DESIGN AND CONSTRUCTION OF A POWER CONTROL & UNDER-VOLTAGE DETECTOR

BY

OJIH OGHENENYORE

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

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DECLARATION

I, Ojih Oghenenyore with matriculation number 2006/24466EE of the Electrical and Electronics Engineering Department, declare that this work was done by me and has never been presented in any other institution of knowledge for the award of a degree. I hereby relinquish the copyright of this work to the Federal University of Technology, Minna.

Ojih Oghenenyore

Name of Student

14/11/2011

Signature and Date

for Mallam S. Zubair

Name of Supervisor

14/11/2011

Signature and Date

Engr. A.G Raji

Name of H.O.D

(March 15, 2012)

Signature and Date

Engr Dr. G. I. Ighalo

Name of External Examiner

6/3/2012

Signature and Date

DEDICATION

This project is dedicated to my beloved brother Mr. Ojih .k. Akpojotor (Chartered Accountant) for his inspiration by setting the pace for others to follow.

ACKNOWLEDGEMENT

I wish to use this medium to acknowledge and appreciate my parents for their support morally, physically, financially, spiritually and in several other ways too numerous to mention. For God used you (parents) to stand as my earthly pillars. Also to appreciate my siblings and friends that stood by me all through my Academic years. My profound gratitude goes to beloved mother for positive ethical training and unseasonal prayers, love and care made it possible for me to be able to face the challenges experienced on my quest to securing my degree (B.ENG), I would forever remain grateful to you. I reserve special appreciation to my project supervisor; Mallam Zubair and his colleague Mallam Isiyaku for their advice and guide which the realization of my project is a product of their unlimited contribution not forgetting Mr. Adejo Achonu for his immense contribution and his availability at a time of need.

ABSTRACT

This project is on the design and construction of a simple power control circuit using a TRIAC to provide suitable power for resistive and slightly inductive loads and an under-voltage detection device to serve as a protection device to domestic and industrial appliances. This can be achieved by the phase control method whereby the power delivered to the load is controlled by the timing of the Triac turn-on point. The phase control method can be implemented on resistive and slightly inductive loads. The circuit waveforms for a phase controller with an inductive load or an active load (for example, a motor) are more complex than those for a purely resistive load. The circuit waveforms depend on the load power factor (which may be variable) as well as the triggering angle. The operation of a phase controller with a resistive load is the simplest situation to analyse. Waveforms for a full wave controlled resistive load. The triac is triggered at angle (d), and applies the supply voltage to the load. The triac then conducts for the remainder of the positive half-cycle, turning off when the anode current drops below the holding current, as the voltage becomes zero at 180°.

The Under voltage protector compares a phase-to-phase voltage with a lower limit value. This function is used for asynchronous motors and pumped–storage motor generators and prevents instability due to voltage. To stabilize the voltage during a power deficiency, the under voltage protection function can be used for load shedding.

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CHAPTER ONE

INTRODUCTION

1.1 POWER CONTROL

A power control device is a fundamental device which uses a TRIAC that has the ability to sustain load of greater power requirement than that produced by the generating source. It is mainly used in power control circuits to give full wave control and it provides a wider range of control in AC circuits. This enables the voltage to be controlled between zero and full power. [5]

The Diac is used to trigger a Triac by the "Phase Control" method. The AC mains waveform is phase shifted by the RC circuit so that a reduced amplitude, phase delayed version of the mains waveform appears across the Capacitor. As this wave reaches the break over voltage of the Diac, it conducts and discharges the Capacitor into the gate of the Triac, so triggering the Triac into conduction. The Triac then conducts for the remainder of the mains half cycle, and when the mains voltage passes through zero it turns off. Sometimes into the next (negative) half cycle, the voltage on the Capacitor reaches break over voltage in the other polarity and the Diac again conducts, providing an appropriate trigger pulse to turn on the Triac. [3]

By making the Resistor a variable value, the amount of phase delay of the waveform across the Capacitor can be varied, allowing the time during each half cycle at which the Triac fires to be controlled. In this way, the amount of power delivered to the load can be varied. [3]

1.2 UNDER VOLTAGE DETECTION

Sudden fluctuation in supply is a very big problem in industries and domestic applications. It causes a major loss for industries, offices and homes. This project gives a low cost and powerful solution for this problem. This Circuit protects refrigerators ACs, Microwave ovens as well as other appliances from under voltage fluctuations. [8]

Under voltage protection compares a phase-to-phase voltage with a lower limit value. This function is used for asynchronous motors and pumped–storage motor generators and prevents instability due to voltage. To stabilize the voltage during a power deficiency, the under voltage protection function can be used for load shedding. A further criterion for power deficiency in networks is a drop in the frequency below the nominal frequency. To combine the two criteria in a protection function, the response value of the under voltage function can be made to depend on the frequency. If the network frequency then deviates from the nominal frequency, the under voltage threshold is raised. [8]

Operational amplifier UA741CN is used here as a comparator in the circuit. The unregulated power supply is connected to the series combination of resistors. The same supply is also connected to 6.8v zener diode through a resistor. The voltage at non-inverting terminal of op-amp is less than 6.8V. The same unregulated supply is given to the 6.8V zener.

1.3 OBJECTIVE OF THE PROJECT

The objective of this project includes

1. To design and construct a simple device that can perform as a power control device and as an under voltage detector.
2. To design and construct a device that can alternate for the use of a generating set that produces sufficient power for a pressing iron and other heating equipment that require greater input power at a far much reduced cost.
3. To design and construct a low cost and reliable device that can handle heavy loads up to 20A.

4. To Auto switch on buzzer to alert personnel when voltage drops below specified conditions

1.4 SCOPE OF WORK

In this project, power rectification and the detection of over voltage was not taken into consideration. It was strictly based on power control and under-voltage detection.

1.5 METHODOLOGY OF THE PROJECT

The method employed in this project involves the following;

First, the circuit diagram was designed which comprises of possible least circuitry components. This is to avoid the use of too many components. Each unit of the project was first tested on a bread board and each module under test was given enough time during the test process in order to ensure their reliability.

1.6 PROJECT LAYOUT

Chapter One: Focuses on the introduction, historical background, objective of the project and methodology adopted.

Chapter two: Mainly on the literature review and it also contains the theoretical background of the project.

Chapter three: Contains the design and construction, circuit diagram analysis, power unit, circuit requirements, etc.

Chapter four: Circuit construction testing and discussion of result.

Chapter five: Conclusion and recommendation for future works.

CHAPTER TWO

2.0 HISTORICAL BACKGROUND

During the 1970s, energy issues became prominent, and one of those issues was to improve the efficiency of energy utilization.

Electricity generation is the process of generating electric energy from other forms of energy. The fundamental principle of electricity generation was discovered during the 1820s and early 1830s by the British scientist Michael Faraday. For electric utilities: it is the first process in the delivery of electricity to consumers. Electricity is most often generated at a power station by electromechanical generators. Primarily driven by heat engines fuelled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. [7]

Electricity was discovered by a British named Michael Faraday (1791 - 1867) which relates to the research of Dr. William Gilbert's investigation that reaction of amber magnets first recorded the word electric in a report on the theory of magnetism.

In 1831, Faraday found the solution. Electricity could be produced via magnetism by motion. He also discovered electricity via the process called electrolysis. He pointed to the existence of charged particles of matter now called ions and therefore came out with the conclusion that electrons are responsible for the flow of electricity. [5]

After the invention of electricity voltage drop and resistive losses on the voltage distribution circuit where the first set encountered in its utilization for electronic equipment to perform well. They need a certain stability of the power supply. The variation of voltage came as a result of variation in the transmission voltage. [7]

During the battle between the advocates of A.C and D.C, due to the invention of transformers, the advocates of alternating current prevailed and the steady development of electricity generating system stations commenced. [6]

After the invention of electricity, voltage drop and resistance losses on the voltage D.C distribution circuit were the first set of problems encountered in its utilization. For electronic equipment to perform better, they need certain stability in the power supply. However as a solution to these problems, remarkable landmark was made by George Westing house by introducing the A.C transformer. [6]

The earliest attempt of obtaining voltage regulator employed a motorized system controlled by a control circuit to change the taps on the secondary of the auto transformer so as to step up the voltage when the input voltage is low or step down when the input voltage is high. This came as a result of variation in the transmission voltage. The limitations of this system are thus; it is bulky, costly and the mechanical parts easily wear out.

These traditional mechanical relays have a lot of disadvantages which makes them ineffective.

2.1 LITERATURE REVIEW

The term thyristor is a generic name for a semiconductor switch having four or more layers and is, in essence, a P-N-P-N sandwich. Thyristors form a large family and it is helpful to consider the constituents which determine the type of any given thyristor. If an ohmic connection is made to the first p region and the last n region, and no other connection is made, the device is a diode thyristor. If an additional ohmic connection is made to the intermediate n region (n gate type) or the intermediate p region (p gate type), the device is a TRIODE thyristor. If an ohmic connection is made to both intermediate regions, the device is a tetrode thyristor. All such devices have a forward characteristic of the general form. There are three types of thyristor reverse characteristic: blocking (as in normal diodes), conducting (large reverse currents at low reverse voltages) and approximate mirror image of the forward characteristic (bidirectional thyristors). Reverse blocking devices usually have four layers or less whereas reverse conducting and mirror image devices usually have five layers. The simplest thyristor structure, and the most common, is the reverse blocking triode thyristor (usually simply referred to as the 'thyristor' or SCR 'silicon controlled rectifier'). [3]

The most complex common thyristor structure is the bidirectional triode thyristor, or triac. The triac is able to pass current bidirectional and is therefore an A.C power control device. Its performance is that of a pair of thyristors in anti-parallel with a single gate terminal. The triac needs only one heat sink, but this must be large enough to remove the heat caused by bidirectional current flow. Triac gate triggering circuits must be designed with care to ensure that unwanted conduction, that is, loss of control, does not occur when triggering lasts long.

Thyristors and triacs are both bipolar devices. They have very low on-state voltages but, because the minority charge carriers in the devices must be removed before they can block an applied voltage, the switching times are comparatively long. This limits thyristor switching circuits to low frequency applications. Triacs are used almost exclusively at mains supply frequencies of 50 or 60Hz, while in some applications this extends up to the 400Hz supply frequency as used in aircraft. The voltage blocking capabilities of thyristors and triacs are quite high. The devices are available as surface mount components, or as non-isolated or isolated discrete devices, depending on the device rating. [3]

TRIAC, from Triode for Alternating Current, is a generalised trade name for an electronic component which can conduct current in either direction when it is triggered (turned on), and is formally called a bidirectional triode thyristor or bilateral triode thyristor.

A TRIAC is approximately equivalent to two complementary unilateral thyristors (one is anode triggered and another is cathode triggered SCR) joined in antiparallel (paralleled but with the polarity reversed) and with their gates connected together. It can be triggered by either a positive or a negative voltage being applied to its gate electrode (with respect to A1, otherwise known as MT1). Once triggered, the device continues to conduct until the current through it drops below a certain threshold value, the holding current, such as at the end of a half-cycle of alternating current (AC) mains power. This makes the TRIAC a very convenient switch for AC circuits, allowing the control of very large power flows with mill ampere-scale control currents. In addition, applying a trigger pulse at a controllable point in an AC cycle allows one to control the percentage of current that flows through the TRIAC to the load (phase control). [10]

TRIAC OPERATION

The triac can be considered as two thyristors connected in antiparallel. The single gate terminal is common to both thyristors. The main terminals MT1 and MT2 are connected to both p and n regions of the device and the current path through the layers of the device depends upon the polarity of the applied voltage between the main terminals. The device polarity is usually described with reference to MT1, where the term MT2+ denotes that terminal MT2 is positive with respect to terminal MT1. The on-state characteristic of the triac is similar to that of a thyristor. Due to the physical layout of the semiconductor layers in a triac, the values of latching current (IL), holding current (IH) and gate trigger current (IGT) vary slightly between the different operating quadrants. In general, for any triac, the latching current is slightly higher in the second (MT2+, G-) quadrant than the other quadrants, whilst the gate trigger current is slightly higher in fourth (MT2-, G+) quadrant. [3]

For applications where the gate sensitivity is critical and where the device must trigger reliably and evenly for applied voltages in both directions it may be preferable to use a negative current triggering circuit. If the gate drive circuit is arranged so that only quadrants 2 and 3 are used (i.e. G operation) then the triac is never used in the fourth quadrant where IGT is highest. For some applications it is advantageous to trigger triacs with a pulsating signal and thus reduce the gate power dissipation. To ensure bidirectional conduction, especially with a very inductive load, the trigger pulses must continue until the end of each mains half-cycle. If single trigger pulses are used, one-way conduction (rectification) results when the trigger angle is smaller than the load phase angle.

A device with a relatively insensitive gate will be more immune to false triggering due to noise on the gate signal and also will be more immune to commutating dv/dt turn-on. Sensitive gate triacs are used in applications where the device is driven from a controller IC or low power gate circuit. [3]

TRIAC COMMUTATION

Unlike the thyristor, the triac can conduct irrespective of the polarity of the applied voltage. Thus the triac does not experience a circuit-imposed turn-off time which allows each anti-parallel thyristor to fully recover from its conducting state as it is reverse biased. As the voltage across the triac passes through zero and starts to increase, then the alternate thyristor of the triac can fail to block the applied voltage and immediately conduct in the opposite direction. Triac-controlled circuits therefore require careful design in order to ensure that the triac does not fail to commutate (switch off) at the end of each half-cycle as expected. It is important to consider the commutation performance of devices in circuits where either dI/dt or dV/dt can be large. In resistive load applications (e.g. lamp loads) current surges at turn-on or during temporary over-current conditions may introduce abnormally high rates of change of current which may cause the triac to fail to commutate. In inductive circuits, such as motor control applications or circuits where a dc load is controlled by a triac via a bridge rectifier, it is usually necessary to protect the triac against unwanted commutation due to dv (com)/ dt

The commutating dv (com)/dt limit for a triac is less than the static dv/dt limit because at commutation the recently conducting portion of the triac which is being switched off has introduced stored charge to the triac. The amount of stored charge depends upon the reverse recovery characteristics of the triac. It is significantly affected by junction temperature and the rate of fall of anode current prior to commutation (dI (com)/ dt). Following high rates of change of current the capacity of the triac to withstand high reapplied rates of change of voltage is reduced. Data sheet specifications for triacs give characteristics showing the maximum allowable rate of rise of commutating voltage against device temperature and rate of fall of anode current which will not cause a device to trigger. Consider the situation when a triac is conducting in one direction and the applied ac voltage changes polarity. For the case of an inductive load the current in the triac does not fall to its holding current level until sometime later. At the time that the triac current has reached the holding current the mains voltage has risen to some value and so the triac must immediately block that voltage. The rate of rise of blocking voltage following commutation (dv(com)/dt) can be quite high. The usual method is to place a dv/dt-limiting R-C snubber in parallel with the triac. Additionally, because commutating dv/dt turn-on is dependent upon the rate of fall of triac current, then in circuits with large rates of change of anode current, the ability of a triac to withstand high rates of rise of reapplied voltage is improved by limiting the di/dt using a series inductor.

THE DIAC

It is also worthwhile to consider the operation and characteristics of the diac in the context of multilayer bipolar devices. The diac is more strictly a transistor than a thyristor, but has an important role in many thyristor and triac triggering circuits. It is manufactured by diffusing an n-type impurity into both sides of a p-type slice to give a two terminal device with symmetrical electrical characteristics. The diac blocks applied voltages in either direction until the break over voltage, VBO is reached. The diac voltage then breaks back to a lower output voltage VO. Important diac parameters are break over voltage, break over current and break back voltage. [3]

The DIAC, or 'diode for alternating current', is a diode that conducts current only after its break over voltage has been reached momentarily.

When this occurs, diode enters the region of negative dynamic resistance, leading to a decrease in the voltage drop across the diode and, usually, a sharp increase in current through the diode. The diode remains "in conduction" until the current through it drops below a value characteristic for the device, called the holding current. Below this value, the diode switches back to its high-resistance (non-conducting) state. This behaviour is bidirectional, meaning typically the same for both directions of current.

Most DIACs have a three-layer structure with break over voltage around 30 V. In this way, their behaviour is somewhat similar to (but much more precisely controlled and taking place at lower voltages than) a neon lamp.

DIACs have no gate electrode, unlike some other thyristors that they are commonly used to trigger, such as TRIACs. Some TRIACs, like Quadrac, contain a built-in DIAC in series with the TRIAC's "gate" terminal for this purpose.

DIACs are also called symmetrical trigger diodes due to the symmetry of their characteristic curve. Because DIACs are bidirectional devices, their terminals are not labelled as anode and cathode but as A1 and A2 or MT1 ("Main Terminal") and MT2. [9]

2.2 THEORITICAL BACKGROUND

Triacs can be used to substitute for mechanical relays with a higher level of quality and reliability. The triac is a three terminal AC semiconductor that is triggered into conduction when a low energy signal is applied through its gate. Unlike the silicon controlled rectifier, the triac may be thought of as two complementary SCRs in parallel. [4]

There are two main techniques of controlling thyristors and triacs - on-off triggering (or static switching) and phase control. In on-off triggering, the power switch is allowed to conduct for a certain number of half-cycles and then it is kept off for a number of half-cycles. Thus, by varying the ratio of "on-time" to "off-time", the average power supplied to the load can be controlled. The switching device either completely activates or deactivates the load circuit. In phase control circuits, the thyristor or triac is triggered into conduction at some point after the start of each half-cycle. Control is achieved on a cycle-by-cycle basis by variation of the point in the cycle at which the thyristor is triggered. [4]

STATIC SWITCHING

Thyristors and triacs are the ideal power switching devices for many high power circuits such as heaters, enabling the load to be controlled by a low power signal, in place of a relay or other electro-mechanical switch. In a high power circuit where the power switch may connect or disconnect the load at any point of the mains cycle then large amounts of RFI (radio frequency interference) are likely to occur at the instants of switching. The large variations in load may also cause disruptions to the supply voltage. The RFI and voltage variation produced by high power switching in A.C mains circuits is unacceptable in many environments and is controlled by statutory limits. The limits depend upon the type of environment (industrial or domestic) and the rating of the load being switched. RFI occurs at any time when there is a step change in current caused by the closing of a switch (mechanical or semiconductor). The energy levels of this interference can be quite high in circuits such as heating elements. However, if the switch is closed at the moment the supply voltage passes through zero there is no step rise in current and thus no radio frequency interference. Similarly, at turn-off, a large amount of high frequency interference can be caused by di/dt imposed voltage transients in inductive circuits. [4]

Circuit-generated RFI can be almost completely eliminated by ensuring that the turn-on switching instants correspond to the zero-crossing points of the A.C. mains supply. This technique is known as synchronous (or zero voltage) switching control as opposed to the technique of allowing the switching points to occur at any time during the A.C cycle, which is referred to as asynchronous control. In A.C circuits using thyristors and triacs the devices naturally switch off when the current falls below the device holding current. Thus turn-off RFI does not occur. [4]

ASYNCHRONOUS CONTROL

In asynchronous control the thyristor or triac may be triggered at a point in the mains voltage other than the zero voltage crossover point. Asynchronous control circuits are usually relatively cheap but liable to produce RFI. [4]

SYNCHRONOUS CONTROL

In synchronous control systems the switching instants are synchronised with zero crossings of the supply voltage. They also have the advantage that, as the thyristors conduct over complete half cycles, the power factor is very good. This method of power control is mostly used to control temperature. The repetition period, T, is adjusted to suit the controlled process (within statutory limits). Temperature ripple is eliminated when the repetition period is made much smaller than the thermal time constant of the system. [4]

PHASE CONTROL

Phase control circuits are used for low power applications such as lamp control or universal motor speed control, where RFI emissions can be filtered relatively easily. The power delivered to the load is controlled by the timing of the thyristor or triac turn-on point.

The two most common phase controller configurations are 'half wave control', where the controlling device is a single thyristor and 'full wave control', where the controlling device is a triac or a pair of anti-parallel thyristors. These two control strategies are considered in more detail below:

RESISTIVE LOADS

The operation of a phase controller with a resistive load is the simplest situation to analyse. Waveforms for a full wave controlled resistive load. The triac is triggered at angle (d), and applies the supply voltage to the load. The triac then conducts for the remainder of the positive half-cycle, turning off when the anode current drops below the holding current, as the voltage becomes zero at 180°. The triac is then re-triggered at angle (180+d)°, and conducts for the remainder of the negative half-cycle, turning off when its anode voltage becomes zero at 360°. The sequence is repeated giving current pulses of alternating polarity which are fed to the load. The duration of each pulse is the conduction angle a, that is (180-d). The output power is therefore controlled by variation of the trigger angle d.

For all values of a other than a=180° the load current is non-sinusoidal. Thus, because of the generation of harmonics, the power factor presented to the A.C supply will be less than unity except when d=0.

For a sinusoidal current the rectified mean current, IT (AV), and the rms current, IT (RMS), are related to the peak current, IT (MAX). [4]

INDUCTIVE LOADS

The circuit waveforms for a phase controller with an inductive load or an active load (for example, a motor) are more complex than those for a purely resistive load. The circuit waveforms depend on the load power factor (which may be variable) as well as the triggering angle.

For a bidirectional controller (i.e. triac or pair of anti-parallel thyristors), maximum output, that is, sinusoidal load current, occurs when the trigger angle equals the phase angle. When the trigger angle, d, is greater than the load phase angle, j, then the load current will become discontinuous and the triac (or thyristor) will block some portion of the input voltage until it is retriggered. If the trigger angle is less than the phase angle then the load current in one direction will not have fallen back to zero at the time that the device is retriggered in the opposite direction. However, the gate pulses which occur one half periods later have no effect because the triac is still conducting in the opposite direction. Thus unidirectional current flows in the main circuit, eventually saturating the load inductance.

This problem can be avoided by using a trigger pulse train. The triac triggers on the first gate pulse after the load current has reached the latching current IL in the 3+ quadrant. The trigger pulse train must cease before the mains voltage passes through zero otherwise the triac will continue to conduct in the reverse direction. [4]

The triac offers the circuit designer an economical and versatile means of accurately controlling AC power with several advantages over conventional mechanical relays.

CHAPTER 3

DESIGN AND CONSTRUCTION

3.1 DESIGN

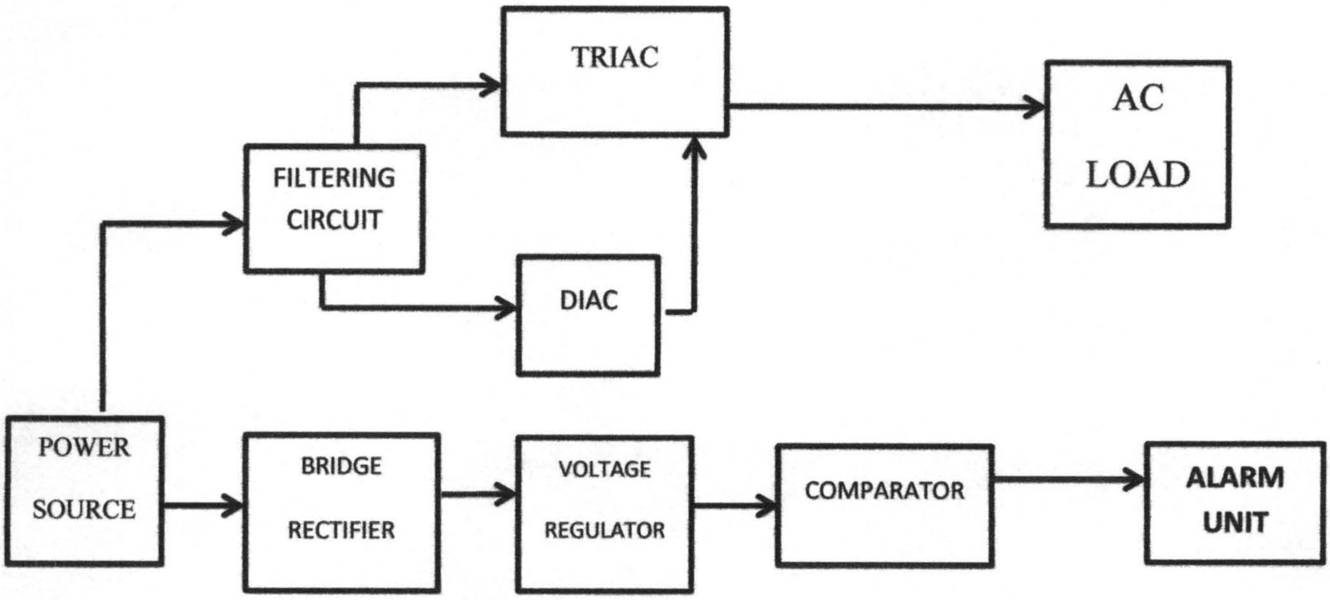
The design of this project was carried out with the use of top down approach; that is; design that is achieved through the breakdown of systems into sub levels or segment or units.

The steps taken for this design involves the block schematic layout, the circuit design, the circuit simulation, the bread board design, test and records of the results, the fixing and soldering of components on the Vero board and finally the entire circuit being housed in a case.

The design and construction of the power booster/under voltage protection device are based on seven main stages, which are:

1. AC main supply
2. Rectified DC supply
3. Regulated DC supply
4. Unregulated DC supply
5. Comparator
6. Transistor
7. Alarm unit
8. Triac
9. Diac

3.1.1 Block schematic of power booster/under voltage protection device shown below.



3.2 POWER SUPPLY

Power supply is necessary for the conversion of the A.C voltage of our electrical utility to the D.C voltage required in electronics and electrical equipment. The transformer used in this project is AC 220/240V 50Hz, DC 12V × 1 500mA. Step down transformer primary is 220V while the secondary side voltage is 240V.

3.3 BRIDGE RECTIFIER

Rectification is the conversion of AC to DC, in this project work, A full wave bridge system of rectification was adopted. With this method, there is no need for a Centre tapped power transformer; the output is twice that of Centre tap circuit for the same secondary voltage.

During the positive Half cycle, diodes D1 and D3 are forward biased and therefore are conducting, while diodes D2 and D4 are reversed biased and are therefore non-conducting.

The full wave bridge rectifier circuit with a filtering capacitor can be shown below:

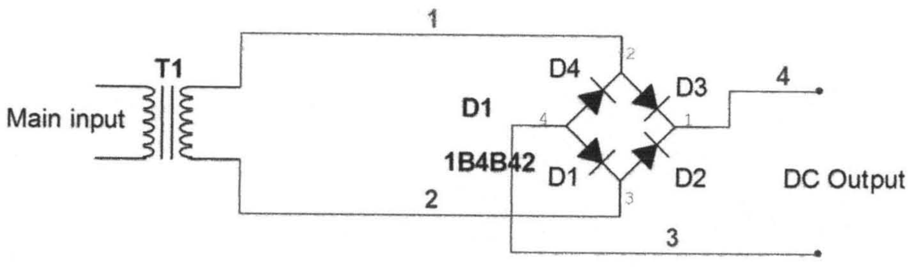


Fig. 3.3.1 Full wave bridge rectifier circuit

The wave from of the secondary voltage to the bridge rectifier is AC. input is shown below:

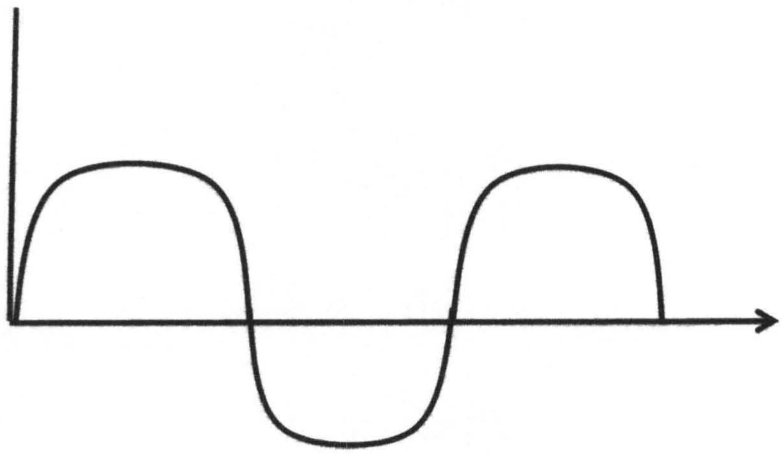


Fig 3.3.2 Input waveform of AC supply

3.4 FILTERING / SMOOTHERING

In order to obtain constant or smooth signal at some fixed value, a capacitor is connected across the D.C. output. The current from the rectifying circuit charges the capacitor and it is later discharged steady as current flows through the load. If the average charging current equals the steady discharging current, the capacitor remains charged. The potential difference between its plates is not absolutely steady but varies regularly. The full wave bridge rectifier circuit with a filtering capacitor can be shown below:

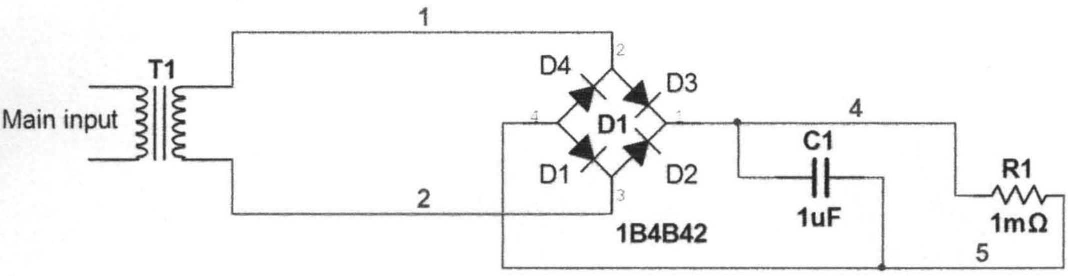


Fig 3.4.1 Full wave bridge rectifier circuit

Ripple voltage Vr is the deviation of the load voltage from its average Value or DC value.

The output after smothering / filtering is a D.C. output. The wave form is as shown below:

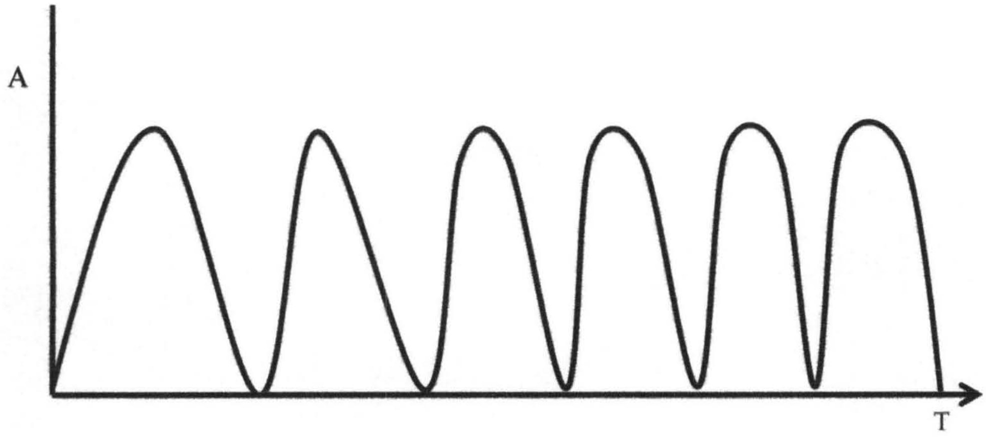


Fig 3.4.2 Rectified output waveform

The full wave rectification efficiency can be calculated using the formula below:

$$\int = \frac{0.812RL}{Rd + RL} \quad \text{.............................. (I)}$$

Where RL, Load resistance, Rd = Diode resistance

After full wave rectification, the relationship below gives the D.C. voltage with the peak amplitude:

Vdc = (Vrms2— 1.4) V ....(II)

For 12Vrms input, the peak DC. Voltage is therefore

Vdc = (12"2— 1.4) .... (III)

Vdc = (16.97 — 1 .4) .... (IV)

Vdc = i5.6V 16V .... (V)

3.5 OPERATIONAL AMPLIFIER

An operational amplifier is an integrated circuit amplifier with a very large voltage gain, high input impedance and low output impedance.

They are available in hundreds of different types; the most general group being the D.C. coupled differential voltage amplifier, inverting and non-inverting inputs and a single ended output.

The symbolic diagram is shown below:

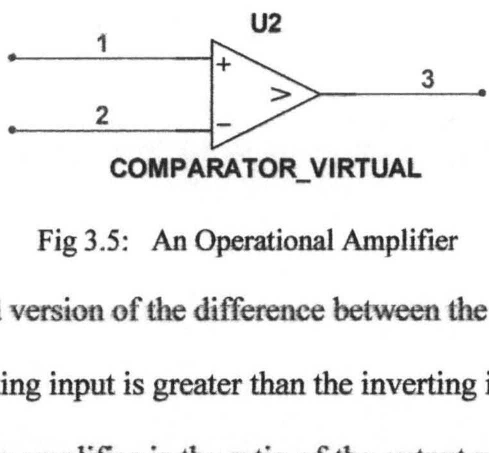


Fig 3.5: An Operational Amplifier

The output is an amplified version of the difference between the two inputs (when the non-inverting input is greater than the inverting input).

The voltage gain, AV of the amplifier is the ratio of the output voltage to input voltage with reasonable condition for source resistance and load resistance. An operational amplifier infinite voltage gain, infinite bandwidth and zero output voltage are equal unfortunately; this device would also have infinite cost. The basic inverting and Non-inverting amplifier circuit are shown below:

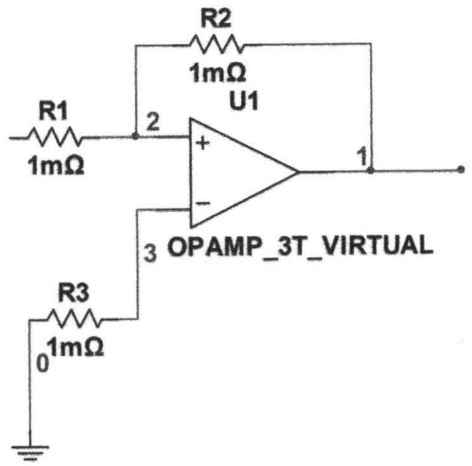


Fig 3.5.1: Inverting Amplifier

AV= $\frac{Vout}{Vin} = -R2/R1$ ....A

Zin=R1; Zout=Fraction of an Ohms; R3=R1/R2 ....B

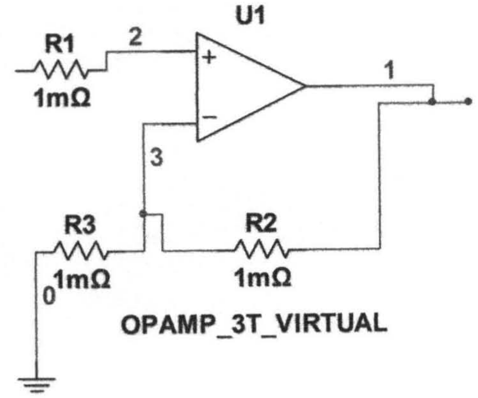


Fig 3.5.2: Non-Inverting Amplifier

AV=Vout/Vin=1 + R2/R1 C

Zin=fraction of an Ohms

3.6 LOW VOLTAGE COMPARATOR

The low voltage comparator OP Amp is configured to operate in the inverting mode since its input voltage is connected to inverting input pin 3 and reference voltage to the non-inverting input pin 2 of the comparator.

At normal voltage range, the inverting input pin 3 is higher than the set reference voltage at pin 2, it produces an output and no output if voltage at pin 3 is less than or equal to voltage at pin 2(reference voltage). The could either be low or high and it passes through the 1k resistor to the transistor and thus, a low voltage would cause the transistor to be in its ON state which then triggers the alarm to sound and otherwise when the transistor is OFF.

3.7 TRIAC

The triac, or bidirectional triode thyristor, is a component that can be used to pass or block current in either direction. It is therefore an A.C power control device. It is equivalent to two thyristors in anti-parallel with a common gate electrode. However, it only requires one heat sink compared to the two heat sinks required for the anti-parallel thyristor configuration. Thus the triac saves both cost and space in A.C applications. The condition when terminal 2 of the triac is positive with respect to terminal 1 is denoted in data by the term 'T2+'. If the triac is not triggered, the small leakage current increases as the voltage increases until the break over voltage V(BO) is reached and the triac then turns on. As with the thyristor, however, the triac can be triggered below V(BO) by a gate pulse, provided that the current through the device exceeds the latching current IL before the trigger pulse is removed.

The triac, like the thyristor, has holding current values below which conduction cannot be maintained. When terminal 2 is negative with respect to terminal 1 (T2-) the blocking and conducting characteristics are similar to those in the T2+ condition, but the polarities are reversed. The triac can be triggered in both directions by either negative (G-) or positive (G+)

pulses on the gate, as shown in Table 1. The actual values of gate trigger current, holding current and latching current may be slightly different in the different operating quadrants of the triac due to the internal structure of the device. [3]

Quadrant	Polarity of T2 wrt T1	Gate polarity
1 (1+)	T2+	G+
2 (1-)	T2+	G-
3 (3-)	T2-	G-
4 (3+)	T2-	G+

Table 1: Operating quadrants for triacs

The advantage of this device is the excellent insulation it provides between the low power and high power circuits, (typically several thousand volts). This provides safe isolation between the low voltage input and high voltage output. [2]

3.8 DIAC

The **DIAC**, or 'diode for alternating current', is a diode that conducts current only after its break over voltage has been reached momentarily.

When this occurs, diode enters the region of negative dynamic resistance, leading to a decrease in the voltage drop across the diode and, usually, a sharp increase in current through the diode. The diode remains "in conduction" until the current through it drops below a value characteristic for the device, called the holding current. Below this value, the diode switches back to its high-resistance (non-conducting) state. This behaviour is bidirectional, meaning typically the same for both directions of current.

Most DIACs have a three-layer structure with break over voltage around 30 V. In this way, their behaviour is somewhat similar to (but much more precisely controlled and taking place at lower voltages than) a neon lamp.

DIACs have no gate electrode, unlike some other thyristors that they are commonly used to trigger, such as TRIACs. Some TRIACs, like Quadrac, contain a built-in DIAC in series with the TRIAC's "gate" terminal for this purpose.

DIACs are also called symmetrical trigger diodes due to the symmetry of their characteristic curve. Because DIACs are bidirectional devices, their terminals are not labelled as anode and cathode but as A1 and A2 or MT1 ("Main Terminal") and MT2. [9]

3.9 THEORY OF OPERATION OF THE CIRCUIT

The power Supply is provided by a 24O/24volts 1000mA AC transformer then the I2volts output AC is rectified by D1-D3 then filtered by capacitor the

Voltage supply to the LM941 OP amp is regulated using 7812 regulator which takes is a considerable higher voltage range and produces an output of 12v.

The non-inverting input and inverting input of the op amp are filled from unregulated supply via resistor. Since the unregulated supply varies with change in supply voltage in primary winding of transformer. Therefore, since it is configured in inverting mode when there is less input voltage in the inverting input pin 3 with respect to the reference voltage at pin 2 non-inverting input, its output goes low else high. The voltage at pin 2 is fixed using a zener diode to a constant voltage of 6.8V. The 10K resistor connected to the zener limits the flow of current through the zener diode while the variable resistor connected to Pin 3 is used to set the threshold voltage.

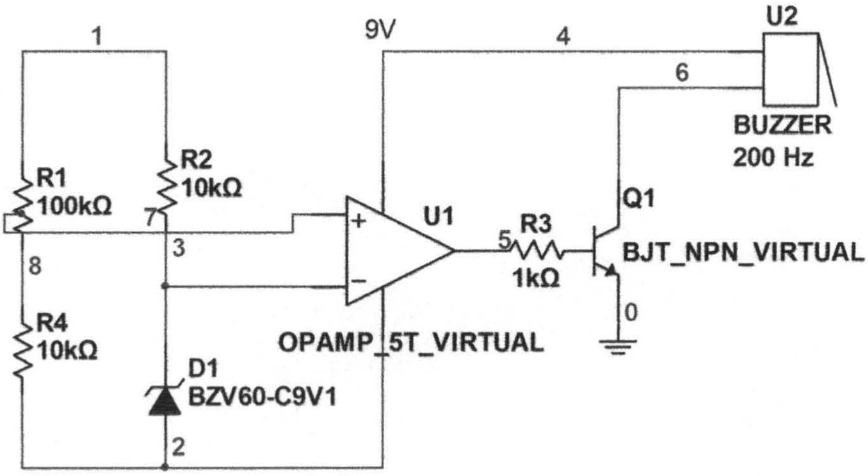


Fig3.6: Low Voltage Circuit

The operation of the POWER CONTROL circuit involves the Triacs which are mainly used in power control to give full wave control. This enables the voltage to be controlled between zero and full power. With simple "half wave" thyristor circuits the controlled voltage may only be varied between zero and half power as the thyristor only conducts during one half cycle. The triac provides a wider range of control without the need for additional components, e.g. bridge rectifiers or a second thyristor, needed to achieve full wave control with thyristors. The triggering of the triac is also simpler than that required by thyristors in AC circuits, and can normally be achieved using a simple DIAC circuit.

The DIAC is designed to have a particular break over voltage, typically about 30 volts, and when a voltage less than this is applied in either polarity, the device remains in a high resistance state with only a small leakage current flowing.

Once the break over voltage is reached however, in either polarity, the device exhibits a negative resistance.

When the voltage across the diac exceeds about 30 volts (a typical break-over voltage) current flows and an increase in current is accompanied by a drop in the voltage across the Diac. Normally, Ohm's law states that an increase in current through a component causes an increase in voltage across that component; however the opposite effect is happening here, therefore the Diac exhibits negative resistance at break-over. The Diac is used to trigger a Triac by the "Phase Control" method. The AC mains waveform is phase shifted by the RC circuit so that a reduced amplitude, phase delayed version of the mains waveform appears across C. As this wave reaches the break over voltage of the Diac, it conducts and discharges C into the gate of the Triac, so triggering the Triac into conduction. The Triac then conducts for the remainder of the mains half cycle, and when the mains voltage passes through zero it turns off. Sometime into the next (negative) half cycle, the voltage on C reaches break over voltage in the other polarity and the Diac again conducts, providing an appropriate trigger pulse to turn on the Triac.

By making R a variable value, the amount of phase delay of the waveform across C can be varied, allowing the time during each half cycle at which the Triac fires to be controlled. In this way, the amount of power delivered to the load can be varied.

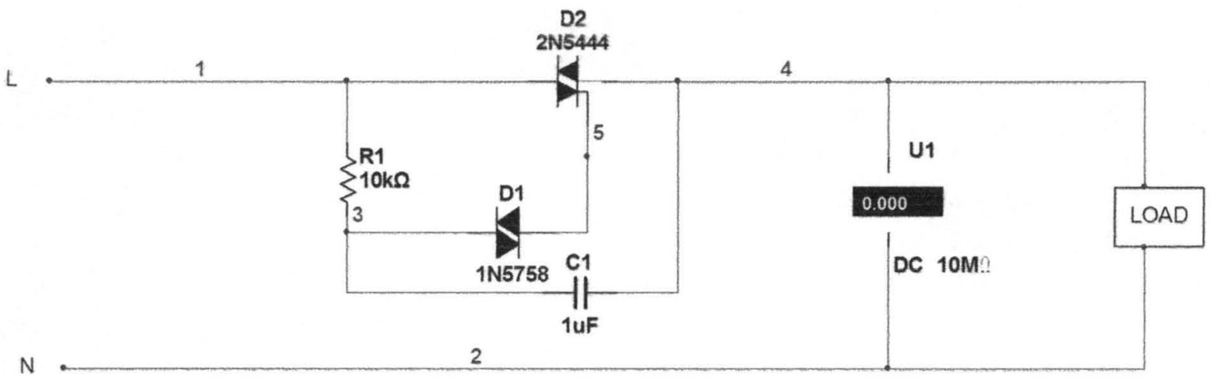


Fig 3.7: A simple A.C power control circuit.

3.9.1 FUNCTIONS OF COMPONENT USED

i. Resistor

An electronic component used to reduce or limit the amount of current flowing in a circuit. This opposes the flow of current, this opposition is called resistance and it is measure in Ohms. Resistors have standard color code which can be used to identify their resistances. The code to determine the resistance of resistor is shown below:

Fig 3.9.2: A resistor

ii. Variable resistor

This is a type of resistor whose resistance value can be adjusted.

iii. Transistor

The transistor is a fundamental unit of many switching arrangement associated with digital systems and it is responsible for great advancement in electronics, there are two types of transistors, [hey are; bipolar junction transistor (BJT), current operated device and field effect transistor (FET), voltage controlled device.

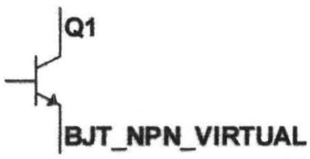


Fig 3.9.3: A transistor

iv. Transformer

This is a static piece of apparatus by means of which electrical power in one circuit is into electrical power of the same frequency in another circuit. It can raise or lower the voltage in a circuit but a corresponding decrease or increase in current.

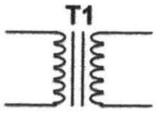


Fig 3.9.4: A transformer

If the efficiency of a transformer is 100%, the power in the primary is equal to the secondary winding.

$IpVp = VsIs$ I

Therefore$\frac{Vp}{Vs} = Is/Ip$ II

Vs = Voltage in the secondary winding

Vp =Voltage in the primary winding

Ip = Current in the primary winding

Is =Current in the secondary winding

Since the product of the number of turns in primary winding and the voltage in the secondary is equal to the product of the primary voltage and the number of turns in the secondary winding, hence,

Therefore $\frac{Vp}{Vs} = \frac{Is}{Ip} = Np/Ns$ III

Where Np = number of turn in the primary winding; Ns = number of turns in the secondary winding.

v. Capacitor

This component stores electrical charges. Basically, it consists of two (2) plates separated by an insulator called dielectric. The types include ceramic, mica, film and electrolytic.

Fig 3.9.5: A capacitor

vi. Diode

This is a semiconductor device which allows current to flow through it in one direction; Diodes are made from germanium or silicon.

Fig 3.9.6: A diode

vii. Zener diode

This is used for voltage regulation and makes use of the breakdown property of diodes when reverse biased. This diode is designed to breakdown when the reverse current suddenly changes from a very small value to a very large value which is independent of the voltage (V)

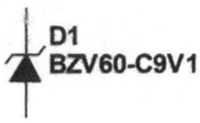


Fig 3.9.7: A zener diode

Viii. The Triac

The triac is similar in operation to two thyristors connected in reverse parallel but using a common gate connection. This gives the triac the ability to be triggered into conduction while having a voltage of either polarity across it. In fact it acts rather like a "full wave" thyristor. Either positive or negative gate pulses may be used

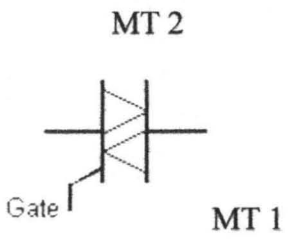


Fig 3.9.8: A triac

ix. The Diac

This is a bi-directional trigger diode used mainly in firing Triacs and Thyristors in AC control circuits. Its circuit symbol is similar to that of a Triac, but without the gate terminal, in fact it is a simpler device and consists of a PNP structure (like a transistor without a base) and acts basically as two diodes connected cathode to cathode.

Fig 3.9.8: A diac

Diac circuits use the fact that a diac only conducts current only after a certain breakdown voltage has been exceeded. The actual breakdown voltage will depend upon the specification for the particular component type.

When the diac breakdown voltage occurs, the resistance of the component decreases abruptly and this leads to a sharp decrease in the voltage drop across the diac, and a corresponding increase in current. The diac will remain in its conducing state until the current flow through it drops below a particular value known as the holding current. When the current falls below the holding current, the diac switches back to its high resistance, or non-conducting state.

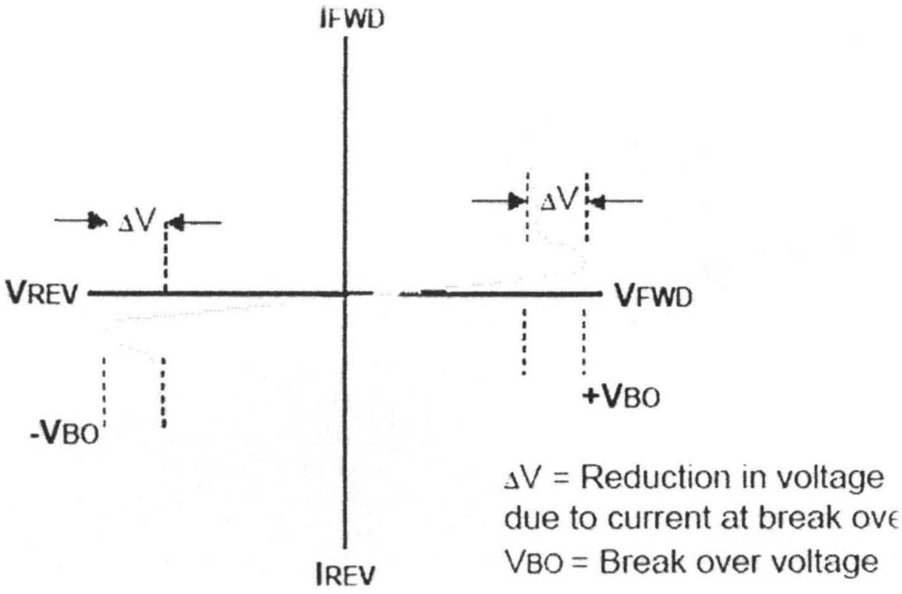


Fig a: Typical Diac Characteristics.

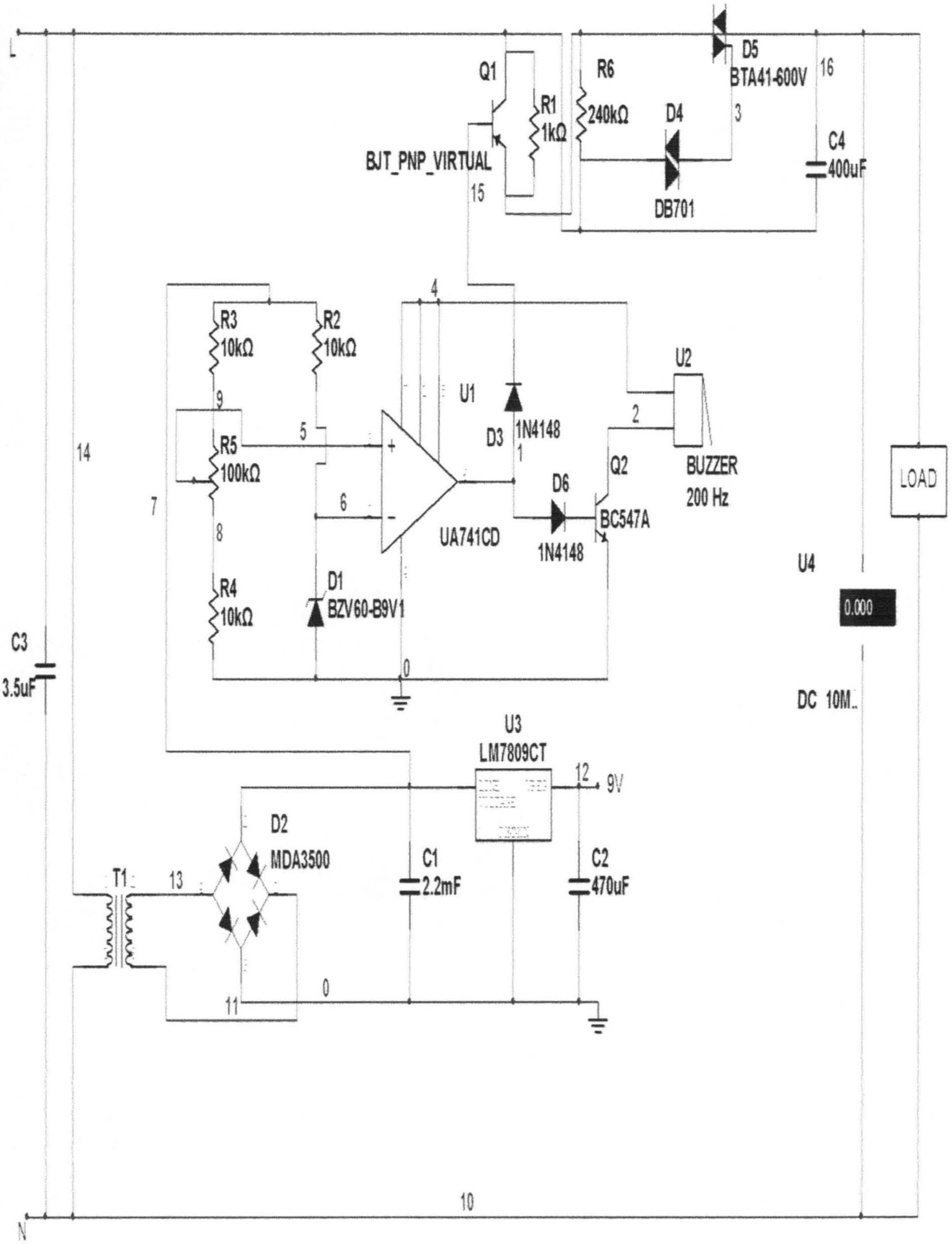


Fig 3.9.9: Circuit Diagram Representation

CHAPTER FOUR

TEST AND RESULTS

4.0 TEST

The under-voltage device showed during test that at a voltage below 160V (This wholesomely depends on the present value of the variable resistor), the buzzer sounds indicating that the input voltage is below standard regulated safe voltage of operating a load. Therefore, loads should be cut off from the power source.

The power control device demonstrated during test that it can function for voltages as low as 120V and as high as 280V without encountering any breakdown. This function is irrespective of the source which could be a Generator or National grid (PHCN).

It was noticed during test that resistance tests on these devices are of limited use; Triacs often operate at mains voltage and when they fail the results can be dramatic. At least the violent blowing of a fuse will be the usual result of a short circuit. Such a fault can be confirmed by measuring the resistance between the two main current carrying terminals of a Triac. A short circuit in both directions means a faulty component. It is quite possible however, for these devices to be faulty and not show any fault symptoms on a multimeter test. They may seem OK at the low voltages used in such meters, but still fail under mains voltage conditions.

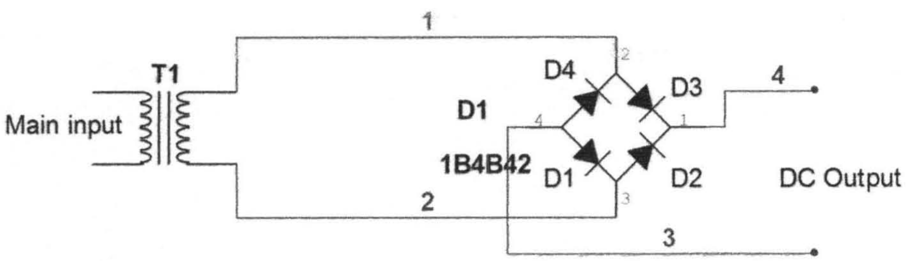
The normal method of testing would be the checking of voltages and waveforms if the circuit was operating or substitution of a suspect part when damage (e.g. blown fuses) is apparent. In many cases these components will be designated "safety critical components" and must only be replaced using manufacturers recommended methods and components. It is common for manufacturers to supply complete "service kits" of several semiconductor devices and possibly other associated components, all of which must be replaced, since the failure of one power control device can easily damage other components in a way that is not always obvious at the time of repair.

For any work on mains, powered circuits must be done with the mains supply fully disconnected and any charge storing (e.g. capacitors) components discharged.

4.1 RESULT

It was observed that the test for the under-voltage device condition was met as the buzzer sounds to indicate a low voltage. At normal condition, the buzzer was observed to remain silent. The institute of Electrical Engineering regulation for electrical equipment of building stipulate, that for safe utilization of electrical energy, the fluctuation of normal supply at any time must not exceed ±10 % of the stipulated voltage. In Nigeria, the normal domestic supply phase voltage is known to be 240V. Thus, interpreting the above regulation statement for the mains. The supply must always range between 216V to 264V. Setting the value of the variable resistor at 75Ω produced a voltage of 146.67V indicating that for voltages of this value, the buzzer sounds. The mathematical representation is proven below;

LOW VOLTAGE RESULT



$\frac{75}{100} * 8 = 6V$

220 = 12

? = 8

Therefore, $\frac{220 * 8}{12} = 146.67V$

Low voltage result at approximately 147V.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From, the test and results, it can be concluded that the Power control/Under-voltage device can safely be applied to sensitive domestic and industrial electronic equipment. It can be concluded also that a simple component (TRIAC) can perform the function of two thyristors; the triac provides a wider range of control in AC circuits without the need for additional components, e.g. bridge rectifiers needed to achieve full wave control.

This project has proven also the possibility of designing and constructing a low cost protective and power boosting device which can function effectively as a domestic appliance.

The results obtained from the testing of this project reveals that the device can compete favorably with other standard devices of this nature as it can perform the following operations:

1. It has the capacity to detect fluctuation in voltage.
2. It can operate on low voltage
3. Voltages can be controlled between zero and full wave.
4. It provides excellent insulation between the low power and high power circuits[1]
5. Simple design and cost
6. Complete elimination of manpower
7. Connection by two wires, without polarity issue
8. Absence of a separate power supply
9. Low power dissipated by the passive components
10. Excellent power variation circuit for resistive or slightly inductive loads

11. With highly inductive loads, the circuit can only operate satisfactorily within the limits of a slight decrease in the conduction angle. [4]

LIMITATIONS

1. The TRIAC is less versatile than SCRs when turn off is considered.[2]
2. The TRIAC remains blocking even when no gate signal is applied due to the frequency handling capability produced by the limiting $dv/_{dt}$.[2]
3. The load to be controlled is preferably a resistive or slightly inductive load, hence non-resistive loads are not suitable.[2]
4. On the detection of low voltage, loads are not automatically cut off.

5.2 RECOMMENDATION

Any work on mains powered circuits must be done with the mains supply fully disconnected and any charge storing (e.g. capacitors) components discharged unless this is absolutely unavoidable

If you have not been trained in the safe working practices that are essential for work on these types of circuit DON'T DO IT! These circuits can kill!

This project can confidently be recommended for domestic use as well as industrial applications.

Further work can be done on this project as it took into consideration low voltage detection; therefore

1. An automatic load cut off circuit can be included.
2. Over-voltage detection can be introduced.

The exposure of students to technical works such as project building should be increasingly supported, as this will enable them familiarize with circuits and construction details which would be of essential improvement to their understanding and acquiring knowledge as well as a general improvement in the academic community and the nation at large.

REFERENCES

[1] HTTP://WWW.LEARNELECTRONICS.ORG

[2] HTTP://WWW. CIRCUITSTODAY.COM

[3] POWER SEMICONDUCTOR APPLICATIONS (PHILIPS SEMICONDUCTORS); pp.510, pp.489-495, pp.496

[4] TRIAC ANALOG CONTROL CIRCUITS FOR INDUCTIVE LOADS; PP 3, PP 12,

[5] B.L THERAJA & A.K THERAJA, TEXTBOOK ON ELECTRICAL TECHNOLOGY, PP 1700, 1740, 297- 316, 2401, 2402, 2114

[6] A BRIEF HISTORY OF ELECTRICAL ENGINEERING EDUCATION, FREDERICK E. TERMAN, FELLOW, IEEE

[7] ELECTRICITY GENERATION AND SUPPLY, 1ST EDITION, BY PROF. ENGR. (DR) ORIA USIFO

[8] OVER-/UNDER VOLTAGE PROTECTION OF ELECTRICAL APPLIANCES

[9] HTTP://EN.WIKIPEDIA.ORG/WIKI/DIAC

[10] HTTP://EN.WIKIPEDIA.ORG/WIKI/TRIAC