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# Design and Construction of a 500 Watts Undervoltage/Overvoltage Stabilizer with Delay

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ABSTRACT

This paper contains details of the design and construction of an under voltage/ overvoltage protector for a single phase load in other words called an AC voltage stability. For the overvoltage protection, if the incoming voltage is above the reference voltage, the relay is activated and the output supply is stepped down by the transformer. In the event of an incoming voltage that is lower than the reference voltage, the relay activates the step up part of the transformer. The introduction, review of related literature, design and construction details of the system is contained in this work, distributed from chapter one to five.

Keywords: Delay, Over-voltage, Relay, Stabilizer, Transformer, Transistor, Under-voltage

## INTRODUCTION

Protective devices are equipments connected to electric power systems to detect abnormal and intolerable conditions and to initiate appropriate protective and corrective actions. These devices include lightning arresters, surge protectors, voltage stabilizer fuses, and relays with associated circuit breakers, recloses, and so forth. From time to time, disturbances in the normal operation of a power system occur. These may be caused by natural phenomena, such as lightning, wind, or snow; by falling objects such as trees; by animal contacts or chewing; by accidental means traceable to reckless drivers, inadvertent acts by plant maintenance personnel, or other acts of humans; or by conditions produced in the system itself, such as switching surges, load swings, or equipment failures. Protective devices must therefore be installed on power systems to ensure continuity of electrical service, to limit injury to people, and to limit damage to equipment when problem situations develop.

**Brief Description of Circuit Disturbances**

Protective devices are applied commensurately with the degree of protection desired or felt necessary for the particular system. Of great importance to the protection of domestic and industrial electrical appliances are over voltage\under voltage protectors. Lightning in the area near the power lines can cause very short-time over-voltages in the system and possible breakdown of the insulation. When the voltage in a circuit or part of it is raised above its upper design limit, this is known as overvoltage [1]. 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. Electronic and electrical devices are designed to operate at a certain maximum supply voltage, and considerable damage can be caused by voltage that is higher than that for which the devices are rated.

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. One of the purposes of electromagnetic compatibility compliance is to eliminate such sources. On the other hand, Low-voltage conditions can cause electrical devices like motors to draw excessive currents, which can damage them. Voltage drop [2] is the reduction in voltage in an electrical circuit between the source and load. In electrical wiring national and local electrical codes may set guidelines for maximum voltage drop allowed in a circuit, to ensure reasonable efficiency of distribution and proper operation of electrical equipment.

**Project Motivation**

Following the epileptic nature of power supply in the country which has only the PHCN (Power Holding Company of Nigeria) as the only statutory organization instituted by decree to supply electricity, it has become inevitable to provide a reliable form of protection for various equipment mostly domestic such as television sets, refrigerators e. t. c. which voltage variations and power cuts adversely affect. It will be interesting to know that a simple circuit put in place can protect costly equipment from high as well as low voltages and voltage surges protected by the delay part of the circuit until power resumes.

**Problem Definition**

The problem calls for a device that will monitor the power supply to a single phase electrical appliance and isolate the load from the supply in event of over or under voltage.

**Aim of Project**

The proposed solution to this problem is the aim of this project which is to design and construct a single phase over-voltage/under-voltage monitor for electrical appliance. A system with the capacity and ability to detect irregular mains voltage and isolate the load, and also to automatically connect the load when the error in the mains is corrected is the aim of the project.

METHODOLOGY

The approach to achieve the desired aim of this project work involves research work on the internet, school library among other public research points. The research result then aids the design of the block diagram from which the circuit diagram evolves. Practical experimental work on a breadboard was thereafter carried out to ascertain me workability of the circuit diagram. The block representation of the system showing the sequence of operation is shown below.

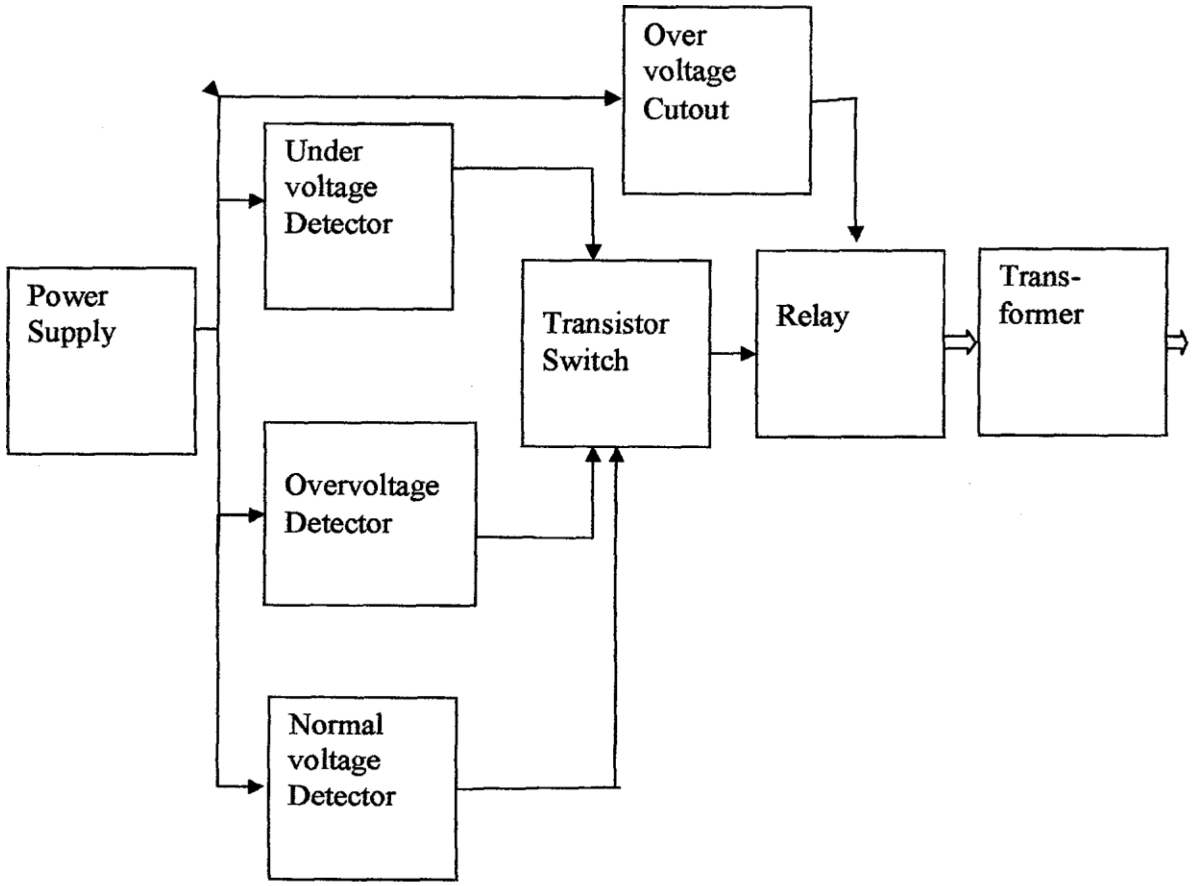


**Figure 1 Block Diagram of the operation of Circuit Operation**

## Assumptions and Limitations

Every system has one or two assumptions and limitations. This section contains the assumptions and limitations of the project.

**List of Assumptions**

This is the list of assumptions that will be considered in the design.

- The system can be directly applied to monitor mains voltage of about 150V-270V for any electrical appliance of less than 500Watts.
- There will be no delay in switching off the output terminal once an error is detected.

**List of Limitations**

This is a list of limitations that are inherent in the design preventing it to function in certain ways.

- The transformer utilized in the power supply may not withstand high voltages above 270V, as such the monitoring such voltage may cause damage to the system.
- Due to the size of relay in the output switching unit, the system can only drive a load below 500Watts.

## LITERATURE REVIEW

[3] in a paper titled 'The prevention of interruption of electricity supply' designed a magnetic cutout which could operate on reverse current flow and hence would detect a current in-flow to the faulted equipment. However, he did a good job with the magnetic cutout; but the magnetic cutout had little or no advantage over this under - voltage, overvoltage stabilizer because the under-voltage, over-voltage stabilizer protects electrical appliances against voltage surges and high or low voltages whereas the voltage cutout may protect only against surge. Power system protective relays characteristics were also appraised by [4] where he explained the operational characteristics and various methods of appraisal for protective relays. In his work, the result of observed values should tally with specified values on the relays but due to losses that occur in circuits, deterioration of electric components in relays with age, the value does not tally. However, the range was small. He also identified the importance of 2 or 3 relays on a circuit for protection in case anyone of them fails to operate or is inadequate at some point.

In this project provision was made in the circuit for more than one relay for specific purposes. A relay for the over - voltage part, another relay for the under - voltage part, a third relay for the delay, and a fourth relay for normal supply straight through part of me circuit. These provisions will reduce over working of the relays and help improve accuracy of specification which [5] wrote about. Another research where a faults study analysis was carried out on the 11KV distribution network Zaria using digital computer method by [2] where he explained the significance of fault study analysis so as to know the value of the abnormal current or voltage that will occur due to faults of different kinds and to design or select appropriate interrupting devices such as relays and circuit disconnection of faulted lines and equipment with minimum damage and disturbance to the operation of the remaining system. In this project provision is made to protect connected electrical appliances using a delay circuit that protects against surges and the under voltage/over voltage part that protect me system against low and high voltages.

## THEORITICAL BACKGROUND

Over the years-since the invention of electricity supply system, different approaches have been made towards the design of a reliable protecting system for over voltage and under voltage protection. All of these approaches use the following components.

1. **Zener Diode**

A two-terminal semiconductor junction device with a very sharp voltage breakdown as reverse bias is applied. The device is used to provide a voltage reference. The voltage across the Zener itself defines a higher level from which the current is drawn. Thus, a stable noise-free Zener defines its own stable noise-free current.

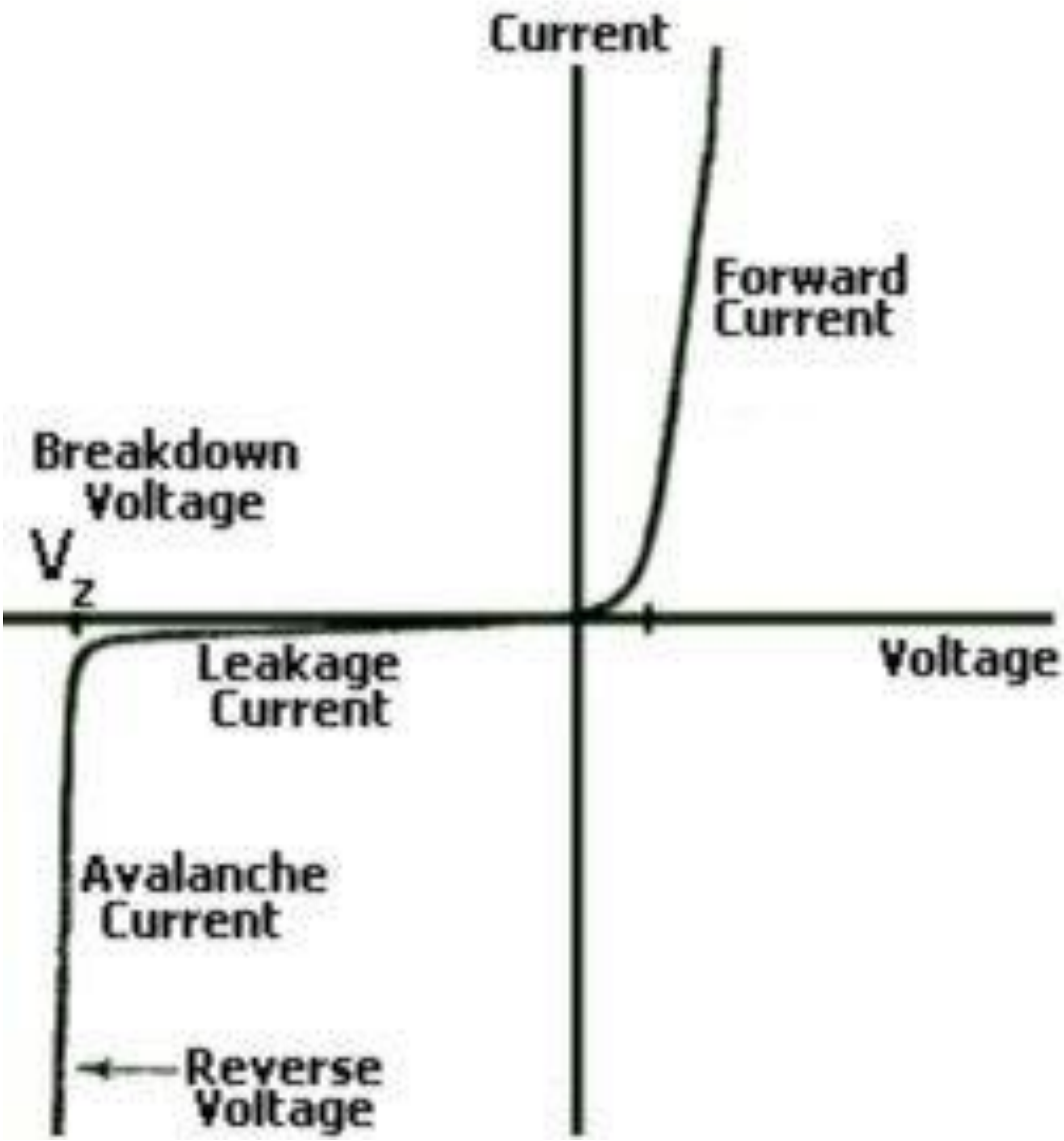


**Figure 2 Zener Diode Breakdown Voltages**

## 2. Integrated Circuits

**LM 324**

The LM324 series consists of four independent, high gain, internally frequency compensated operational amplifiers 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. For example, the LM 324 series can be directly operated off of the standard 5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional gl5V power supplies. In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage. The unity gain cross frequency is temperature compensated. The input bias current is also temperature compensated

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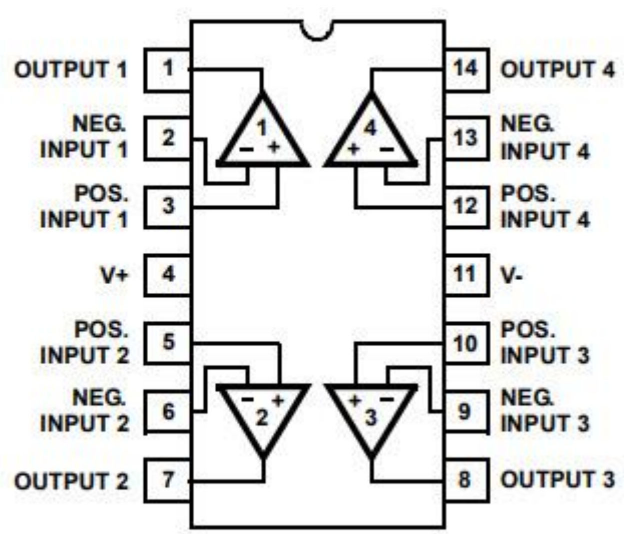



**Figure 3 Internal Configuration of LM 324 IC**

## 3. UTO - TRANSFORMERS

An autotransformer (sometimes called auto former) [5] is an electrical transformer with only one winding. The winding has at least three electrical connection points called taps. The voltage source and the load are each connected to two taps. One tap at the end of the winding is a common connection to both circuits (source and load). Each tap corresponds to a different source or load voltage. In an autotransformer a portion of the same winding acts as part of both the primary and secondary winding. A failure of the insulation or the windings of an autotransformer can result in full input voltage applied to the output. This is an important safety consideration when deciding to use an autotransformer in a given application. Furthermore the input and output are not isolated; thus, if the “neutral” side of the input is not at ground voltage, the “neutral” side of the output will not be either. Because it requires both fewer windings and a smaller core, an autotransformer for power applications is typically lighter and less costly than a two-winding transformer, up to a voltage ratio of about 3:1 - beyond that range a two winding transformer is usually more economical. In three phase power transmission applications, autotransformers have the limitations of not suppressing harmonic currents and as acting as another source of ground fault currents. A large three-phase autotransformer may have a "buried" delta winding, not connected to the outside of the tank, to absorb some harmonic currents. A special form of autotransformer called a "zig zag" is used to provide grounding (earthing) on three-phase systems that otherwise have no connection to ground (earth). A zig-zag transformer provides a path for current that is common to all three phases (so-called "zero sequence" current). Like multiple-winding transformers, autotransformers operate on time-varying magnetic fields and so cannot be used directly on direct current.

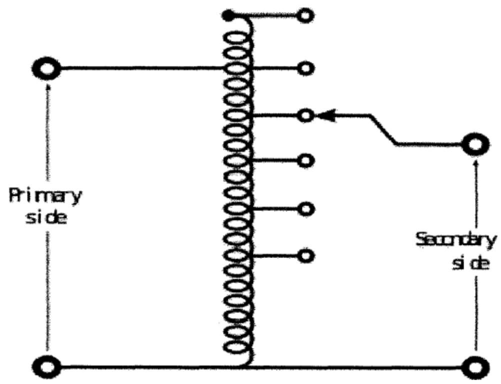
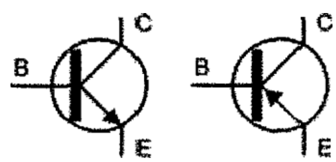



**Figure 4 Diagrammatic Representation of an Auto-transformer**

## 4. TRANSISTORS

### Types of transistor

There are two types of standard transistors, NPN and PNP, with different circuit symbols. The letters refer to the layers of semiconductor material used to make the transistor. The leads are labeled base (B), collector (C) and emitter (E).




NPN PNP

**Figure 5 Transistor circuit symbols**

### Transistor as a switch

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

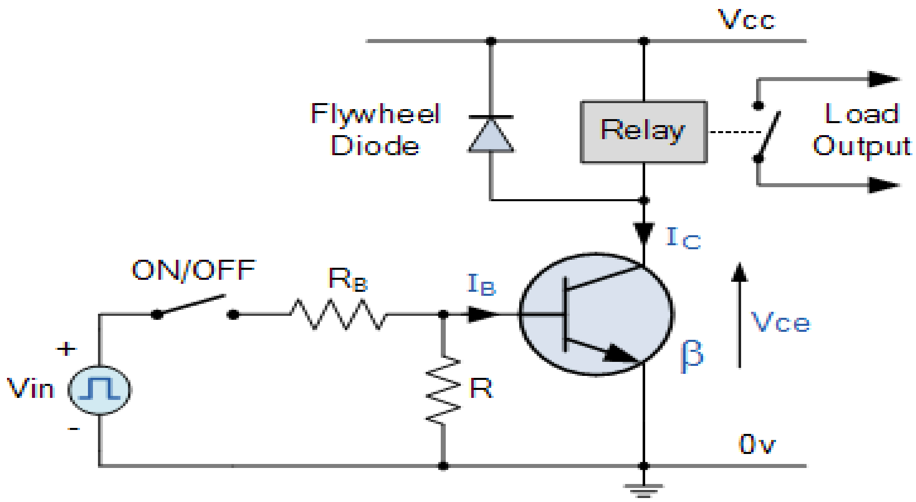



**Figure 6 Diagram of a Transistor acting as Switch**

- In the OFF state: power = $I_c$ x $V_{CE}$, but $I_c$ == 0, so the power is zero.
- In the fully ON state: power = $I_c$ x $V_{CE}$, but $V_{CE}$ = 0 (almost), so the power is very small.

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

**Selecting the appropriate transistor**

1. A resistor $R_B$ is required to limit the current flowing into the base of the transistor and prevent it being damaged. [2] However, $R_B$ must be sufficiently low to ensure that the transistor is thoroughly saturated to prevent it overhearing, this is particularly important if the transistor is switching a large current (> 100mA). A safe rule is to make the base current $I_B$ about five times larger than the value which should just saturate the transistor. The transistor's maximum collector current Ic (max) must be greater than the load current Ic.

$$\textbf{Load current Ic} = \frac{\textbf{supply voltage Vs}}{\textbf{load resistance RL}}$$

2. The transistor's minimum current gain $h_{FE}$ (min) must be at least five times the load current Ic divided by the maximum output current from the Ic.

$$h_{FE}\text{(min)} > 5 \times \frac{\text{load current Ic}}{\text{max.Ic Current}}$$

3. Choose a transistor which meets these requirements and make a note of its properties: Ic (max) and $h_{FE}$(min).

4. Calculate an approximate value for the base resistor:

$$R_B = \frac{\text{Vc x hFE}}{\text{5 x Ic}}$$ where Vc = 1C supply voltage

(In a simple circuit with one supply this is Vs)

5. For a simple circuit where the Ic and the load share the same power supply (Vc = Vs) you may prefer to use: $R_B = 0.2 \times R_L \times h_{FE}$

6. Then choose the nearest standard value for the base resistor.
Finally, remember that if the load is a motor or relay coil a protection diode is required.

## 5. RELAYS

Transistors cannot switch AC or high voltages (such as mains electricity) and they are not usually a good choice for switching large currents (> 5A). In these cases clay will be needed, but note that a low power transistor may still be needed to switch the current for the relay's coil [l].

**Advantages of relays:**

- Relays can switch AC and DC, transistors can only switch DC.
- Relays can switch high voltages, transistors cannot.
- Relays are a better choice for switching large currents (> 5A).
- Relays can switch many contacts at once.

**Disadvantages of relays:**

- Relays are bulkier than transistors for switching small currents.
- Relays cannot switch rapidly; transistors can switch many times per second.
- Relays use more power due to the current flowing through their coil.
- Relays require more current than many ICs can provide, so a low power transistor may be needed to switch the current for the relay's coil.

Selection of an appropriate relay for a particular application requires evaluation of many different factors:

- Number and type of contacts - normally open, normally closed, (double-throw)
- Contact sequence — Make before Break or Break before Make
- Rating of contacts - small relays switch a few amperes, large contactors are rated for up to 3000 amperes, alternating or direct current.
- Voltage rating of contacts - typical control relays rated 300 VAC or 600 VAC, automotive types to 50 VDC, special high-voltage relays to about 15000V.
- Coil voltage - machine-tool relays usually 24 VAC, 120 or 250 VAC, relays for switchgear may have 125 V or 250 VDC coils, and sensitive relays operate on a few milliamperes.
- Coil current - Usually in me range of 40-200 mA for 0-24 VDC coils e. t. c.

These robust and reliable electromagnetic relays use the induction principle discovered by Ferraris in the late 19th century. The magnetic system in induction disc over current relays is designed to detect over currents in a power system and operate with a pre determined time delay when certain over current limits have been reached, hi order to operate, the magnetic system in the relays produces rotational torque that acts on a metal disc to make contact, according to the following basic current/torque equation:

$$T = K \times \varphi 1 \times \varphi 2 \, \mathrm{Sin}\boldsymbol{\theta}$$

Where
K - is a constant
$\varphi 1$ and $\varphi 2$ are the two fluxes $\boldsymbol{\theta}$ is the phase angle between the fluxes

## 6. RECTIFIERS

Overview

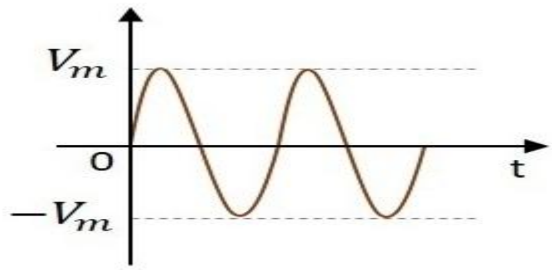



**Figure 7 Alternating Current (A. C) Wave form**

As we have noted when looking at the elements of a Power Supply, the purpose of the rectifier section is to convert the incoming ac from a transformer or other ac power source to some form of pulsating dc. [5] The circuit required to do this may be nothing more than a single diode, or it may be considerably more complex. However, all rectifier circuits may be classified into one of two categories, as follows:

**Half-Wave Rectifiers** : An easy way to convert ac to pulsating dc is to simply allow half of the ac cycle to pass, while blocking current to prevent it from flowing during the other half cycle. The resulting output is shown below. Such circuits are known as half-wave rectifiers because they only work on half of the incoming ac wave.

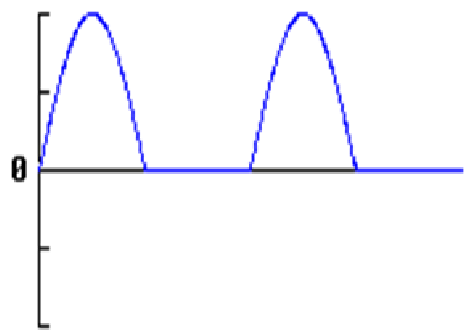



**Figure 8 Half Wave Rectifier Wave form**

**Full-Wave Rectifiers:** The more common approach is to manipulate the incoming ac wave so that both halves are used to cause output current to flow in the same direction. Because these circuits operate on the entire incoming ac wave, they are known as full-wave rectifiers. Rectifier circuits may also be further classified according to their configuration.

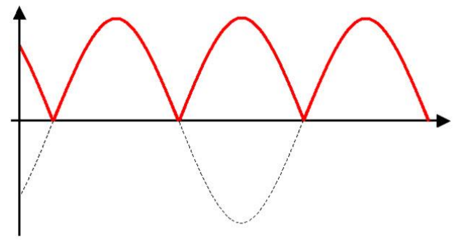


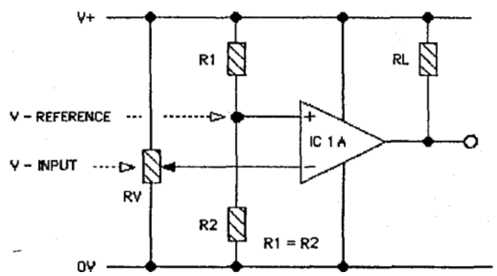
**Figure 9 Full Wave Rectifier Wave form**

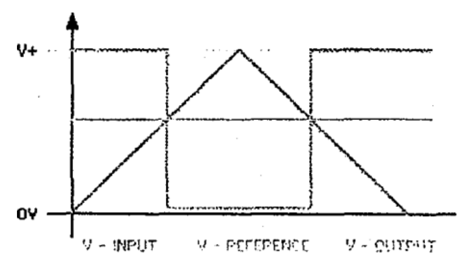
## 7. COMPARATORS

The following drawing shows the two simplest configurations for voltage comparators. The diagrams below the circuits give the output results in a graphical form. For these circuits the REFERENCE voltage is fixed at one-half of the supply voltage while the INPUT voltage is variable from zero to the supply voltage. In theory the REFERENCE and INPUT voltages can be anywhere between zero and the supply voltage but there are practical limitations on the actual range depending on the particular device used.

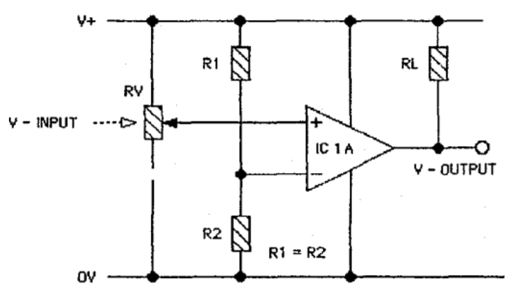
**Basic Operation of Voltage Comaparators**

**CIRCUIT-A**




**CIRCUIT-B**



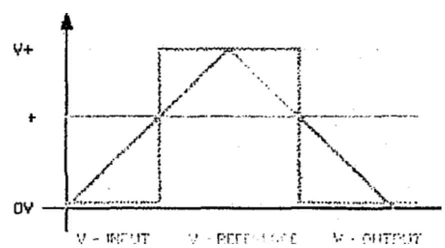




**Figure 10 Basic Operations of Voltage Comparators (Paisley 2002)**

## CIRCUIT DESIGN

This chapter contains details of the circuit design. It consists of the block representation of the system, the circuit diagram, the basic principle of operation and a brief circuit analysis.

**BLOCK DIAGRAM**

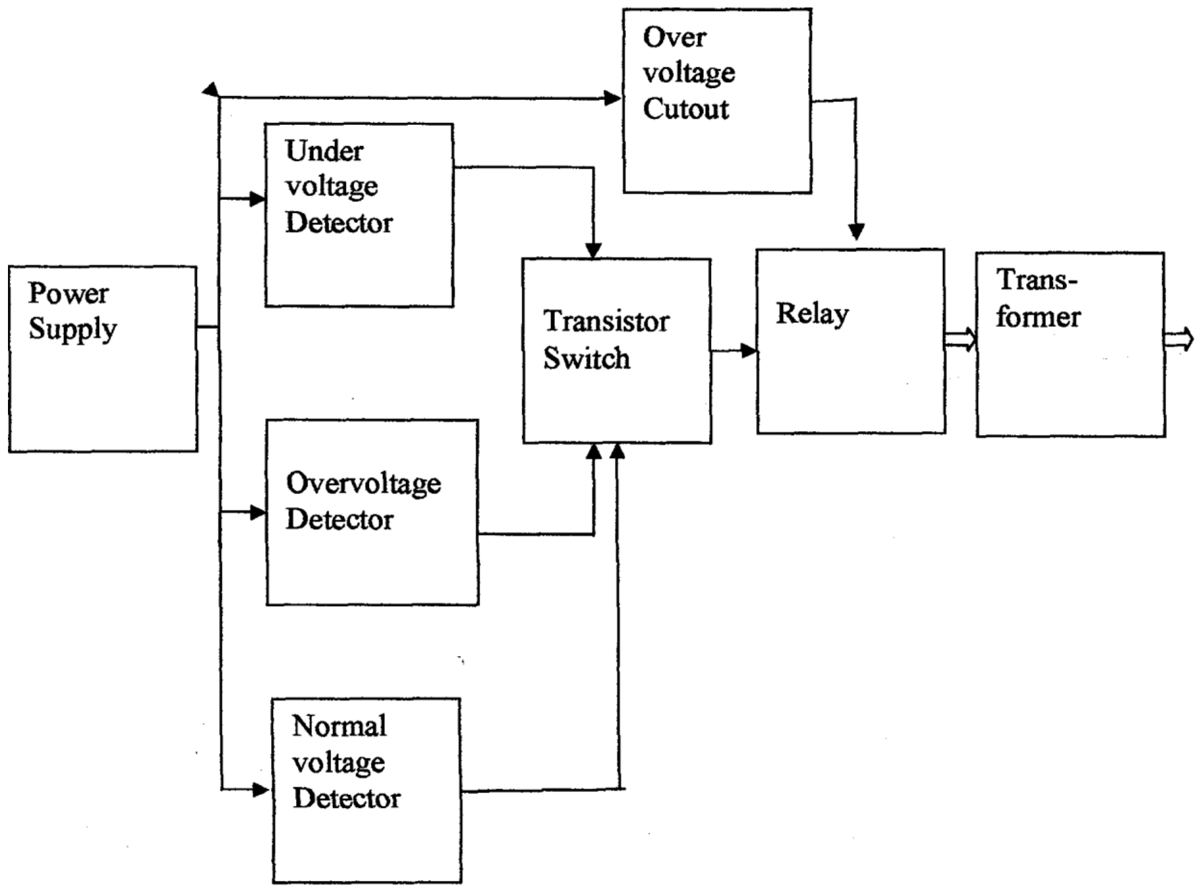
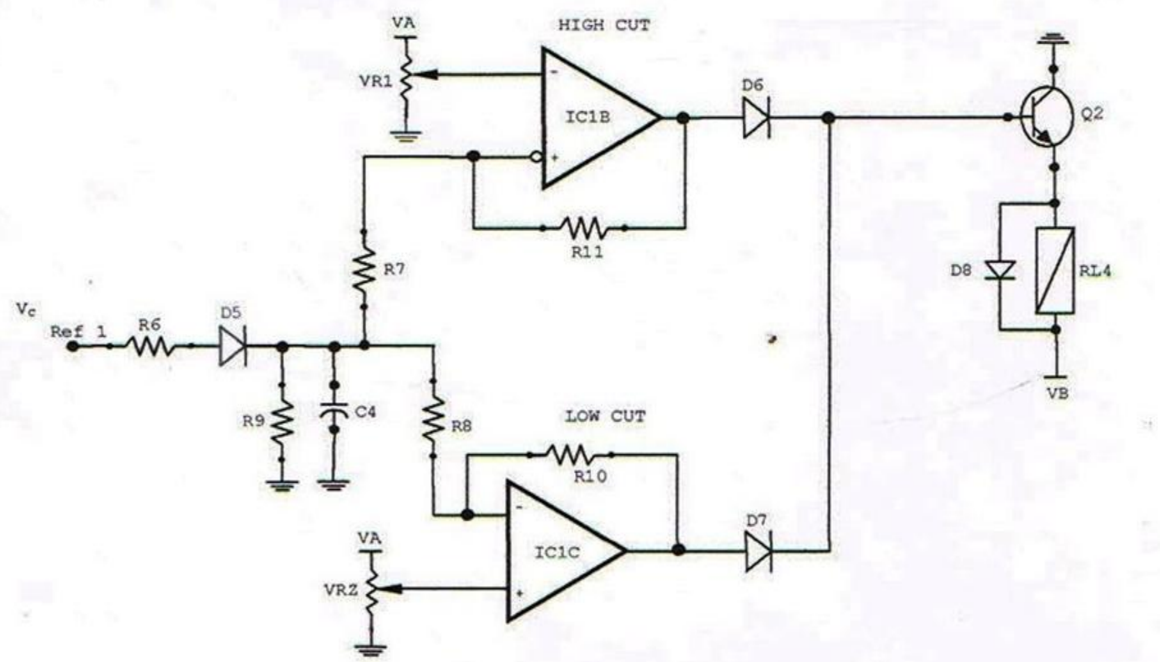
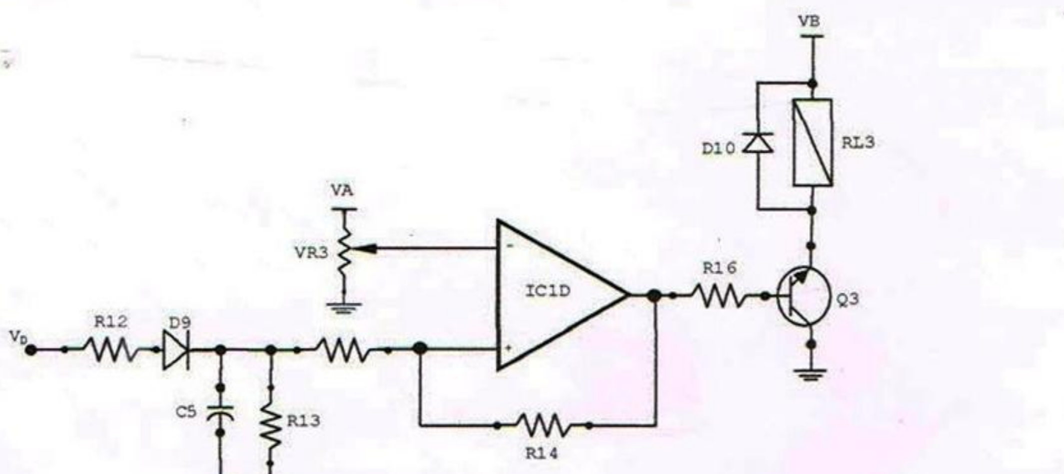



**Figure 11 Block Diagram of Circuit Operation**

**CIRCUIT DIAGRAM**




HIGH/LOW CUT




PHCN SELECTION RELAY CIRCUIT

**Figure 12 Circuit Diagrams of High/Low Voltage Cuts and the Relay Circuit**

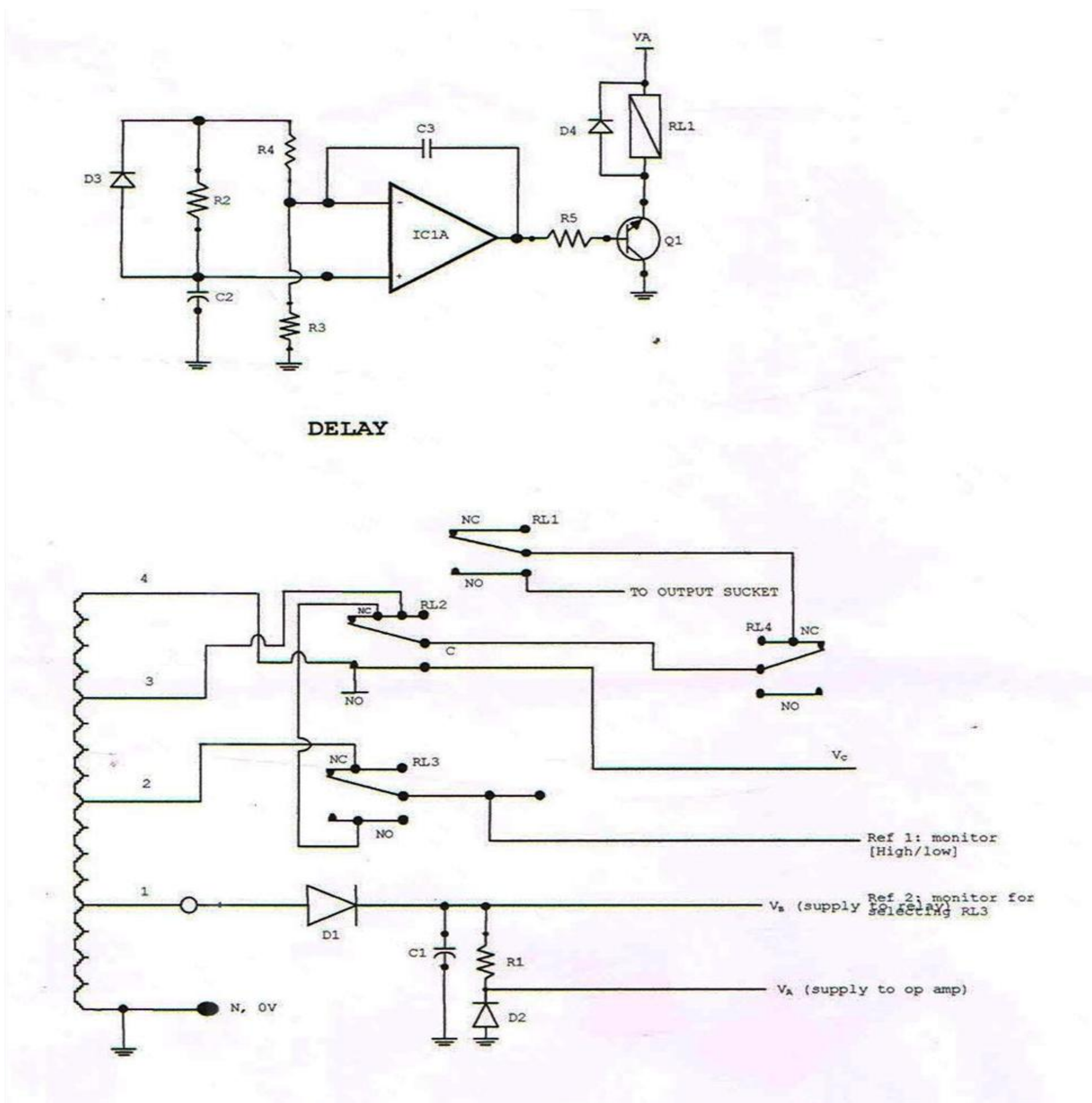



**Figure 13 Circuit Diagram of the Voltage Stabilizer**

**Principle Of Operation**

Tin's circuit protects electrical appliances from over voltage, under-voltage, and surge. As shown in the block diagram, the system consists of a power supply unit which converts the input AC voltage to about 12V DC. The under-voltage /over-voltage units are fed from the power supply thus they monitor and detect variations in the mains voltage. Any error detected is amplified by the signal amplifier stage to a level capable of activating the electromechanical relay which then isolates me load from the mains. A straight through is connected to another signal amplifier which is connected to another relay that activates when there is normal supply of power within the required range. While a fourth signal amplifier is connected from the mains supply to cut out voltages that will exceed unfavorable values for the transformer been used. The circuit diagram shows the components interconnection. 4 operational amplifiers contained in the LM 324 1C are used here in comparator mode. The regulated power supply is connected to the series combination of resistors Rl and Zener diode D2, the supply from the 7.5V Zener is what is used to supply the 1C (LM324). As the AC supply to the electrical appliances is given through the normally closed terminal of the relay, the supply is not disconnected during normal operation. When the AC voltage increases beyond 240V, the voltage at the non-inverting terminal (pin 3) of operational amplifier N1 increases. The voltage at the inverting terminal is still 4.62V because of the zener diode. Thus now if the voltage at pin 3 of the operational amplifier N1 is higher than 4.62V, the output of the operational amplifier goes high to drive transistor Tl and hence energize relay RL and the yellow LED lights up. Consequently, the AC supply is stepped down and appliances are protected against over-voltage. Now let's consider the under-voltage condition. When the line voltage is below 200V, the voltage at the inverting terminal (pin 2) of operational amplifier N2 is less than the voltage at the non-inverting terminal (3.60V). Thus the output of operational amplifier N2 goes high and it energizes the relay through transistor Tl. The AC supply is disconnected and electrical appliances turn off and the green LED lights up. Thus the appliances are protected against under-voltage. The relay circuit energizes in two conditions: first, if the voltage at pin 3 of 1C 2 is above 4.62V, and second, if the voltage at pin 2 of 1C 2 is below 3.60V. Over-voltage and under-voltage levels can be adjusted using presets VR1 and VR2, respectively. However, one of the operational amplifiers of theLM324 1C is used for the delay part of the circuit and protects any electrical appliance connected to it mainly against surges.

**Circuit Analysis**

Every unit of the system as contained in the block diagram shall be separately analyzed.

**Power Supply Operation And General Calculations**

The power supply to the control panel and relay power supply is shown in the circuit diagram. The source of the supply is taken from one leg of the transformer windings with respect to ground is a. c. It is then converted to d. c. using a half wave rectification and filtered. Part of this d. c. supply is what supply the relays rated 12V,10Amps and 400 ohms relays, another part is Zener clipped and used to supply the operational amplifier circuits

From the circuit diagram, for half wave rectification,

Average d. c. voltage is given by $V_{avc} = \frac{\sqrt{2}}{\pi} V_{rms}$ **(1)**

The actual d. c. voltage seen at $V_b$ would be 2 times the above equation with the help of Capacitor Cl

$V_{avc} = \frac{\sqrt{2}}{3.142} x13.5 = 6.077V$

$V_{dc} = V_{avc} \times 2$ **(2)**

$V_{dc}$= 2x6.077 = 12.15V approximately 12Volts

For this design Cl is chosen to be 1000uF/25V

$V_B$ =12.15V

For this design the choice of zener diode is a 7.5V zener with the following specification obtained from the manufacturer

$V_Z$ = 7.5V (Normal)

$V_z$ = 7.0 (minimum)

$V_Z$ = 7.9 (maximum)

$I_{ZT}$ = 5mA

Hence, Voltage across $R_1$

$V_B - Vz = I_{zT}R_1$ **(3)**

$V_B$ = 12V

$V_Z$ V=7.5V

$I_{ZT}$ = 5mA

12 – 7.5 = $(5x10^{-3})$ $R_1$

$R_1$= 900 ohms

The standard value of resistor close to that value is 1K ohms

For this design Rl= IkΩ

Assuming possible voltages supplied by PHCN are listed below and their possible d. c. equivalent are listed below. They are used to calculate values or parameters for low and high voltage cuts. Hence, we use the formula to calculate the possible d. c. values for each a. c. input.

**Table 1 Possible Input Voltages < a. c.) and their corresponding Voltages (d. c.)**

| $V_{rms}$ (V) | $V_m = \sqrt{2}\, V_{rms}$ (V) | $V_{dc} = \frac{Vm}{\pi}$ (V) |
|---|---|---|
| 100 | 141.42 | 45 |
| 140 | 197.98 | 63 |
| 150 | 212.13 | 67.5 |
| 190 | 268.7 | 85.5 |
| 200 | 282.84 | 90 |
| 220 | 311.13 | 99 |
| 230 | 325.26 | 103.5 |
| 240 | 339.4 | 108 |
| 245 | 346.48 | 110 |

**Design Of Low/High Voltage Cut-Off**

The window voltage for which supply to the output of the socket is chosen is between 191 to 244 Volts a. c. Any voltage outside this range of 244V a. c. is termed high voltage and the control circuit for high cut acts to disconnect supply to the output through switching of low/high cut transistor, similarly if the voltage goes below 190V a. c. the low voltage act to disconnect supply voltage. On the diagram VR2 and VR3 are adjusted for high/low voltage cutoff setting. Point Vo is the virtual ground for the operational amplifier, Vc is voltage across capacitor C4 with respect to ground. $V_E$ is the output voltage at the output of the operational amplifier. RIO and Rl 1 are feedback resistor use to keep the operational amplifier from chattering. R6 is a dropping resistor used to drop the voltage from PHCN to low voltage before it is rectified. For high voltage IC1B is referenced at 4.62V with variable resistor VR2 for voltage limit of 245V.

For low voltage ICIC is referenced at 3.60V with VR3 for voltage limit of 190V a. c.

Having satisfied these conditions, we go ahead and design choice of resistors needed.

When the circuit is in Normal operation, voltage at the output of the operational amplifier is zero Volts.

Using the voltage divider rule, we calculate voltage at point C on the diagram.

$$\left(\frac{R9}{R9+R16}\right) \times V_{dc} \text{ equivalent for high voltage} = V_c \qquad \textbf{(4)}$$

At point D, if $V_E = 0$ (Assuming)

$$\left(\frac{R10}{R8+R10}\right) \times V_c = V_D \qquad \textbf{(5)}$$

From d. c. equivalent for 245V a. c. = 110V d. c. if $R_9$ is chosen to be 10k, and $R_6$ =

220k, then $V_c = \left(\frac{10K}{10K+220K}\right)$ x 110 = 4.78V

$V_C$ = 4.62V
Vc = 4.78V (calculated)
$R_{10}$ = 1MΩ (feedback) Chosen

$\left(\frac{1M}{1M+R8}\right)$ x 4.78 = 4.62 So $R_8 \approx$ 33kΩ

Similarly, the calculation is carried out for low voltage cut. Here the potentiometer setting is adjusted to voltage of 3.60V for low voltage cut. The values obtained are the same as obtained for high voltage.

From the circuit diagram, when the voltage from PHCN becomes higher so also is the d.c. voltage at the non inverting input of IC1B becomes higher, when this exceeds the reference input the output of the operational amplifier ICIB becomes high, this switch on the transistor to cut off supply to output. Similarly for low voltage, when voltage from PHCN is low applied voltage to the inverting input of ICIC is also low if this goes below the present value at its non inverting input, output of operational amplifier ICIC is high which also cut off supply to the output socket.

## DELAY CIRCUIT ANALYSIS

$R_2C_2dVc/dt + Vc = V$ **(6)**

Where Vc is Voltage across the Capacitor

The Time Constant for the above differential equation, $T = R_2C_2$

Given that $R_4 = R_3$ =10K and $C_3$ = 0.0 1Uf

The Voltage at V is found using the Voltage divider rule

$V_A = (R_4/R_4+R_3)\ V$ **(7)**

V = 12Volts

$V_A = \left(\frac{10K}{10K+10K}\right)$ x 12 = 6 Volts

Point A is referenced at 6 Volts

$Vc = V\ (l\text{-}e\ ^{-t/R2C2})$ **(8)**

The delay time for this project is taken to be

t=10 s; V=12V; Vc = 6V; R=? ; $C_2$ = 100uF

Therefore, $\frac{-t}{R2C2} = 1-\ln\left(\frac{Vc}{V}\right)$ **(9)**

$-t = R_2C_2\,(1-\ln\frac{Vc}{V})$

$-10 = R_2 \times 100 \ 1n\ (l- \frac{6}{12})$

$R_2$ = 144.27 KΩ (Standard resistor close to these value is $R_2$ = KΩ)
1cmax = $100_m$A,
B =290,

$I_B = \frac{1c}{B}$ **(10)**

$V_{ce}$ = 0.25v, $V_{BE}$ = 0.7V,
1B =100 x$10^{-3}$ /290=3.4 x $10^{-4}$

KVL around the base of transistor is

Vout from op amp- VBE = $I_B R_7$
$R_7$ = 30KΩ

## SWITCHING CIRCUIT

This unit consists simply of a transistor switch and an electromechanical relay

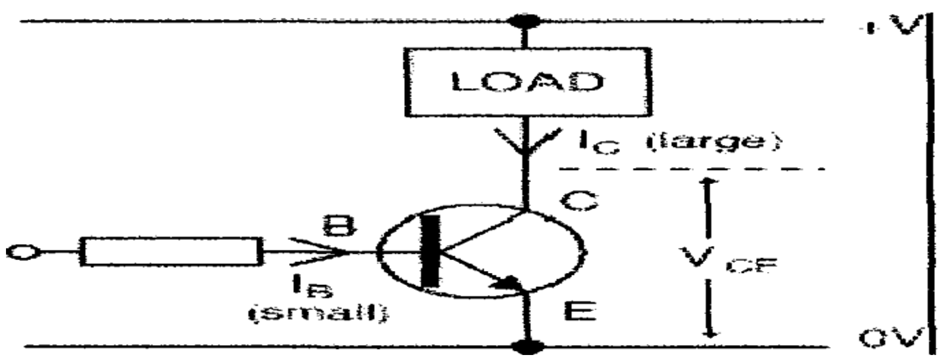



**Figure 14 Switching Circuit**

**Using a transistor as a switch**
When a transistor is used as a switch it must be either OFF or fully ON. In me fully ON state the voltage VCE across the transistor is almost zero and the transistor is said to be saturated because it cannot pass any more collector current Ic. The output device switched by the transistor is usually called the 'load'. The power developed in a switching transistor is very small.

- In the OFF state: power == Ic x VCE, but Ic = 0, so the power is zero.
- In the full ON state: power = Ic x VCE, but VCE = 0 (almost), so the power is very small. This means that the transistor should not become hot in use and you do not need to consider its maximum power rating. The important ratings in switching circuits are the maximum collector current Ic (max) and the minimum current gain $h_{PE}$ (min). The transistor's voltage ratings may be ignored unless you are using a supply voltage of more than about 15V. As shown below a diode is connected across the load to protect the transistor from damage when the load is switched off. The diagram shows how this is connected 'backwards' so that it will normally NOT conduct. Conduction only occurs when the load is switched off, at this moment current tries to continue

flowing through the coil and it is harmlessly diverted through the diode. Without the diode no current could flow and the coil would produce a damaging high voltage 'spike' in its attempt to keep the current flowing [6].

**Choosing The Transistor**

Relay coil resistance = 400, Supply voltage = 24V

Load current = 0.03 A = 30mA, so transistor must have Ic (max) > 30mA. The maximum current from the 1C is 5mA, so transistor must have $H_{FE}$ (min) > 30. Therefore, a low power transistor BC547 with Ic (max) =100mA and $H_{FE}$ (min) = 110 is chosen.

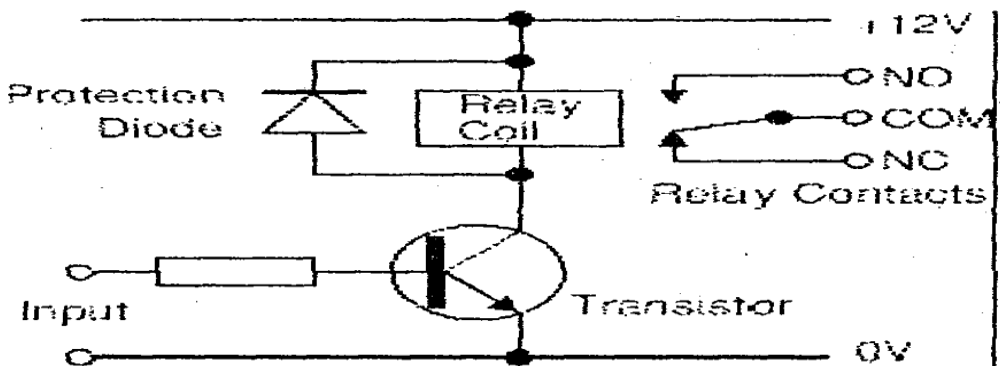



**Fig15 Switching Transistor Circuit**

CONSTRUCTION, TESTING AND RESULTS

This section contains details of the construction of the circuit board and enclosure. It also contains the assuming, testing and result and list of tool used in the construction work.

**Circuit Construction**

This construction work was carried out in sequence. First the required components were assembled and tested individually to ensure that the components are in correct sharp before being used. The strip board was then cleared with iron brush to remove dirt that might affect soldering. The components were then mounted on the board and soldered one after the other and following the circuit diagram arrangement. The components were mounted on the board by passing their terminals through the holes on the board from the non conducting surface to the surface with the conducting tracks.

To avoid damage from heat and for easy replacement, the ICs were not directly mounted on the board but were mounted on 1C sulkers. Great care was taken to ensure that components like transistors and ICs were mounted the correct way round for proper biasing. The following steps were followed to ensure good electrical and mechanical soldered joints.

- The strip board was made very clean.
- The terminals of all components were made clean also using a small size iron brush.
- Good mechanical contact was made between the points to be soldered.
- Using the 60W soldering iron heat was slightly applied to the joint,
- A good soldering flux was applied between the heated joint and the soldering iron. The flux was allowed to melt and flow freely over the joint.
- The flux was then allowed to cool naturally over the joint thereby forming a shinny strong mould.

**Enclosure Construction**

The casing is practically a metal enclosure, gotten from an old and non-functional voltage regulator for many reasons which include the fact that the weight and size of the transformer are large so the need for a very strong casing that can match this size and weight is necessary. Using a hand drill with tiny drilling bit, screw holes and other relevant ventilation holes were performed. Factors that were considered before choosing a specific shape and size include, a large enough space inside the enclosure to prevent over compression of the circuit board.

**Assembling**

Having constructed the circuit board and obtaining the enclosure and being satisfied with me functionality of the constructed circuit, the project was assembled. Assembling was simply fixing the circuit board firmly on the enclosure and screwing that there was no conducting object like the lead ball, nail etc inside the enclosure and also that enclosure was not too small for the circuit board since this might cause compression which might result to breakage or the Vero board track. Proper connections were made between me units. This was a bit complicated and demanded great care and attention since the use of a lot of connecting wires were involved.

**Transformer Design**

Determination of number of turns of 500W rated Transformer.

**Determination of Number of turns in the transformer**

Determination of number of turns of 500W rated Transformer.

In order to achieve a good number of turns, flux density of 1.63tesla was assumed and the following calculation was made

$$A = \sqrt{P/5.58} \qquad \textbf{(11)}$$

Where A = Area in square meter ($M^2$), P = power in watts (W) = 500W and 5.58 is a constant

$A = \sqrt{500/5.58} = 9.466CM^2 = 9.466 \times 10^{-4}\ M^2$

$$E = 4.44\ F\Phi_m N \text{ and} \qquad \textbf{(12)}$$

$$\Phi_m = B_m \times A \qquad \textbf{(13)}$$

Where E = emf of transformer in volt (V), F = frequency in Hertz (Hz) = 50Hz, $\Phi_m$ = flux in Weber (w), $B_m$ = flux density in tesla = 1.63tesla, A = Area in square meter ($M^2$) = 9.466 x $10^{-4}$ $M^2$ and N = number of turns

$\Phi_m = 1.63 \times 9.466 \times 10^{-4} = 1.542 \times 10^{-3}$ w = 15.42mw

$E = 4.44 \times F \times \Phi_m = 4.44 \times 50 \times 1.542 \times 10^{-3} = 0.362$ V/tum

**Determination of wire diameter**

$$A = I/D \text{ and } d = \sqrt{(A \times 4)/\pi} \qquad \textbf{(14)}$$

Where A = cross-sectional area in square millimeters ($mm^2$), D = current density = constant = 3.08A/$mm^2$, 1 == current in Amperes (A), d = diameter in millimeters (mm) and π = 3.142

Primary current $I_1$

$I_1 = 500/12 = 41.6A$

$A_1 = I_1/D = 41.6/3.08 = 13.51mm^2$

$d_1 = \sqrt{(13.51 \times 4) / 3.142} = 4.14$ mm

Secondary current $I_2$

$I_2 = 500/220 = 2.27A$

$A_2 = I_2/D = 2.27/3.08 = 0.73mm^2$

$d_2 = \surd((0.73 \text{ x } 4) / 3.142) = 0.96\text{mm}$

**Determination of Number of turns for the power supply portion (12V)**

Using, $E = 4.44 \text{ x } F \text{ x } \Phi_m$ **(15)**

12V/0.36V = N Where E = 0.362V/turn

N=33.33tums

**Determination of Number of turns for the under voltage portion (Below 214V)**

214V/0.36V=N

N= 594.4 - 33.33 = 561.1tums

**Determination of Number of turns for the over voltage portion (Above 240V)**

240V/0.36V = N

N = 666.6 - 561.1 = 105.53 turns

**Determination of Number of turns for the cut off voltage portion (Above 240V and below 270V)**

270V/0.36V = N

N = 750 - 105.53 = 644.5turns

The maximum wattage of the transformer was determined by me E- core of lamination. Also, the size of the wire or its volume, determines the number of turns of the transformer, hence the wattage.

## TESTING AND RESULT

Tests using the Variac were carried out under supervision. However, Static and dynamic test were also the two other types of test carried out on the completed work. First, visual inspection was done to ensure that all connections and component were properly fixed, and then a resistance test was performed with an ohm meter. This was in the form of checking all close track, jumper wires etc for open or short circuit. Being satisfied with this test, dynamic test then followed. Power was fed to the circuit for a very short time and them cut-off. Using the finger as a heat sensor, the temperature of the components was felt to see if any was overheating. Being satisfied, the power switch was the completely turn out. Voltage test then followed. This was performed with a digital voltmeter. Voltage level at different points on the board was taken and compared with design specification. The following readings were obtained. Please see Appendix.

## CONCLUSION

This paper contains details of the design and construction of a 500 Watts under voltage/ overvoltage Stabilizer for a single phase load in other words called AC voltage stability. The system also protects the load against surge which might affect it. Basically, the system is built around the Zener diode rectifier circuit which is connected to an integrated circuit (LM 324) consisting of 4 operational amplifiers, 2 of which are configured in the comparator mode and one for the delay and the fourth one for a voltage pass through for normal voltage operation between 191V to 240V. However, the Zener rectifier circuit fixes a reference voltage level for the comparator which feeds an electromechanical relay. For the overvoltage protection, if the incoming voltage is above the reference voltage, the relay is activated and the output supply is stepped down by the transformer. The reverse is the case for the under-voltage protector. In the event of an incoming voltage that is lower than the reference voltage, the relay activates the step up part of the transformer.

However, if the incoming voltage is too high for specification, the operational amplifier cuts it out. For normal supply voltages, another operational amplifier activates another relay to deliver the normal output voltage.

## AIM AND SIGNIFICANCE

The problem calls for a device that will monitor the power supply to a single phase electrical appliance and isolate the load from the supply in event of over or under voltage. The proposed solution to this problem is the aim of this project which is to design and construct a single phase over-voltage/under -voltage monitor for electrical appliance. A system with the capacity and ability to detect irregular mains voltage and isolate the load, and also to automatically connect the load when the error in the mains is corrected is the aim of the project.

## LIMITATIONS

This is a list of limitations that are inherent in the design preventing it to function in certain ways.

- The transformer utilized in the power supply may not withstand high voltages above 270V, as such the monitoring such voltage may cause damage to the system.
- Due to the size of relay in me output switching unit, the system can only drive a load below 500Watts

## RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER WORK

With a better number of turns ratio in the transformer windings, a wider range of input voltages can be stabilized for better performance of the system and to keep the connected electrical appliance working even at relatively low or high voltages.

## REFERENCES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## APPENDIX 1

| Component Name | Specification | Source |
| --- | --- | --- |
| Op - Amp LM 324 | Maximum power dissipation = 1260mW 40uAmps | Data sheet, LM324 www.nationalsemiconductors.com Aug. 2003 |
| Transistor BC 547 | Maximum power dissipation = 500mW, collector saturation current lc =100mA, current gain Hfe =110. | Transistor Information www.sound.westhost.com |
| Diode 1N 4001 | Peak reverse voltage vp = 35 volts, maximum forward bias current = l Amp. | Data sheet www.semiconductors.philips.com |
| Zener diode (7.5V) | Minimum voltage = 7V, Maximum voltage = 7.9V, test current = 5Ma. | Data sheet www.nteinc.com, www.rselectronics.com |

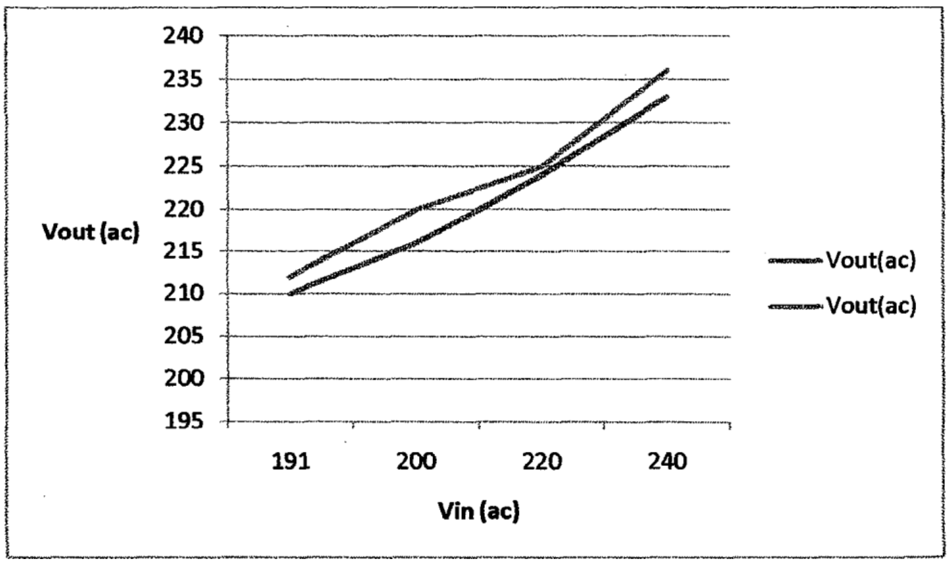
## APPENDIX 2
### Tests and Results Using Variac With 60 Watts Load

| $V_{in}$(ac) | $V_{out}$(ac) |
| --- | --- |
| 191 | 210 |
| 200 | 216 |
| 220 | 224 |
| 240 | 233 |

### Tests and Results Using Variac With 160 Watts Load

| $V_{in}$(ac) | $V_{out}$(ac) |
| --- | --- |
| 191 | 212 |
| 200 | 220 |
| 220 | 225 |
| 240 | 236 |

**Plotting a Graph of the various input voltages (ac) against the various output voltages (ac) as shown below, it is seen that as the input voltages are varied (increased) there is a corresponding increase in the output voltages. Also there as the load increased the corresponding voltages also increase, hence a linear relationship exists between the load and the voltage.**




**Graph of input voltages at different loads against out put voltages.**