DESIGN AND CONSTRUCTION OF AUTOMATIC BATTERY CHARGER WITH OVER VOLTAGE PROTECTION

BY:

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FOR THE AWARD OF:

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IN

ELECTRICAL/ COMPUTER ENGINEERING.

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DECLARATION

I hereby declare that this project work was wholly and solely conducted by me under the close supervision and guidance of Engr. Asula of the department of Electrical and computer Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna.

Student's Signature: ____________________

Date: ____________________

Supervisor's Signature: ____________________

Date: ____________________

CERTIFICATION

I hereby certify that this project titled: ***Design and Construction of automatic battery charger with overvoltage (surge) protection*** was carried out by : Musa Salihu Makoju, under the supervision of Engr. T Asula of the department of Electrical/ Computer Engineering. Federal University of Technology, Minna, Niger state – Nigeria.

Supervisors' Name: ***Engr T. Asula***

Supervisors' Signature: ______________________

Date: ______________________

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H. O. Ds' Signature: ______________________

Date: ______________________

External Examiners, Name: ______________________

External Examiners' Signature: ______________________

Date: ______________________

DEDICATION

This project work is dedicated firstly, to Almighty Allah. whom, by His kindness, gave my parents the wisdom to send me and see me through school; and secondly, to my parents: Alhaji and Mallama Salihu and Fatimah Salihu Makoju: thirdly, to my brothers: Mallam Mohammed Jamiu Salihu Makoju, Hassanah and Hussainah Salihu Makoju (now married); Hauwa'u Salihu Makoju, Rahmatullah Salihu Makoju, Abdulrahman and Yusuf Salihu Makoju. Sayeedah and Maryam Salihu Makoju and lastly, my step mum: Mallama Halima Salihu Makoju.

ACKNOWLEDGEMENT

I would have loved to list all the good friends I encountered during the cause of my schooling in the University, but sincerely speaking, some I might have forgotten their names but not their faces: Some are late, and for those living, I appreciate you all. Amongst them all not in the order of importance are: Allah (S.W.T), who gave me life and strength to bring this course to a logical conclusion, my parents and Siblings; my guardian and his family i.e. Mr. Janmah Stephen Usman of FUT Staff School, my big uncle of NDIC, Abuja i.e. Alhaji Ahmed Abdul Ganiyu and family, big friends and brothers i.e. Alhaji Abdulkadir, O. Isah; Alhaji Murtala Sani Omolori, Mr Ajake Amoto Abdul; Alhaji Aminu Saifudeen (HOD, Civil/Building, FAAN Minna Airport); Alhaji Dahiru Gado, FAAN, Minna ; Mr. Emmanuel Asuquo (Rainbow Computers); Mr. Dele Alabi, (DANA, Kaduna) and a host of others which space will not permit me to mention.

My high regards equally goes to the present Head of Department, Electrical/Computer Engineering, Engr. Musa Danjuma Abdullahi (FNSE, MSC), whom I would describe as magnanimous, easy going, gentle and above all, very kind, sometimes, some of the uncommon things you display uncommonly could be responsible for true fulfillments and happiness because, in trying to impart in others happiness, you derive joy yourself. I say may Allah reward you abundantly. This Indian proverb fits you most appropriately: "That you are just like a cloud that receives only but to give away". Keep on the good work.

To my able Supervisor, my mentor, jovial but frank, a knowledge and authority in his own field, a grade 'A' teacher and student as well, a realist who is angered by nonchalance and non performance but forgives and overlooks. The little time I have spent with you have taught me something: that: there are still very jovial, loving people and that, one keeps meeting them every day. Engr. Asula, I say thank you and I appreciate you so much.

I would equally want to acknowledge the efforts of some of my lecturers as thus: Engr. Usman, Engr. Isah Rumalah, Engr. Attah and all other support staff of the Electrical/Computer Engineering department.

This acknowledgement will be incomplete without given deserving honour to whom it is due. This honour is due to my big brother and friend, kind, understanding, loving, sharing guiding and caring, this is all due to you. Mr. Onah Hillary Osondu of the department of Mathematics/Computer Science, Kaduna Polythecnic, Kaduna. You are truly a worthy friend, for you know, we all need people who can advise, inspire, encourage and help us to perform better. These does not only seek to reduce our

burdens, struggles and stress, but they help us to avoid costly mistakes by minimizing our liabilities and maximizing our opportunities. No man is an Island says Jonne Done. I thank you very much. To those I forgot to mention. this is not deliberate.

TABLE OF CONTENT

LIST OF FIGURES

ABSTRACT

Over the years, many power supplies and chargers have been built, but this power supply makes use of minimum components and the charger is automatic in that it does stop charging when the battery is fully charged with visual indicator to help a passer by understand. (Red L.E.D).

The -12V to + 12V power supply meets the 95% voltage required at home and in the laboratories for normal operations. The charger could charge batteries requiring less than and up to 12V, such as Car batteries, it can equally be used to charge other types of batteries.

The theory, design, circuit analysis and block diagrams with values are provided to give adequate information about the design. The circuit was tested and assembled and it performed satisfactorily.

CHAPTER ONE

1.1 INTRODUCTION

Charging a battery implies causing electrons to migrate into the terminals i.e (positive and negative). The electrons are caused to flow or migrate from a source which is at a higher potential than the instantaneous potential of the battery to be recharged. The source of the migrating electrons is reffered to as battery charger which is usually powered by A.C mains of 230V supply. The charger converts the A.C into appropriate D.C level to charge the battery.

Before this present time, battery chargers were usually made up of very big transformers with a power diode for rectification, these types of batteries are very bulky and non-automatic due to the electrical components used in the design, thus, they consume and waste power.

This project intends to divulge into automatic battery charger with over voltage protection. It is automatic because unlike the conventional battery chargers which as earlier stated use only transformer and power diodes, this uses silicon Controlled Rectifiers (SCR.) as switches, which regulates the influx of electron into the charging ports of the battery (terminal).

However, for the SCRs to operate, power supply giving rise to direct current are quite essential. The constant power supply has to be rectified to direct current. The constant power supply is sinusoidal in i.e. alternating from the positive path to the negative path on a Curve-linear path when displayed on an oscilloscope. Rectification involves changing the alternating current output to direct current out put by continual reversal of it's direction of flow, rising to a maximum value on one direction, dropping to zero, and then rising to maximum in the opposite direction.

To change such an oscillating signal into a unidirectional path, a device is required that allows current to flow in one direction but prevent flow in the opposite direction. Such a device is known as a diode.

If an alternating current is applied to a diode, there would only be conduction during one half cycle giving pulsating but unidirectional output. This is termed half wave rectification. Efficiency result if both halves of the alternating input cycles were used. This can be achieved by using two diodes coupled together; each arranged to conduct at alternate cycle, this is termed full-waves rectification.

A simply rectified output consist of a series of half sine waves, though, it is not smooth. The non-smooth nature is due to variation in power supply which is termed as Ripples. This ripples produces intolerable and unacceptable hum in audio and amplifying circuits. A filter is thus adopted to smoothen the rectified output. A filter consist of suitable arrangement of a capacitor and/ or an inductor with a desirable resistor, the capacitor is charged by the unsmooth output and slowly discharges until recharged to peak value by the next current wave. This gives rise to direct current with a reduced amount of ripples. A practically pure direct current is obtained by adopting an improved capacitor with high capacitive reactance.

Variation in the alternating input result in fluctuation in the rectified output. When a constant output is required, some means of stabilization is adopted at the output. This is done by passing the rectified output through a device whose conducting properties are essentially independent of the input.

In Chapter one, battery charger and over voltage protection was introduced. The charger and the power supply has a variable voltage supply to cater for both laboratory and domestic needs. Literature Review is also made herein.

Chapter two discusses brief history of batteries, the chemistry and different types of batteries, different forms of charging is equally discussed, battery ratings, battery failure, effect of temperature and the direction of current flow in batteries were discussed. Furthermore, the transformer, rectifiers and their various forms i.e. half-wave rectifier, full-wave rectifier and the bridge-rectifiers were discussed. Filtering circuits and voltage regulators were not left out of the discussion.

Chapter Three discusses how the power supply and the charger were designed. This chapter is further divided into sections, section one comprised of the transformer, rectifier and switch. Sections two consist of smoothening of the rectified voltage and voltage regulators. Section three consist of the charging section for the 12V battery charger. the principle of operation and the power supply were also discussed.

Chapter four discusses the layout, construction and testing of the entire project.

Chapter five is testing, conclusion and recommendation about the project.

Attached is Appendix A: Circuit diagram.

1.2 LITERATURE REVIEW

The design of modern batteries dates back from the discovery by an Italian, Alexandro Volta. In the year 1800, he described the first battery known as Volta pile or Voltaic cell. It consisted of a number of cells in series, each made up of a disc of silver, a disc of paper or cloth soaked in salt solution, and a disc of zinc. The first cell not subject to polarization was developed by John Daniell in 1836. His cell has negative electrode which was dipped into a dilute sulphuric acid electrolyte and a positive electrode of copper in a saturated copper sulphate solution. The two liquids were separated by a porous membrane. A conventional depolarizer was first used in 1839 by Sir William Grove. who made a cell which consisted of a zinc negative electrode dipped into dilute sulphuric acid and separated by a porous pot from the depolarizer-nitric acid- which is surrounded by a positive electrode of plantinum. Robert Bunsen Later replaced the plantium with carbon. The Lechlanche cell was presented in 1868 by Gerges lechanche.

At first, these cells were principally used to recharge storage batteries or accumulators of the lead-acid type.

CHAPTER TWO

A primary cell once discharged, is no longer usable. The chemical action that discharged the battery cannot be reversed, and the cell cannot be regenerated as a source of electric power. The secondary type of battery cell is rechargeable. The chemical action is reversible; the electrodes and electrolyte can be restored to the same make up that existed before the discharge. This action is called charging the cell. The charging circuit must be supplied by an external A.C.. voltage source, with the cell serving just as a load resistance. The discharging and recharging of a cell is called recycling of the cell. Since a secondary cell can be recharged, it is also called a storage cell and a battery made up of such cells is called a storage battery.

A cell is therefore considered as being composed of a plate of copper and zinc dipped into dilute tetraoxo sulphate iv acid. Thus, the essence of a battery charger is to inject from both plates of which one is positive and one negative sufficient amount of current to recycle the electrons in the electrolyte of the cell in a battery. The most common type of storage battery is the lead-acid battery used in cars and other automobiles.

2.1 BASIC CHEMISTRY OF THE BATTERY

When the copper and zinc plate of a sinple cell are joined by a wire, the zinc slowly begins to dissolve in the tetraoxo sulphate iv acid, bubbles of hydrogen are formed on the copper plate. At this time, electron drift through the wire from the zinc plate to the copper plate.

This action may be explained as thus: Pure tetraoxo sulphate iv acid has the chemical formula as H_2S0_4, but when added to water, the $S0_4^-$ group of atoms separate or dissociate from each hydrogen H_2 atom taking two electrons with them, one from each hydrogen atom. The hydrogen atom therefore has a net positive charge. In this electrically charged condition, the atom or groups of atoms are referred to as ions. The ionization of tetraoxo sulphate iv acid in water can be represented by:

$$H_2S0_4 \longrightarrow 2H^+ + S0_4^{2-}$$

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This is illustrated in the Figures below.

See Figure 1: a,b,c,d.

The Charging process

PbO_2	+	$2H_2SO_4$	+	Pb
(Positive plate)		(Electrolyte)		(Negative Plate)

The Discharge process

$PbSO_4$	+	$2H_2O$	+	$PbSO_4$
(positive plate)		(Electrolyte)		(Negative plate)

Usually, when zinc dissolves in acid, internal molecular energy is produced and the solutions gets warmed. In the simple cell, the action of the acid on the zinc results in the production of electric energy. At the same time, as the zinc ions enter the solution from the zinc plate, an equivalent number of hydrogen ions will leave the solution and deposit themselves on the copper plate. Here they receive an electron from the copper, become neutral atoms and are liberated to form gas bubbles.

When a simple cell is in use, it is found that the current rapidly falls to a very small value. This defect results from the formation of a layer of hydrogen bubbles on the copper plate and is called polarization of the cell. If the zinc used in the simple cell is of the impure commercial variety, bubbles of hydrogen will be seen coming off the zinc. This is called local action and must not be confused with polarization, which is the name given to the formation of hydrogen bubbles on the copper plate. Local action is caused by the presence in the zinc of small impurities such as iron or carbon which sets up the tiny local cells at the zinc surfaces. Bubbles of hydrogen are given off current which goes through the wire from the zinc to the copper. We may think of the zinc ions as being attracted into the solution which could be described by saying that the zinc dissolves in the sulphuric acid to produce zinc sulphate.

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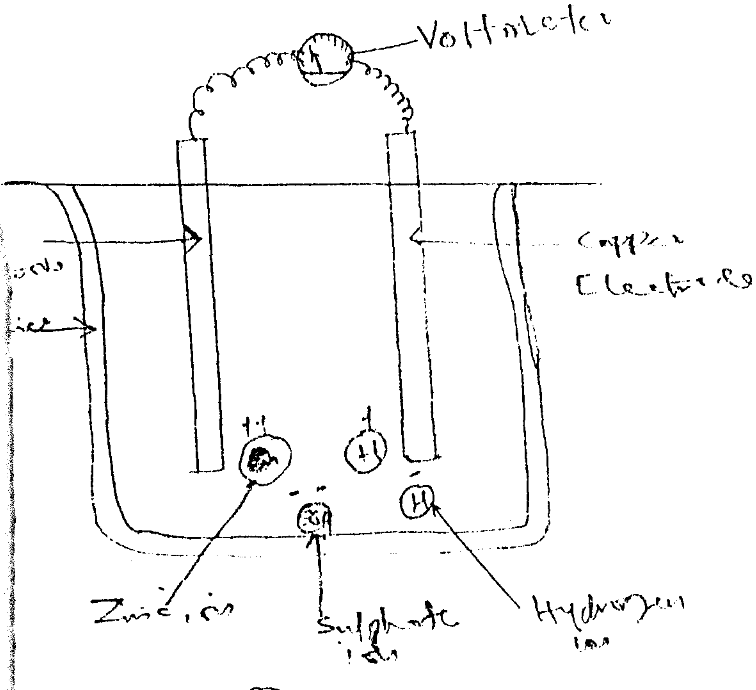
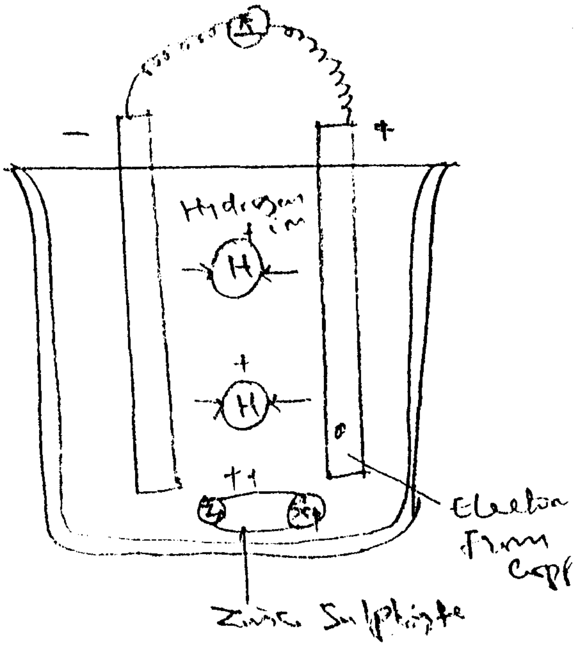
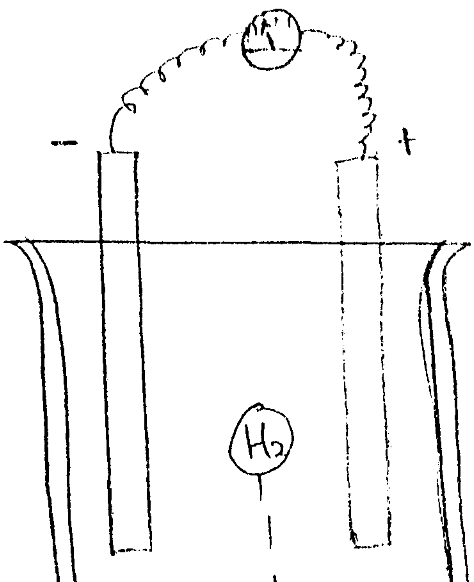


(a)

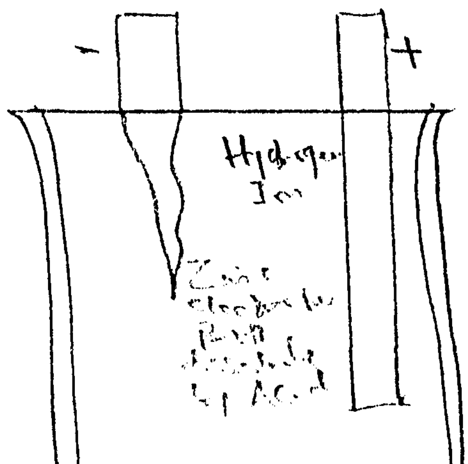


(b)

Electron flow



C



d

from the impurities and the surrounding zinc slowly dissolves in the acid. This can easily be prevented by cleaning the zinc in the tetraoxo sulphate iv acid and then rubbing a small globule of mercury over the surface with a small piece of cotton wool. The mercury dissolves pure zinc out of the plate and forms a bright coating of zinc amalgam all over the surface. The local action will not occur since the amalgam covers up the impurities and prevent them from coming in contact with the acid.

2.2 TYPES OF BATTERIES

i Laclanche cell

ii Dry cell

iii The lead-acid cell

iv Alkaline battery

The first two are examples of primary cell while the last two are examples of secondary cells.

2.3 CHARGING A BATTERY

Charging a battery means causing electrons to flow into the negative terminal. In the Car, this is performed by the alternator. A battery may also be charged using a battery charger. The charger converts the AC into the proper DC voltage level to charge the battery. A battery has certain internal resistance. These include: the resistance of the plates and connectors and the resistance offered by the electrolytes. The resistance offered by electrolyte is greater at lower temperatures. Therefore, at low temperature, a battery offers a greater resistance to charging current. When a battery charger is connected to a battery, the charger voltage (which is applied to the battery terminals) is equal to the internal voltage plus the voltage drop across the internal resistance. This is stated as thus:

$C.V = I.V + V.d.$

Where C.V = Charger voltage;

I.V = Internal Voltage of the battery

V.d = Voltage drop across the terminals of the Battery.

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The voltage drop = IR, is caused by the charging current I flowing through the internal resistance R, this is found using Ohms' law. The internal voltage of the battery varies with the state of charge. When the state of charge is low, the internal voltage is low; similarly, when the state of charge is high, the internal voltage is high. Therefore, when a battery is low in charge, it accepts more charging current because of the greater voltage difference between the charger and the internal voltage. When the battery is fully charged, it will accept only a small amount of charging current because of the smaller voltage difference. Hence, a battery tends to self-regulate it's discharging current. Because of the internal resistance of the battery, heat is generated when a battery is charged ($P = I^2R$). If the charging current is too high, the battery can be damaged by over heating. When a battery is being charged, the temperature of the electrolyte should never go above *125^0f* *(51.7^0c)*.

Some charging methods employed include: constant current, constant voltage methods, booster or high rate charging and trickle charging or slow rate charging methods.

CONSTANT CURRENT CHARGING:

A charger of this type generally employs a rectifier. The rectifier may be of gas filled bulb type or series of copper oxide or other chemical drives. The rectifier also incorporates some form of rheostat to adjust the amount of charging current as it conforms to the battery manufacturers recommended values. If batteries of different ratings are being charged in series, the charging rate should be divided by the battery with the lowest rating. If somehow, the rating cannot be determined, the battery may be charged at the 1.5A rate.

CONSTANT VOLTAGE CHARGING

The constant voltage charging is operated on the principle that as the battery nears its charge, the terminal voltage increases. This type of charger is nothing but a motor generator-set. The generator may give 7.6v for 6v battery and it could give 15v for 12v batteries. When a battery that is in a discharge condition is connected to the generator, a high rate of charging current will flow into the battery. As the battery nears its charge, it's terminal voltage will increase with increase in opposition to charging current. This means that the charging current tapers off as the battery approaches the charged condition. It is note worthy that this action is based on the assumption that the battery temperature does not temperature of the electrolyte so that it is prevented from exceeding 50°c. Typical *60AH* Car battery having an electrolyte specific gravity of 1.150 with a 40A current rate could require one hour for charging. The charging time will be less with higher electrolyte gravities. Hence, the charging time will be half an hour for an electrolyte with 1.145 – 1.200 to 1.225, when the electrolyte specific gravity reaches 1.225, a completion charge rate should be given to the battery.

A battery should not be subjected to more than 5 10 times to high rate of charging in its life time otherwise, its life span will reduce considerably. In addition, new batteries should not be charged by this process.

2.4 EFFECT OF TEMPERATURE ON BATTERIES

High temperature increases the chemical activities in a battery. In high temperature areas (tropical areas), batteries are manufactured with an electrolyte that is weaker in acid. The batteries life is lengthened because, the weaker acid is less deteriorating to plates and separators.

At low temperatures, the effectiveness of a battery is greatly reduced. As internal resistance of a battery increases, the chemical activities is retarded.

2.5 BATTERY FAILURE

Battery failure can be classified as over charging, cycling, sulphation and external short circuit. There are other failures which could result from causes outside the battery; failure such as improper voltage regulator adjustment, defective generator, loose battery mounting, battery terminal corrosion etc.

Sometimes, it would be necessary to open up the battery to determine the cause of failure.

2.6 THE POWER SUPPLY

Electronic system requires a source of D.C. power supply except in the case of battery powered (portable) equipment, the A.C mains (240V, 50Hz) must be connected to the appropriate D.C voltage. This is performed in a power supply unit (PSU) which usually comprises of a transformer.

rectifiers, filters and voltage regulator. The first three stages bring out an unregulated or 'raw' D.C supply. The unregulated supply is not of high quality, its D.C output voltage can fall quiet significantly with load current demand and it is super imposed on the mean D.C voltage, an A.C component (or hum) at a mains-related frequency.

2.7 THE TRANSFORMER

In a power supply unit, the transformer is the component which converts (or transforms) the A.C. mains voltage to a higher or (usually) lower A.C. voltage. Fundamentally, a transformer consists of two coils (or windings) inductively coupled by a magnetic core. The input winding, called the primary winding wherein the incoming mains voltage is fed ,and secondly, the output winding, called the secondary side or unit where from the transformer A.C voltage is fed out. The ratio of the primary to the secondary voltage is equal to the ratio of the number of turns in each winding. This is shown in *Fig. 2*

2.8 RECTIFIERS

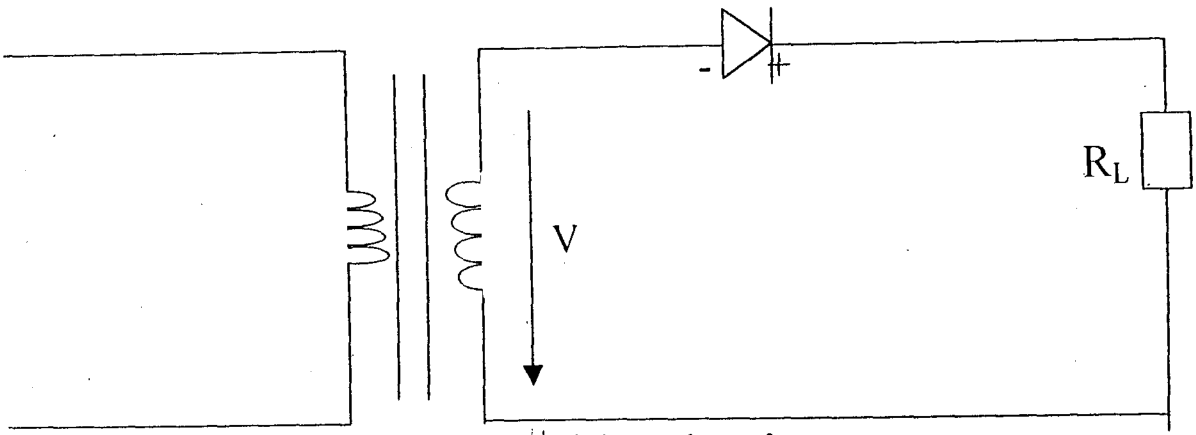
The wave form of the transformer secondary voltage is bi-directional and sinusoidal. To convert this A.C. as mentioned earlier involves usually the use of one or more silicon diodes selected to handle the required voltage and current. The essence of rectification is to ensure that the incoming A.C mains from the output of the transformer is converted to an acceptable level of voltage, thus, the voltage is required to be converted to a D.C (direct current) level. The rectifiers are of different kinds as:

i Half wave Rectifier

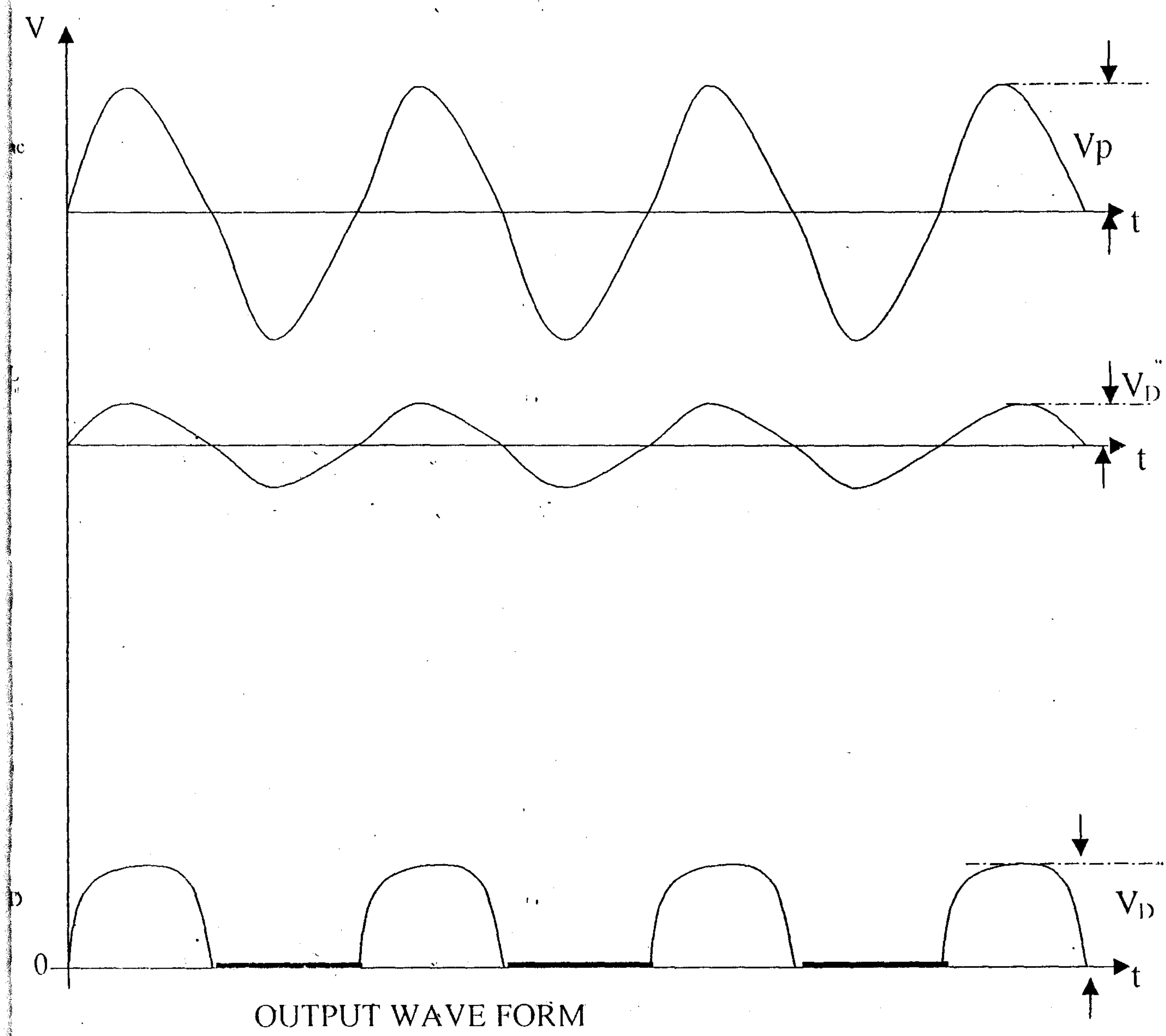
ii Full- wave Rectifier

iii Bridge Rectifier.

These different types of rectifiers are adopted to realize different results. It is mention worthy that: The bridge rectifier is a combination of both the half wave rectifier and full wave rectifiers with the constituent diodes properly biased.



a) **Half – wave Rectifier circuit**



OUTPUT WAVE FORM

2.9 HALF WAVE RECTIFIER

The circuit in figure 3 (a,b) assumes a sinusoidal voltage $V = VSin\omega t$ at the secondary of the transformer and a rectifier diode is connected in series with a resistive load across which the output direct current (A.C) is to be developed.

In effect, the secondary of the transformer is acting as a voltage generator and the voltage delivered to the circuit will be shared between the diode and the load in the circuit.

Where $V = V_D + IR_L$

V_D = diode instantaneous voltage drop

I = instantaneous current

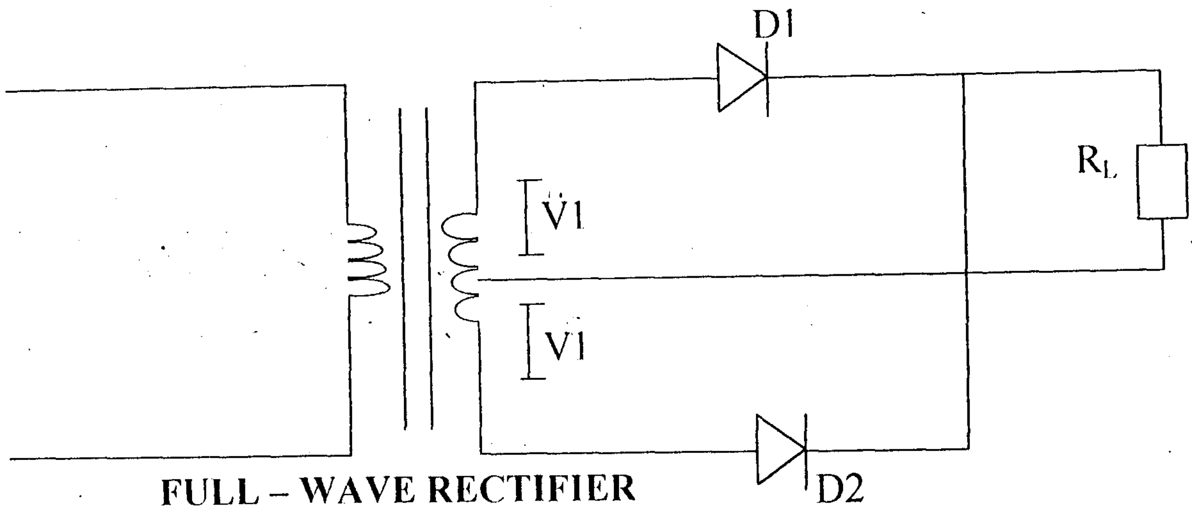
When V is positive, the diode is forward biased hence, V_D is small, at a peak value of about 0.6V and current is delivered to the load. When V is negative, the diode is reversed biased, and since reverse bias resistance is very much greater than R_L, the instantaneous voltage drop across the diode is equal to the applied voltage V. Only small leakage current flows to the load and the effect can usually be ignored. The wave forms are shown in the figures presented. The average voltage is given by integrating the positive half cycle over a complete cycle.

2.10 FULL WAVE RECTIFIER:

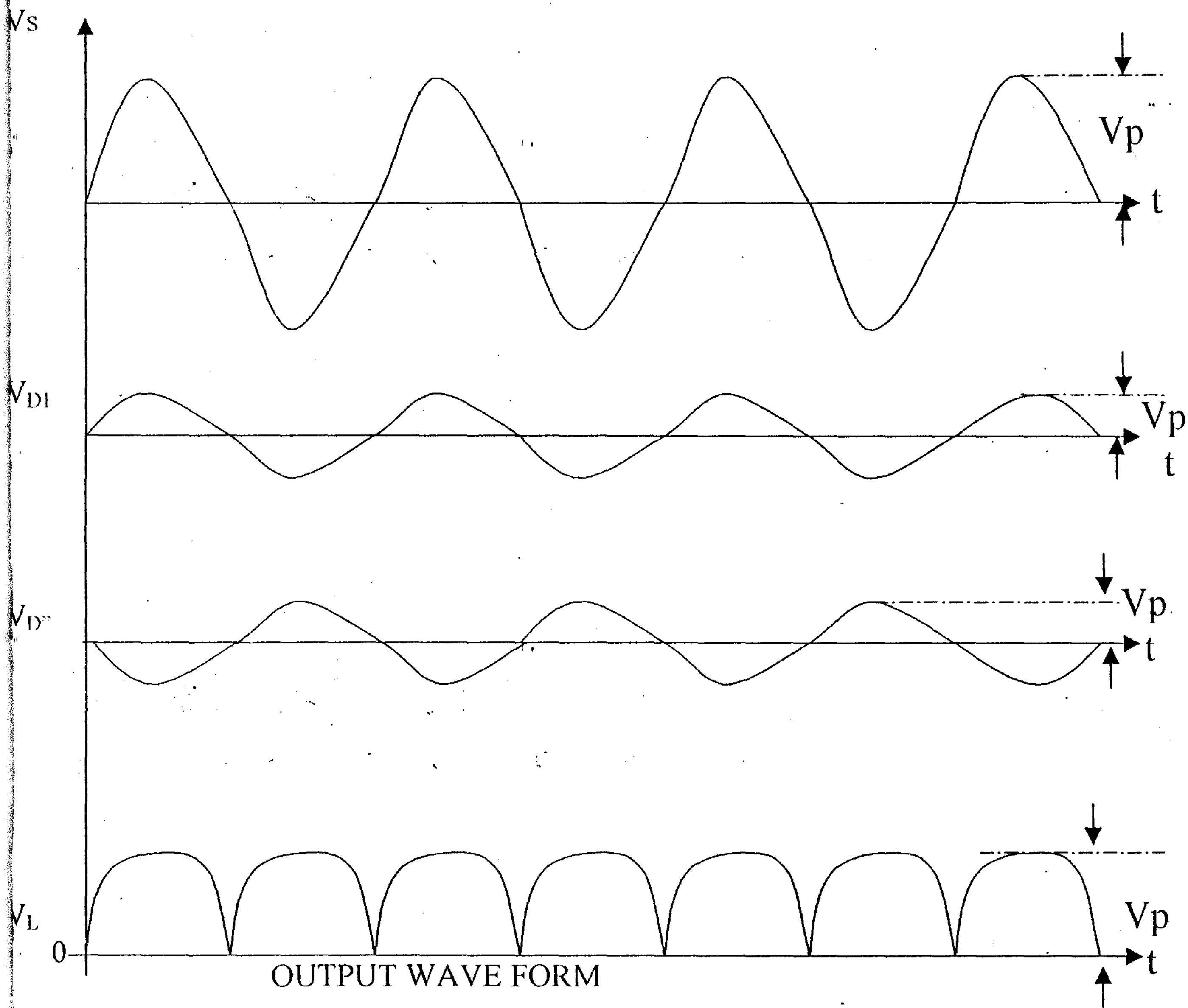
By using a second diode, connected as shown in Fig. 4 (a,b). It is possible to have current flowing in the load resistor for the whole of the input voltage cycle. The circuit basically consist of two half-wave rectifiers that conduct at alternate half cycles.

The transformer secondary has a center tap so that during the first cycle of input voltage, the diode D_1 conducts and the resulting current flow and voltage across resistor R is the same as that for the half wave arrangement.

During the second half cycle of input voltage, the diode D_2 conducts, while D_1 is off, providing current flow through and a voltage drop across R_1 as before. The wave form is shown in the figure here presented.



FULL – WAVE RECTIFIER



OUTPUT WAVE FORM

The voltage developed is given by:

$V_{dc} = 2/\Pi(Vp - V_D) = 0.637(Vp - V_D) volts$

The amount of ripples is reduced compared with the circuit of half wave rectifier.

2.11 THE BRIDGE RECTIFIER:

The full-wave bridge rectifier does not require a centre-tapped transformer, the circuit is as shown in the figure here presented i.e fig.5 (a,b,c,d).

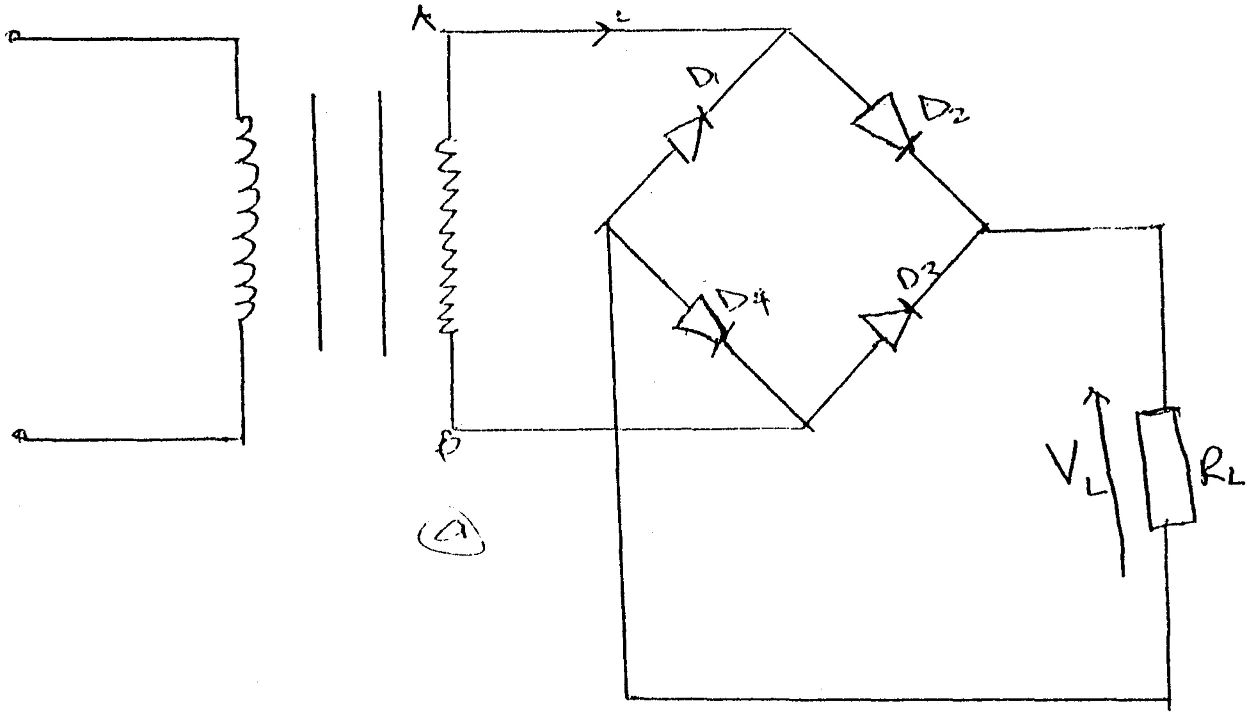
During the first positive half cycle, when point A is positive with respect to point B, diodes D_2 and D_4 conducts while diodes D_1 and D_3 are reverse biased.

As shown, the transformer winding is always connected to the load but the sense of connection reverses with each reversal of the alternating input voltage. There is a voltage output similar to that of the full wave rectifier but with a peak output voltage equal to the peak input voltage of the secondary, $2V_o$ volts, since two diodes are conducting in series for each input half-cycle. The resulting wave form is shown as presented in figure 6.

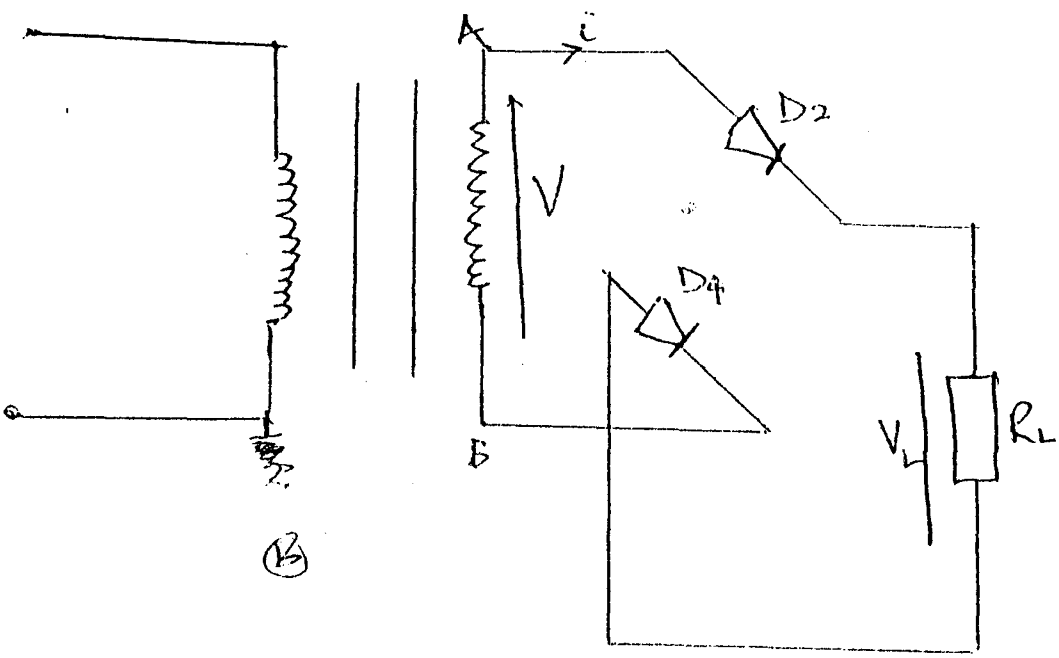
The half-wave rectifier is simple but its average DC voltage output is low with considerable ripple. The ripple component has a frequency of the same value as the input wave form i.e 50Hz if mains supply is used.

The full-wave and the bridge rectifiers both give improved average direct current voltage levels with reduced ripples.

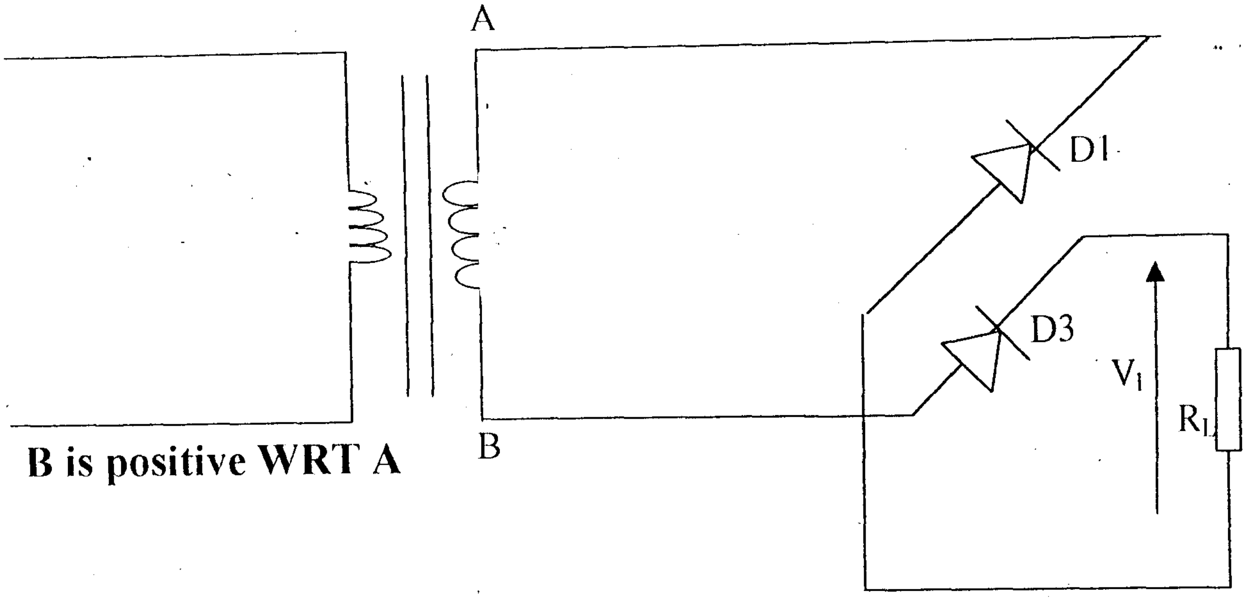
Rectification is applicable obviously in direct current power supply. These are numerable, but include most electronic gadgets, electrical traction, electrolysis and battery charging, radio, T.V and in amplifier circuits. The type of amplifier and the nature of the associated smoothing and stabilization circuitry depends entirely on the intended application of the resulting supply of power. For small power installations such as domestic radio receivers, the semi-conductor diodes and the vacuum diode are the principal rectifying elements.



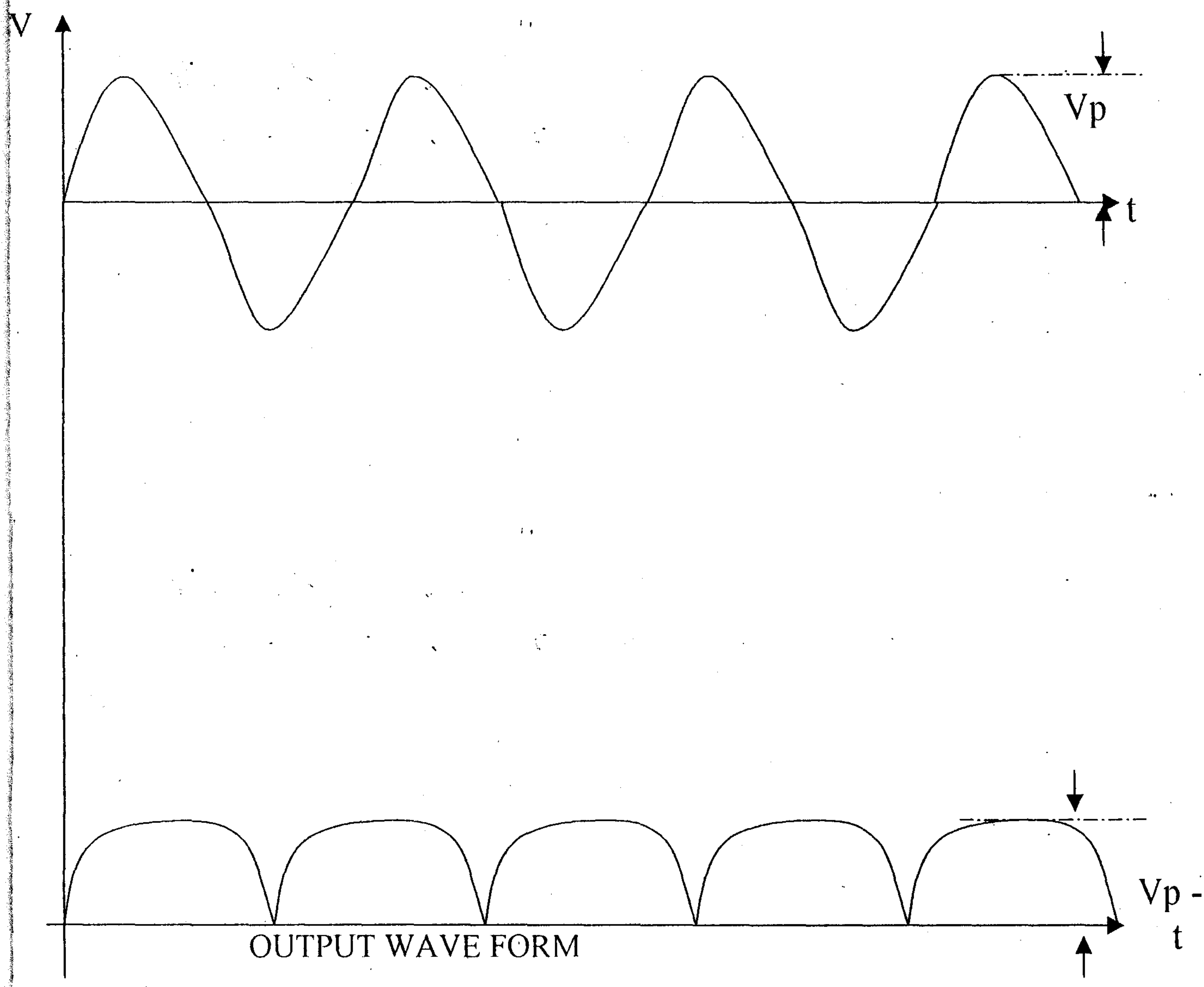
Bridge Rectifier.



A is Positive WRT B



B is positive WRT A



2.12 FILTER

At the output of the rectifier, the voltage is unidirectional i.e it is either positive or negative with respect to earth, depending on which way the diodes are connected. But, it is by no means constant. It contains harmonics of frequencies. The ripple can be largely filtered (smoothened) as shown in the figures below (fig.7).

2.13 SMOOTHING CIRCUITS:

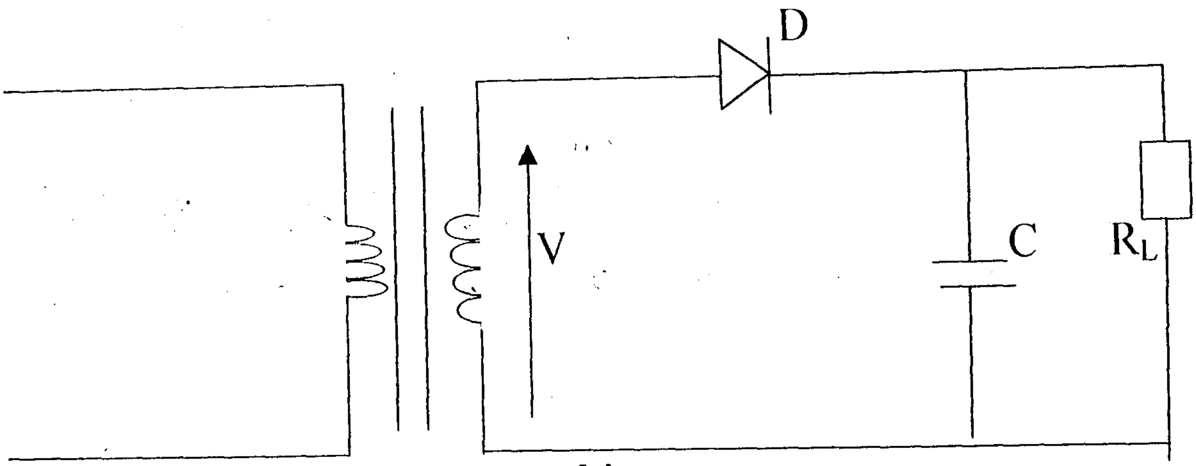
Capacitive smoothening:

The simplest way to smoothen the voltage output of a rectifier is to minimize the ripples and give a better approximation of a D.C voltage. This is achieved by using capacitors in parallel with the resistive load as shown in fig. 7(b). The effect of adding a capacitor is to prevent the output voltage from falling to zero as the diode cuts off. During the positive half-cycle of input voltage, the diode conducts and its forward currents will flow to charge the capacitor. The output voltage and the voltage across the capacitor become maximum. When the diode becomes reversed biased, since the voltage across the capacitor is grater than the applied voltage, the capacitor now begins to discharge through the load resistor R_L. Thus, the voltage across the capacitor and hence, the output voltage falls exponentially with a time constant t seconds. The instantaneous voltage across the capacitor and load at any time during the period the diode is cut off is given by:

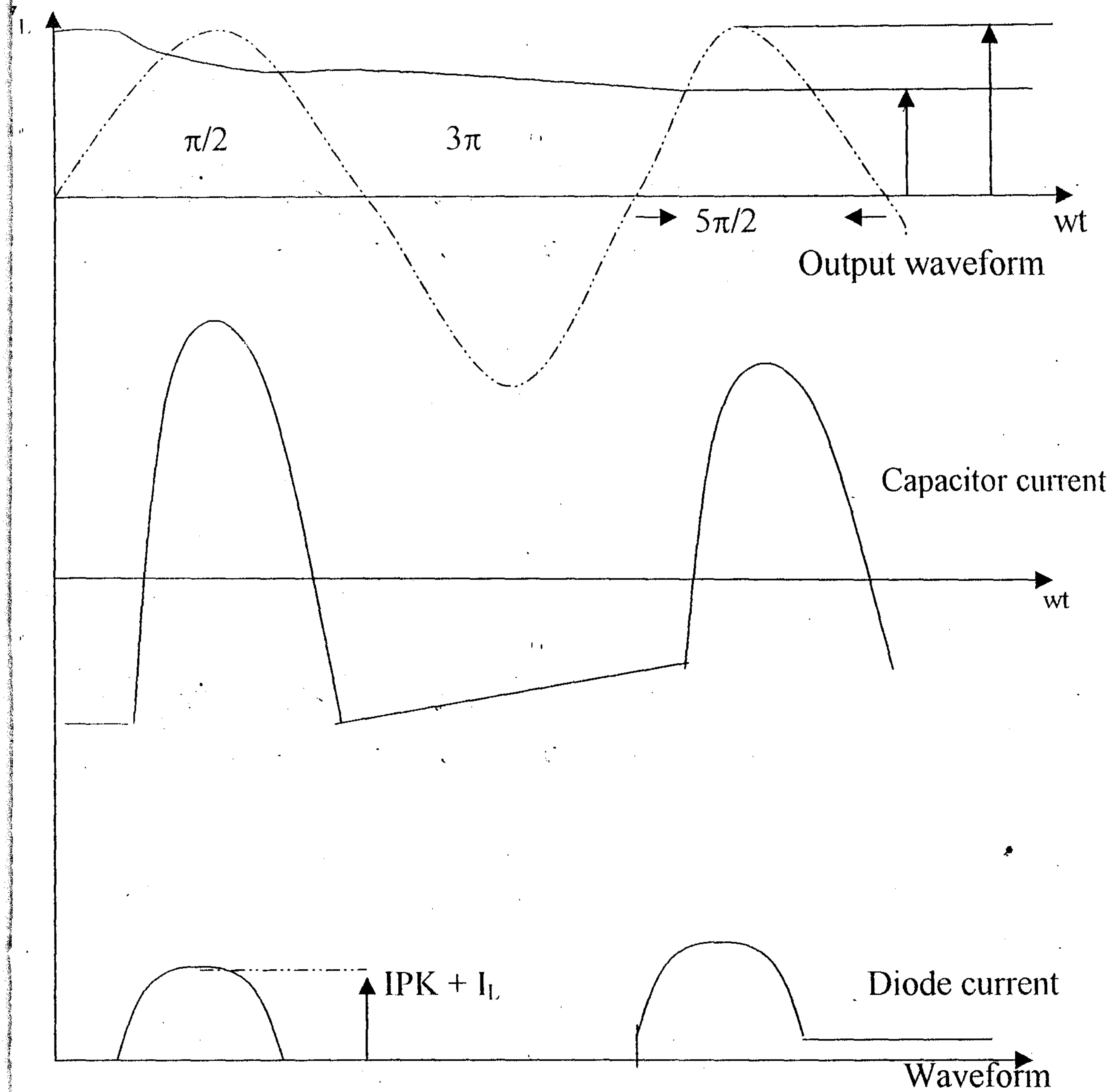
$V_L = (Vp - V_D)\, e^{-t/CR}$ *(volts)*

If the time constant $t = CR_l$ is chosen to be much greater than the period of the supply wave form, then the capacitor will not loose much of it's charges before the diode conducts again and restore the output voltage to its peak value once more. Voltage and current wave form are here in presented. From the wave forms, it can be seen that the output wave form consist of a mean value *Vac* upon which is super imposed a ripple voltage. The peak value of which is:

$Vripple = (V_p - V_D) - Vac.$



a) Capacitive smoothing



From the figure presented, it would appear that the ripple voltage could be reduced by increasing the time constant, so that the capacitor *C* discharges more slowly and would therefore not have fallen by so much when the input voltage again causes *C* to charge. The time constant may be increased by using large value of *C*. However, there is a limit to the upper value that *C* can accommodate. Since the diode only conducts when the input voltage is greater than V, then the lower the ripple voltage the smaller the time available to recharge the capacitor. The current pulse delivers the required load current (since the mean current passed by the diode must equal the load current). This value could be exceeded if the value of *C* is too large, causing damage to the transformer or diode or even both.

When the diode has charged *C* to a peak value, this value is maintained at Vp, so that the diode must be able to withstand a *PIV* (peak inverse voltage) of approximently $2Vp$. The maximum reverse bias voltage which a diode can withstand is usually specified by the manufacturer, so that suitable diode can withstand safely the peak inverse voltage of 2Vp selected.

Full wave rectifier can be smoothened in much the same way as for a half-wave circuit with small but important difference listed here under:

i Ripple voltage for full and bridge rectifiers circuit is at twice the frequency of the half wave circuit. Thus, the discharge time is reduced by half-wave circuit, while the ripple voltage reduced equally by half.

ii In full-wave circuit, each diode alternately charge the capacitor and when the diode conducts, it must pass enough current to charge *C* to it's peak value, since the capacitor will discharge less in the full-wave circuit. Then the peak current through each diode is less (approximately half the value of the half-wave).

iii The peak inverse voltage for the full wave is 2Vp and for the bridge rectifier is 2Vp. To calculate the output A.C. voltage and the peak value of the ripple voltage is not easy.

Referring to the output wave form of fig.6(a,b), for a half wave rectifier, it can be seen that the diode conducts at an angle of 0 radian and cuts off again at an angle of $\Pi/2$ radian. The fall in voltage after the diode cuts off is exponential and continues until $2\Pi + O$ radian later, when the diode conducts again, the process is repetitive. The output wave form may be simplified without two much loss of accuracy as presented in figure 7 (b).

2.14 RECTIFIER AND CAPACITOR RATINGS

In circuit design, it is important that components are selected not just by value but by their maximum voltage- current and power ratings as well. Otherwise, component failure could occur. Rectifier diodes and smoothen capacitors are no exception.

In a bridge rectifier, the maximum reverse bias on each diode is equal to $Vmax$, the peak secondary voltage, for a half-wave rectifier and a full-wave rectifier using two secondary windings, the maximum reverse bias voltage is twice the peak secondary voltage. The peak inverse voltage (PIV) rating of the rectifier should exceed these figures.

Rectifier diodes have three current ratings indicating their ability to withstand different flow of current loads. The mean forward current, the peak repetitive current and the peak non-repetitive current. For full-wave and bridge rectifier circuits, the average current per diode is one half of the D.C output current. In a half-wave rectifier, the single diode carries the full current. The peak repetitive current is the peak current circuit required in every cycle or half cycle to charge the smoothing capacitor and provide the load current.

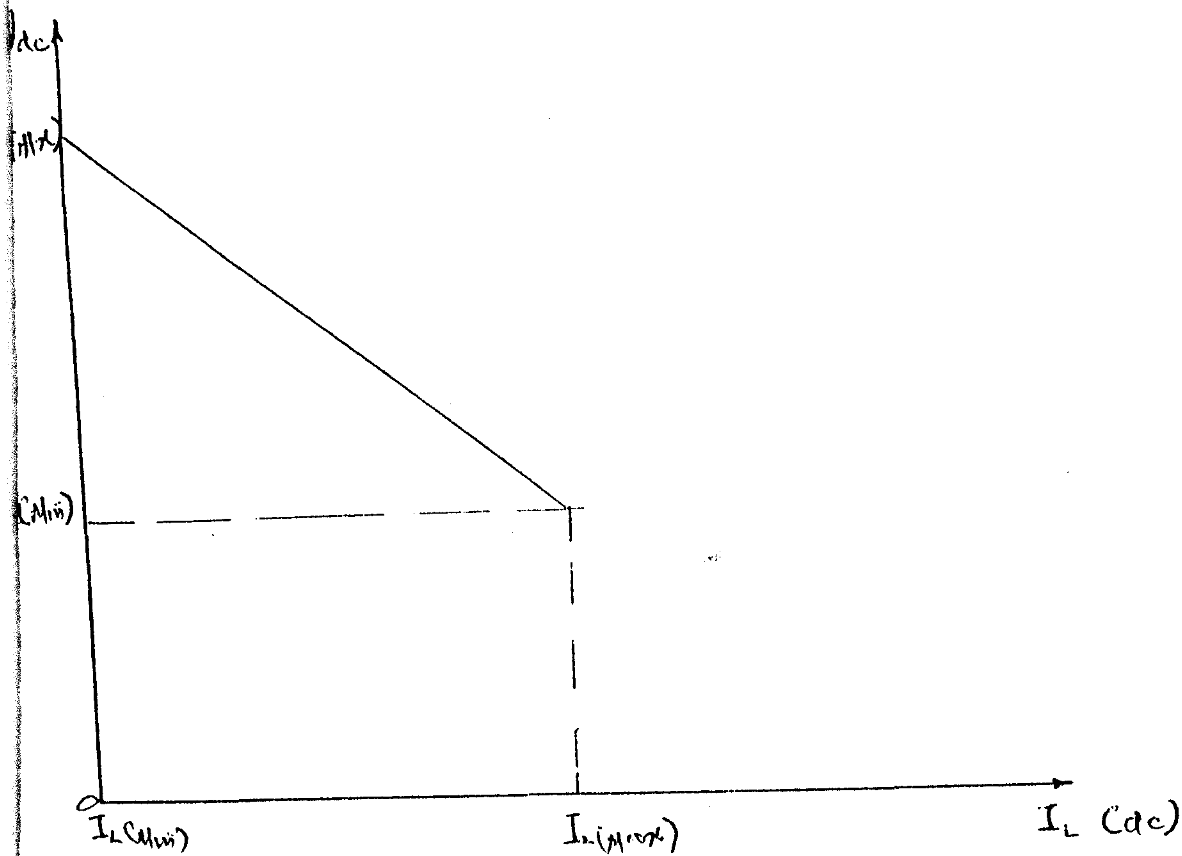
2.15 REGULATOR

The secondary/ primary voltage ratio is not sustained as current drawn by a load across the secondary is increased. This is due to losses; magnetic (or iron losses) arising from eddy current in the core and copper losses as in the resistive loads and the resistance of the wire used in the core. The fall in voltage due to losses is called regulation, commonly defined as:

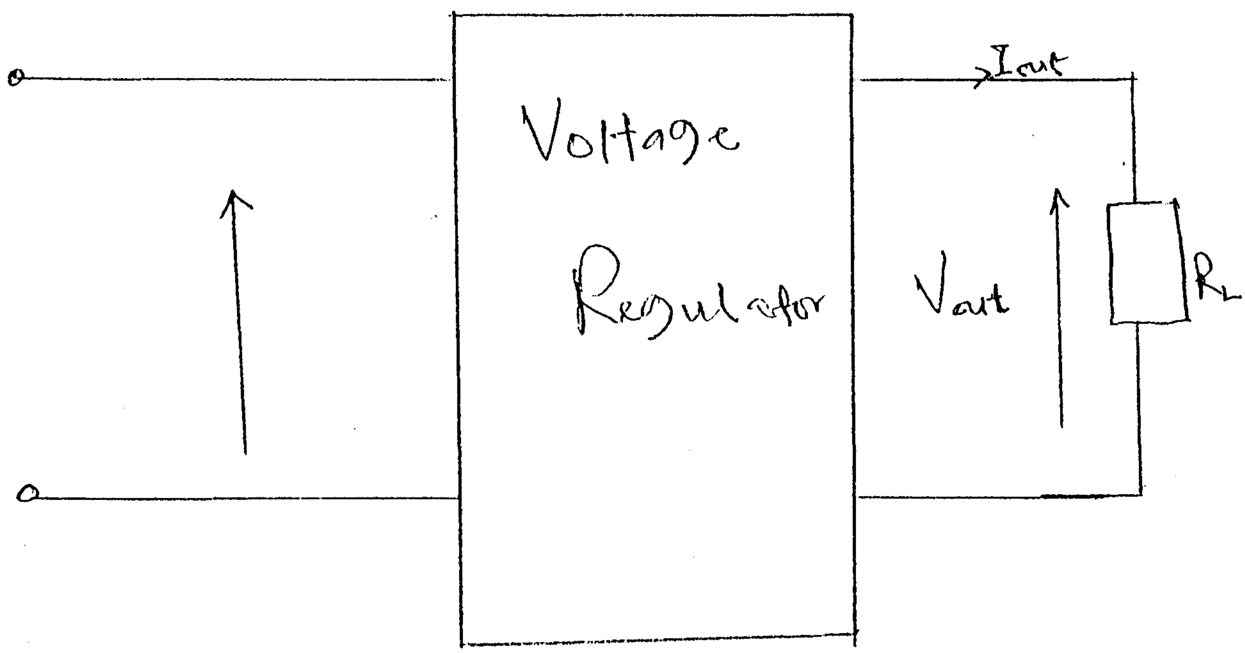
Regulation = V_{dc} *(max)* – V_{dc} *(min)*/ V_{dc} *(max) X100%*

Where *Vdc (max)* = the no-load secondary voltage and *Vdc(min)* = the voltage under full load. It is usual for a transformer secondary voltage to be specified at the full load current which is calculated from the quoted VA(power) rating and secondary voltage.

The regulation curve is shown in the figure below . The curve shows that V_{dc} *(min)* occurs at I = 0 and V_{dc} *(max)* occurs at the maximum value of I. Ideally, V_{dc} should not vary with charging load circuit, this suggests a horizontal straight line of value V_{dc} *(max)* on the graph. In practical circuit application. the same output resistance of the power supply could cause problems. since signal voltages could appear across the power supply and find its way to other signal circuit causing possible oscillation due to feed back. At high signal frequencies, this is not a problem, since the shunt capacitor of the rectifier circuit appears as a short circuit at these frequencies.



(a) Regulation Curve



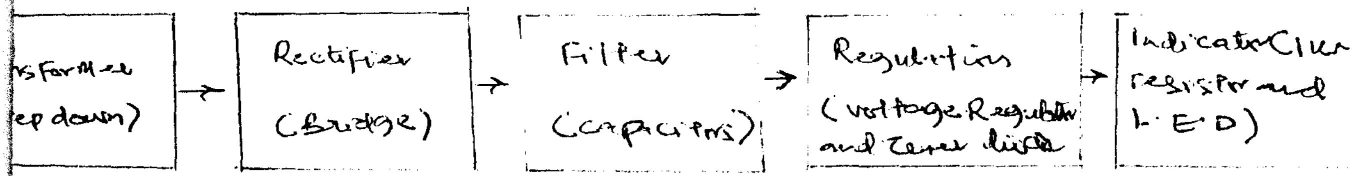
(b) Block Diagram of a Voltage Regulat

CHAPTER THREE

3.1 DESIGN AND CONSTRUCTION

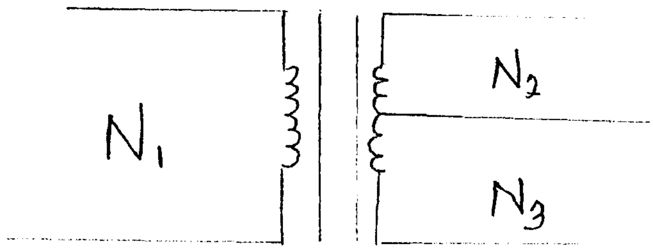
3.2 POWER SUPPLY DESIGN

The block diagram shows typical D.C power supply which includes the following units. transformer, rectifier, filter, voltage regulator.



3.3 TRANSFORMER:

A transformer is an electrical device which is made of coils wound around a magnetic core. It makes use of the principle of electromagnetic induction to transform electrical energy from one coil to another at different levels. In this project, a step down centre tapped transformer of 24V is used to provide the necessary voltage required in the circuit.



The center tap transformer used in the construction of this project.

For a sinusoidal input voltage, the flux Φ varies alternately i.e. $\Phi = \Phi_{max} Sin wt$

The instantaneous voltage in the primary is due to Faraday's law:

$E_t = d\Phi N_1/dt = 2\Pi F N_1 \Phi_{max} Coswt$ ____________________ 1

where $w = 2\Pi F$

Thus, $E_{tmax} = 2\Pi F N_1 \Phi_{max}$ or the r.m.s. value of E_t is:

$E_{r.m.s} = 2\Pi F N_1 \Phi_{max} / \surd 2 = 4.44\ F N_1 \Phi_{max}$ 2

Since the flux is the same for the primary and secondary winding, the secondary voltage and current could be derived from:

$V_{out}/V_{in} = E_{out}/E_{in} = 4.44FN_{out}\ \Phi_{out\ max}/\ 4.44FN_{in}\ \Phi_{in\ max} = N_{out}/N_{in}$

$(\Phi_{out\,t} = \Phi_{in})$

$V_{out}/V_{in} \quad = \quad N_{out}/N_{in}$

Thus, $V_{out} \quad = \quad (N_{out}/N_{in})\,V_{in}$ 3

Where V_{in} is the input voltage

V_{out} is the output voltage

N_{in} is the number of turns in the primary winding

N_{out} is the number of turns in the secondary winding

Φ_{out} max is the maximum flux in the secondary winding

Φ_{in} max is the maximum flux in the primary winding

E_{out} is the e.m.f value of the secondary winding

E_{in} is the e.m.f value of the primary winding

And

$I_{in}\,N_{in} = I_{out}\,N_{out}$

Or

$I_{out} \quad = \quad (N_{in}/N_{out})I_{in}$ 4

Where I_{in} is the input current

I_{out} is the output current combining equation 3 and 4,

$V_{out}/V_{in} \quad = \quad N_{out}/N_{in} \quad = \quad I_{in}/I_{in}$ 5

The transformer of fig has prints: *Primary voltage is* V_{out} *24V, Secondary current is* I_{out} *1000mA*

From $V_{in}/V_{out} = I_{out}/I_{in}$

Or $I_{in} \quad = V_{out}\,I_{out}/V_{in}$

That is $I_{in} \quad = \quad (24X\,1000)/240 \quad = \quad 100mA$

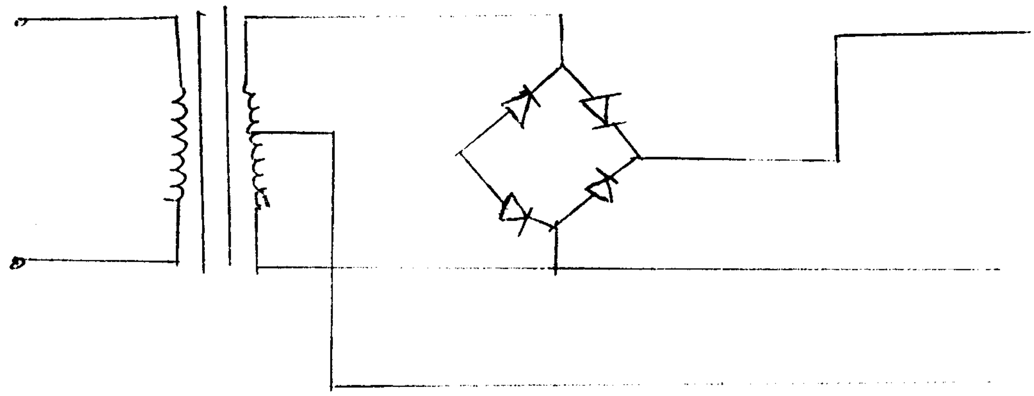
The transformer ratio a can be calculated by:

$V_{out}/V_{in} \quad = \quad N_{out}/N_{in} \quad = \quad 240v/24v \quad = \quad 10$

3.4 RECTIFICATION

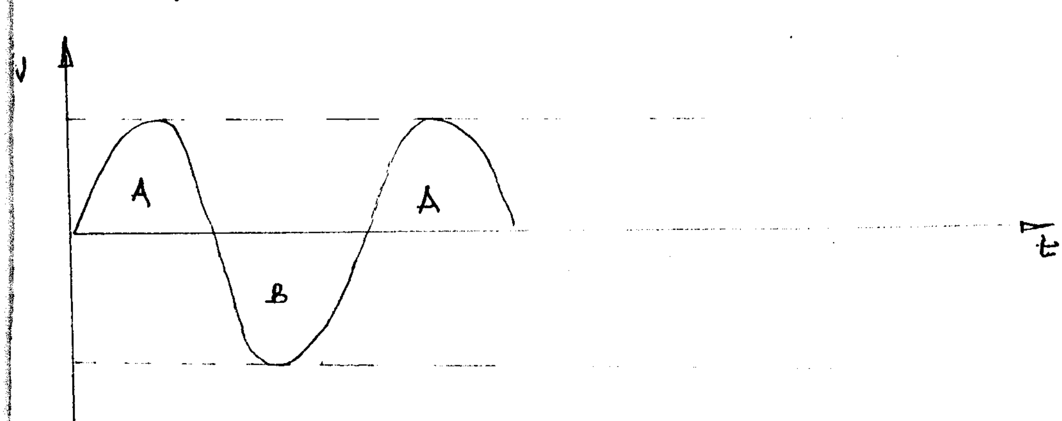
Rectification involves the conversion of A.C to D.C with the application of rectifiers. A rectifier is an electronic device which offers resistance to the flow of current in the positive direction (known as forward bias) and resistance to flow of current in the negative direction (known as reverse bias). Rectifiers may be used to carry out half or full wave rectification depending on the application. In this project, we shall be concerned only with full wave bridge rectifier which in essence allows the flow of D.C current in the output throughout the alternating cycles of the input signal. A common type of bridge rectifiers is made of four discrete diodes arranged in a bridge form.

The rectifiers are connected as shown in figure below.

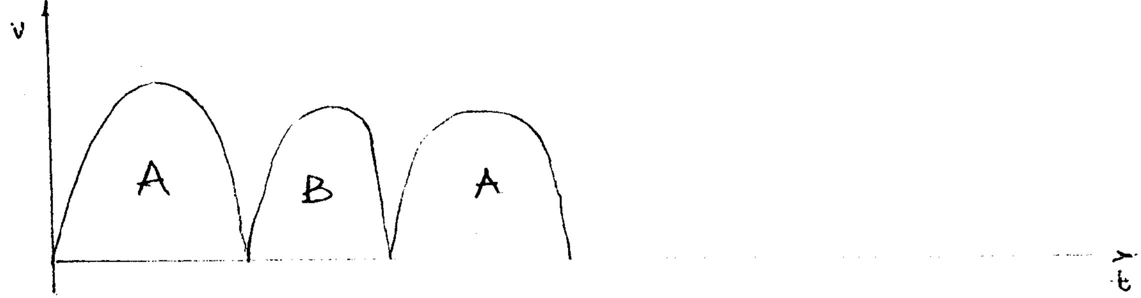


Full bridge rectifier used in the construction

Diodes D_1 and D_3 conduct alternately (A) while D_2 and D_4 conduct on the negative half cycle, alternately (B). Both conducting cycles drive current to the load in the same direction.



(a Input wave form showing the conduction cycle



(b) Output wave form showing the conduction

3.5 FILTERING

The filter is required to smoothen the pulsating D.C output of the rectifier. Various types of filters are built using a combination of inductor and capacitor or each single one in combination with resistor.

However a single capacitor in parallel with the output from rectifier performs the required filtering action. The capacitor stores energy during the conduction period and delivers it to the load during the non conducting period, hence time of flow through the load is prolonged.

In this project, two capacitors are used for filtering, the first capacitor is used to filter a positive 12 volts while the second capacitor is used to filter a negative 12 volts. Those two capacitors must be large enough to store sufficient amount of energy to provide a steady supply of current, otherwise, the output voltage will drop as the load demands more current.

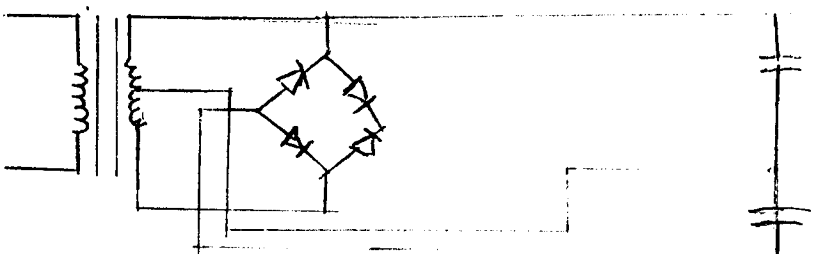


Fig Shows two capacitors used in filtering +12V and -12V

The approximately output wave form can be represented by the figure below.

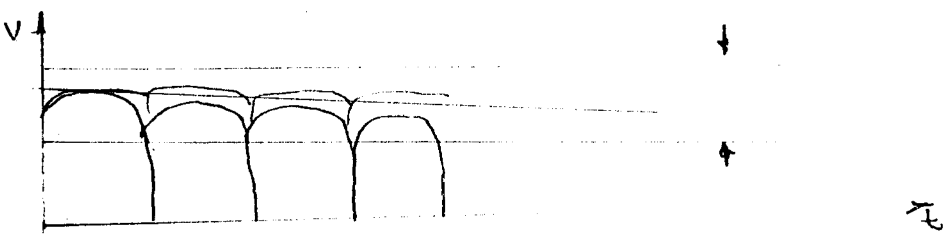


Fig showing the approximated output wave form

The capacitor used to filter (+12v) is 50V, 2200μf capacitor. Its pick to pick ripple voltage can be calculated by the equation below.

Vpp = IT/C   where C= 2200μf, But I = 1A

T = 1/f, where f = mains frequency = 50Hz; = 1/50;

Vpp = (1A X 20X10³s)/(2200X10⁶)   = 9v

The capacitor used to filter (-12v) is 16v, 470 μf capacitor it's pick to pick ripple voltage is:

Vpp = IT/C   where C = 470 μf, I = 1A.

T = 1/f =   1/50Hz;

Vpp = (1A X 20X10³s)/(470X10⁶)   =   42.55v

3.6 REGULATION

Regulated power supply can be obtained by using a voltage regulator circuit. A regulator is an electronic control circuit which is capable of providing a near constant D.C output voltage even if there are variations in load or input.

In this project an integrated circuit voltage regulator 7812 and a zener diode (12v) are provided for regulating the supplies.

7812 Voltage Regulator:

The aim of this integrated circuit is to reduce the variations to zero or at least to the minimum possible value.

The minimum input voltage is 14v and the maximum input voltage is 35v D.C. the output is +12v D.C.

Zener diode 12v

In this construction, the zener diode is used to reduce the variation to zero of the negative 12v. This is achieved by shunting the diode between 12v supply and the ground (GND).

The L.E.D.

Its aim is to indicate that the power supply is on.

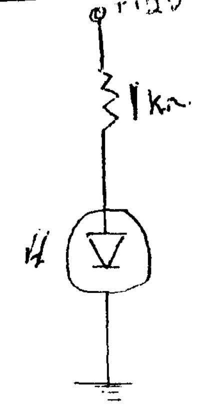


Figure above shows the circuit of the power supply indicator network.

The voltage across silicon diode is 0.7 : The current flowing in this network is:

$I = (Vcc - 0.7)/ 1k\Omega = (12v - 0.7v)/1000\,\Omega = 0.0113A = 11.3mA$

The 12v zener diode has the following characteristic:

$V_z = 12v$ $P_z = 300mw$, *Tolerance* $= 5\%$

The zener diode current I_z can be deduced from the equation:

$Pz = V_z I_z$ *(where P_z is the power rating of the zener diode and V_z it's voltage rating).*

$I_z = P_z / V_z = (300 X 10^3 w) / 12v = 0.025A;$ $I_z = 25mA$

The zener diode internal resistance R_z is:

From $V_z = I_z R_z$; $R_z = V_z / I_z = 12v/(25X10^3) = 0.48\Omega$

3.7 SUPPLY INDICATOR NETWORK

This network has two components:

I A limiting resistor

It is a color code resistor. From the E.C.G book the range of current for the L.E.D to be protected is 10 to 50Ma, the voltage across the indicator network is 12V. Therefore, the resistor range for the diode to be protected is *12V/50mA* to *12V/10mA*, that is 240ohms to 1200ohms.

It is a color code resistor of 1KΩ. Its use is to limit the current that has to flow in the L.E.D. The larger the value of the resistor, the less the brightness of the L.E.D. But if the value of the resistor is not enough to limit the current, the L.E.D could be destroyed.

3.8 OVER VOLTAGE PROTECTIVE DEVICE

The block diagram below is for the over voltage protective device with the following sections.

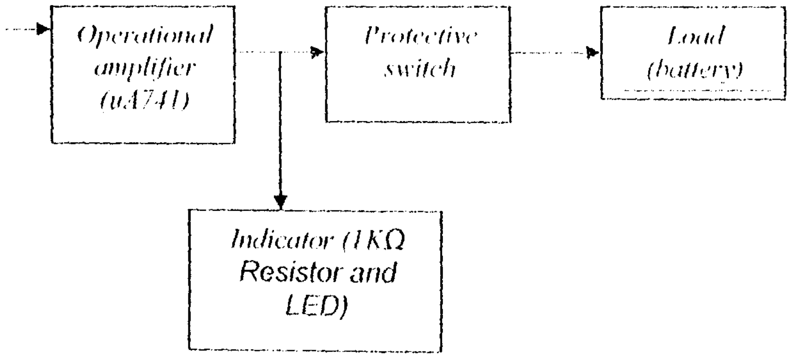


Fig. The operational amplifier uA741

This operational amplifier has five basic terminals that is, two inputs terminals, one output terminal and two power supply terminals. The significant of other terminals varies with the type of operational Amplifier

The uA741 used in this project has eight pins

1 Pin 2 is the inverting input terminal

2 Pin 3 is the non-inverting input terminal

3 Pin 4 is the negative power input terminal

4 Pins 5 and 1 are used for D.C. offset

5 Pin 6 is the output terminal

6 Pin 7 is the positive power supply (+12)

7 Pin 8 is not connected.

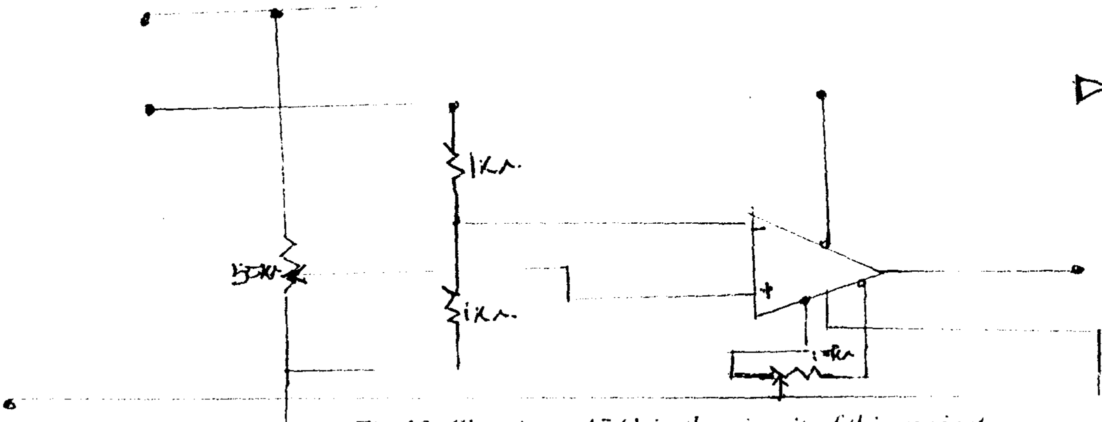


Fig 13: Showing uA741 in the circuit of this project

The reference voltage V_{ref} could be found by voltage divider theorem

$V_{ref} = (1k\Omega)/(1k\Omega + 1k\Omega) X V_{cc}$ *Where* V_{cc} = *(collector voltage = 12v)*

$V_{ref} = 1k\Omega/(2k\Omega) X (12v) = 6v$

The 50kΩ variable resistor is set in such a way that the pin 3 of uA741 is connected at the middle of this resistor. So V_{in} (input voltage to the non inverting terminal)can be calculated.

$V_{in} = 25 k\Omega/(25 k\Omega + 25 k\Omega) X (12v)$; *but* $V_{cc}/V_{ref} = 12v/6v = 2v$; $V_{in} = 6v$

If $V_{ref} \geq V_{in}$; then, $V_o = -(V_{cc} - 2) = -(12 - 2) = -10v$

Where *Vo* is the output voltage from the op amp

But when the battery is fully charged, V_{in} will be greater than V_{ref}.

$Vo = +(Vcc - 2) = +(12-2) = +10v$

This is achieved because of offset done by connecting pin 1 and pin 5 to a *10kΩ variable* resistor and the *10kΩ* variable resistor is connected to the negative supply (-12v). And also the biasing was done by connecting pin 7 to the positive supply (+12v) and pin 4 to the negative supply (-12).

The double 1N4001 acts as one way "value" to current flow, i.e it allows current to flow in one direction only. So V_{ref} is constant even if the battery is charged.

2 Fully Charged Indicator Network.

It uses the same components for power indicator network

When the battery is fully charged, ($Vin > V_{ref}$) or $Vo = 10v$, there will be voltage across this network and the L.E.D will come ON.

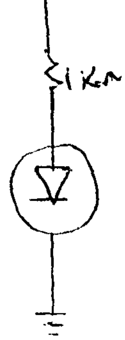


Fig: showing the circuit of fully charged indicator

The voltage across a silicon diode is 0.7v

The current flowing in this network can be calculated by:

$I = (10v - 0.7) / 1000\ \Omega = 0.00093A = 9.3mA$

Protective Switching

Very often, most transistors are used as electronic switches. With the help of such switches, a given load can be turned On or Off by a small signal. This control signal might be the one appearing at the output of digital logic or a microprocessor. The power level of the control signal is usually very small. It is incapable of providing enough base drive to switch a transistor On or Off, hence the transistor is made to switch the load.

When using ZN2222 as a switch, two levels of control signal are employed. With On level, the transistor operates in the cut-off region (open) where as with the other level, it operates in the saturation region and acts as a short-circuit.

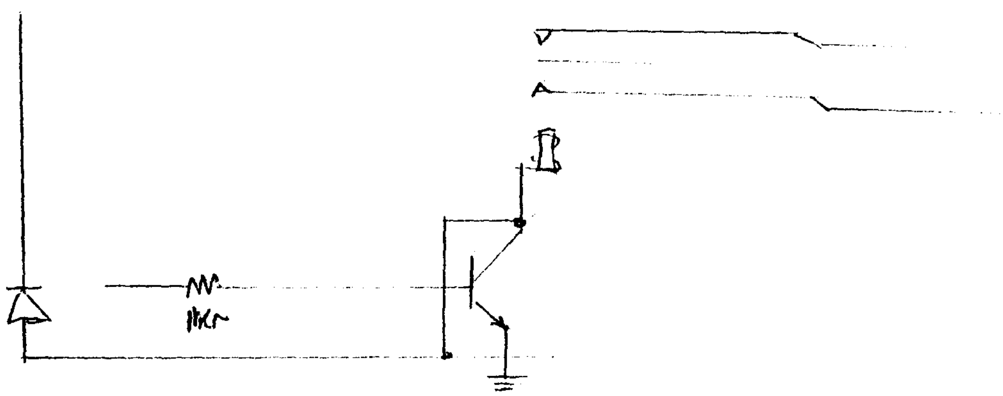


Fig: Switching transistor and Relay used in the circuit

From ECG book, from the circuit, $R_B = 330\Omega$; $V_B = V_{out}$ *(Op amp.)* $= 10v$

The base current I_B can be found from the equation

$V_B - V_{BE} = I_B R_B$; $I_B = (V_B - V_{BE})/R_B$;

$I_B = (10v - 0.7v) / 330\Omega; = 28mA$

The collector current Ic can be obtained (From *EGG* book $\beta = Ic/I_B$,where β is d.c current gain and is equal to 200)

So, $Ic = \beta I_B$; $Ic = 200 \times 28mA = 5600mA$; $I_c = 5.6A$

The relay coil resistance is R_c which can be calculated from $V_{cc} = I_c R_c$

$Rc = 12v/5.6A = 2.143\Omega$

The diode IN4001 is a free wheeling diode used as a protective device.

When the battery is charged, current will flow through the inductor of the relay storing energy in it. When this battery is disconnected and uncharged, the current in the inductor must drop rapidly to zero producing a strongly negative voltage transient in the inductor of the relay. The energy in the inductor is thus dissipated in the diode.

3.9 THE RELAY

Relays are electrically controlled switches. In the usual type, a coil pulls in an armature when sufficient coil flows. Because it is important to keep the battery isolated from the circuit, relays are useful to switch the circuit while keeping the control signal electrically isolated.

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CHAPTER FOUR

PRINCIPLE OF OPERATION OF THE CHARGER

4.1 PRINCIPLE OF OPERATION OF THE POWER SUPPLY

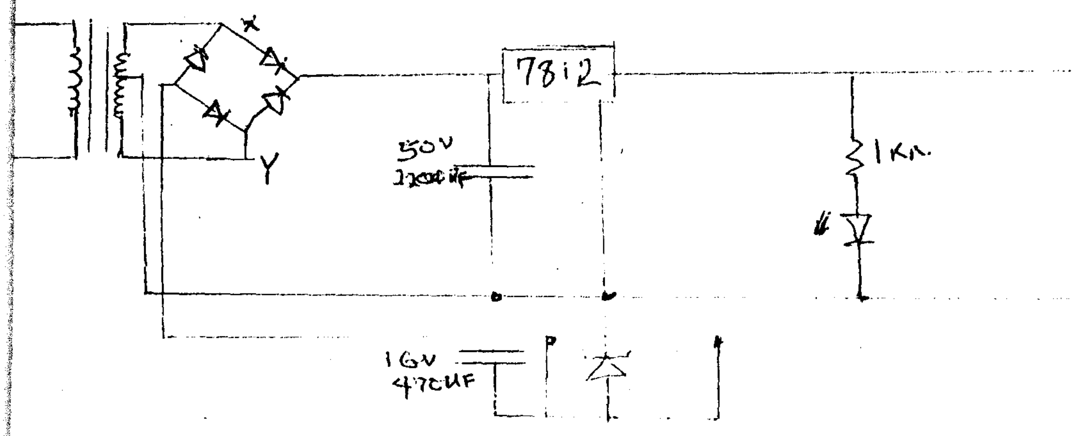

Fig: the power supply of the charger

The power supply is designed in such a way that both positive and negative voltages are obtained. This is the reason why a center tapped transformer is used.

This transformer, after tapping down the incoming voltage (240V from NEPA), provides at its output positive 12V and negative 12V alternating voltage. Both positive and negative voltages A.C has to pass through an electronic device circuit which is composed of four (4) discrete diodes arranged in a bridge form as shown in figure above.

When point X is positive with respect to point Y (positive half cycle, current flows through diode D_1, positive 12v wire, negative 12v wire and through D_2 to point Y during the negative half cycle, when Y is positive with respect to x current flows by way of D_3 positive 12v wire, negative 12v wire and D_4 to point X. This is termed as bridge rectification.

Now the output voltages are not A.C., but pulsating D.C which needs to be smoothened. In order to do so, two capacitors are placed in parallel with the output of the rectifier. The 50v, 220µF capacitor is used to filter the positive voltage and the 16v, 470µF is used to filter the negative voltage.

The required filtering action is performed when the capacitors store energy during the conduction period and deliver it to the circuit during the non-conducting period.

The two output voltages from the filters have some variations. To reduce these variations to zero or at least to a minimum value, the two output voltages have to pass through a regulator. The positive voltage is regulated by the I.C. 7812 while the negative voltage is stabilized by a 12V zener diode. Now both negative and positive regulated voltages are obtained.

.2 Principle of operation of the protective device

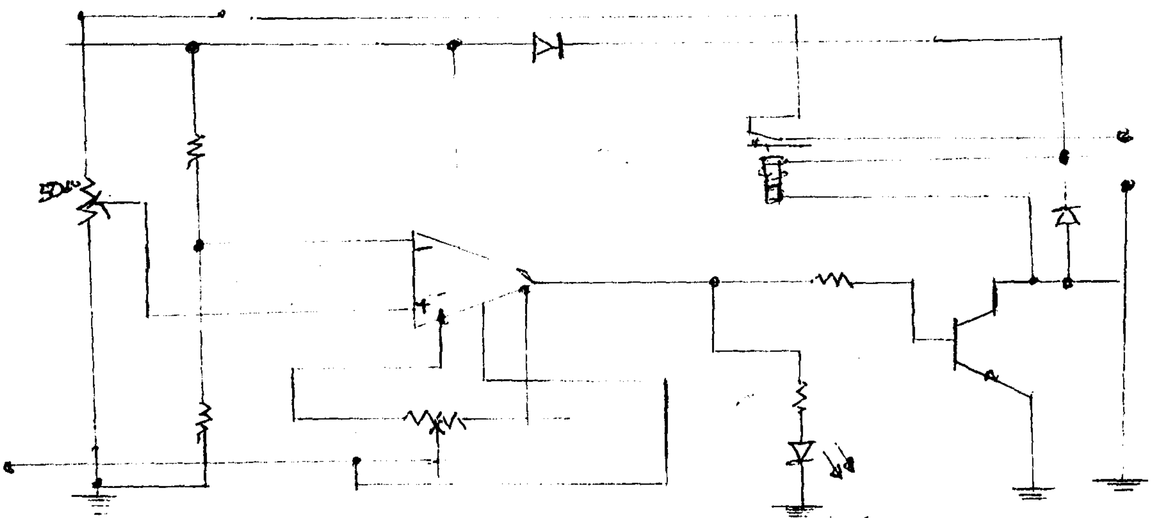

Fig. : Showing the protective device of the charger

As shown in the figure above, the regulated positive voltage (V_{cc} = 12V) is established across the two resistors of 1kΩ. That is, the half of V_{cc} (V_{ref} = $V_{cc}/2$) is established at the inverting input (pin 2) of the amplifier.

The V_{cc} also supplies voltage to the operational amplifier at pin7. It passes through the diode, D5 to the coil of the relay and ends at the first contact of the relay. The pole of the relay is connected to the positive plate of the battery. The second contact of the relay is the 50kΩ variable resistor. This resistor is set in such away that the half of established voltage across it will be established across the non inverting input of the amplifier. The other pin of 50kΩ variable resistor, the two resistors (1KΩ) network, the indicator network, and emitter of the transistor (ZN2222) are grounded.

The same ground is connected to the negative of the battery. The biasing and the offset of the amplifier are done by supplying negative voltage (-12) to pin 4 and the variable resistor (10kΩ) which is connected to pin 1 and pin 5.

When discharged battery is connected at the terminal of the charger, current flow from the 7812 IC, passes through the diode D5 and reaches the first contactor which is connected to the pole of the relay. This pole is connected to the positive plate of the battery. The charging voltage is established across the battery while charging.

When the battery is fully charged (12V), the diode D5 blocks the current flow to feed back the two resistor (1kΩ each) network subsequently, current flows through the wire, and established voltage greater than V_{cc} across the 50kΩ variable resistor network. That is a voltage greater than $V_{cc}/2$ is established at pin 3(non-inverting input).

Since the non inverting voltage is greater than the inverting input voltage, the amplifier operates and gives an output voltage, V_{out}

$V_{out} = V_{cc} - 2 = 10$ V

The L.E.D will come ON and the 10v across the 1kΩ resistor to saturation and acts as a closed switch. This makes current to flow in the coil of the relay. The flow of current will produce a magnetic effect which disconnects the pole from the first contact of the relay thereby disconnecting the battery from further charging.

CHAPTER FIVE

5.1 CONSTRUCTION AND TESTING

The construction started first by designing the component layout for the charger and the circuit was drawn on a paper. After all the components were assembled, the circuit was built on a single bread board. After confirming that the circuit was functional, the circuit was transferred on to a vero board.

A 14 pin dual-in line socket was used to plug the operational amplifier into the circuit. The use of the I.C socket facilitates the troubleshooting of the I.C as it can be removed for checking.

The I.C socket was first soldered on the board and then using the I.C pins position as a guide, the best layout was determined. The other components were fixed on the board in their various positions. Before soldering, proper checking of component connections was done. The capacitors were checked to be sure that they filtered properly.

The relay was mounted at the end of the Vero-board since it was the last component before the positive terminal which should be connected to the battery for charging. The wire that should be connected to the negative terminal of the battery is fixed on the ground connection. Three wires that should be connected to the output of the transformer were fixed at their various positions. After all this work, all the components were soldered carefully.

During the first test the circuit did not operate correctly. After troubleshooting, the two variables resistor (50kΩ and 10kΩ), the zener diode and the amplifier were discovered to be defective. They were replaced with non defective ones. Before testing for the second time, all components and wires were checked carefully again. The power supply to the wires was also checked to be sure that the needed voltages were supplied.

When everything was sure to be intact, the circuit was energized. The two L.E.Ds came ON and the relay made a click to indicate the disconnection of the wire that should have been connected to the positive terminal of the battery.

A discharged battery was connected to the terminal of the charger, the green L.E.D went OFF, and the relay made a click to indicate the connection of positive terminal. The relay made a click to indicate the disconnection of the battery as soon as battery is fully charged and the green L.E.D came ON. The voltage across the battery was 12v. Since the circuit was operated appropriately.

5.2 CONSTRUCTION:

A wooden case of 20cm x 15cm x 10cm was constructed. Two wholes were made for the two indicators. The various boards and the transformer were carefully incorporated in the case. The only access to the inside of the case is the top lid that was secured by two small screws.

5.3 RESULTS

The results of tests conducted on the charger have been mentioned already in the construction and testing unit but for purpose of adding more, second time mention of it will be well.

When everything was ready, the circuit was powered, the two indicators came ON. A charged battery was connected to the output terminal of the charger, the two indicators came ON but the relay made a click to disconnect the battery from the charger.

When a discharge battery (if voltage < 12v is connected, the green L.E.D goes OFF and relay makes a click to connect it after two hours, the green indicator comes ON and the relay makes a click to disconnect it. The battery voltage was increased up to 12v. Now, when a discarded battery was connected, the green indicator still came ON but no click was heard from the relay, this means that this battery can not take charge

5.4 CONCLUSION AND RECOMMENDATION

Having tested all the stages, it can be seen that the battery charger and the power supply can be achieved from basic electronic principle using BJTs, SCRs, variable resistors, Integrated Circuit e.t.c

The objective of the project is thus, achieved. It is tested and functioned very satisfactorily.

There is no fear of overcharging or undercharging since there is an L.E.D visual indicator and the voltage level could be pre-selected.

It can thus be recommended that: for further project work, other means of monitoring the voltage of the battery can be used.

The project could be modified and used to charge different types of batteries including car batteries.

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CIRCUIT DIAGRAM OF AUTOMATIC BATTERY C R LOAD
PROTECTION