DESIGN AND CONSTRUCTION
OF AN
AUTOMATIC PHASE CHANGER

By

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CERTIFICATION

This is to certify that this work titled " Design and Construction of an Automatic Phase Changer" was carried out by ADI RASAQ under the supervision of Engineer M. S Ahmed for the award of Bachelor of Engineering in Electrical/Computer Engineering of the Federal University of Technology, Minna.

Sign 6/12/05

Engr M.S Ahmed (project supervisor) Date

Sign 06/07/06

HOD of Elect/comp. dept Date

Sign ....

External Examiner Date

DEDICATION

This project is dedicated to:

Almighty Allah, the King of the kings, the Lord of the world;

My Sweet mother, Late Hajia Alimat Oluwatoyin Adi

My Darling wife, Hajia Ramatallahi Omobolanle Adi

My beloved son, Sultan Oluwatoyin Adi.

ACKNOWLEDGEMENT

All praises is due to Almighty Allah, the Lord of the worlds for His protection over me through the period of undergoing this programme, His wisdom saw me through it all and allowed the programme to see light at the end of the tunnel against all odds.

Many thanks to my Supervisor, Engr. Shehu Ahmed for his tireless effort, unlimited sacrifice of his private time, his moral and financial support and whose positive criticism brought out the full potential in me towards the actualization and successful completion of a meaningful project like this. May Allah continue to have you at His mercy and may He allow your wealth of experience flourish all the time. All your effort to see other people acquire knowledge shall never be in vain. (Amen).

A million thanks to other lecturers of the department, who at one time or the other imparted knowledge in me, may Almighty Allah bless you all.

This acknowledgement would be incomplete if I fail to reckon with moral and spiritual support of my late mother, Hajia Alimat Oluwatoyin Adi who was always in contact with Almighty Allah on my behalf before she gave up the ghost and my beloved wife who never ran out of patient with me at all situations; Her love, commitment, tolerance, understanding, sacrifice and prayer serve as the pillar and brick wall of my courage to continue to stride in a positive direction all the time, may Almighty Allah, the custodian of all things on earth and in heaven, the all knowing, the most beneficent and the most merciful shower His infinite mercy on both of them in this life and life hereafter (Amen).

ABSTRACT

This project deals with the design and construction of Automatic Phase Changer for three phase system. It prevents equipment from disastrous effect of PHCN supply and ensure constant supply of electricity to equipment. It gives one phase output and it is meant for domestic consumption with permission from PHCN

The project is made up of many features each forming a segment of the device. Transformation and rectification section takes the AC voltage, steps it down and then rectified it respectively to its required DC voltage for electronic use. Voltage level selector helps to pick the highest voltage level at any instant of time which is usually indicated by light emitting diodes (LED) present at output side.

Switching operation was achieved through +12V relays and the rate of switching is satisfactory. It has been recommended that using this equipment, a constant supply of electricity to our domestic appliances is guaranteed with the exception of a complete power failure or power outage from all the three phases supply.

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CHAPTER ONE

1.0 INTRODUCTION

Electrical and electronic equipment require constant power supply of electricity so as to prevent them from failure; this failure may be partial or total depending on the intensity of variation of both voltage level and frequency of the power supply. Since the supply from PHCN cannot be predicted and sometimes not desirable, hence the need for the equipment or device that could take varying or unstable input and gives a fairly constant and regulated supply. Other example of these devices includes Automatic Voltage Regulator (AVR), Power Intermittent Interruptible Protector (PIIP), and Uninterrupted Power Supply (UPS). Fuses and circuit breakers are also used as surge protector for high current / voltage. With the above mentioned equipment, the reliability of these appliances is enhanced.

Also, automatic control plays an important role in our way of life from the simple control required in an automatic bread toaster to other sophisticated control systems. Automatic control is of great interest to engineers and scientists in order to meet requirement of stability, accuracy and speed of response of every control system. With the advancement in technology, automatic control has been greatly improved upon to relieve people of many monotonous activities of which are beyond the physical activities of people to duplicate. Automatic control systems are dynamic systems whose study provides a basis for understanding the behavior of other dynamic systems. This concept is therefore important because automatic control is important.

This project, design and construction of automatic phase changer is meant to reduce or overcome the dangerous or disastrous effect of continuous failure in power supply to sensitive appliances. This failure could either be from Power Holding Company of Nigeria (PHCN) or electrical faults on any of the three phases.

Although the project is actualized for academic purpose, it could however be used in areas where single load input is designed i.e. for domestic consumptions. It monitors all the three- phases (Red, Yellow and Blue) when a phase goes off it automatically switches to another phase, it is also designed to give the highest voltage level at any instant of time 9i.e. when supply is available on the three phases at a go).

The automatic switching or changing among phase is carried out with use of electronic circuit, digital integrated circuits with other relevant components. The equipment however seize to work in the event of complete failure on all the phases and only start to operate again when power is resumed on any of the phase or all the phases.

1.1 OBJECTIVE OF THE PROJECT

The main objective of the project is to design and construct an automatic phase changer that would be able to efficiently and reliably switch between phases whenever there is power failure or low voltage on any of the supplying phases.

The device should be able to compare the imput voltage with its reference or default voltage so that the voltage below 150V or above 250V should be seen as power failure. Therefore only voltages between the ranges of 150V to 250V will be supply so as to prevent consumers equipment from being damaged.

It should be able to select the best voltage level as the output supplied voltage. Switching between phases would be done very fast and unnoticed.

The light emitting diodes (LED) would indicate which phase (s) is active and of the phases is supplying at a particular time. The block diagram of the Automatic phase changer is shown in fig. 1.1 below.

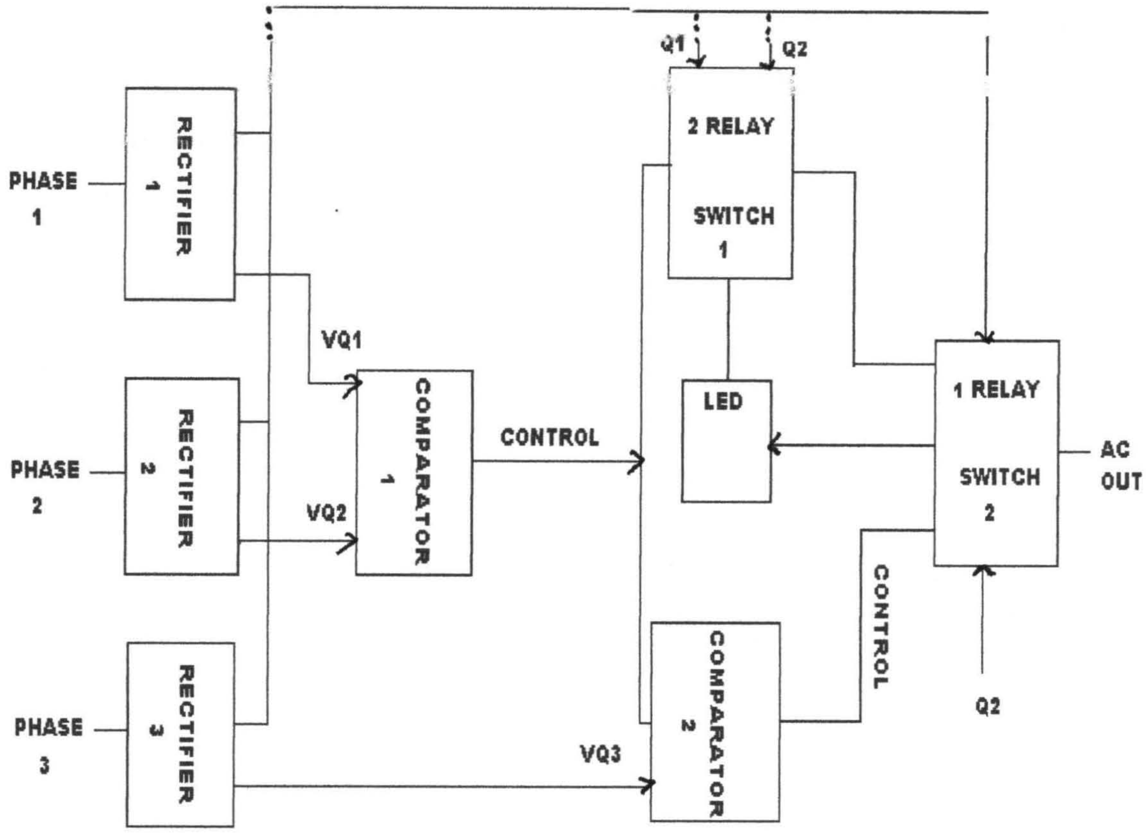


FIG 1.1 BLOCKS DIAGRAM OF AUTOMATIC PHASE CHANGER.

1.2 PROJECT LAYOUT

This project is written in five chapters in which chapter one is the general introduction of the project topic, its design and construction and its usage while chapter two give the literature review and general description of components clearly used to analyze the elements constituting the entire project. The third chapter deals with design calculation and procedure while chapter four deals with construction and testing of result. The last chapters discussed the problems encountered in the process of constructing the project, some recommendation are made to improve on it and conclusion drawn.

1.3 POWER FLUCTUATION AND FAILURE: ITS CAUSES AND CONSEQUENCE(S)

Technological advancement overtime has been very tremendous. This has led to an increase in the demand for electricity especially in the urban area where migration is very high. People migrate in large number into urban cities for job opportunity and better living due to availability of necessary infrastructures. This resulted into structural development and creation of satellite town, which needs to be supplied with electricity. However, the building of more generating and transmitting stations is not at the same pace with the increasing demand for electricity. These leads to excessive loading of the transformer causing an appreciable voltage drop along the distribution line down to the consumer. Intermittent drop in power generation is also a major cause of power failure as load shedding arrangement are drawn and enforced during this period to keep the stations within their capacity. Lack of proper planning and maintenance culture in the power sector has also brought about degradation in the power supply. These and some other factors have been responsible for erratic supply in Nigeria.

Consequently, consumers do no longer enjoy stable power supply, and even when available, it is either a case of low voltage or high voltage which could damage equipment and even cause fire outbreak, due to short circuit as a result of heating effect of the cable. To prevent the damage of domestic equipments and appliances, that's why the usage of this constructional project would be helpful and important.

CHAPTER TWO

2.0 LITERATURE REVIEW

Electricity is generated in bulk quantities in power stations or centers. As consumer locations vary over vast geographical areas, the electric energy must be transmitted over an electric power network connecting the power stations with every consumer. Generated energy at the power stations is transmitted on transmission lines via the National grid.

In Nigeria, about 16KV is produced from the generators. This is stepped up to 330KV with the aid of gigantic transformer, before getting to a transmission station from where it is transferred to the National grid (N. C. C) for proper control and further transmission. 132KVis transmitted to transformer station (Area control centers) from where it is distributed at both 33KV and 11KV to distribution transformers. The distribution at sub-station transformer steps it down to 415V line voltage and 220V phase voltage for both industrial and domestic use. Power supply to consumer is therefore available as either three phases and a neutral or as single phase and a neutral. The single phase powers all single phase equipment and apparatus while the three phase all equipment with three phase input.

2.1 THEORY OF THE COMPONENTS USED

For the actualization of this project, various electrical/electronic components were used with due consideration on their characteristic and function. Components used for the construction of this project include Resistor, Capacitor, Diode, Transistor, Transformer, Relay, and others.

2.1.1 RESISTOR

A resistor is a passive component that offers opposition to the flow of electric current. It displays a voltage drop across its terminals and produce heat when an electric current passes through it. The property of resistor that made it to be able to oppose the flow of electric current is known as resistance. Resistance must be present in every electronic or electrical circuit or else, there would be no control over the quantity of electrons which flow in the circuit hence no control of current flows in the circuit too which may have adverse effect of damaging other components in the circuit design. The electrical resistance measured in ohms is equal to the ratio of the voltage drop across the resistor terminals measured in volts divided by the current measured in amperes.

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}} \text{ (ohms)}; \qquad R = \frac{V}{I} \text{ (ohms)}$$

Resistors are classified mainly according to construction, which may be composition, film-type, wire-wound or integrated circuit. The most widely used of the resistor type is the composition resistor because of its low cost, high reliability and small size. It is basically mixture of resistive materials, usually carbon, and a suitable binder molded into a cylinder, Copper wire leads are attached to the ends of the cylinder and the entire resistor is molded into a plastic or ceramic jacket. The overall length of the jacketed resistor including the leads is 13-34mm for resistor varying in power rating from 0.25 to 2w.

They are available in the range of several ohms to 10-20 Megaohms and with tolerances of 20%, 10% or 5%. The value of the resistors are determined by the colour code on the resistors and its equivalent colour numerical numbers. The first colour code represents first digit, the second colour code represent the second digit while the third colour code represents the number of Zeros and the last represent the tolerance of the resistor The fig 2.1.1 shows the typical colour coded resistor.

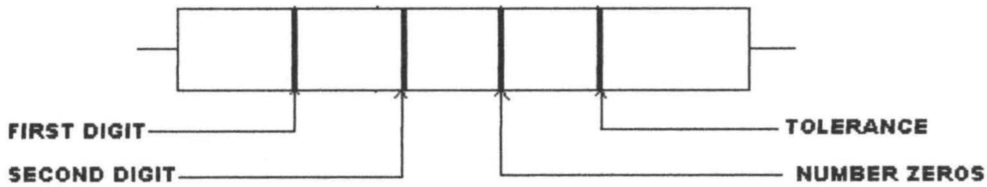


Fig. 2.1.1 A COLOUR CODED RESISTER

2.1.2 RECTIFIERS

Majority of electronic equipment rely on DC power source for their normal operation. As the power required becomes larger, the DC obtained from rectification is neat and cheaper (in the long run) than those from a battery. The diodes used as rectifiers converts energy from an AC source into the DC energy which is desired for the operation of electronic circuits. The usual rectifier circuits are the half-ware, full-wave (center tapped) and the full-wave bridge rectifier. The most effective is the bridge rectifier (2).

2.1.3 BRIDGE RECTIFIER

The bridge rectifier is used where the source has no centre-tap and the advantages of the higher output are required. Generally, however, a rectifying circuit converts AC voltage into a pulsating DC voltage. The circuit diagram of a bridge rectifier is shown below:

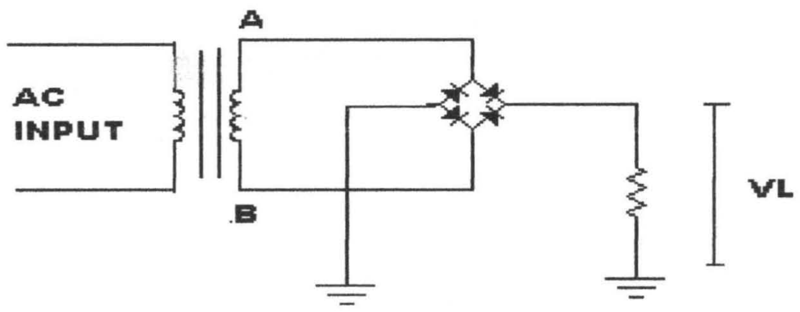
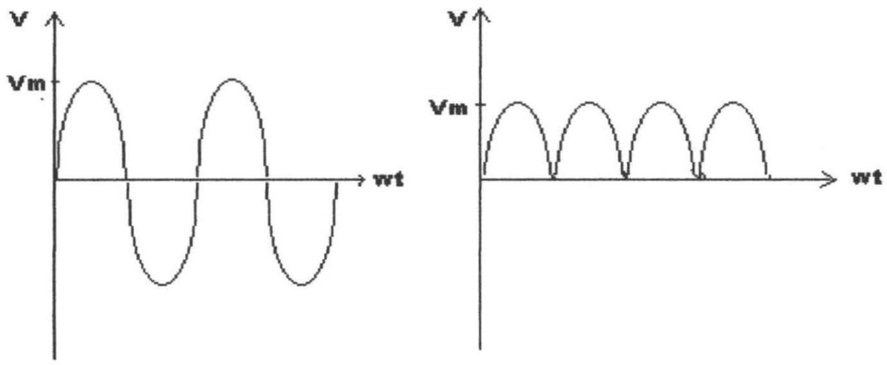


Fig 2.1.3a: CIRCUIT DIAGRAM OF A BRIDGE RECTIFIER

When point A is positive with respect to B, current flows from A through diode D_1 to the load R_L and through diode D_2 to point B, during the negative half cycle when B is positive with respect to A, current flows by way of D_3, R_L and D_4 to point A, the maximum voltage across the diode in the reverse direction is known as the peak inverse voltage (PIV). So when choosing diode for rectification, care has to be taken in order to select one that has a breakdown voltage greater than the PIV. The input and output waveform are as shown in fig. 2.1.3b below.

Thus, the maximum voltage develop is V_m



(a) INPUT WAVEFORM **(b) OUTPUT WAVEFORM**

Fig. 2.1.3b WAVEFORM FOR A BRIDGE RECTIFIER.

For a full name rectifier circuit as show in fig 2.1.3a, the filtered voltage has a DC level with some voltage riding on it.

2.1.4 CAPACITOR

A capacitor is an electrical device capable of storing electrical energy. It is formed when two metal plates (conductors), separated by an electrical insulator (dielectric), are enough close together that when a voltage is connected across them, the electric charge on one side of the insulator influences the electric charge on the other sides of the insulator. In a shorter term, a capacitor can be said to consist of metal plates facing one another and separated by an insulating material called the dielectric. The two plates of the capacitor must always be metal because they are the conductors, which carry the electrons to and from the dielectric. The material used for the dielectric determines the type of capacitor. If the dielectric is air, the capacitor is called an air capacitor. If it is mica, the capacitor is called a mica capacitor and so on. Other common capacitor types are ceramic, tantalum, paper, plastic and electrolytic capacitor.

The capacitance, which is the ratio of the charge q, on one of the plates of a capacitor to the potential difference V, between the plates is measured in farad i.e.The purpose of a capacitor in any circuit is to act as storage tank for electrons. There are many capacitors in most electronic equipment and their applications are as follows:

1. They are used in filter circuit to remove unwanted AC voltages or interfering signals.
2. They are used in by-passing AC signal to ground.
3. They are used as coupling devices when it is necessary to pass on AC voltages but block DC voltages.

Fiq 2.1.4 below shows a typical basic capacitor.

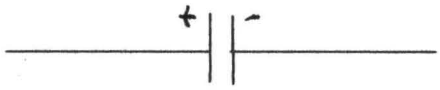


Fig 2.2.2: BASIC CAPACITOR

2.1.4 DIODE

A diode is a two terminal device with a characteristic very close to that of a simple switch. A diode can therefore be said to be a device that conduct current in only one direction.

Fig 2.1.5a CONDUCTION

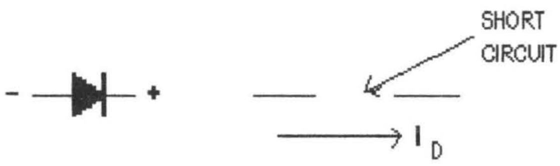


Fig 2.1.5b NON CONDUCTION

To determine whether a diode is in the region of conduction or non-conduction, it is by noting the direction of the current to be established by an applied voltage. If the resultant diode current, I_d, has the same direction as the arrow head of the diode symbol and the polarity of the applied voltage is consistent with that of the diode as shown in fig. 2.1.5a above, the diode is said to be operating in the conducting region. If the resultant diode current, I_d, has the opposite direction and the polarity of the applied voltage is reversed with that of the diode as shown in fig 2.1.5b above, the diode is said to be operating in the non-conducting region. A diode is therefore a short circuit for the region of conduction and an open circuit in the region of non-conduction. Diodes are used for different function, which includes rectification, voltage regulation, clipper logic gates, one-way switch etc. Diodes are of different type and some examples are: PIN diode, zener diode, light emitting diode (LED), varactor diode, photovoltaic cell etc.

Zener diodes are used to provide voltage drop, which is to a large extent independent of the current flowing through the diode. The zener diode is connected in the reserve biased condition.

A light emitting diode (LED) is a diode that will give off visible light when it is energized. Primarily close to the junction and within the structure of a forward biased PN junction, there is recombination of holes and electrons, which require that the energy passed by the unbound free electron be transferred to another state. This energy is given off as heat and sometimes in form of photons. In materials like gallium arsenide phosphide (Ga As P) or Gallium phosphide (Ga, p), the number of photons of light energy emitted is sufficient to create a very visible light source.

2.1.6 TRANSISTOR

The junction transistor is a bipolar device, in that current low in the transistor is due to movement of both holes and electrons. The transistor consist of two PN diodes formed with one common section so giving a three element as shown below:

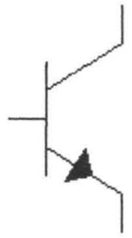


Fig. 2.1.6a NPN TRANSISTOR

Fig 2.1.6b PNP TRANSISTOR

The common section called the 'base' may be of either p or n type semi conductor, resulting in two types of transistor known as the NPN and PNP types. The central base section, which is extremely thin, separates the emitter (e) and collector (c) section of the transistor. The mode of operation of NPN transistor is exactly as that of the PNP transistor except that the polarities of applied voltages and currents and that of the charge carriers are reversed.

Considering the NPN transistor in normal use, as a linear amplifying device, the transistor is used with the emitter to base junction forward biased and with the collector to base junction reversed biased. This means that the emitter is negative with respect to the base because the collector – base junction is reversely biased. Assuming that the emitter connection is an open circuit, then the only current flowing in the collector connection will be the small reverse current of the collector – base junction. And this current is termed the collector – base leakage current (I_{CBO}).

The transistor configurations available as shown in fig 2.1.6c – 2.1.6e are:

1. Common base configuration.

2. Common emitter configuration.

3. Common collector configuration.

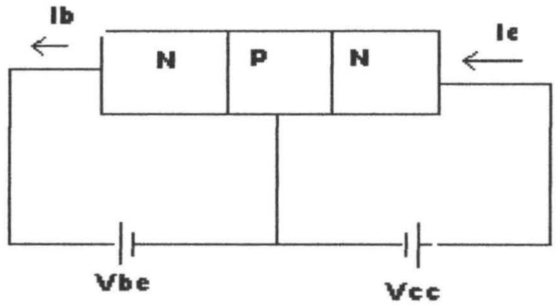


Fig. 2.1.6c COMMON BASE CONFIGURATION

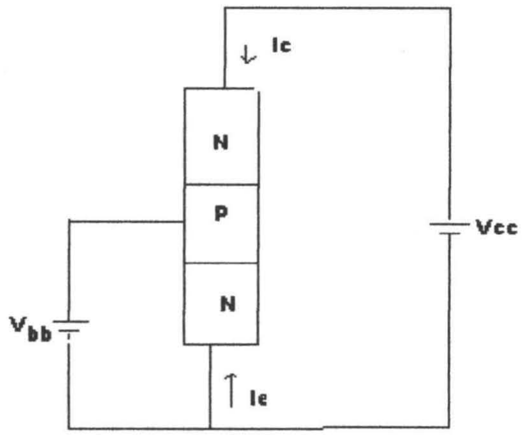


Fig. 2.1.6d COMMON EMITTER CONFIGURATION

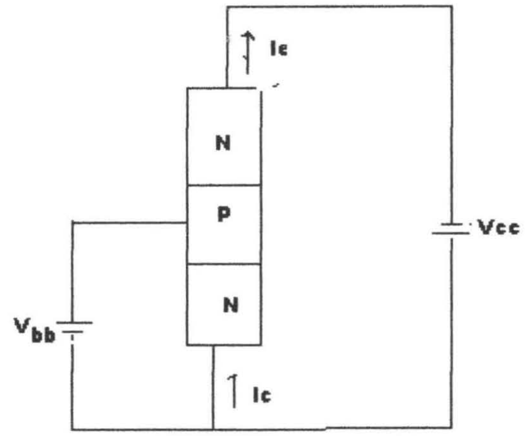


Fig 2.1.6e COMMON COLLECTOR CONFIGURATION

Transistor can also be used as switch. At saturation, the current IC is quite high and the Voltage V_{Ce} very low. The resultant is a resistance level between the two terminals determined by:

$$Rsat = \frac{V_{ce}sat}{Ic\ sat}\ (\Omega)$$

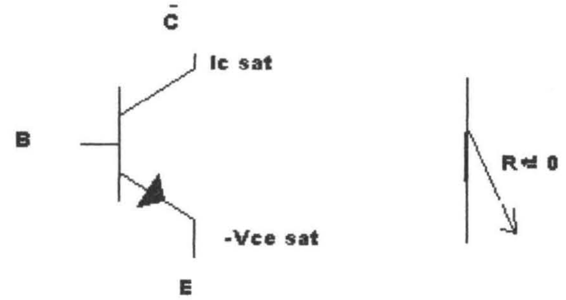


Fig. 2.1.6f SATURATION CONDITION AND ITS RESULTING TERMINAL

When input voltage is equal to zero (Vi = 0); cut off condition will result in a resistance level of the following magnitude:

$$R_{cut\ off} = \frac{Vcc}{Iceo} \cong 0(\Omega)\ \text{(i.e. tends to zero)}$$

The infinity resistance value is an open circuit equivalent.

2.1.7 TRANSFORMER

A transformer is a piece of electrical apparatus which consist of two or more electrical circuit interlinked by a common magnetic circuit for the purpose of transferring electrical energy between them. It is basically two coils of wire which share a single core and this coils are physically positioned so that energy is transferred from one coil to the other. A transformer therefore is a static device that:

1. Transform electrical power from one voltage and current level to the other.
2. It does so without a change of frequency.
3. It accomplishes this by electromagnetic induction and.
4. Where the two electric circuits are in mutual inductive influence of each other.

It works with little power loss and high efficiency of the order of 98%. Transformers that convert voltage to a high level are called step-up transformer while those that convert voltage to a lower level are called step-down transformer. The first coil, in which electric energy is fed from the AC supply mains, is called primary winding and the other from which energy is drawn out, is called secondary winding.

If the number of turns of wire on the secondary side is larger than that of the primary, the voltage at the secondary side would be larger than that voltage at the primary side. And if the numbers of turns of wire on the primary is larger than that on the secondary, the voltage at the primary side would be greater.

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

For current transformation, if the number of turns of wire on the secondary is greater than that on the primary, the secondary current will be less than that current in the primary,

$$\frac{I_2}{I_1} = \frac{N_1}{N_2}$$

Fig 2.1.7 below shows a typical transformer core with its winding and the circuit symbol

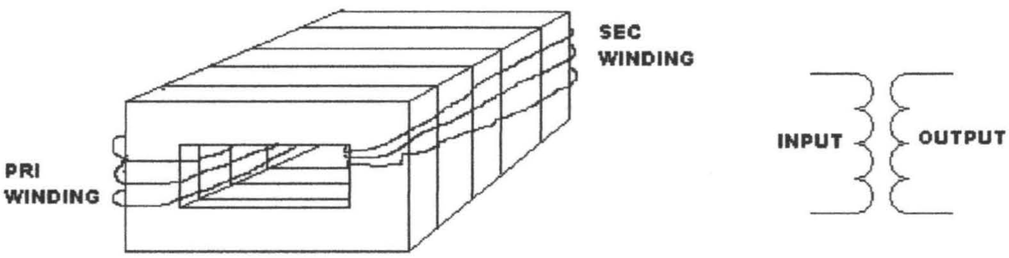


Fig 2.1.7 THE TRANSFORMER

2.1.8 RELAY

A relay is an electrically operated switch. Electric current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contact. The coil currents can be on or off so relays have two switch positions and they are double throw switches. It allows a circuit to switch a second circuit which can be completely separate from the first. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical. Relays are usually single pole double throw (SPDT) or double pole double throw (DPDT). Relay's switch connections are usually labeled normally open (NO); normally close (NC); and (COM).

In choosing a relay, the following features should be considered

1. Coil voltage.
2. Coil resistance.
3. Physical size and arrangement.
4. Switch ratings (voltage and current).
5. Switch contact arrangement (SPDT, DPDT, etc)

Fig 2.1.8 below shows a typical relay with its usual labeled switches connection

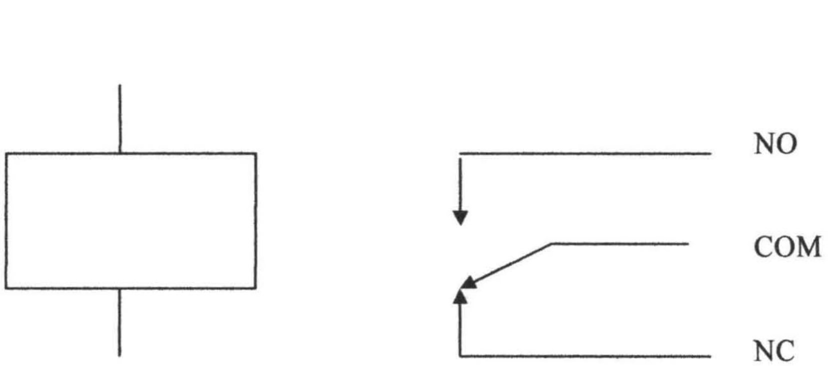


Fig 2.1.8 CIRCUIT SYMBOL FOR A RELAY

Advantages of relay are that:

1. They can switch AC and DC.
2. The can switch high voltage,
3. They are better choice for switching large currents (Greater than 5A).
4. They can switch many contacts at once.

2.2 PROTECTION FOR RELAYS AND OTHER COMPONENTS

A signal diode is connected across the relay coil to provide a protection against brief high voltage spike produced when the relay coil is switched off. This is done to protect transistors and ICs (chips) from being damaged.

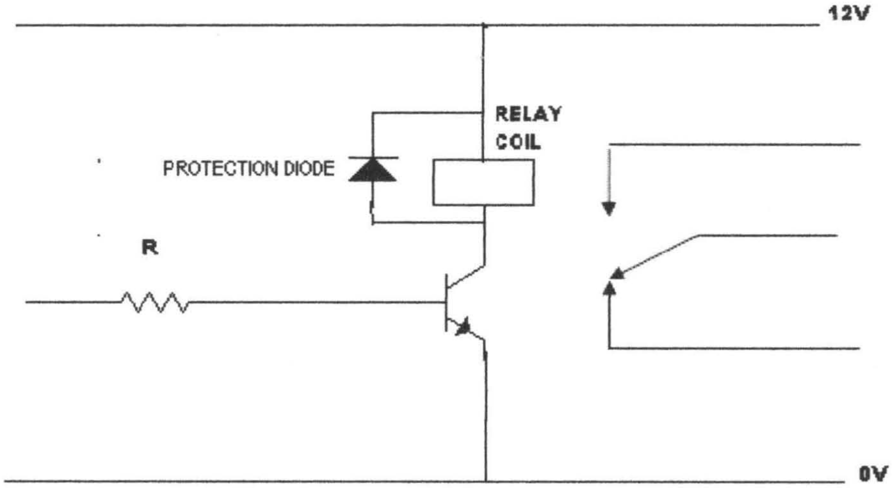


Fig. 2.2.6 CIRCUIT FOR RELAY PROTECTION

CHAPTER THREE

3.0 DESIGN PROCEDURE AND CALCULATIONS

Basically, the phase selector is a two-stage phase to phase components having the first stage of comparison by selecting the higher input of transistor Q_1 and transistor Q_2 and passing the selected phase to the second caparison stage to select the higher input between the compared input in the first stage and a phase of transistor Q_3.

The design of the Automatic three phase changer involves the design of:

i. A suitable power supply.

ii. Potential divider comparator.

iii. The Driver.

iv. The control and switching.

3.1 THE DESIGN OF THE POWER SUPPLY

In designing any power supply, it is necessary to determine the rating of the transformer. It can be done provided that Transformer Utilization Factor (TUF) is known. The value of TUF depends on the amount of power to be delivered to the load and the type of rectifier.

$$TUF = \frac{\text{(DC power delivered to the load)}}{\text{(AC power rating of the transformer secondary)}}$$

$\therefore$ AC rating of the transformer = DC power delivered to the load x TUF

COMPONENTS	QTY	CURRENT	TOTAL CURRENT mA	VOLTAGE
Relay	3	12V/100	0.12	12V
Others		100mA	10mA	
Total Estimate			10.12ma	12V

The D. C. power delivered to the load is thus given by

$P_{AC} = 12V \times 10 \times 12mA = 121.44 Watts$

For full ware rectifier, TUf = 0.693

Therefore, the rating of the transformer $= \frac{121.44}{0.693} = 175.24$ watts

3.2 THE SELECTION OF THE RECTIFIER

The rectifier used is full wave bridge rectifier that is used frequently for electronic circuit using D. C. power supply. It requires four diodes with a transformer of a maximum voltage (V_{5m}). The diagram below shows the full wave bridge rectifier.

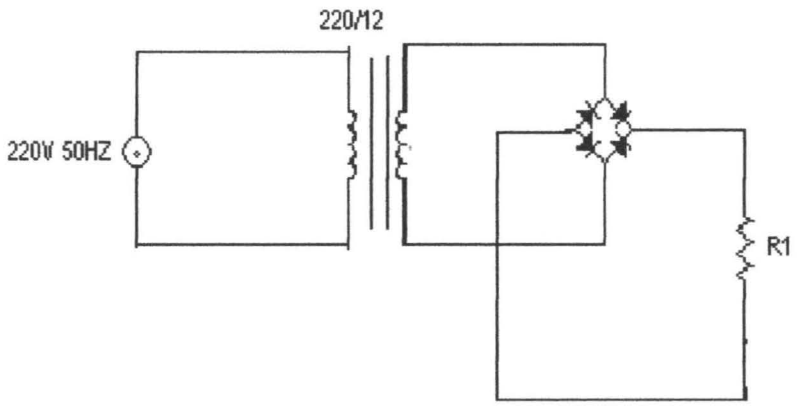


Fig 3.2: FULL WAVE BRIDGE RECTIFIER CIRCUIT.

i. **Average and r.m.s value**

$$V_1 = \frac{V_m}{\sqrt{2}} = 0.707Vlm \quad \text{(i)}$$

$$V_{L(DC)} = \frac{2\,V_{LM}}{\delta} = 0.707V \quad \text{(ii)}$$

$V_{L(AC)} = \sqrt{\{V_L^2 - V^2_{L(DC)}\}}$ (iii)

ii. Peak Inverse Voltage (PIV)

The peak inverse voltage rating of each of the four diodes is equal to V_{sm}(the entire voltage across the secondary). Therefore the peak inverse voltage rating of the four diodes is $V_{sm} = \sqrt{2} \times V_s$. where V_s is the r.m.s value of secondary.

$$V_{sm} = \sqrt{2} \times V_s \quad \text{(iv)}$$

$$\therefore V_{sm} = \sqrt{12} \times 12V = 6.97 \times Vs = 12V_s$$

With a safety factor of 1.5, then PIV = 19.97 x 1.5V

$\therefore$ PIV = 25.45V

iii. Ripple factor

$$\delta = \frac{V_{L(AC)}}{V_{L(DC)}} \quad \text{(v)}$$

$$V_{L(AC)} = \sqrt{\{V^2_L - V^2_{L(DC)}\}} = \sqrt{\{V^2_{L1} - V^2_{L2}\}} \quad \text{(vi)}$$

$$V^2_{L1} = \frac{4V_{LM}}{\sqrt{2} \times 3 \times 3.14} \quad \text{(vii)}$$

$$V^2_{L2} = \frac{4 \times V_{LM}}{\sqrt{2} \times 15 \times 3.14} \quad \text{(viii)}$$

$$V_{L(AC)} = \frac{(4 \times V_{LM})}{(\sqrt{2} \times 3 \times 3.14)} + \frac{(4 \times V_{LM})^2}{(\sqrt{2} \times 15 \times 3.14)} = 0.305V_{LM}$$

$$\delta = \frac{V_{L(AC)}}{V_{L(DC)}} = \frac{0.305V_{LM}}{0.636V_L} = 0.482$$

3.3 SELECTION OF FILTER

The main function of a filter circuit is to minimize the ripple content in the rectifier output. The output of various rectifiers' circuit is pulsating. It has a DC value and some AC components called ripples, therefore, the output is not useful for driven electronic circuit / devices. As a matter of act, these circuits require stead DC output that approaches the smoothness of a battery's output. A shunt capacitor filter is shown in the figure below:

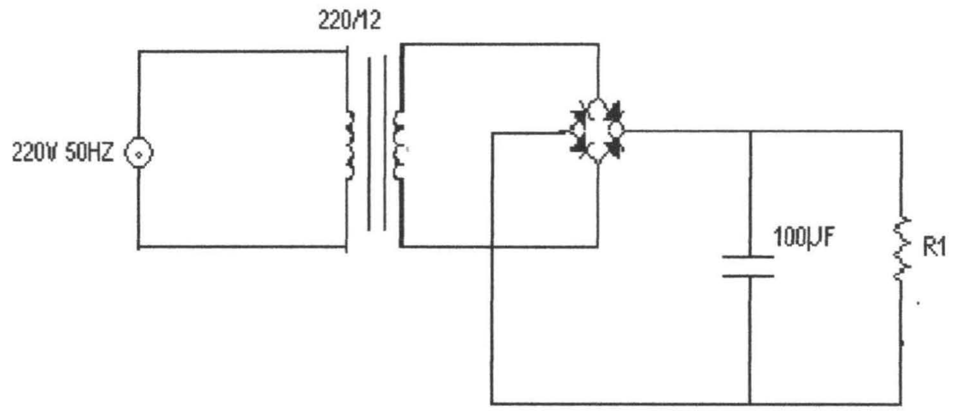


Fig 3.3a: OUTPUT OF SHUNT CAPACITOR FILTER CIRCUIT.

$V_{r\,(p\text{-}p)}$ is the amount by which capacitor voltage falls during discharge period and can be approximated to a straight line discharge if we assume the discharge rate to remain constant at DC level, I_{DC} therefore charge lost dQ in time Tr is I_{DC} x Tr.

i.e $\quad dQ = I_{DC} \times Tr.$

$$\therefore V_{r(D\text{-}p)} = dQ/C = \frac{I_{DC} \times Tr}{C} = \frac{V_{DC}}{fr \times R_L}$$

$$\text{Where } I_{DC} = \frac{V_{DC}}{R_L} \text{ and } Tr = \frac{I}{fr} \qquad \text{(ix)}$$

Triangle ripple has an r.m.s value given by

$$V_{rms} = \frac{V_{r(p\text{-}p)}}{2 \times \sqrt{2}} \qquad \text{(x)}$$

Substituting eqn (ix) into eqn. (x), we have

$$V_{rms} = \frac{V_{DC}}{2 \times \sqrt{3} \times fr \times c \times R_L} \quad \text{(xi)}$$

Since fr equals to double of the time input frequency for a full wave rectifier.

$$\delta = \frac{V_{r(p-p)}}{V_{DC}} \quad \text{(xii)}$$

$$\delta = \frac{1}{2 \times \sqrt{2} \times fr \times R_L \times C} \quad \text{(xiii)}$$

$$\delta = \frac{I_{DC}}{4 \times \sqrt{3} \times f \times C \times V_{ip}} \quad \text{(xiv)}$$

$$\therefore C = \frac{I_{DC}}{4 \times \sqrt{3} \times \delta \times C \times V_{ip}}$$

In the power supply used for the design circuit, the secondary load current of the transformer is I_L = 500mA.

Therefore, $I_{DC} = \frac{2 \times \sqrt{2} \times 500}{3.14} = 450.15mA$

Since $V_{IP} = 12V$

$$C = \frac{450.15 \times 10^6}{4 \times \sqrt{3} \times 50 \times 0.482 \times 12} = 2.2459 \times 10^{-4}$$

$$C = 2.2459 \times 10^{-4} \times 10^6 = 224.59\mu F.$$

Since a bigger capacitor would tend to reduce the ripple magnitude, therefore a filter capacitance of 1000μF is used in this circuit.

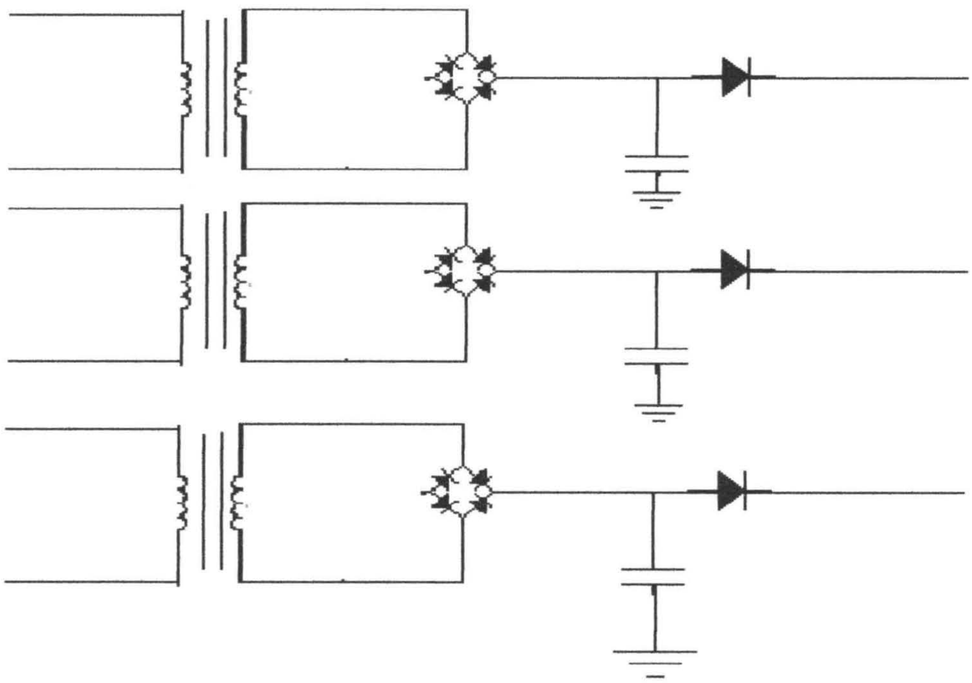


Fig 3.3b: Power Supply Unit.

3.4 THE DESIGN OF THE DRIVER

The driver employed in this project is a switching circuit of transistors. The transistors used have a gain of 200V to 300V with frequency of 80MHz, collector current I_C max of about 0.15A, V_{CBO} 0f 60V and a maximum power dissipation of 0.4volts. V_{BE} ranges from 0.64V to 0.72V but adequate base drive has been provided to meet all switching conditions.

The transistor calculation is thus:

$$V_{CE} = V_{CC} - I_C R_C \qquad (1)$$

Where R_C = Relay Resistance

The diagram below shows the transistors driver circuit.

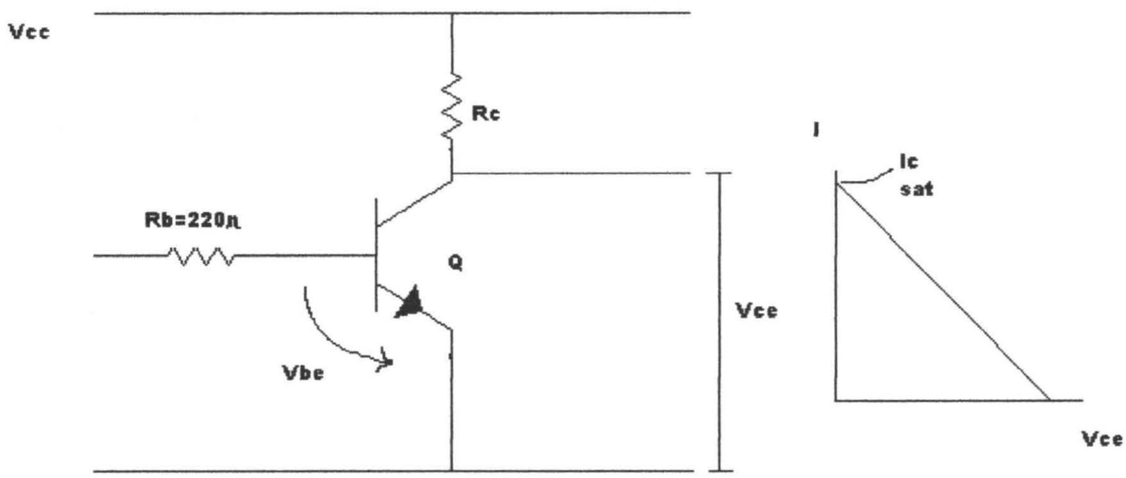


FIG: 3.4 THE TRANSISTOR DRIVER'S CIRCUIT AND ITS CHARACTERISTICS

In the above application, the switch in the non-wear portion of its operating characteristics. For a large enough value of Base current, I_B, the transistor Q_1 saturates if $V_{in} \geq V_{BE}$.

Assuming $V_{BE} = 0.7V$ (for typically silicon made transistor)

$$\therefore I_B = \frac{V_{in} - V_{BE}}{R_B} \qquad (2)$$

$$\text{And} \quad \frac{I_C}{V_{CE}} \qquad \frac{\beta I_B}{V_{CC} - I_C R_C} \qquad \begin{matrix}(3)\\(4)\end{matrix}$$

For the project work, V_{in} is derived from the mid point of the potential divider formed by the two 10kn resistance. The transistor switches on when V_t (mid point voltage) is greater than or equal to 0.72V

$$I_B = \frac{0.72 - 0.7}{220} = 91\mu A$$

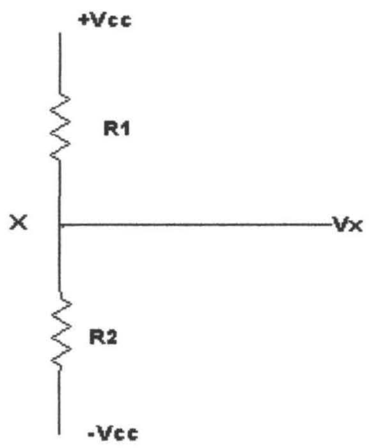
$$V_{CE} = V_{CC} - I_C R_C i$$

I_{CC} hfe = 300 (typical)

$= 12 - (R_C \times 0.027273)$

3.5 THE POTENTIAL DIVIDER COMPARATOR SELECTION

The circuit responsible for the potential divider comparison is shown below:



To deduce the voltage at midpoint X i.e V_{+1}, the equation below holds:

$$\frac{\{|+V_{CC}| + |-V_{CC}|\} \times R_2}{R_1 + R_2} - |-V_{CC}|$$

Where $+V_{CC} = -V_{CC}$. $V_x = 0v$

If $+V_{CC}$ is greater than $-V_{CE}$, V_t is greater than 0v and if $-V_{CC}$ is less than $-V_{CC}$, thus V_x is less than 0 volts.

R_C = relay coil resistance = 430Ω

V_{CE} = 12 – {430 x 0.027273}

= 12 – 11.72939V

= 0.27261V

$I_C = \frac{V_{CC}\ Amps}{430} = 27.907mA$

Power dissipation =

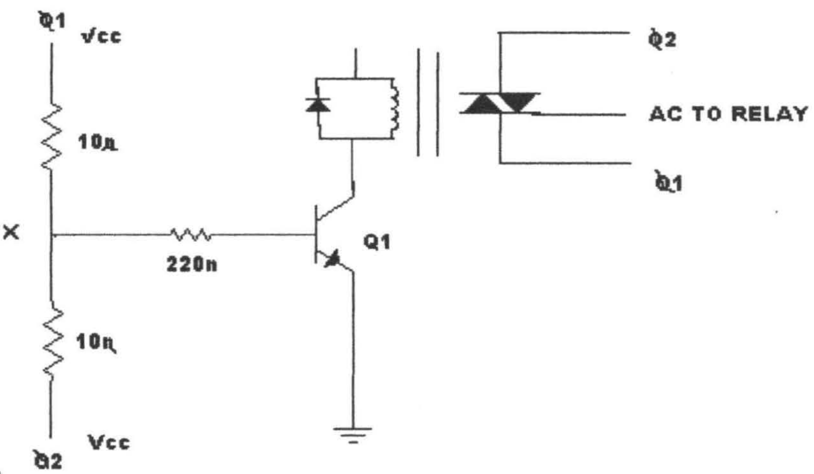
$$V_{CC} \times I_C = (0.27261 \times 27.907)W$$
$$= 7.6077mW$$

3.6 MODE OF OPERATION

The automatic phase changer or selector works on the principle of the detection of a higher voltage in one phase and it is comparison based.

The three phases are fed into the system via three 12v – 0 – 12v, 0.5A transformers and the outputs of each transformer feeds a full-wave bridge rectifier dual output to convert the AC input to DC.

Two voltages are used for the comparison, a positive and negative voltage. Phase 1 is compared with phase 2 by applying the positive output of phase 1 rectifier to the top end of a potential divider formed through the series connection of two 10kn resistances whose midpoint is connected to the base of a sanitary transistor as shown in the circuit diagram in fig 3.6a The negative voltage from phase 2 rectifier is applied to the lower end of the potent



ial divider.

Fig 3.6a: THE POTENTIAL DIVIDER CIRCUIT

Depending on which voltage is higher (which is a function of the voltage on each phase), the midpoint x goes either positive or negative with respect to ground. If phase one is greater than phase two, x will assume a higher positive potential and the phase difference is greater than 12V, X rises to a value high enough to switch the associated transistor on, selecting phase one which is connected to the normally open contact of the relay.

If phase two is greater than phase one, x assumes a negative level which effectively turns the transistor off. The phase selected in the first comparison is now compared with a third phase (phase three). In addition to switching between phase one and phase two, phase one also provides a switching of the negative voltage associated with each phases rectifier. The negative output of the selected phase is now compared with the positive output of phase three's rectifier as shown below.

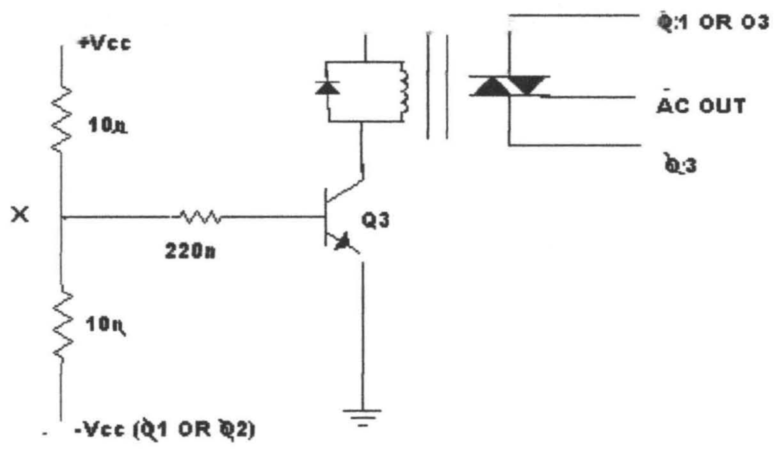


Fig 3.2b: CIRCUIT FOR COMPARISM OF PHASE THREE WITH SELECTED PHASE OF ONE OR TWO

Depending on the magnitude of the signed voltages across the potential divider, the point Y can either be positive or negative. If phase three is higher in voltage, phase three switches on. If the phase difference is greater than 12V i.e phase three is greater than the phase selected in the first selection by 12V or more. If the phase selected during first selection is passed on to the output as the selected AC source. If both phases are equal in level i.e $|Q_3 - Q_4| < 12V$, a default phase, which is phase two in this project is selected.

Satisfactory operation is guaranteed by using relays capable of operating on a wide range of voltages i.e $6V \approx 12V$, with 10A contact current capacity. Hence, this prototype phase selector is limited to operating appliances with a rated maximum power requirement of 2400watts; (i.e. 240V x 10A).

For a higher power switching capability, contractors would be used or heavy duty relays with contact current up to 100A; though these could not be found during the construction work.

When the transistors saturate, $V_{CE} = 0.11V$

$$\text{Resistance } \delta \text{ relay coil} = 403\Omega$$

CHAPTER FOUR

4.0 CONSTRUCTION AND TESTING

4.1 CONSTRUCTION

The construction of this project involves the use of various components. These components comprised of both the passive and active devises. Examples of passive components are resistors, capacitors and relays while that of active components are transistors and diodes.

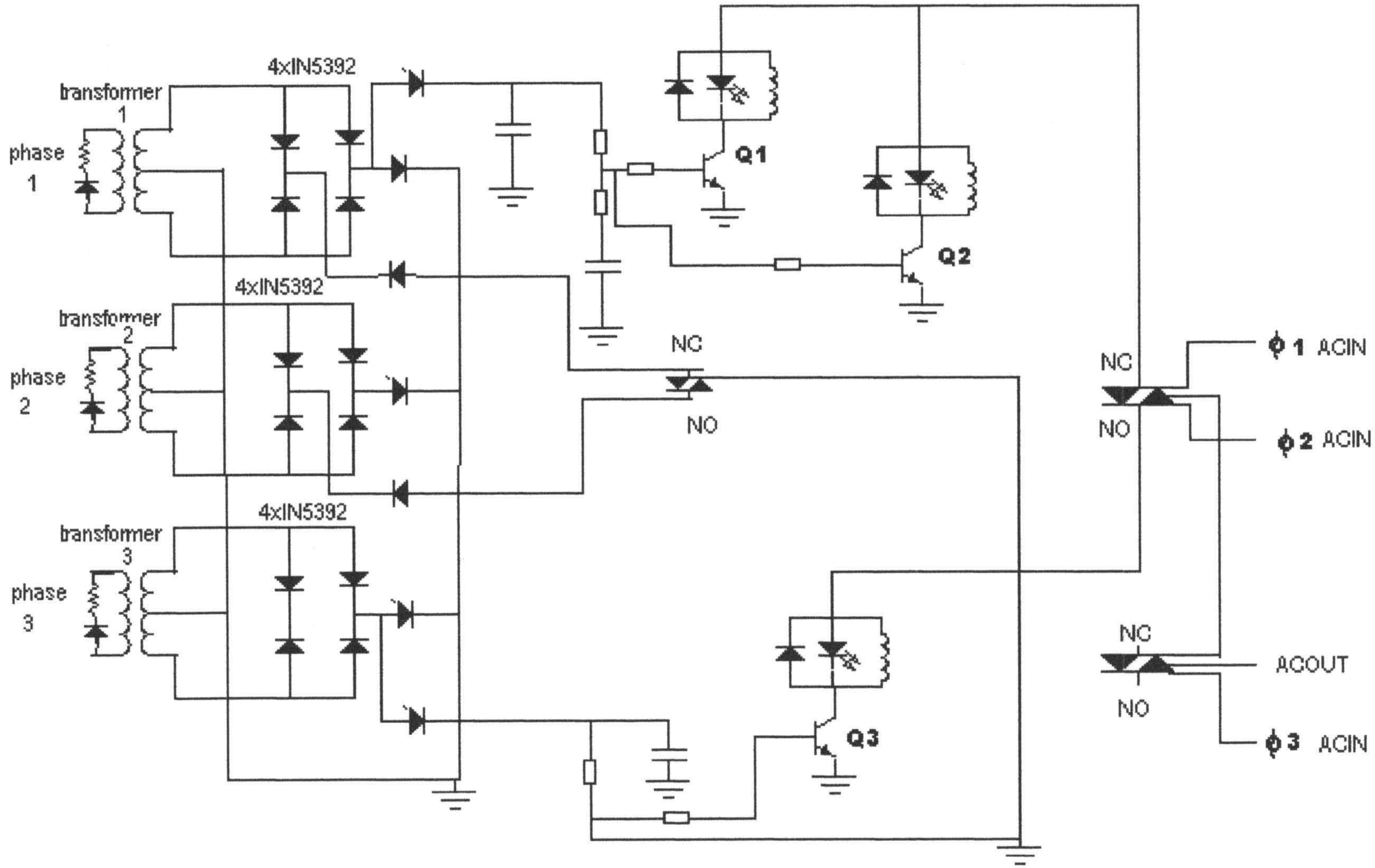
Before construction, each component was subjected to series of tests to confirm that they are in good condition. The major instrument used to carry out this test was Multimeter. Other component used is transformers.

The tool used during construction procedure include soldering iron, vero-board, pliers, set of screw drivers, hammers, soldering lead, soldering sucker, files, drilling machine, cutter and a digital meter.

The circuit construction is divided into two stages namely, the power supply stage and the control circuit & driver stage. They are built on a single board measuring 18cm X 18cm and the construction started by designing the component layout for the system shown in figure 4.1 and then implemented on a board. This was done in such away that minimal space was used.

The transistors were soldered on the board with minimum heat to prevent damages of components especially the passive ones. Other components were then fixed on the board in their various positions. Before soldering, proper checking of components connection was done. Polarized components such as electrolytic capacitors were checked to ensure they were fitted in the right way and right terminals.

The choice of material used for the construction of casing is rubber tile based on the cost, the workability and physical outlook of equipment. The casing was perforated



THE CIRCUIT DIAGRAM OF AUTOMATIC PHASE CHANGER for ventilation purpose to prevent deformation and damage of the device due to heat build-up when device is in operation.

4.2 COMPONENT TESTING.

The components used in the design and construction of this project were carefully selected and the nearest values of components were chosen where calculated values were not readily available. Multimeter has been of great help in the testing procedure of each component and the overall testing of this project. It helps to tell the state of the components whether good or bad. It also gives the workability of each stage of construction.

4.2.1 RESISTOR TESTING.

I – the Multimeter was switched to the ohmic range

II – The [probes of the meter were placed on each side of the resistors irrespective of the terminal

II – The resistance value of the resistor was read on the display

4.2.2 DIODE TESTING

- The ohmic range of the Multimeter was selected.

- The negative probe of the meter was placed on the cathode side of the diode and the positive probe of the anode.

- For forward biased condition, a low resistance was observed and for reversed condition, open circuit occurred.

4.2.3 CAPACITOR TESTING.

- The ohmic range of the Multimeter was selected

- Probes are placed accordingly, based on the polarity of the meter and capacitor.

- Increase of the resistance value confirms the good condition of the component.

- If the value is constant, the component is bad.

4.2.4 TRANSISTOR TESTING.

Placing probes on any of the two terminals of a transistor an output is obtained as shown below.

POSITIVE	NEGATIVE	RESULTS
E	B	Open circuit
E	C	Open circuit
B	E	Low resistance
B	C	Low resistance
C	B	Open circuit
C	E	Low resistance

4.2.5 TRANSFORMER TESTING

For a step-down transformer, higher resistance at its primary side as compared to its secondary side confirms its good condition.

4.2.6 RELAY TESTING.

- Ohmic range was selected

- When the common of the relay is connected to one pin and there is no deflection, the pin is the normally open terminal (NO) and when there is no deflection, it is normally closed terminal (NC).

4.3 VERO- BOARD AND COMPONENTS ARRANGEMENT

Copper Vero-board was used for the construction. This board is of two types. They are

(i) Copper matrix Vero-board: It is a semi-printed board, curve connection of soldering is allowed and thus little use of jumper wire. It makes connection of joints tidier but however consumes more lead.

(ii) Copper strip Vero-board: Only straight connection is allowed and more use of jumper wire.

A copper matrix board was used for the purpose of this construction. The arrangement of components was on segments basis so as to follow normal flow of signal. They were reasonably placed but somehow closed due to number of components used as compared to the size of the board. The spacing is however moderate. Jumpers were also used to link points on the board where components could not be connected directly. This also enhances proper soldering.

4.4 SOLDERING PROCEDURE AND PRECAUTIONS

Soldering is a process by which electrical connection is made between two or more components through the printed copper conductor to form a continuous path and normal flow of current using soldering lead.

The soldering was properly and carefully done and a method of joint -to - joint method was used. Dry joints were avoided and soldering of low melting points was used. Since application of heat can damage these components, care was taken while soldering semiconductors.

The following precautions were considered during the process of soldering.

1. A light duty soldering iron was used
2. Excessive heat was prevented to avoid damage
3. The surfaces to be soldered were made clean

Inspection was however made after soldering to ensure that the components were well soldered and that the connections were right.

4.5 OVERALL TESTING AND COUPLING.

Various stages of the project were tested after construction. The output of one stage was ensured to be alright before coupling them to the other stages. This was followed by general testing.

4.6 CASING CONSTRUCTION

The casing for the device has been designed putting some factors into consideration. These factors include strength of the material and also cost. Another factor that is most important is prevention against electric shock thereby ensuring the safety of the people using the device. Having considered all these factors, a rubber tile was carefully selected. Mechanical strength and the weight of the components were also taken into consideration. The dimension of the casing and the isometric projection of the device is shown in fig 4.6 below.

Length = 18cm

Breadth = 18cm

Height = 15cm

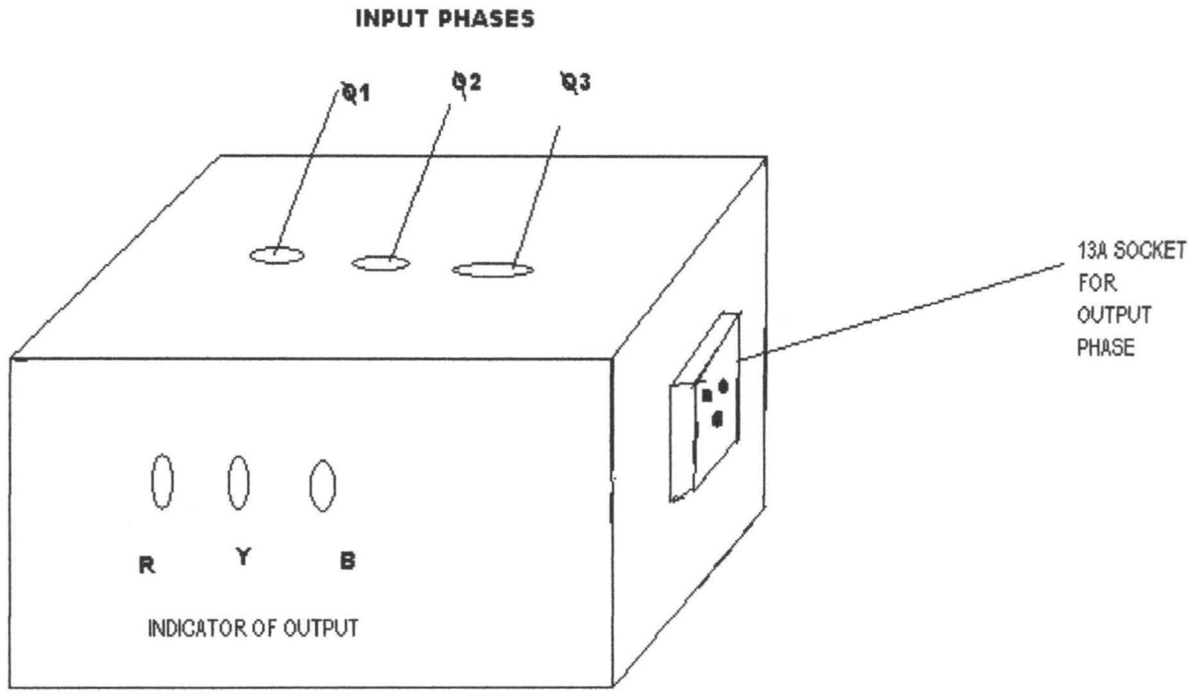


FIG 4.6: ISOMETRIC PROJECTION OF THE CASING

CHAPTER FIVE

5.0 DISCUSSRION OF RESULT, CONCLUSSION AND RECOMMENDATION.

5.1 DISCUSSION OF RESULT

Various appliances are connected to the output of the device and each of the sub-system performed its normal operation as expected once switched on. The output of the device is measured and was found to be that the highest of the three phases input was selected. At a point when the three phases input were the same, phase two that serve as the reference voltage/phase was selected.

The fluctuation of the supply was directly observed and monitored by the device and the selected phase indicated by the light emitting diodes (L E D) connected to the front of the box or casing.

5.2 CONCLUSSION

The main objectives of this project being the design and construction of automatic phase changer has been achieved and has provided both theoretical and practical knowledge in terms of exposure and experience while transforming the design circuit diagram to reality (actual construction).

The project was not only able to switch automatically but also gives desired additional features like phase indicators, selecting the highest voltage level at any instant of time and when any of the phases goes off. This gives enough credit to knowledge.

The results obtained from the tests carried out have justified the appropriateness of the desired modifications, constructional details and improvisation carried out in this project. Though so challenging and tasking, the project has however been a success.

5.3 RECOMMENDATIONS

Though the main objective of this project was achieved, the following can be made to improve on the rating and performance

(i) A digital display may be included so as to show both the input voltage that is been supplied to the device as well as the output level that is given out by the device.

(ii) Solid state relay and some other digital integrated circuits could used to increase the rate of switching.

On a final note, to improve the performance of the device, the output of the device should be regulated to properly handle variations in the power line as required for domestic supplies by IEE regulations

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