak inverse voltage (PIV).

For rectifier diodes, PIV= $1.5 \times \sqrt{2} \times V_{r.m.s.}$

PIV = $1.5 \times \sqrt{2} \times 15 = 32v$.

The D3SBA20 was selected since the PIV specified for it by the manufacturer is about 1000v which is greater than 32v.

3.3.6 CHOICE OF THE FILTER CAPACITOR

The filter capacitor was selected base on ripple factor, and the peak voltage of the $V_{r.m.s}$ of the transformer.

$I_{d.c} = 500ma$

$V_{r.m.s} = 24V_{r.m.s}$

Ripple factor = 0.08

$V_{d.c} = 24v$.

V_R = Ripple voltage = $I_{d.c} / (C \times 2 \times f)$

f = mains frequency

V_R = ripple factor $\times V_{d.c}$

$V_R = 0.08 \times 24 = 1.92v$

$1.92V = (500 \times 10^{-3}) / (2 \times C \times 50)$

$C = 2500\mu f$.

3.3.7 CHOICE OF CAPACITOR VOLTAGE

The capacitor voltage rating should be greater than V_{peak}.

$V_p = V_{r.m.s} X \sqrt{2}$

$V_p = \sqrt{2} X 24 = 33.94V$.

A capacitor of 50V was selected since 50V > 33.94V.

The capacitor rating is the 2500 μf/50V.

3.3.8 CHOICE OF THE VOLTAGE REGULATOR

Since a d.c voltage of 12v is required by the circuit, an IC voltage regulator (7812) with a voltage rating of 12v was used to regulate the output voltage.

Shown in Fig. 3.10 is the complete circuit diagram of the power supply unit with the components values.

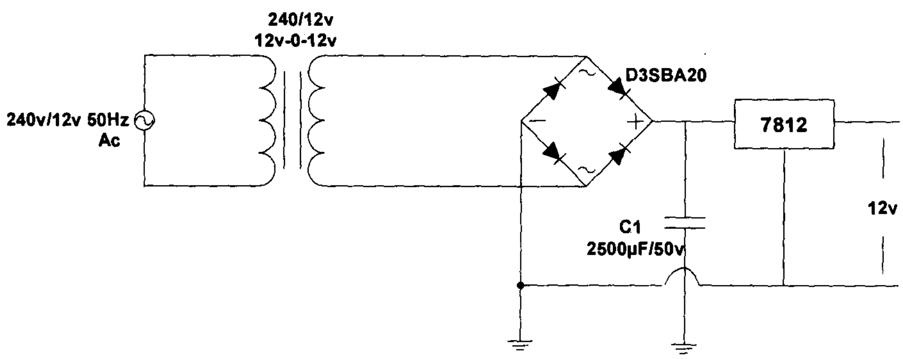

Fig. 3.10: Complete Circuit Diagram of the Power Supply Unit.

3.4 VOLTAGE COMPARING UNIT

3.4.1 THE VOLTAGE COMPARATOR

In electronics, a **comparator** is a device which compares two voltages or currents and switches its output to indicate which is larger is, that is it looks at two input signals and switches its output according to which of the inputs is greater. A comparator is similar to an op – amp because it has two input voltages (non-inverting and inverting) and one output. It differs from the op – amp circuit because it has no negative feedback and it has a two state output, either a low or a high voltage. Because of this, comparators are often used to interface with analog and digital circuits. A dedicated voltage comparator will generally be faster than a general-purpose op-amp pressed into service as a comparator. A dedicated voltage comparator may also contain additional features such as an accurate, internal voltage reference and a single threshold point (no hysteresis) [19].

Dedicated Voltage Comparator Chips

A dedicated voltage comparator chip, such as the LM339, is designed to interface directly to digital logic (for example TTL or CMOS). The output is a binary state, and it is often used to interface real world signals to digital circuitry (see analog to digital converter). If one of the voltages is fixed, for example because a DC adjustment is possible in a device earlier in the signal path, a comparator is just a cascade of amplifiers. For high speed the same techniques as in binary logic may be applied to avoid deep saturation of the amplifiers, which would otherwise lead to long recovery times. Also like in binary logic the speed is not as high as if the amplifiers would be used for analog signals. Slew rate has no meaning for these devices. The LM339 accomplishes this with an open collector output. When the inverting input is at a higher voltage than the non inverting input, the output of the comparator is connected to the negative power supply. When the non inverting input is higher than the inverting input, the output is floating (has a very high impedance to ground).

A pull-up resistor may be required because of the uncommitted transistor at the output of this device. The comparator has an uncommitted transistor with both the collector and the emitter terminals available. This is shown in Fig. 3.11 below:

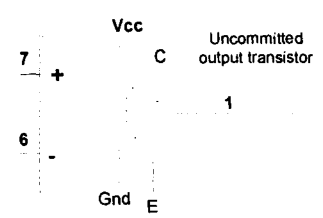

Fig. 3.11: Voltage Comparator LM339 Showing the Uncommitted Output Transistor.

This makes the output of this device very flexible. It can be used to drive many kinds of logic circuit.

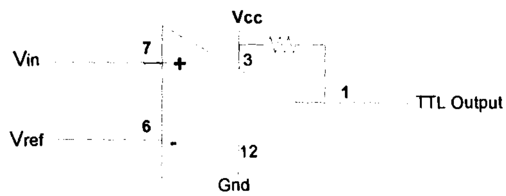

Fig. 3.12: Voltage Comparator LM339 Showing the Pull-Up Resistor.

With a pull-up resistor of 4.7KΩ about and a 0 to +12V power supply, the output takes on the voltages 0 or +12 and can be interfaced to TTL logic:

$V_{out} <= V_{cc}$ when $(V_+ > V_-)$ else 0.

3.4.2 THE QUAD VOLTAGE COMPARATOR LM339

The LM339 consists of four independent precision voltage comparators, with an offset voltage specification as low as 20mV max for each comparator, which were designed specifically to operate from a single power supply over a wide range of voltages.

Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though they are operated from a single power supply voltage.

The LM339 series was designed to directly interface with TTL and CMOS.

When operated from both plus and minus power supplies, the LM339 series will directly interface with CMOS logic where their low power drain is a distinct advantage over standard comparators [20].

Applications: A/D Converters, Wide range VOC, MOS clock generator, High voltage logic gate and Multivibrators.

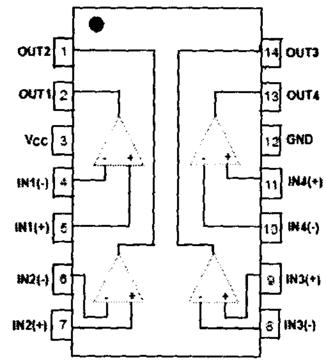

Fig. 3.13: Pin Configuration of the LM339 Comparator.

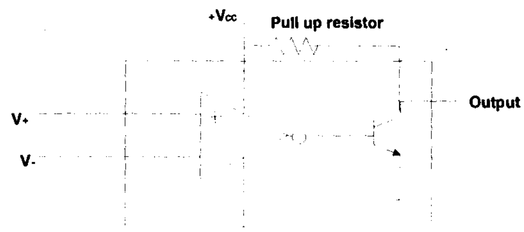

Fig. 3.14: The Open Collector Pulls up Resistor Arrangement of the LM339 Comparator.

3.4.3 DESIGN OF THE VOLTAGE CONTROL (COMPARING) CIRCUIT

(A) RHEOSTAT SETTING FOR THE VOLTAGE CONTROL CIRCUIT

The voltage level was set for the under/over voltage level as 6.0V and 6.8V respectively. This necessitated the choice of the potentiometer and the values were used based on the voltage divider network depicted in Fig. 3.15(a) and Fig. 3.15(b) below:

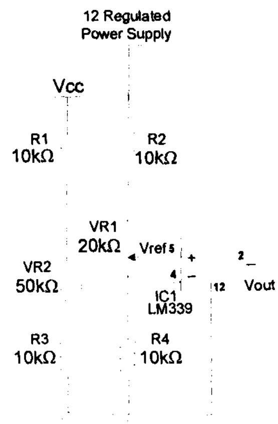

Fig. 3.15(a): Voltage Divider Network for the Under Voltage Control Unit.

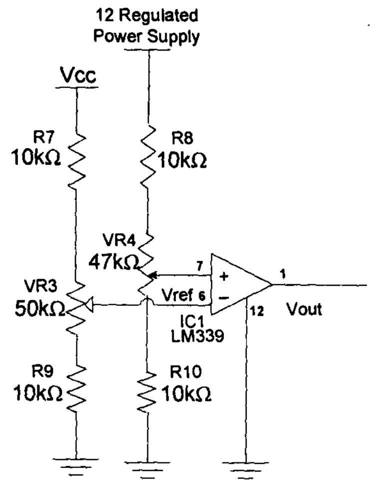

Fig. 3.15(b): Voltage Divider Network for the Overvoltage Control Unit.

Summarily, the reference voltage for the over / under voltage can be adjusted to any voltage level based on the power supply voltage the user wish to control, that is;

i. For normal operation the supply voltage should be greater than the reference voltage for the under voltage condition (i.e. Vcc > Vref) and less than the voltage level of the overvoltage condition (i.e. Vcc < Vref).

ii. For under voltage condition, the potentiometers should be adjusted such that the reference voltage is greater than the supply voltage (i.e. Vref > Vcc).

iii. For over voltage condition, the potentiometers should be adjusted such that the supply voltage is less than reference voltage (i.e. Vcc < Vref).

This makes the comparator control the voltage level such that the appliances are turned on during normal operations and switched off during the over/under voltage conditions.

(B) UNDERVOLTAGE CONTROL UNIT

The under voltage control circuit comprises of a resistors, potentiometer and a comparator. R1, R2 limits the current flowing in the potentiometers.

V_{R1} is a variable resistor and it is used to set Vref to 6V while VR2 is used to set the supply voltage Vcc to a voltage less than Vref at the under voltage condition.

The comparator gives a high output when Vcc < Vref.

With a pull-up resistor of 4.7KΩ connected to +12V power supply, the output takes on the voltages +12volts and can be interfaced to TTL logic. Then the 1KΩ resistor is used to limit the current flowing to the switching unit. Fig. 3.16 is the circuit diagram of the under voltage control circuit.

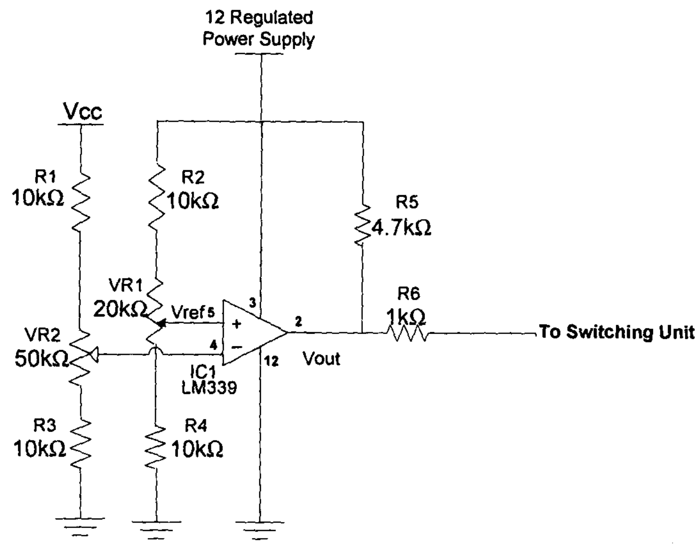

Fig. 3.16: Circuit Diagram of the Control Circuit for Under Voltage.

(C) OVERVOLTAGE CONTROL UNIT

The over voltage control circuit comprises of a resistors, potentiometer and a comparator. R7, R8 limits the current flowing in the potentiometers.

V_{R4} is a variable resistor and it is used to set Vref to 6.8V while VR3 is used to set the supply voltage Vcc to a voltage less than Vref at the over voltage condition.

The comparator gives a high output when Vcc > Vref. With a pull-up resistor of 4.7KΩ connected to +12V power supply, the output takes on the voltages +12volts and can be interfaced to TTL logic. Then the 1KΩ resistor is used to limit the current flowing to the switching unit. Fig. 3.17 is the circuit diagram of the over voltage control circuit.

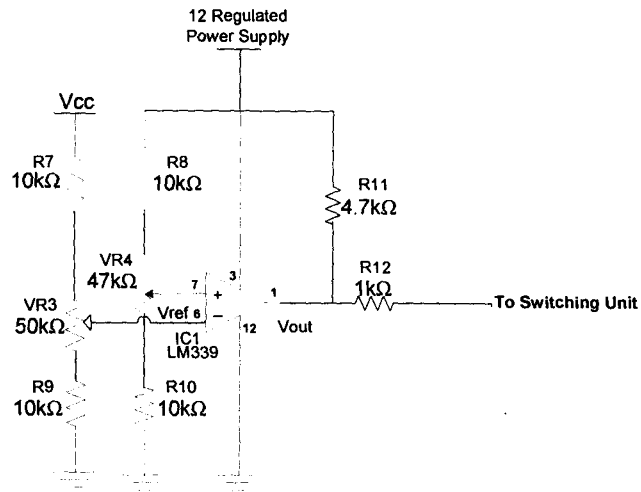

Fig. 3.17: Circuit Diagram of the Control Circuit for Overvoltage.

3.4.4 DESIGN OF THE SWITCHING CIRCUIT

The switching circuit is made up of a network comprising of an NPN transistor (2N2222), an electromechanical relay, diodes and current limiting resistors. Shown in Fig. 3.18 is the switching circuit diagram without the component values.

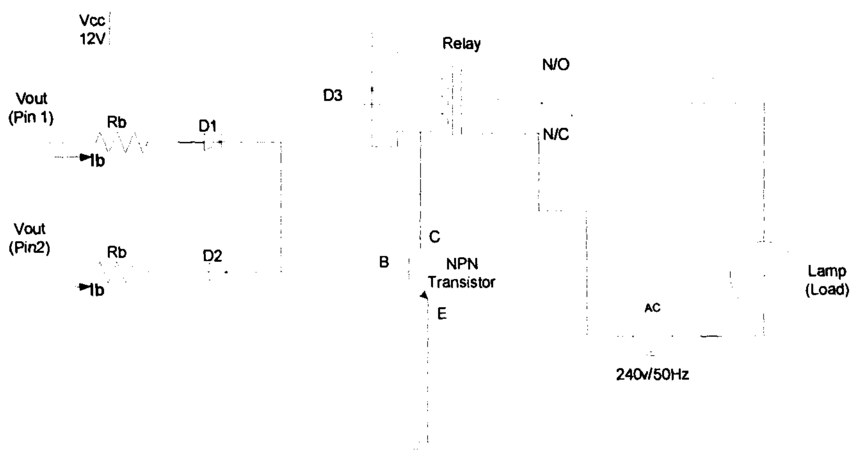

Fig. 3.18: Circuit Diagram of the Switching Circuit without Components Values.

3.4.5 CHOICE OF TRANSISTOR AND RESISTORS.

The transistor used in the switching network is a high speed switch 2N2222 and it has the following properties:

It is a silicon Planar Epitaxial NPN transistor in Jedec TO-18 (for 2N2222A) metal case. They are designed for high speed switching application at collector current up to 500mA, and feature useful current gain over a wide range of collector current, low leakage currents and low saturation voltage. .

The Following values were calculated for the resistors:

From the datasheet shown above, the following parameters were deduced:

$V_{be} = 0.6V$

V_{out} = comparator output = 12V

$I_b = 12mA$, $I_c = 150mA$.

From the relation;

$I_b = (V_{out} - V_{be}) / R_b$

$R_b = (V_{out} – V_{be})/I_b$

$R_b = (12 – 0.6)/0.012$

$R_b = 950\Omega$

From the above calculations, a resistant value of 1KΩ was taken for the base resistors.

Two diodes, D1 and D2 (1N4007) was also connected to the base of the transistor to prevent feedback between the two output from the comparator.

The collector of the transistor was connected to the 10A12V, 400Ω relay. A "free-wheeling" diode (D3) was also connected between the relay and the collector of the transistor to prevent "back emf" from the relay coil from damaging the transistor.

The relay is connected to the appliance in the Normally Closed(N/C) configuration so that whenever the abnormal condition occurs, the relay is energized and switches its configuration to the Normally Open(N/O) state and the load(i.e. the appliance) in this case a lamp(bulb) is disconnected from the powers supply.

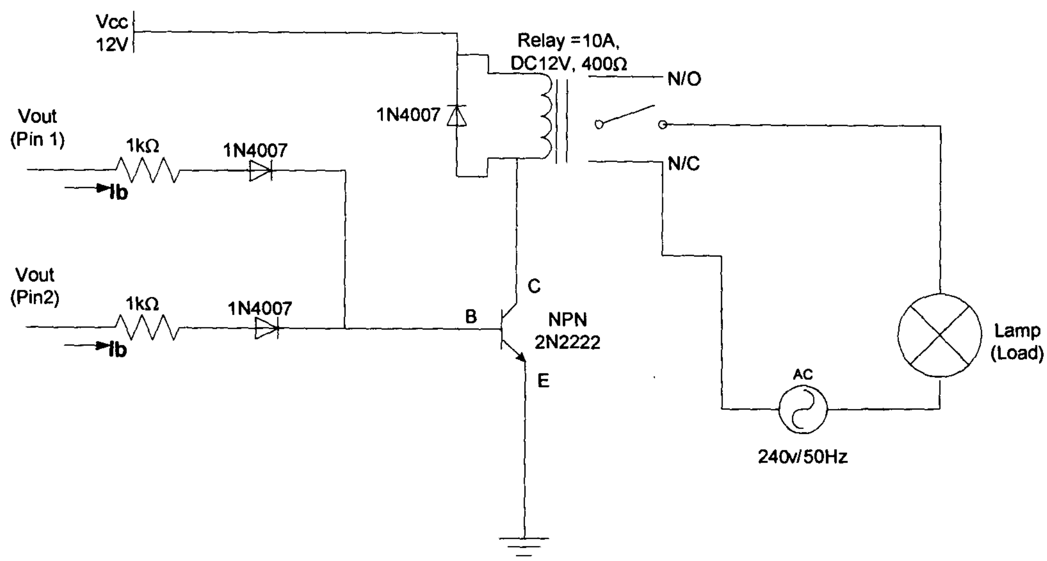

Fig. 3.19: Over/Under Voltage Switching Circuit.

3.5 ALARM UNIT OF THE OVER/ UNDERVOLTAGE PROTECTION CIRCUIT.

3.5.1 THE LOW VOLTAGE POWER AMPLIFIER LM386

The alarm circuit of the over/under voltage protection circuit was achieved with the aid of Low Voltage Audio Power Amplifier LM386 which posses the following characteristics:

The LM386 is a power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value up to 200. The inputs are ground referenced while the output is automatically biased to one half the supply voltages. The quiescent power drain is only 24 milliwatts when operating from a 6 volt supply, making the LM386 ideal for battery operation [21].

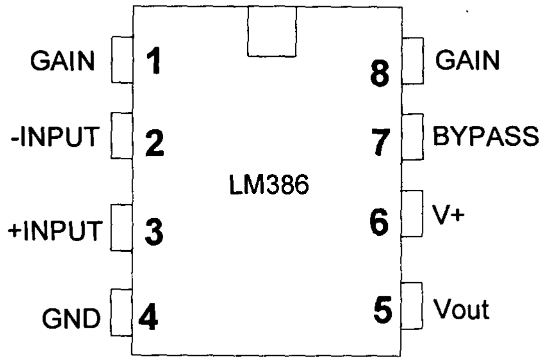

Fig. 3.20: Pin Out of the LM386 Amplifier

The alarm circuit is a two tone siren type alarm. It falls under the category of warning-alert alarm systems. It gives an emergency warning signal and also alerts the users of the abnormal voltage condition. The alarm circuit is a combination of low value capacitors, resistors and an 8Ω loudspeaker unit. The components are connected such that it generates a frequency which is amplified. Positive voltage of between 4V-12V is a fed to pin 6 of the amplifier and pins 1 and 8 are connected together. The input signals are fed through pins 2 and 3 through a low value capacitor and a resistor respectively. Amplification is achieved from pin 5(V_{out}), pin 4 goes to ground and pin 7 is not connected. Fig. 3.21 shows the circuit of the alarm.

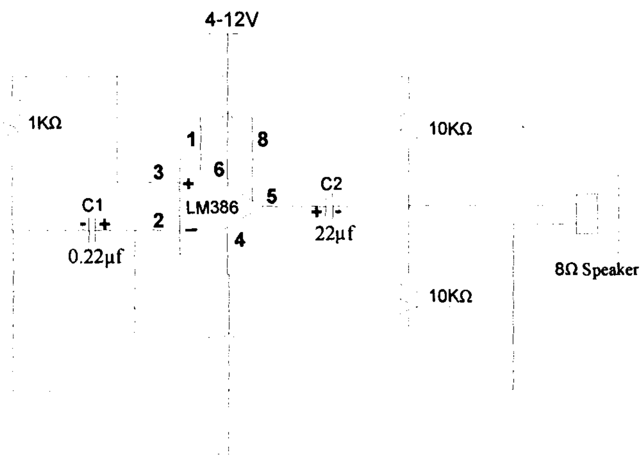

Fig. 3.21: Circuit Diagram of the Alarm.

Frequency is generated when the voltages are coupled via a capacitor to create a tone, due to the charging and discharging of the capacitor. The tone frequency is about 2.1 KHz. to increase the frequency of the tone reduce the value of the capacitor, C1 and to increase the bass, increase the value of the capacitor C2.

A positive 5 volt regulated DC, was used to power the circuit as depicted in fig. 3.9 shown above in the voltage regulation unit.

3.5.2 SWITCHING NETWORK OF THE ALARM

The alarm is activated by the abnormal condition of the power supply (i.e. either over/under voltage conditions). To provide for efficiency and fast switching, the outputs of the comparator (Pin1 and Pin2) was connected to another transistor and the collector of the transistor was connected to another relay as shown in Fig. 3.22 below:

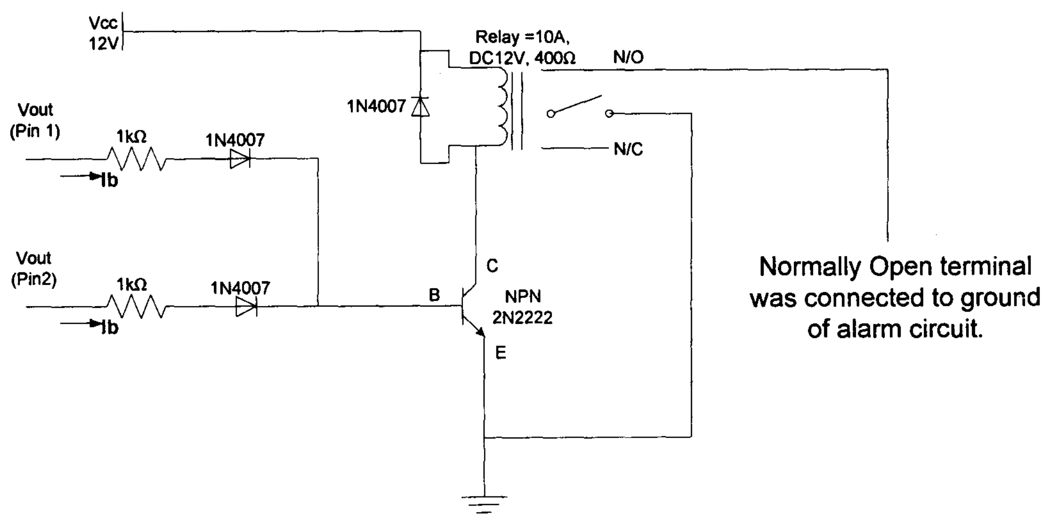

Fig. 3.22: Switching network of the alarm circuit.

The complete circuit diagram of the alarm switch is shown below:

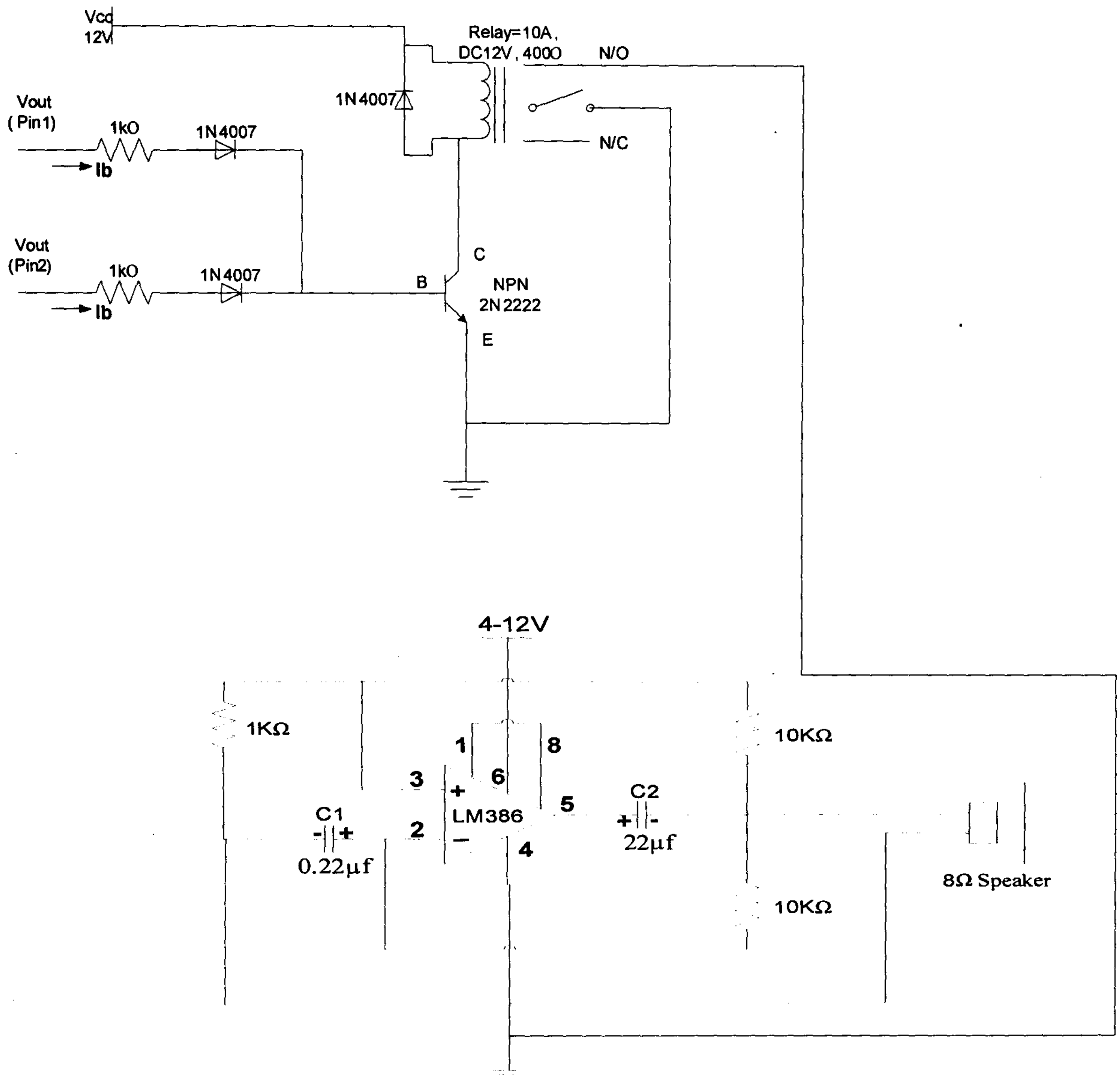

Fig. 3.23: Complete Circuit Diagram Showing the Switching Network and the Alarm Circuit.

CHAPTER FOUR

4.0 CONSTRUCTION AND TESTING.

The power supply, the alarm and the switching stages were simulated on computer with a circuit simulator (Multism) and then tested separately on a bread board and each stage worked satisfactorily. The whole circuit was connected together then simulated on the computer and also tested on the breadboard and confirmed to be working as desired.

Each stage was then transferred to the Vero board and confirmed to be functioning as designed to.

4.1 TEST

This test aims at determining the voltage conditions (levels) at which the appliance will either connect to power supply (ON) or (OFF) from power supply.

4.1.1 PROCEDURE

The apparatus for performing the test are 240/120 step-down transformer, a dimmer switch (to be used for adjusting the voltage levels), insulated flat nose screw drivers, and a voltmeter.

Due to the difficulty in securing an autotransformer to set the variable resistors for both the minimum voltage and maximum voltage cut-out operation, a little ingenuity in exploiting the main working operations of the circuit is applied for the testing.

The IC LM339 acts as the main voltage sensor that activates the transistor switch for both on or off operation.

In real life, the value of the variable resistance is present for the under voltage or overvoltage switching "ON" and switching "OFF" actions of the transistors (with the use of an autotransformer) but by varying the value of the resistance the voltage supply to the transistor changes and the circuit interprets this as a drop or rise in supply voltage hence it operates the normally open relay contacts and either maintains or switches off power to the appliance it is protecting. The value of over voltage switch (transistor) rheostat resistance is reduced to simulate an over voltage condition and the value of the under voltage rheostat has been restored (to its original approximate value) to simulate the under voltage conditions.

The circuit is further tested with a 240/120V step down transformer, to further confirm the under voltage condition.

4.2 SUMMARY OF OPERATION

The responses of the voltage switch to the simulated voltage conditions is classified in to the following conditions

i) Under voltage conditions

ii) Normal voltage condition

iii) Overvoltage condition

4.2.1 Under voltage condition (0-180V)

From the test, observation shows that at voltage levels from 120-180V, the relay switch is actuated. The normally open contacts remain open due to the low voltage and red LED remains "ON" to indicate that there is power supply to the circuit and consequently the green LED remains "ON" indicating that there is an abnormal voltage condition and that there is no power supply to the load, subsequently the alarm comes on.

4.2.2 Normal voltage condition (180V-240V)

Where the power supply is taken back to normal mains supply (190-240V) the circuit operates normally with the green LED indicator going "OFF" indicating normal voltage condition and the alarm is deactivated.

4.2.3 Overvoltage condition (above 240V)

When an overvoltage condition is simulated, the transistor goes high and the green LED comes "ON" indicating abnormal voltage condition, the relay contacts is energized, power supply to the load is disconnected and the alarm is activated.

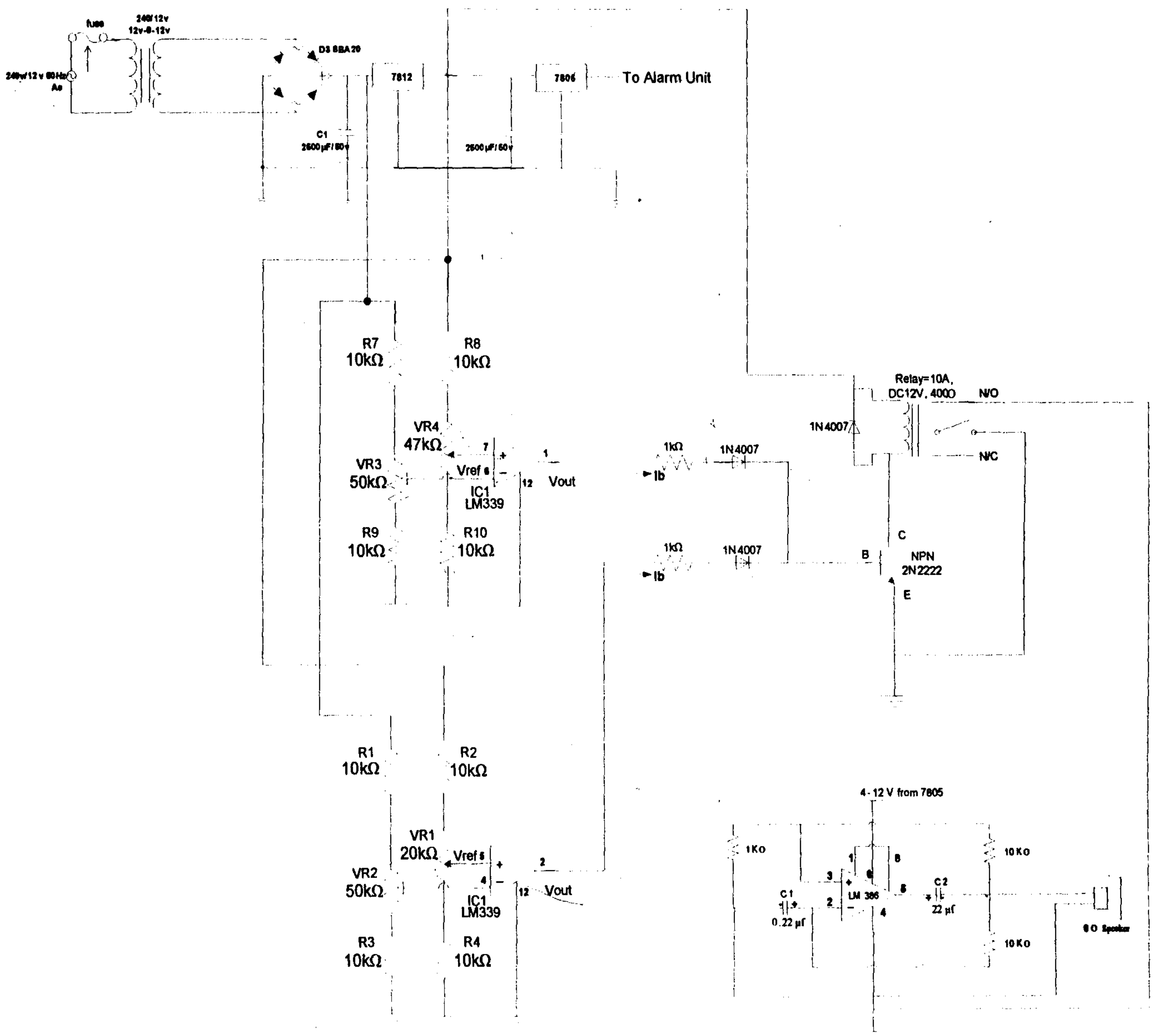

Fig. 3.24: Complete Circuit Diagram of the Over/Under Voltage Protection Circuit with an Alarm.

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CHAPTER FIVE

5.1 RESULT AND CONCLUSION.

The result from the testing of the project shows that the device will compete well with other devices and it is capable of;

i. Detecting voltage fluctuations and abnormal voltage conditions.

ii. Disconnection of power supply to protect appliance at the preset abnormal voltage levels.

iii. Automatically restoring power to the appliance when the situation becomes normal and it is cheap and affordable by domestic users and small business owners.

5.2 RECOMMENDATION

The device is suitable for electrical devices/appliances with input rating of not more than 240V/10A; therefore for the efficient operation equipment to be protected by the project should fall below this range.

5.3 SUGGESTIONS

The efficiency of the device can be improved upon by increasing the output of the device to be able to supply loads with input current by replacing the current relay with a higher rating. The principle of operation of this project could be implemented for {3-θ} three phase loads.

5.4 CONCLUSIONS

This project has shown the possibility of designing and constructing a low cost device which can be used to protect electrical/electronic appliances against abnormal voltage conditions effectively.