DESIGN AND CONSTRUCTION OF A REGULATED DC POWER SUPPLY UNIT

BY

ADAM AHMED

REG: NO. 99/8022EE

A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

OCTOBER 2006.

DEDICATION

I wish to dedicate this project to the Almighty Allah for His mercy and protection over me throughout my academic career.

I`m also dedicating this project to my beloved mother and in memory of my late father whose support and encouragement made this struggle a reality. May Almighty Allah grant him aljanah firdausi [Amen].

DECLARATION

I, Adam Ahmed hereby declare that this project was wholly conducted by me under the able supervision of Assoc. Prof. Y.A. Adediran in the Department of Electrical and Computer Engineering, Federal University of Technology Minna. Niger State.

Adam Ahmed
Student

13/10/06
Signature and Date

Assoc. Prof. Y.A. Adediran
Supervisor

Signature and Date

Engr. M.D Abdullahi
Head of Department

Signature and Date

External Examiner

Signature and Date

ACKNOWLEDGEMENT

My greatest and immeasurable thanks go to the Almighty Allah for giving me good health, wisdom, and direction without which this project work and my course of study would not have been possible.

I remain grateful to my parents, Mall Adam Suleiman and Mallama Fati Adam, and my ever - loving brothers and sisters, Abudullahi Adam, Ajarat Adam, Aishat Adam, Umar Mustapha, Musa N. Usman for their enormous support, care and encouragement throughout my academic career. My profound gratitude also goes to my uncles Engr. Mustapha N. Suleiman, Mall. Madiwu Suleiman, Mall Aliyu Suleiman, Alh. Ahmadu Husseini and Alh. Yahaya Moh'd for their moral and financial support.

I appreciate the effort of my able supervisor Assoc. Prof. Y.A. Adediran for sincerely and selflessly seeing to the success of this project work. I wish to express my sincere appreciation to my H.O.D. Engr. M.D. Abdullahi, my academic adiviser Engr. J.G. Kolo and other staff in the Department of Electrical and Computer Engineering for their concern and encouragement.

I acknowledge the efforts of the following people Engr. Achanya, Engr. Moshod Aliyu, Engr. Shuaib M. Gupa, Mall Yunusa Ndagi, Comrade Kudu Usman, Abdulkadir Sambo, Bello Sambo, Abdullahi Usman Kuta, Hajia Rabi Salejo, Aisah Lawal.

I appreciate the efforts of my friends and colleagues;

Hon. Rabiu Moh'd, Ahmed D. Ahmed, Bello Hassan, Abdullahi Sani, Moh'd Zakari, Abudul-kadir Abdul-Hamid, Moh'd B. Ndagi, Obabu S. Dauda, Austin British and Oyedibu Gbenga.

My priceless gratitude goes to my beloved Princess Khadijat Saa'd for her love, care and support to the success of my academic career.

Finally, I give great kudos to entire member of Zuriya Abdulsalam. Sonlawos and Abaya who are numerous to mention

To God be the Glory.

ABSTRACT

This project work is on the design and construction of d.c power supply, the power supply has a fixed d.c voltage of 11V. It consists of four stages namely; transformer stage which reduces the mains supply level to 12v, rectifier stage which converts the a.c to d.c voltage, filter stage which removes the ripples from the rectified voltage and regulating stage which controls the d.c. voltage to constant 11 volts.

TABLE OF CONTENTS PAGES

CHAPTER FOUR: CONSTRUCTION 20

CHAPTER ONE

INTRODUCTION TO D.C POWER SUPPLY

Power supply can be grouped into two different forms namely; A.C and D.C. Many systems require D.C for their operation. But taking the statistics of electronic devices in use, they generally operate on D.C source including motor cars that use accumulator. This defines the uniqueness of D.C power supply in present day generation.

Having emphasized on the uniqueness of D.C power supply, the question is how reliable are the dry cells and batteries? They are known to have low voltage which amounts to limited life time as a result of increase in internal resistance with deteriorating battery condition. [1]

The problem is how local electric supply which is 240 Vr.m.s can be made to power the house-hold electric gadgets. The answer to this question gave birth to the ideal Design and construction of D.C power supply unit.

It calls for the lowering the PHCN supply of 240 Vr.m.s into smaller voltage using a step-down transformer and rectifier which converts the A.C output of the transformer into D.C voltage, a filter which removes the ripples from the rectified voltage and regulator which keeps the terminal voltage of the D.C supply constant. [2]

1.1 POWER SUPPLY UNIT

Generally, the use of electrical power is desired most by the central A.C system. Many systems need D.C for their operation. Therefore, conversion of A.C to D.C enables the elimination of non-cost effective batteries from numerous electrical system such as Radio, torch light.

D.C power supply refers to complete circuitry which performs the conversion from A.C to D.C including the Transformer, Rectifier, Filter, and voltage regulator.

The D.C power supply unit provides the necessary D.C voltage and current with low level of A.C ripples good stability and regulation. It must be able to provide stable D.C out put irrespective of the input voltage and changes in the load current or temperature [1,2]

TRANSFORMER [STEP-DOWN STAGE]

Its main function is to step-down the A.C supply voltage to suit the requirement of the solid state electronic device.

VOLTAGE RECTIFICATION STAGE

Since diodes have the characteristic of having a much greater conductivity in one direction than in the other, diodes are being used for this purpose

Voltage rectifier is a circuit which uses one or more diodes to convert A.C to D.C and the process is known as voltage rectification.

VOLTAGE REGULATION STAGE

The main function of this unit is to keep the terminal voltage of the D.C supply constant. Even when A.C input to the transformer varies, or the load connected to the power supply unit varies. [1, 2, 3]

CHAPTER TWO

LITERATURE REVIEW

Over the years, the need for a D.C power source that is ripple-free, efficient and most importantly regulated output has been on the increase. This has been achieved by the break through made by engineers in the field of electrical and electronic technology it would be worth nothing that these has been a gradual evolution from the days of valves to the present day's use of transistors and integrated circuit. Valves normally operate with a potential difference of 100 V or more between cathode and anode. [3]

Nowadays, valves are not used in portable equipment. In the early days of electronic systems like radio, valves were the only means of amplifying and many people did not have a mains electricity supply in their home. Radio sets were powered by large, heavy-tension batteries of dry cells, giving potential of about 120V. The large current needed for heating element was provided by several lead-acid cells [Accumulator] which needed recharging frequently. Transistor circuits usually operate with low potential difference rarely greater than 30V and they all require direct current. [1, 2]

Many circuits operate on lower potential difference such as 9V, or even as little as 1.5V. The current required by portable radio set is only about one hundred mill ampere and the current used by a pocket calculator or digital watch is measured in micro-ampere.

The very low power requirement and low operating voltage of transistor are the reason why so much battery-powered portable equipment today. But not all transistorized equipment are battery-powered. Audio amplifier, Television set, computer, oscilloscope and many other items are usually mains-powered. [3]

Normally, a transformer is used followed by a circuit that will provide D.C at a steady voltage such as 6V, 9V, 12V or 24V. High voltages are rarely required as they damage most transistors.

The need to power mostly digital circuits which require a high level of efficiency in power supply has paved the way for the advancement in the design of the d.c power supply unit. Several attempts have been made by Engineers to improve on their design with a view to producing a power supply unit that will be of better quality. The first attempt considered was the use of integrated circuit 723 as a voltage regulator connected in the circuitry to too many components. This defeats the economic purpose of the project and, at the same time, reduced the efficiency of the unit. [4]

The second attempt was the use of common integrated circuit 741 connected to other component to form the voltage regulator. This has been proved to be of low efficiency because the I.C. 741 used has been designed as a multi-purpose I.C.

The latest improvement made with respect to previous design was done by the use of I.C LM 723 which was solely designed for voltage and gives efficiency of the unit. Only that the I.C used is still connected in circuitry to many components which tends to reduce the efficiency and reliability of the unit. [5]

In an attempt to improve on this, the following factors are taken into consideration; simplicity of the circuit, ease of maintenance, accessibility, ease of assembly of the circuit, packaging and economic purpose of the project. So two npn silicon transistors and zener diode are used as a voltage regulator and a protective device against short-circuit and over load-current are provided to achieve a better result in the power supply unit. [6]

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.1 In order to design and analyze an entire circuitry properly, it was broken into four stages namely; Transformer stage, rectifier stage, filter stage, and regulator stage.

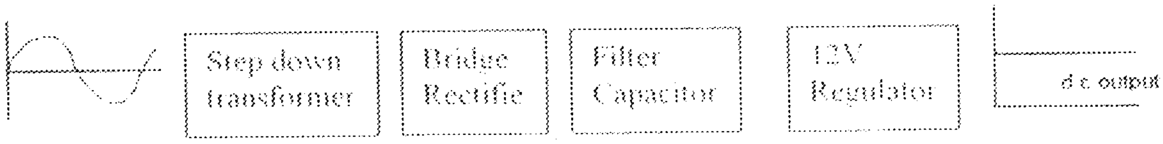


Fig. 3.1 shows the block diagram of a regulated d.c power supply unit.

REGULATED POWER SUPPLY UNIT:

The purpose of regulated d.c power supply is to provide constant d.c voltage at the output terminal no matter how much current is drawn by the load. The voltage is expected to be constant.

VALUE OF THE COMPONENT

T2 = 240V/12V

C1 = 25V 4700 x 10-6

C2 = 1

R1 = 100 Ω

R2 = 100KΩ

R3 = 10KΩ

R4 = 5.6KΩ

R5 = 10KΩ

R6 = 5.6KΩ

TR1 = TIP32

TR2 = C1815

Fig. 3.2 Shows the circuitry diagram of a regulated d.c power supply unit.

3.2 TRANSFORMER:

The transformer used is a step-down type rated 240/12V, 1000mA. This implies that whenever 240V a.c mains supply is applied to the primary of the transformer, a 12V a.c will be obtained at the secondary side of the transformer. From the rating of the transformer, the voltage transformation (RT) can be calculated as:

$$RT = \frac{\text{Secondary Voltage (VS)}}{\text{Primary Voltage (VP)}}$$

Where VS = 12 V and VP = 240V

$$RT = \frac{12V}{240V} = \frac{1}{20}$$

Transformer ratio = 20:1

But $V_{rms} = V_{max}/\sqrt{2}$

$V_{max} = V_{rms} \times \sqrt{2} = 12 \times \sqrt{2} = 16.97V$

therefore f = $\frac{V_{max}/\sqrt{2}}{2 \times V_{max}/\pi} = \frac{\pi}{2}/\sqrt{2} = 1.11$ [6]

3.3 BRIDGE RECTIFIE R

This employs four diodes to convert a.c voltage int.- pulsating d.c voltage. The following advantages are considered in selecting the design:

Much smaller transformer are required

No control tap is required on the transformer

It has less pack inverse voltage [PIV] per rating per diode

the circuit diagram for bridge rectifier is shown below

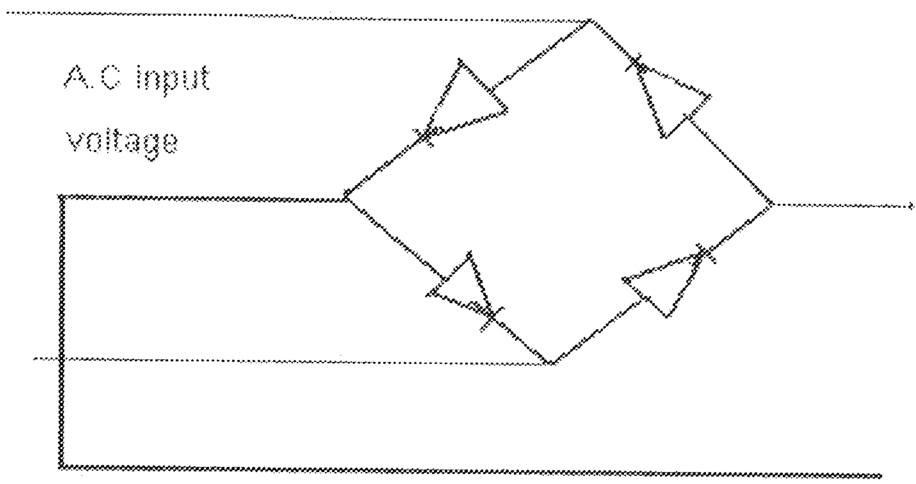


Fig. 3.2 bridge rectifier circuit

$$\text{Rectifier efficiency } \eta = \frac{\text{d.c power}}{\text{r.m.s power}} \times 100\%$$

$$= \frac{\text{d.c Voltage, (Vdc)}}{\text{r.m.s Voltage (Vr.m.s)}} \times 100\% \qquad [7]$$

Using the transformer rating

Vr.m.s = 12V

Vdc = Vr.m.s / form factor (f)

$$Vdc = \frac{Vrms}{\pi/\sqrt{2}} \implies Vrms \times \frac{\sqrt{2}}{\pi}$$

$$= 12 \times \frac{\sqrt{2}}{\pi}$$

Vdc = 10.8V ≅ 11Vd.c

$$\text{Therefore, } \eta = \frac{10.8}{12} \times 100\% = 90\%$$

Ripple content of the Pulsating d.c output, VL (a.c)

$$VL\ (a.c) = \sqrt{V_L^2 - V_L^2(d.c)}$$

VL = Vrms = 12V

VL (d.c) = 10.8V [8]

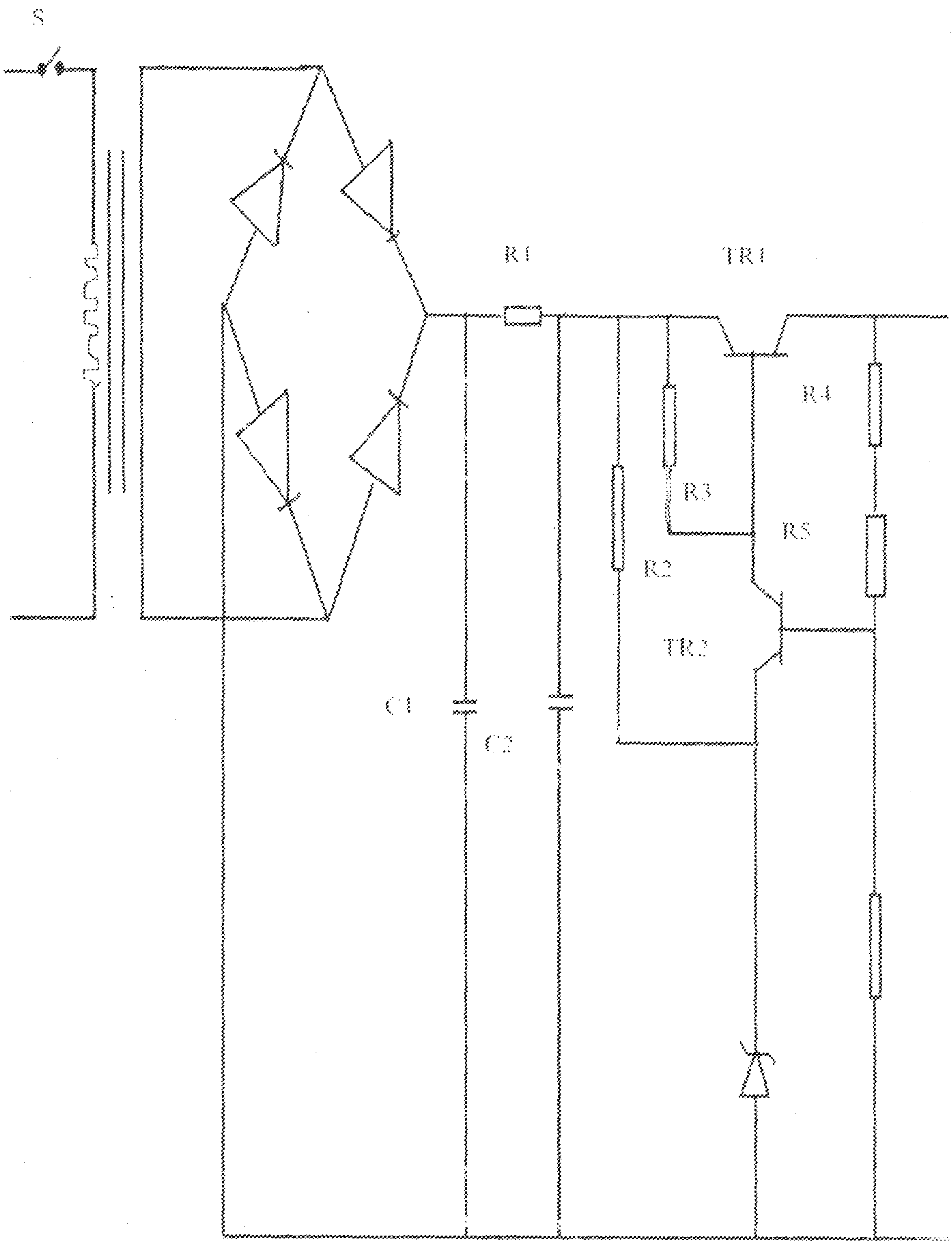


Fig. 3.2 Shows the circuitry diagram of a regulated d c power supply unit

Now VL (a.c) = $\sqrt{12^2 - 108^2}$

VL (a.c) = $\sqrt{27.36}$ = 5.23V

Therefore the ripple factor

γ = VL (a.c) / VL (d.c)

= 5.23 / 10.8 = 0.484 → 48.4%

Peak inverse voltage (PIV) = $\sqrt{2}$ x 12 = 16.97V

3.4 FILTER CAPACITOR

The main function of the filter capacitor is to minimize the ripple content of the rectified out put voltage. These rectifiers are connected across the rectifier out put and in parallel with the voltage regulator as shown in figure 3.2.

The operation of the filter circuit output depend on the property of a capacitor to charge up during conducting half-life and discharge during non-conducting half-life cycle. A capacitor opposes any charge in voltage. When connected across a pulsating d.c. voltage it tends to perform the filtering action. [9]

3.4.1 FILTER DESIGN CALCULATION

Minimized pulsating d.c output of the capacitor. V_{dc}

$$V'_{dc} = \frac{V_{ip}}{1 + I'_{dc} / 4FCV_{ip}}$$

$$I'_{dc} = \frac{V'_{dc}}{R_L}$$

$$\rightarrow V'_{dc} = \frac{V_{ip}}{1 + I'_{dc} / 4FC R_L V_{ip}}$$

where F = frequency = 50Hz

C = capacitor of the capacitance = 420 x 10-6

R_L = Resistance of Load = 6930Ω

V_{ip} = Peak rectified output voltage.

$V_{ip} = \sqrt{2} \times V(a.c)$

$\sqrt{2} \times 12 = 16.970V$

now

$$V'_{dc} = \frac{16.70V}{1 + V'_{dc} / 4x50x4.700x10^{-6} 6930 \times 16.92}$$

$$V'_{dc} = \frac{1677}{1 + 9.0x10^{-6} V'_{dc}}$$

$$V'_{dc} + 9.0 \times 10^{-6} (V'_{dc})^2 = 16.97V$$

$$= 9 \times 10^{-6} V'^{2}_{dc} + V'_{dc} - 16.97 = 0$$

applying quadratic formula

$$V'_{dc} = -1 \pm \frac{\sqrt{1+0.000009+4\times16.97}}{0.000009\times2}$$

$$V'_{dc} = \pm\frac{3.05\times10^{-4}}{1.8\times10^{-5}} \qquad V'_{dc} = 16.94$$

Ripple factor of the pulsating filtered d.c output

$$\gamma' = \frac{1}{4\sqrt{3}FC\,R_L}$$

$$\gamma' = \frac{1}{4\sqrt{3}\times4700\times10^{-6}\times6930}$$

$$\gamma' = \frac{1}{225.658}$$

$$\gamma' = 4.431\times10^{-3}$$

$\gamma' \approx 0.443\%$

ripple content of the output

V_r (r.m.s) = $\gamma' V'_{dc}$

V_r (r.m.s) = 4.431 x 10^{-3} x 16.94

= 0.075Volts

3.4.2 EFFECT OF INCREASING FILTER CAPACITOR

Increase the capacitor size;

increase Vd.c towards the peak rectifier output voltage

Reduce the magnitude of ripple voltage

increase the peak current in the diode.

Reduces the time of flow of current pulse through the diode

3.5 REGULATOR DESIGN

Zener or break down diode is a semi-conductor p-n junction diode with controlled reverse biased property which makes it extremely useful in many applications.

Zener diode is known to maintain a constant output voltage.

$$Iz_{max} = \frac{P_Z}{V_Z}$$ where Iz = Zener diode current

P_Z = Power rating of the diode.

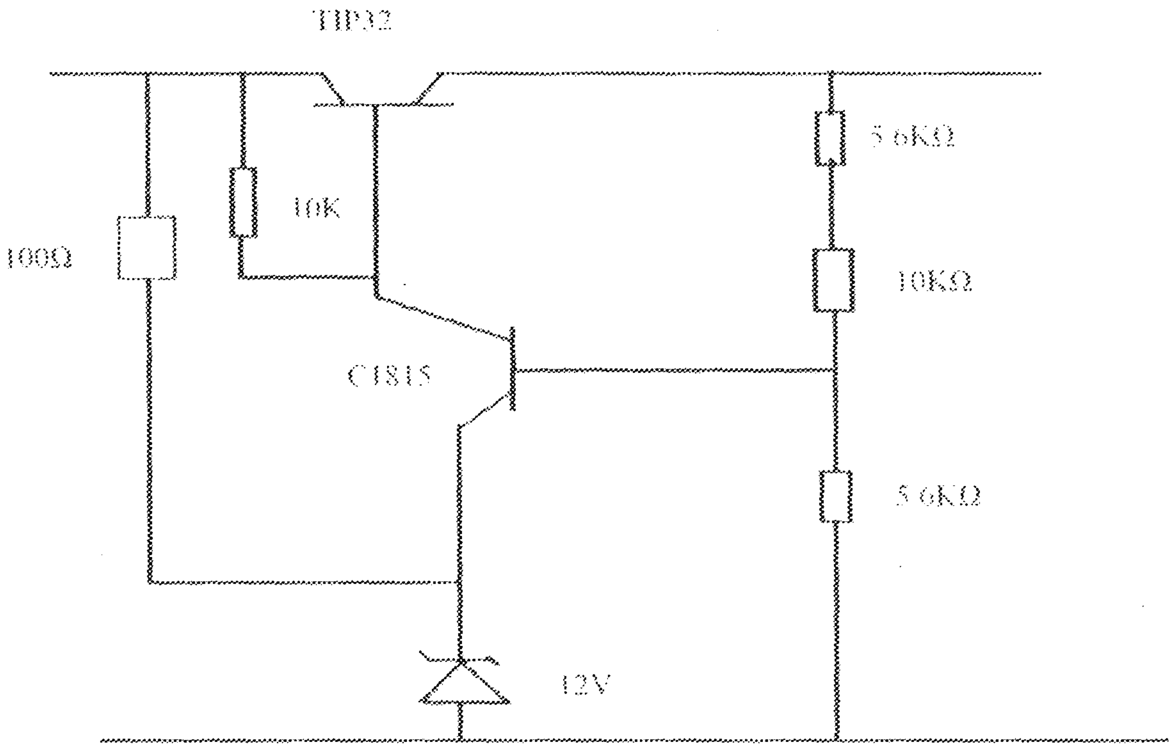


Fig. 3.4 Circuit diagram of the regulator

V_Z = diode voltage

A zener diode with a reference voltage of 12V is used for this project.

Selection of resistor for zener diode

P_Z = 1.44W

V_z = 12V.d.c

$$I_z = \frac{P_z}{V_z} = \frac{1.44}{12} = 0.12\ A$$

$$R = \frac{V_z}{I_z} = \frac{12}{0.12} = 100ohms \qquad [9,10]$$

5.2 SELECTION OF BIASING RESISTOR FOR THE TRANSISTOR

To forward-bias the base-emitter junction, being an npn transistor, the base should be positive with respect to the emitter. This is achieved by R_B connected between the positive supply V_s and the base. If we neglect the base-emitter voltage drop, then.

$$R_b = \frac{V_S}{I_b} \qquad Vs = 12V.d.c \quad I_B = 1.2 \times 10^{-3}\ A$$

$$R_b = \frac{12}{1.2 \times 10^{-3}} = 10\ K\Omega \qquad [10]$$

VOLTAGE REGULATOR

Electronic power supplies that produce rectified d.c voltage for a system generally require more voltage regulation than a battery source. This is primarily due to change in a.c line voltage causing a corresponding change in output voltage. In addition to line change, there are load changes and temperature changes that alter the output of a power supply. A power supply whose d.c. output varies is classified as unregulated power supply

The regulated power supply compensates for those changes and maintains a constant output, this is achieved by circuit called a voltage regulator or stabilizer connected between the unregulated supply and the load performing this function. There are different types of voltage regulator namely;

Zener diode regulator, transistor series regulator, and shunt regulator.

CHAPTER FOUR

CONSTRUCTION

4.1 LAYOUT OF COMPONENTS

Proper component layout in the circuit board makes it possible on bread board to make some changes as the need arises. The bread board layout enables easy fault identification and rectification in case of repairs. In the design of this project, the dimension of each component was considered so as to make the construction easier.

Having been satisfied with the behavior of the circuit, it was then transferred to vero-board where the components were soldered carefully. The construction proceeded with the identification of the various leads for attachment of the components. The power input line was chosen and the transformer secondary tapping attached at the positive and negative ends of the board parallel to each other.

The diodes were then arranged in the forward biased secondary tapping attached at the positive and negative ends of the negative end to effect full-wave rectification. The capacitors were then connected at the output points of the diodes where they will accomplish the filtering function.

All the components have their leads for attachment kept at minimum to prevent accidental short circuit. The circuit was carefully planned minimizing error and make trouble-shooting easier. Adequate allowance was given to each component terminal to prevent bridging during soldering on the circuit.

The 10ohms resistor has leads connected to positive line of the input voltage and lead connected between the base lead of transistor TR1 and collector lead of transistor

TR2. The zener diode was connected in the reverse bias region with one lead connected to the ground of the circuit board and the other lead connected to the emitter lead of transistor TR2. [10, 11]

4.2 ARRANGEMENT AND SOLDERING OF COMPONENT ON VERO BOARD

The soldering was done with great care and in accordance with already laid down rules for soldering. The components were laid on the vero-board and great care was taken to avoid short circuit.

The heat of soldering iron was applied near the legs of the components. The solder in all cases was allowed to flow along the rail, the excess solder was then sucked out with a lead sucker. Telephone insulated cables were used to link terminals that were far from each other. The arrangement of the components on the vero-board was properly made to achieve the desired result and to avoid any fault. [11]

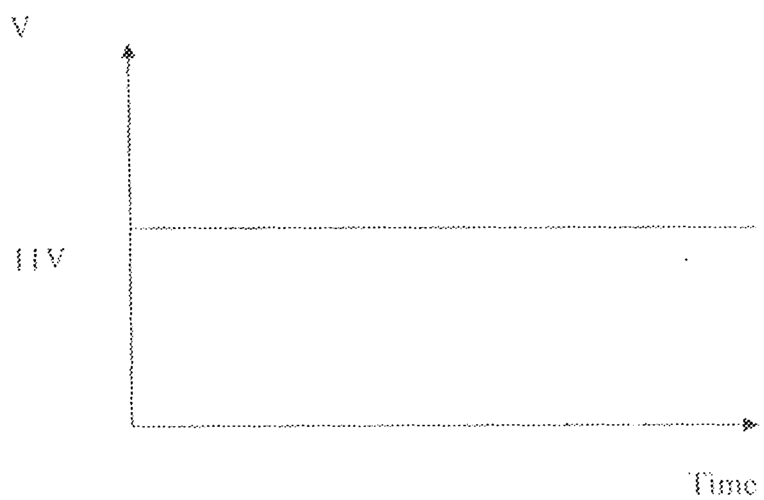
4.3 TESTING

When all the soldering was over, the circuit was traced and retraced to ensure that there was no short circuit or open circuit. The output of the power supply was then monitored by connecting a digital multimeter switch to the voltage range across the output while moving the voltage select knob. The reading was noted and the digital multimedia was then disconnected.

A power indicator circuit, comprising a resistor and light emitting diode, shows the presence of the output d.c. voltage. [3]

4.4 RESULT

The aim of this project was achieved, the d.c. output voltage was 10.8V d.c. which is approximately equal to 11V. The d.c output was found to be ripple-free.



The graph of the D.C output voltage against time.

4.5 DISCUSSION OF RESULT AND SUMMARY

One thing to note is that the desired voltage at the terminals depends on the secondary winding of the transformer. If the torn ratio is such that the primary voltage is 240V a.c and secondary voltage is 12V a.c, it can be manipulated to deliver a 11 volt d.c at the output terminal

Assessment of the work has shown that it can serve the purpose of domestic appliance to 11V d.c only.

If the primary voltage exceeds the normal voltage of 240v or if the primary voltage falls below 220v to about 110v the desired 1 1Vd.c output will not be achieved. [11, 12]

4.6 PRECAUTION TO TAKE WHEN USING D.C POWER SUPPLY

One should be careful when wiring the power supply circuit and never operate the supply when the top of cabinet is off unless one is testing it, even then, one should stay away from incoming A.C because it can cause a serious shock.

One should not operate the power supply if it has gotten wet or shown sign of visible damage.

One should not assemble the power supply without a fuse and one should not use a fuse rated higher than the output current.

4.7 TROUBLE SHOOTING

When the power supply unit is faulty, the fault has to be traced to some particular portions of the unit. The fault may lie in the transformer, the rectifier, the filter section or the regulator.

Firstly, measure the d.c output voltage, if it is zero, the next check should be on the mains input. Is the input reaching the transformer primary? If it is not, there is possibility of faulty plug. If the fuse is blown, it has done so due to some fault conditions and the fault must be cleared before a new fuse is fitted. [12]

Resistance check (with mains plugged) must be used to locate such fault. Use an ohm-meter to measure the resistance of the transformer primary, the secondary and the rectifier.

Secondly, if the fuse is intact and supply is reaching the primary, the next is to measure the secondary A.C voltage, then followed by the other units.

4.7.1 LIST OF SOME TYPICAL FAULTS AND ASSOCIATED SIGNS

FAULTS	SIGNS
Mains transformer shorted Primary or Secondary	(i) Turn-on mains blown or low d.c output (ii) Transformer overheating because of excess current being drawn.
Mains transformer open circuit	(i) D.C output zero (ii) High resistance [Primary or Secondary]

4.8 SOLDERING

Soldering was achieved with the use of soldering iron, soldering lead around a plastic solution tube. Some extra care taken during the soldering is given below;

1. Care was taken to ensure proper contact while using little but enough soldering lead for the joints.
2. Easier and faster soldering was ensured by thinning the terminal of the components with melted soldering lead.

Care was taken to ensure soldering iron temperature was not too high so as to protect the components from damage or over heating

4.9 PROTECTION

If the output of the regulator is subjected to heavy load such as short circuit, device rating may be exceeded, resulting in catastrophic failure, some means of overload protection is incorporated in the regulator

4.9.1 CURRENT LIMITING

The simplest form of circuit limiting is to incorporate a fuse in series with the unregulated supply. However a fuse can take a considerable time to blow by which time damage is done. Alternatively the fuse may be replaced by resistor which limits the current flowing to a safe value

4.9.2 TOOLS USED IN DESIGN AND CONSTRUCTION

1. Breadboard was used for carrying out the construction before it was transferred to the vero-board.
2. Soldering iron and soldering lead were used in soldering the components on the Vero-board.
3. A digital multimeter was used to carry out the test including continuity test, voltage measurement.
4. Suction tube was used to suck soldering misplaced leads from the vero-board to avoid short-circuit and ensure clean construction.

CHAPTER FIVE

CONCLUSION

The study of theory of semi conductor has gradually led to the practical use of device. The incoming 240V mains supply was stepped down to 12V by a step-down transformer. The output of transformer is a bi-directional voltage and it was converted into a uni-directional voltage. This conversion was achieved by the use of a bridge rectifier

The output of rectifier contained some ripples which were filtered out by the filter circuit. The regulator keeps the output d.c voltage constant.

The test carried out and the result obtained show that this project can serve the purpose of domestic appliance to 11V.d.c only. It can be seen that despite the ripples or fluctuation, the zener diode can still give a constant d.c output at the terminal.

5.1 PROBLEMS ENCOUNTERED

Some of the problems encountered are unavailability of some components which were replaced by the equivalent ones. Also there was a problem of variation in main supply from NEPA/PHCN. When the supply was very low to about 110V, the desired 11V.d.c was not achieved

5.2 RECOMMENDATION

Since electronic appliance requires the constant D.C voltage specified by the designer. I will recommend that the design of a back-up D.C power supply be the next project target to encourage a continuous use of the regulated D.C power supply by the designer. It is advisable to have an in-built protection device like fuse which acts as a circuit breaker whenever there is excess inflow current and short-circuit.

I recommend that students should be encouraged to take up d.c power supply project for fast labour.

REFERENCES

[1]. M.D Abdullahi, Analogue Electronics Course Material F.U.T Minna, 2004 Pp 1-6

[2] Charles A.H. Electronics Circuit. John Wiley and Sons Inc. 1992, Pp 201-204

[3] Cooper W.D. Etal Electronics Instrumentation and Tech. 3rd Edition. 1989, Pp 101-107

[4] Holt C.A Electronic Circuits, digital and Analog. John Wiley and Sons Inc. Networks. 1978, Pp 56-65.

[5] Tharaja B.L and Tharaja A.K A text book of Electrical Technology, Channel and company Limited, Now Delhi. 1996, Pp 1457-1465.

[6] Knight S.A Electrical and Electronic Principle, 2nd Edition. 1988, Pp 20-30.

[7] Ralph J.S Electronics (Circuit and Device). 2nd Edition. John Wiley and Sons. 1980, Pp 28-51.

[8] Ritche G.T Transistor Circuit Technique (discrete and integral) Chapmen and Hill. 1993, Pp 40-43

[9] Sanwine S.J Electronics Components and Technology. 3rd Edition.) Chapmen and Hill. 1993, Pp 115-118.

[10] Hughes R. Electrical Technology. Pp 512-520

[11] Green D.C Electrical Technology Level. Pp 513-517

[12] Toro D.V Electrical Engineering Fundamental, 2nd Edition. Prentice-Hill, India Private Limited 1986, Pp 13-18

LIST OF COMPONENTS USED FOR CONSTRUCTION

1. a step down transformer rated 240V/12V
2. Bridge rectifier comprising of 4 diodes rated IN4001
3. Electrolytic capacitor 4700×10^{-6}F/25V
4. Resistors, 100Ω, 100KΩ, 10KΩ, 5.6K Ω
5. Transistors, TIP32 and C1815
6. Zener diode
7. Bread-board
8. Vero board