DESIGN, CONSTRUCTION AND TESTING OF A 1KVA UPS /INVERTER WITH ANALOGUE DISPLAY

BY

AGBONFI GARRICK AGBONFO
REG. NO 98/6835EE

DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING.
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA.

NOVEMBER 2005.

DESIGN, CONSTRUCTION AND TESTING OF A 1KVA UPS /INVERTER WITH ANALOGUE DISPLAY

BY

AGBONFI GARRICK AGBONFO
REG. NO 98/6835EE

DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING.
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA.

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B ENG.) DECREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY MINNA.

NOVEMBER 2005.

DECLARATION

This is to declare that this project was carried out by AGBONTI GARRICK AGBONFO of the department of electrical and computer Engineering, Federal University of Technology Minna under the supervision of Engr. N. N Rumala

Signature

Date

CERTIFICATION

This is to certify that this project was carried out by AGBONIFO GARRICK AGBONIFO of the department of Electrical and Computer Engineering, Federal University of Technology Minna under the Supervision of Engr. S.N Rumala

Engr.S.N Rumala
Project supervisor

9/10/05
Date

Engr. M.D Abdulahi
Head of Department

16/02/06
Date

External Examiner

Date

DEDICATION

This project is dedicated to the Almighty God, my help in ages past and hope for years to come.

ABSTRACT

The aim to this project is to design and construct a digital UPS that has an analogue display for its output voltage. This was achieved by converting a 12 volts D.C Battery source to a 220v A.C supply by the use of an oscillator circuit whose output is amplified by a class B amplifier and powered by a centre tapped, step-up Transformer.

This project write up includes five main chapters. The first introduces the concept of the Digital UPS , its usefulness and its design specifications. The second is literature review, which serves as background knowledge for all the basic active components that make up the various sub-circuits. The third chapter describes the design and analysis of the various sub-circuits along with their various principles of operations. The fourth describes the testing and construction of the final circuit as well as the internal and external physical structures. The last chapter contains the conclusions and recommendations made during the design. Reference sources were also included for future design.

TABLE OF CONTENT

CONTENTS PAGES

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER ONE

1.0 INTRODUCTION

The inconsistency in the supply of utility power in Nigeria has been the cause of great damage to most of our Electrical and electronic appliances. In addition, the country economy has lacked rapid and steady development. However in bid to be as good as most other developed and developing countries, alternative power supply sources are sought to give continuous power, should the utility power fails.

Moreover, there has been a rapid growth in the use and installation of data processing equipment, medical equipment, alarm systems, safety lighting e t c the failure of which may have very critical consequences. All of these factors have prompted a new industry of uninterrupted power supply system. The power system (UPS) provides electric power for critical functions and equipment when the normal supply power fails.

1.1 WHAT IS A UPS

A UPS in electronic terms is a device that is capable of changing electrical Energy from D.C to A.C. It can also be said to be an electronic arrangement used to convert a lower D.C voltage to a higher A.C voltage output at a particular frequency. Therefore, in this project work, a 12volts, 50Hz A.C power output is needed.

1.2 THE BASIC UPS OBJECTIVE

The aim of this project is to design and construct a UPS system, which may be adopted for use in a cottage industry, that is a small scale commercial outfit, say, a barbing /hair dressing salon, when utility power fails.

The usual choice of storage device is the rechargeable secondary battery. This device stores D.C power and must therefore be preceded by a charging circuit, which converts A.C from the main supply to D.C power. Once utility power fails, D.C power stored in the battery is inverted to a.c through suitable circuit and amplified to deliver power to the load. A block diagram representation of the UPS is shown in fig 1.2.1

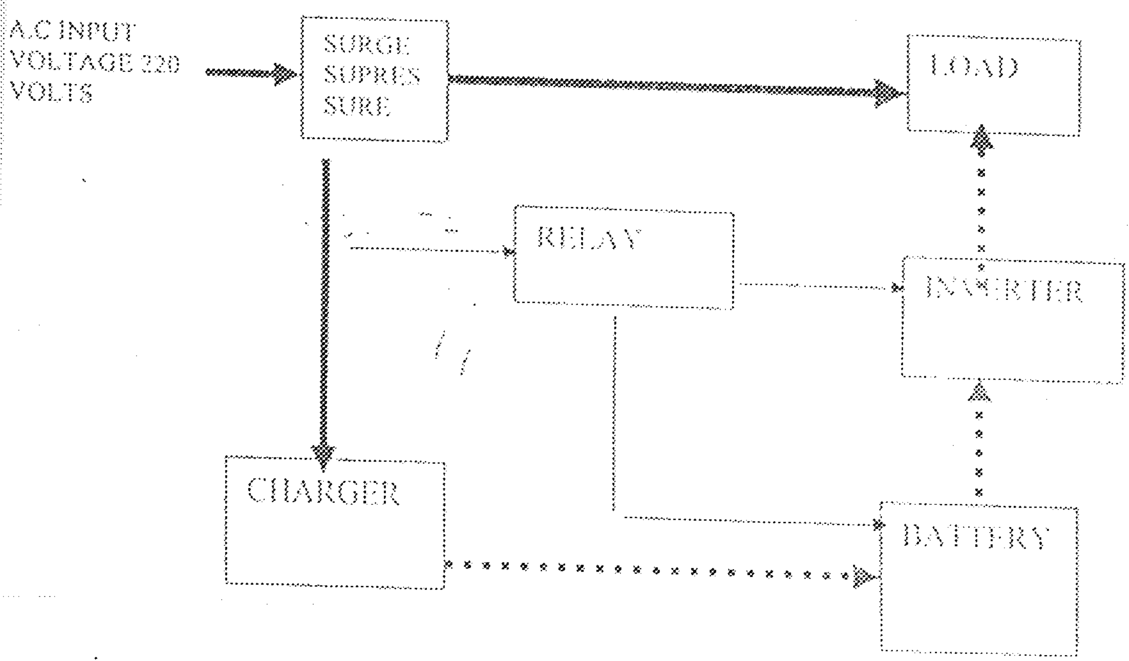


Figure 1.2.1 A block diagram representation of the UPS

1.3 CLASSIFICATION OF UPS BY SOURCE

1. Current (D.C) source UPS : This is used for very high power A.C motor belt drives. This was not considered in this project because of their limited applications.
2. Voltage (D.C) source: This type of UPS requires a D.C voltage input source for its operation.

1.4 THE CHARACTERISTICS OF AN IDEAL UPS

1. The digital Ups must isolate crucial load from the main supply.
2. It must keep transient from load and also filter out the transient generated by the load.
3. Generate power corresponding to the mains supply at the main frequency and voltage.
4. Draw operating power from the mains supply during normal period to reduce cost.
5. The system should have an automatic Battery charging capability.

1.5 ADVANTAGES AND DISADVANTAGES

The adaptation of the UPS system for a small outfit such as named above has advantages which include:

1. Better uninterrupted customer service in the event of power outages. For instance, barbing or hair drying that is been done can be completed with little interruptions and minimal discomfort to the consumer.
2. The UPS is noiseless, generates minimal heat compare to fumes into the atmosphere. The employment of sealed lead acid batteries ensures that no acid leakage occurs.

The major disadvantages is that, for this particular design, the UPS may not operate for more than 1.8hours when fully loaded. Hence for energy conservation purposes, some load shedding may be required so that the most critical jobs are given priority.

1.6 DESIGN SPECIFICATION

OUTPUT POWER: 1KVA

OUTPUT WAVEFORM: PUSLE WIDTH MODULATION

OUTPUT FREQUENCY: 50HZ

OUTPUT VOLTAGE: 220VOLTS

CHARGING TYPE: CONSTANT VOLTAGE

1.7 PROBLEM STATEMENT

The aim of this project is to design and construct a UPS system, which may be adopted for use in a small scale commercial out fit, a lerbing hair dressing salon, when utility power fails. A case study was made of POSH UNISEX SALON at Mypa Junction Minna Niger state, to determine what the average maximum power consumption of such an outfit would be. The following information was obtained for their peak load per[illegible]

EQUIPMENT	NUMBER	UNIT POWER(VA)	TOTAL POWER(VA)
Clippers	5	20	100
Fans	3	60	180
Dryers	4	40	160
Fluorescent	4	40	160
Television	1	70	70
Hair Tongs	3	25	75
Total			745

Hence, for a good safety margin, a rating of about 1KVA is chosen for the UPS. The choice of battery type is influenced by the desire for compactness, ease of charging, discharge rate and the capacity in ampere hours. Hence a singular trailer sized lead acid battery with a rating of 12volts, 150Ah(Ampere-hour) is chosen.

An important point to consider in the design of the inverter for this application is the presence of inductive loading such as fans and Clippers. The inverter must therefore be designed to cope with such loads.

CHAPTER TWO

2.0 LITERATURE REVIEW

An Operational Amplifier is a differential Amplifier with an extremely high open voltage gain. Negative feedback circuits can be employed in op-amp to control the gain when precise gain values are needed. The comparator is an operational amplifier without a feedback. Hence, it is controlled by the high voltage gain

The op-amp was originally developed for use with analog computers but now they found use in almost all aspects of electronics. The op-amp has the following ideal characteristics

1. Infinite voltage gain
2. Infinite input impedance
3. Infinite bandwidth

In practice however they differ from ideal conditions due to manufacturing process and conditions of the components, which make up the op-amps. Below shows the actual characteristics of uA741 op-amp.

Voltage gain-106dB (numerical gain = 200000)

Input impedance = 1M ohms

Output impedance =7500 ohms

Bandwidth up to 1MHz

The voltage gain and bandwidth are two parameters that must be critically looked for, in order to successfully use this device. More information about the parameters could be gotten from IC data sheet.

$V_{out} = A_o V_{in}$

Where A_o is open loop voltage gain and $V_{in} = V^+ - V^-$

Due to the very high A.. V... will tend to saturate upon any difference in input. Other op-amp circuits include, inverting and non-inverting amplifiers, summing amplifier, unity gain buffer e.t.c.

Figure 2.0.1 symbol for an op-amp.

2.1 TRANSISTORS

Transistors are active components used basically as amplifiers and switches. The two main types of Transistors are: The bipolar transistors whose operation depends on the flow of both minority and majority carriers, and the unipolar or field effect Transistors (called FETS) in which current is due to majority carriers only (either electrons or holes). The Transistor as a switch operates in class A mode. In this, the biased circuit is designed such that current flows without any signal present. The value of bias current is either increased or decreased about its mean value by input signal (if operated as an amplifier) or ON and Off by the input signal if operated as a switch.

Figure 2.1.1 Transistor as a switch

For the Transistor configuration, since the Transistor is biased to saturation,

$V_{CE} = 0$ i.e when Transistor is ON

Which implies that

$V = IcRc + V_{CE}$ ---------------------- 2.1a

$V_{in} = I_b R_b + V_{BE}$ ----------------------2.1b

$Ic = hfe\ I_b$-------------------------------------2.1c

$R_b = (V_{in} - V_{BE}) / I_B$--------------------2.1d

Where

Ic is the collector current

Ib is the base current

Vin is the input voltage

Vcc is the collector supply voltage

Vce is the collector emitter voltage

hfe is the current gain

2.2 PUSH-PULL AMPLIFIERS

Push-pull Amplifiers are used in most audio frequency power amplifiers and digital UPS. The push-pull principle requires that a Transistor and a center-tapped Transformer be used. The Transistor may be a complimentary pair (i.e. one is a npn and the other is a pnp) of identical. If a complimentary pair is used, a single-phase wave form could be used to bias their inputs but for the case of identical Transistors an 180^0 phase shift is required.

The figure below shows a push-pull configuration employing identical Transistors

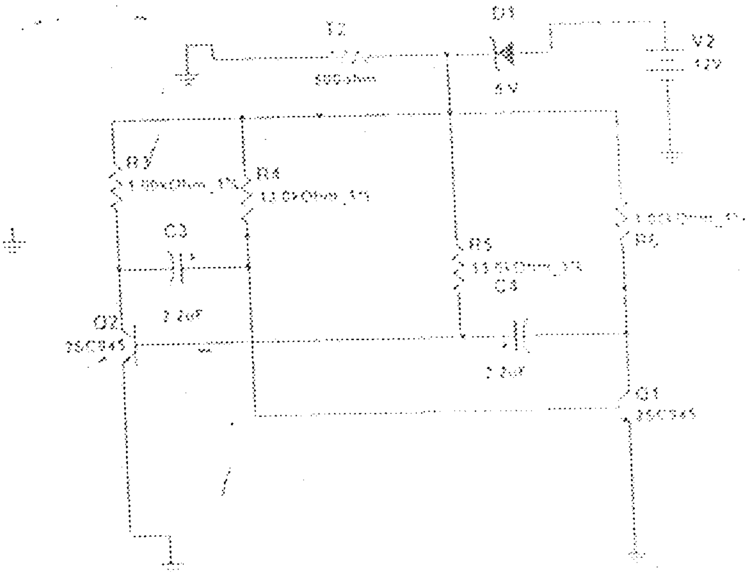


Figure 2.2.1 push-pull Transistor Amplifier

The output of the circuit is such that when an input is applied to the Transistor A, positive half cycle of the output current to the emitter load (which is one of the Transformer). Transistor B conducts in a similar manner but since the wave form is 180^0 out of phase, a series of negative half cycle which now produce an output A.C voltage. Although cross-over distortion might exist, it is a problem in the applications of audio power Amplifier.

Resistor and capacitor filter circuit are used to approximate the square wave to sinusoidal to remove square wave harmonics. For the class B Amplifier in figure above, assuming ideal characteristic, it can be seen that the maximum value of Vin =Vcc while the maximum peak value of current is Imax, so that maximum A.C power P_{ac} is given by $P_{ac} = V_{cc}$

2.3 BATTERY TYPE AND CHARACTERISTICS

The Battery being the sole energy source, is a critical aspect for the design, hence a very reliable Battery charger is required to enable proper charge and discharge cycles. Though the Battery is a bought out part in every sense of it, yet selecting a good one for the inverter require a lot of technical considerations.

For proper selection and maintenance of the Battery to take place, the factors affecting Battery reliability have to be considered. These include:

1. **TEMPERATURE:** The natural problem that cause Battery ageing are strongly affected by temperature. Manufacturing data indicates that the Battery life is reduced by 10% of every additional 10^0F. For this reason it is not only necessary that the inverter design should be such that the Batteries are kept as cool as possible at all times, but also that a Battery with wide operating temperature range should be selected.

2. **BATTERY VOLTAGE:** Batteries are made of individual cells. To make up a Battery of voltage higher than that of a cell, individual cell must b connected in series. When Batteries are kept in constant charge as they are in inverter system, the individual cells are charged in series. Slight manufacturing variation in Battery cells cause some cells to take a larger percentage of charging voltage than others. This causes premature ageing of those cells. The series connected group of cells is only as strong as its weakest link, so when any individual cell becomes weak the whole Battery is weakened. It has been proved that the magnitude of this aging problem is directly related to the number of cell in the string and therefore increases as the Battery voltage increases.

3. **BATTERY CHARGER:** The charging condition of a Battery has a major effect on the Battery life span. The Battery life span is maximized if the Battery is always powered from a constant voltage. This is because maintaining the Battery under a continuous charge arrests some of the Battery natural ageing processes.

4. **BATTERY TYPE:** The possible choice of Battery type for use in Electronics are (i) Nickel-Cadmium (wet cell rechargeable Battery). (ii) Sealed lead-acid Battery

Nickel cell provides 1.2volts per cell and generally available in the 100mAH to 200AH range and work down to $20^{o}C$ (and up to $45^{o}C$)

Lead-acid Battery provides 2V per cell and is generally built to provide 1 to 20AH and work down to $65^{o}C$ (and up to $65^{o}C$).

Both type have relatively flat discharge curves. Lead acid Batteries have low self discharging rate and are claim to retain two third of their charge and after a quick storage at room temperature. nicads Batteries have relatively poor charge retention, typically losing half their charge in four months.

There life span depend on their charge and discharge cycle both nicads and lead acid Batteries claiming to be good for 250 to 1000 charge or discharge cycles (more if they are only partially discharge each time. less if completely discharge or rapidly discharged). Nicads have constant trickle charge current, the comparable life for sealed lead acid Batteries is claimed to be 10years. Due to obvious less advantages of lead acid Batteries over nicads in terms of ampere hour rating life expectance, charge retention, operating temperature and number of cells in series for a given voltage, the sealed lead acid Battery is often recommended for Battery performance.

2.4 CARE AND MAINTAINANCE OF BATTERIES

For maximum performance to be achieved the Battery have to be serviced from time to time. Servicing Battery involves.

1. Regular check and topping of the acid level
2. Cleaning of corroded terminals to ensure proper contact
3. Changing of acid when concentration falls below average level
4. Ensuring that the battery voltage is appropriate to prevent over charging of the Battery.

2.5 CHOICE OF BATTERY

The choice of Battery depend on intended time duration for a given power output of inverters and the charging capability of the charger inside the inverter. For a 1KVAinverter tso operate for one hour at maximum load, the required current is given by

I = (POWER) ÷(VOLTAGE FROM THE BATTERY)----------------2.4a

Hence, using a Battery of 12volts, the time duration will be

T = [(BATTERY VOLTAGE) ÷ (CURRENT)] × [1hr]………………………2.4b

Hence on maximum load and full charge on the Battery, the operating time of the inverter will not exceed the above calculated time. The time frame can however be increased if the load in the inverter is reduced to half

2.6 OTHER PASSIVE COMPONENTS

The realization of the inverter involves the use of both active and passive components. The passive components include resistor, capacitors, diodes and Transformers. These are components that do not require external source of power to operate and also cannot amplify power or voltage.

The active component on the other hand is component capable of amplification for power and in most cases requires an external source to power in order for them to operate. The passive components used in this project include, MOSFET transistor, IC oscillator modules and bipolar transistors.

CHAPTER THREE

DESIGN AND ANALYSIS

3.0 PRINCIPLE OF OPERATION

The principle is based on the performance of push pull Amplifier. The push pull Amplifier in driven from a 50Hz oscillator via a driver stage. The oscillator stage generates waveform of about 50Hz and 180° out of phase to allow alternate switching of the push pull inverter stage. The push pull stage (where conversion is done) is a class B Amplifier.

The Amplifier needs secondary element to operate. Transistor, bipolar transistors and MOSFETs are often used. The switching is done on the secondary of the transformer, which consequently include a high voltage on the primary.

The current demand from the Battery require that charging has to be regular if the Battery must not run down permanently, hence a Battery charger stage which is a regulated D.C from main voltage is used to charge the battery with a logic control senescing circuit (i.e. Electromechanical Relays) to cut off the charging voltage when the Battery is fully charged.

Also a relay is designed to switch main voltage to output when there is a public supply to conserve power for the unit to make it friendlier.

3.1 THE INVERTER CIRCUIT

This is the sub-circuit that converts direct current (D.C) voltage to alternating current (A.C) voltage which determines the magnitude and frequency of the output voltage, frequency of fluctuation, transient present on the utility power system. The inverter unit in co-operate the use of an oscillator, which generates the required alternating current (A.C) output frequency Constance with components that exhibit negative resistance characteristics. It also incorporate a class B Amplifier stage where voltage polarity and power generation takes place

The metal oxide semiconductor field effect transistor (MOSFETS) were used for this design.

3.2 OPERATION OF THE ASTABLE MULTI VIBRATOR

When power is switched ON one of the Transistors will begin to conduct before the other, since the characteristics of no two seemingly similar transistor can be exactly alike. Suppose that Q1 will be very rapidly driven to saturation and Q2 to cut off.

The following sequence of events will occur.

(i) Since Q1 is in saturation, the whole of V_{cc} drops across RL1, hence V_{c1} = 0 and point A is at zero potential.

(ii) Since Q2 is in cut off i.e it conducts no current and there is no drop across RL2, hence point B is at V_{cc}.

(iii) Since A is at 0volt C2 starts to charge through R2 towards V_{cc}

(iv) When voltage across C2 rises sufficiently (i.e more than 0.7 V) it biases Q2 in the forward direction so that it start to conduct and soon driven to saturation

(v) V_{c2} decreas and almost zero when Q2 gets saturated. The potential of point B decreased from V_{cc} to almost 0volt. This potential decrease is applied to the base of Q1 through C2. consequently Q1 is pulled out of saturation and is soon driven to cut off.

(vi) Since now point B is at 0volt,C1 starts charging through R1 towards the target voltage V_{cc}

(vii) When voltage of C1 increases sufficiently Q1 becomes forward biased and starts conducting. in this way the whole cycle is repeated.

$T = T_1 + T_2 = 0.69(R_1C_1 + R_2C_2)$

Since a square wave is needed

$R_1 = R_2, C_1 = C_2$

$T = 0.69 \times 2CR = 1.38RC$

But

$F = 1/T = 1/1.38RC$

For the inverter an output of 50Hz is required

$F = 1/1.38RC = 50$

$RC = 1/(1.38 \times 50) = 1.45 \times 10^{-2}$

Choose C for 1μF, 2% tolerance

$R = (1.45 \times 10^{-3})/(1 \times 10^{-6})K\Omega$

$R = 14.5K\Omega$

Choose R to be 14.5KΩ, 5% tolerance.

$F_{max} = 1/(R_{min}\, C_{min} \times 1.38)$

$F_{max} = 1/(14.21 \times 0.95 \times 10^{-3} \times 1.38)$

$F_{max} = 53Hz$

$F_{min} = 1/(R_{max}\, C_{max} \times 1.38)$

$F_{min} = 1/(14.79 \times 1.05 \times 10^{-3} \times 1.38)$

$F_{min} = 47Hz$

$R_1 = R_2 = 14.5K\Omega$

$C_1 = C_2 = 2.2\mu F$

$RL1 = RL2 = 10K\Omega$

$T_1 = T_2$ Choose 2SC945NPN

3.3 SPECIFICATIONS

FREQUENCY	50Hz
RISE TIME	100ns
FALL TIME	100ns
OPERATING VOLTAGE	12volts
OUTPUT VOLTAGE	12volts

3.4 CLASS B AMPLIFIER STAGE

The class B Amplifier is where voltage polarity and power generation takes place. A centre-tap Transformer is required for switching of the push-pull arrangement. Q1 to Q6 are the power MOSFETS and the zener diodes are to protect the switches from reserve voltage spike.

3.5 TYPICAL ELECTROSTATIC VOLTAGES

ACTION	ELECTRASTIC 10%-20% HUMIDITY (V)	VOLTAGE 65%-90% HUMIDITY (V)
Walk on carpet	35,000	1,500
Walk on Vinyl floor	12,000	250
Walk on bench	6000	100
Handle Vinylenvelope	7000	600
Pick up poly bag	20,000	1,200
Shift position on foam to chair	18,000	1,500

The following specification for MOSFET switch is needed:

$V_{DSS} > 12V$

$R_{on} > 0.02\Omega$

$I_D > 25A$

PD > 400W

Tr and Tf > 100ns

A suitable choice is RFP70N06 MOSFET.

3.6 THE REGULATED D.C SUPPLY

The regulated D.C supply consists of the step-down voltage Transformer (220volts/18volts), a rectifier circuit (Bridge rectifier), a filtering circuit and a voltage regulator. This is shown on the diagram below

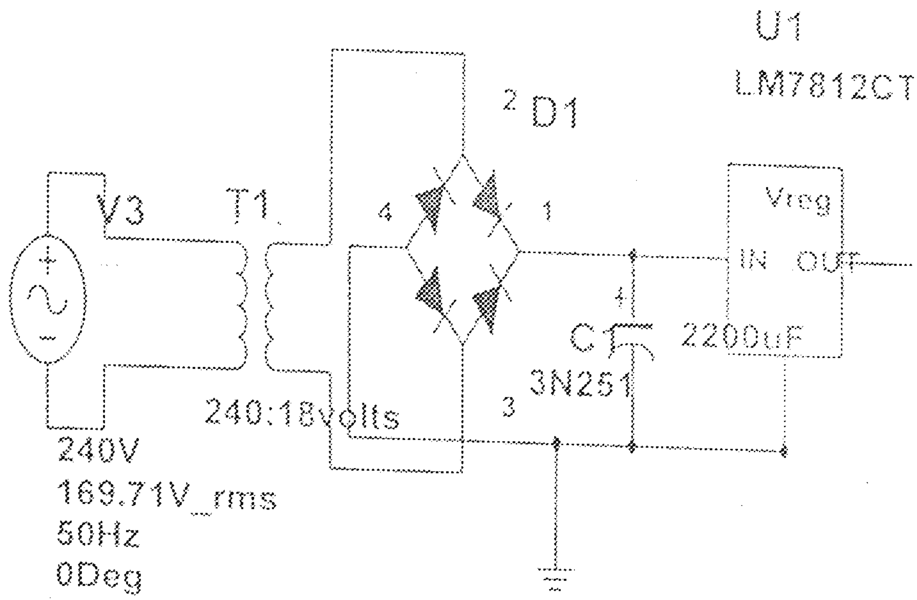


Fig 3.6a A block diagram representing a regulated D.C power supply

The average value of the load voltage is given by

$V_{L(d.c)} = 2V_{LM} / \pi = 0.636V_{LM}$

V_{LM} is the maximum value of the load voltage

The root mean square value (rms) of the load voltage is

$V_L = V_{LM} / \sqrt{2} = 0.707V_{LM}$

The rms value of a.c components of the output voltage is

$V^2_{L(ac)} = V^2_L - V^2_{L(dc)}$

$= V_{LM} \sqrt{0.0707^2 - 0.636^2}$

$= 0.305V_{LM}$

The ripple factor is therefore given as

$Y = V_{L(ac)} / V_{L(dc)} = 0.305 / 0.636 = 0.482$

The maximum inverse voltage of the diode (PIV) is the maximum voltage that occurs across the diode in the reverse direction. For a rectifier

$PIV = V_{SM}$

Since the Transformer utilized a 240 V/ 18V step down a rms voltage of 18v from the Transformer secondary peak voltage is given by

$Vm = 2V_{rms}$

$= \sqrt{2} \times 18 = 25.45V$

The average d.c voltage delivered by the rectifier is given as

$V_{dc} = 0.636V_M$

$= 16.20V$

The ripple factor is given as

$V_r = 0.305V_m$

$= 0.305 \times 25.45$

$= 7.76V$

For shunt capacitor filter, the voltage rating should be at least $2V_M$. Hence a 50V capacitor is used.

An important equation in power supply design which helps to determine the required capacitance value for the current to be drawn is given by

$V_{dc} = V_{ip} - (I_{dc} / 4fC)$

F is the supply frequency

C is the capacitance of the capacitor

$C = I_{dc} / 4f (V_{ip} - V_{dc})$

$= 89.70 / 4 \times 50 (220 - 16.20)$

$= 2200\mu f$

A 12V regulator, LM 7812 was used to obtain a 12V output

3.7 THE INVERTER TRANSFORMER DESIGN

A Transformer is an electrical device which transfer A.C signal from one voltage level to another voltage level. The basic law of Transformer action (Faraday law) is that if a flux links a winding of N turns then a voltage is gener5ated in that winding proportional to the rate of change of flux and the number of liking turns.

$V = N\, dO / dt$

Fig An Iron core Transformer

$V_1 = N_1\, dO / dt$ $V_2 = N_2\, dO / dt$

Hence $V_1 / V_2 = N_1 / N_2$

For a D.C to A.C inverter, a special type of Transformer is required. It could either be of the core or teriodal type. But usually the teriodal type of core is used more often due to its ease of winding. Before choosing the transformer to be used, the following conditions have to be noted.

(i) Power rating (ii) current rating (iii) voltage ratio (iv) frequency

3.7.1 VOLTAGE RATIO

Essentially an inverter Transformer has to be of a center tapped primary and the secondary turns has to correspond $K \times N_p$, where K is a calculated ratio. The D.C source and the required output A.C voltage determines the number of turns both the primary and the secondary will contain

For the purpose of this project a 12V car battery will serve as a D.C source to produce a 240V A.C voltage at the output

From the fourier series a square waveform of this form is obtained in the figure below

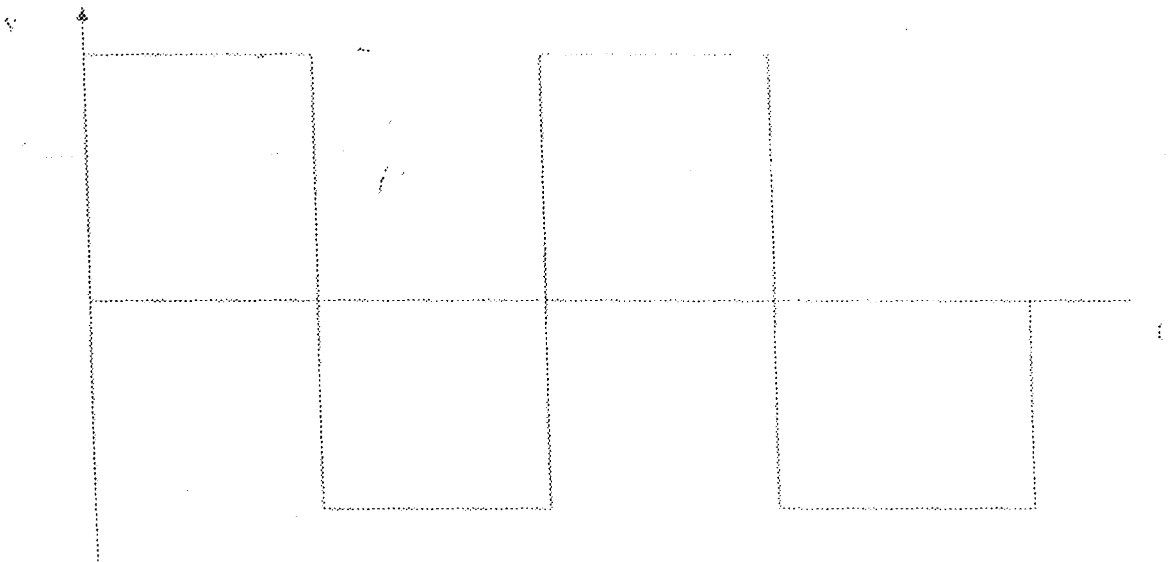


Fig 3.7a   fourier series square waveform

$F(t) = 4A / \pi (\sin wt + 1/3 \sin 3wt + 1/5 \sin 5wt + 1/7 \sin 7wt + \ldots\ldots)$

If we remove all the higher harmonics from the fourth upwards

Let A = 300V

$V_{ms} = \sqrt{(4A/\sqrt{2}\pi)^2 + (4A/3\sqrt{2}\pi)^2 + (4A/5\sqrt{2}\pi)^2}$

= 290V

voltage ratio = 300V / 12 = 25

3.7.2 CURRENT RATING

The current rating will determine the type of D.C source to acquire taking into cognizance momentary load surge running into hundreds of amps.

This particularly affects choice of Transformer in awg rating of the Transformer winding i.e. winding gauge wire has to be of sufficient thickness in order to minimize I^2R losses especially in the primary side which conducts a higher current.

Below is the specification for copper wire

Gauge	Diameter in inches	Feet / Pound	Feet / ohm
16	0.05082	127.9	249.00
18	0.04030	203.4	156.50
20	0.03196	323.4	98.50
22	0.02535	514.2	61.96
24	0.02010	817.2	38.96
26	0.01594	1300.0	24.50
28	0.01264	2067.0	15.41
30	0.01003	3287.0	9.69

It is desirable to lower the primary resistance in order to minimize ohmic losses due to the large current it carries. Taking for example the required data needed for the inverter Transformer.

D.C input switching voltage = 12V

Required A.C output voltage =240V

Average peak A.C output voltage = 300V

Required output power = 1000 watt

From the above data.

Required Transformer Ratio = (Average peak A.C voltage / (D.C input switching voltage)

= 300 / 12 = 25

output current = 1000 / 240 = 4.20A

$I_{in} / I_{out} = N_2 / N_1$

$I_{in} = 105A$

With max voltage drop across R_p (resistance of primary core) set to 0.8V

$R_p = V / I_{in} = 0.8 / 105 = 7.62m\Omega$

A wire of length d and gauge g has a resistance of

$R = d \times (1 \text{ ohm} / 1000 \text{ feet}) \times 1.265^{g-10}$

Assuming an Average of 1 feet per turn

$d = 1.0 \times 25 = 25$

$7.62m\Omega = 25 \times 1/1000 \times 1.265^{g-10}$

$g = 19$

Therefore a wire of gauge 19 and 25 turns is suitable for the primary winding

No of secondary winding will be

$N_2 = N_1 \times 25$

$N_2 = 625$turns

3.7.3 POWER RATING

The sole determinant of a Transformer power rating is the core. The larger the core the less the number of winding required and the higher the power rating. The material the core is made of also determines its efficiency. for this project an iron core rated at 10,000 AT/ M was choosen for the inverter Transformer core while a core rated at 1000 watt is used for the battery charger

3.7.4 FREQUENCY

In compliance with national standard frequency of 50HZ, the best alternatives are Transformer made of metallic cores. But at a higher frequency running into 1KHZ a Ferrite core Transformer is required.

3.8 HEAT DISSIPATION TO THE SYSTEM (HEAT SINKING)

Depending on the amount of power required from the inverter, adequate heat sinking of the IRF540 MOSFETS are

(i) Drain source voltage (V_{DS}) = 60V max

(ii) Drain current (I_D) = 39A max

(iii) Power dissipation (P_D) = 150 watts

(iv) Drain source ON resistance (R_{on}) = 0.08Ω

Voltage drop across device = $I_D R_{on}$

$= 39 \times 0.08$

$= 3.12V$

Power dissipated across device = $I_D V$

$= 39 \times 3.12$

$= 121.68$ watts

The maximum heat the will be dissipated to the system at maximum load will be 121.68 watts.

3.9 BATTERY BACK-UP CAPACITY

The value of the battery voltage when in the fully charged state is about 14.4V. To charge the Battery, appropriate charging current must be applied. For a lead acid Battery with rating of 12V at 150 amperes – hours if the charging time is to be 24 hours from complete discharge, then the initial charging current to be made available should be about

$I_{charging}$ = 150 / 24 = 6.25 ampere / hr

Voltage utilization per unit time is given as

t =(Q × V) / P

Where t is the time the Battery is being used

V is the Battery voltage

P is the power rating of the appliances connected to the UPS

Q is the charging quantity of the Battery (usually 150Ah for a lead acid Battery)

t = (150Ah × 12V) / 1000W

t = 1hr 48mins

Hence, on maximum load and full charge on Battery, the operating time of inverter will not exceed two hours This time can however be exceeded if only important work would be carried out using the necessary appliance while others are switched off.

3.10 SYSTEM MAXIMUM POWER RATING

The system designed is expected to operate at a maximum power rate of 1000VA, 240V a.c at 50Hz frequency. The specified power rating is for a system that is 100% efficient. The following assumption were made.

(i) Let the Transformer used for the design be 90% efficient

(ii) The use of resistive loads was for testing (power factor for resistive load is 1)

Power equation = Current × voltage (in VA)

Also P =VI cos Ø

Power into the system (Pin) = Power out for the system (P_{out}) for an ideal situation

But for a 90% efficient system

$P_{in} = 90\%$ P_{out} 1000VA

$P_{in} = (90/100) \times 1000$

$= 900W$

but at the output , V = 240V a.c

$IV \cos \Theta = 900W$

$I_{out} V_{out} = 900W$

$I_{out} = 900 / 230 = 3.09A$

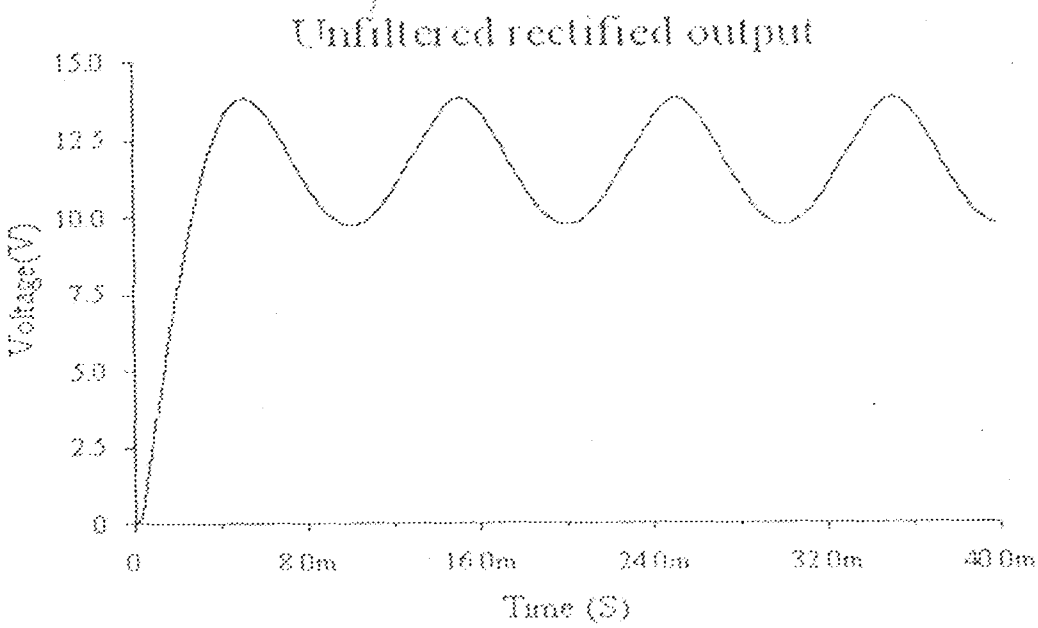
$I_{in} = 900 / 12 = 83.3A$

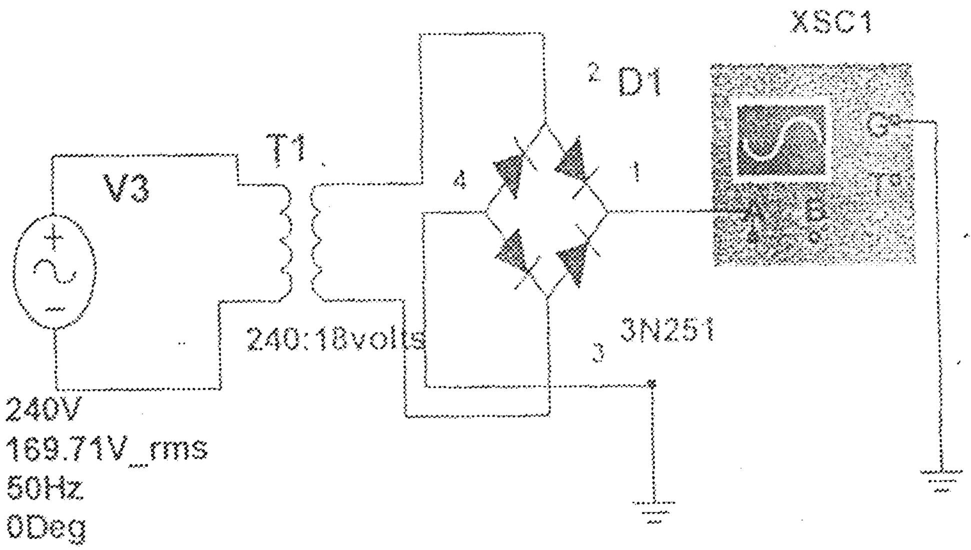
The maximum current into the system is 83.3A. This implies that the MOSFETS should be able to source out about 84A of current.

3.11 COMPUTER AIDED DESIGN (CAD)

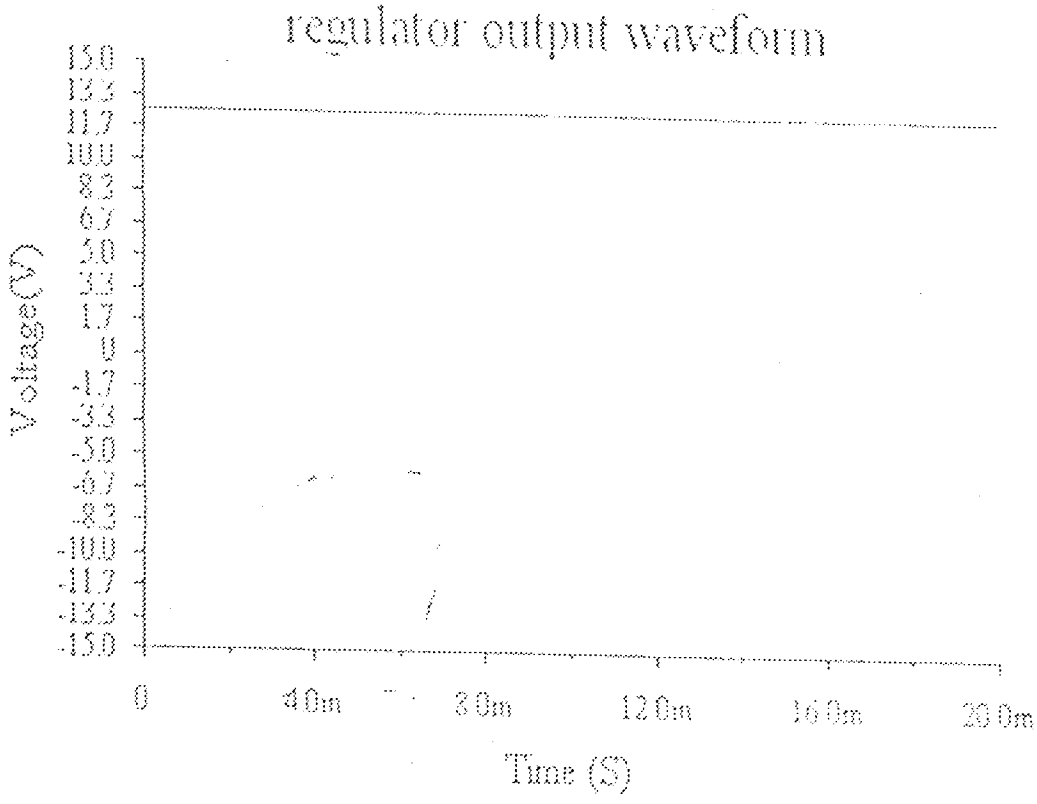
This is a Computer software to analyse the various sections of the UPS design to enable better and easy component specification

The simulated sections are attached to this write – up for easy identification.

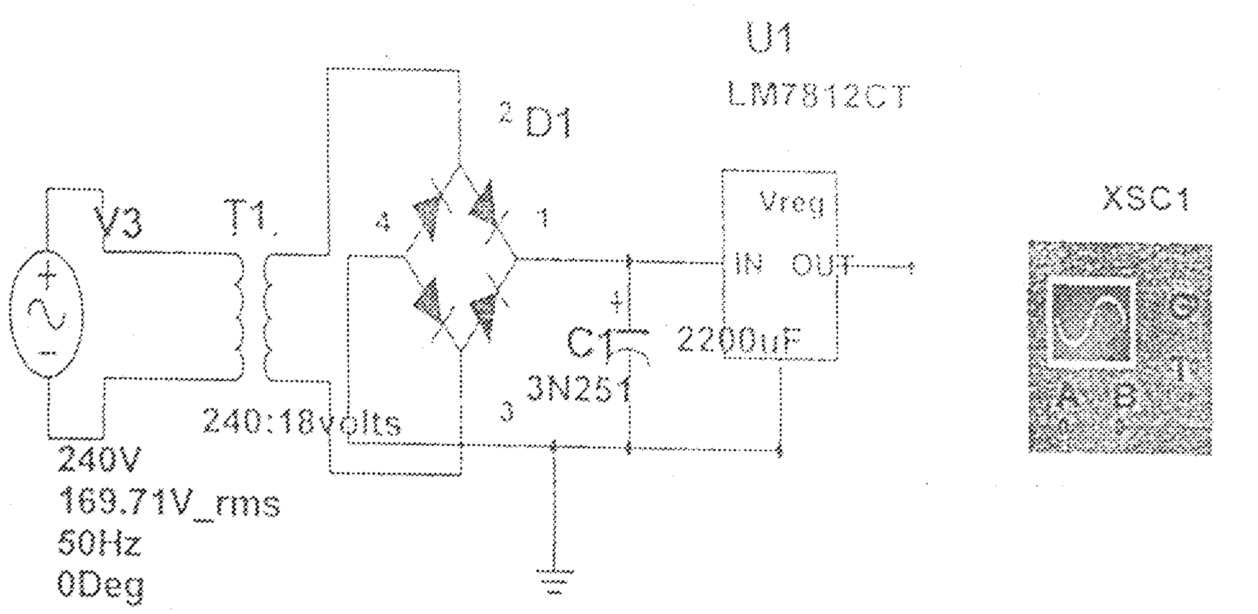




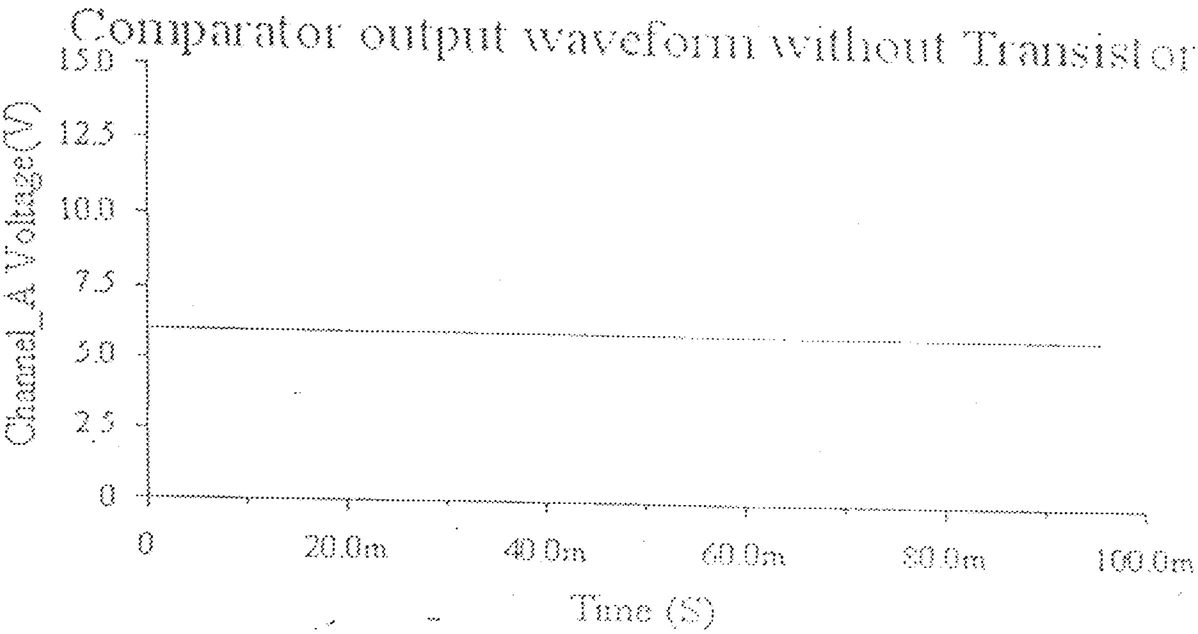
Unfiltered rectified output



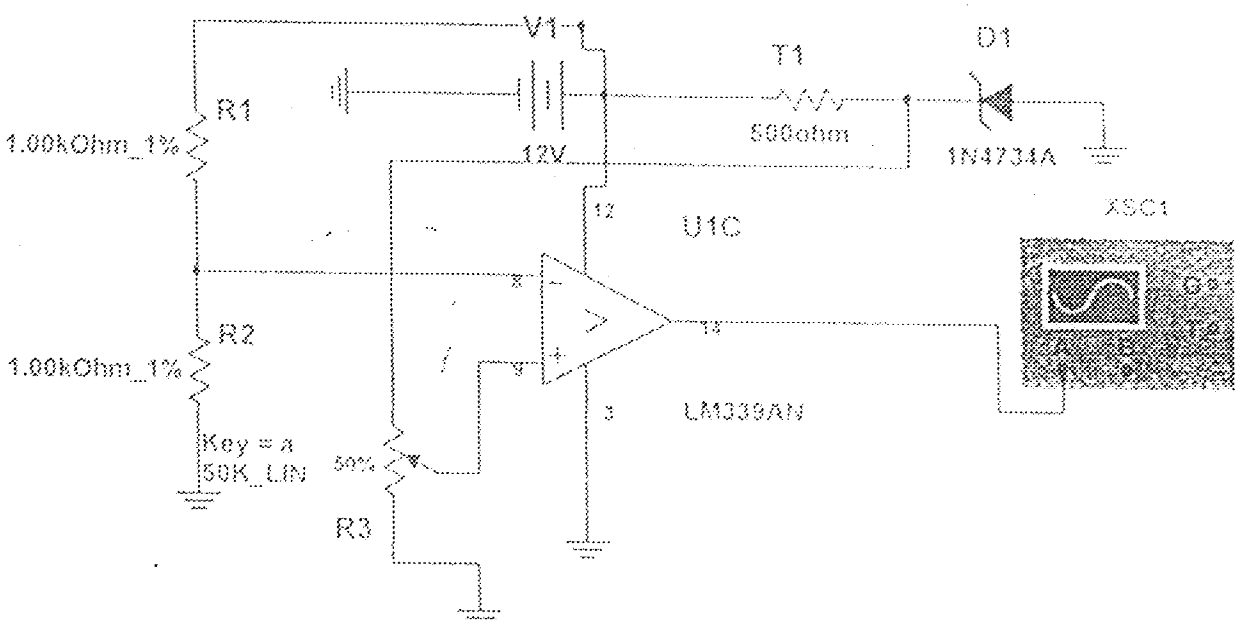
regulator output waveform
Voltage(V)
Time (S)



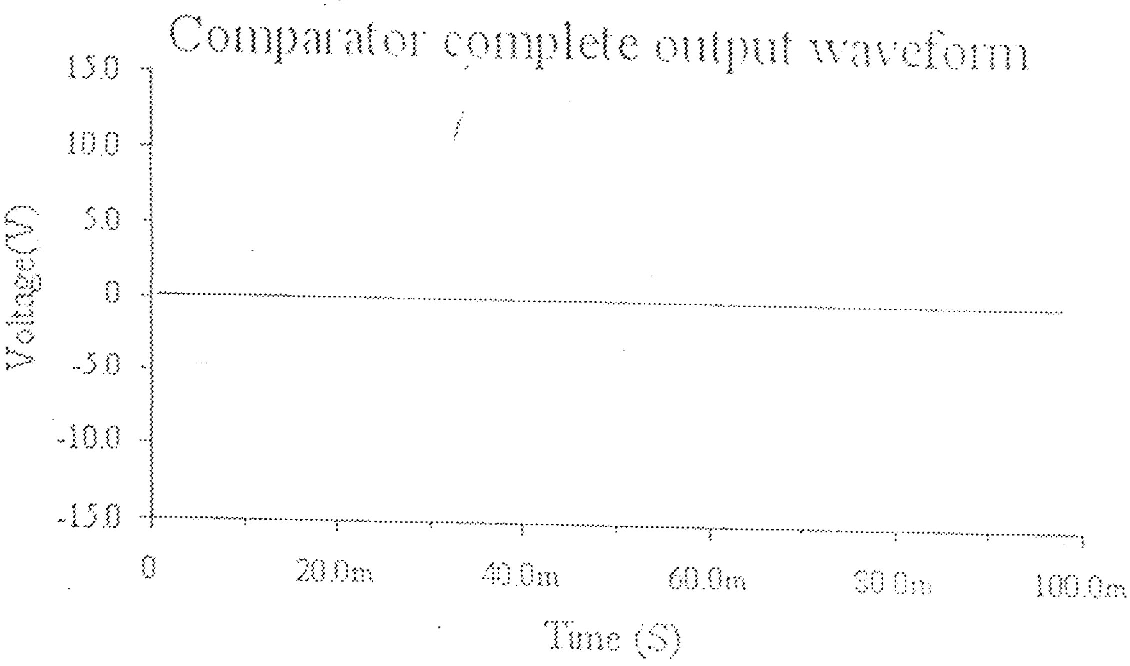
U1
LM7812CT
D1
V3
T1
Vreg
IN OUT
XSC1
C1
2200uF
3N251
240:18volts
240V
169.71V_rms
50Hz
0Deg

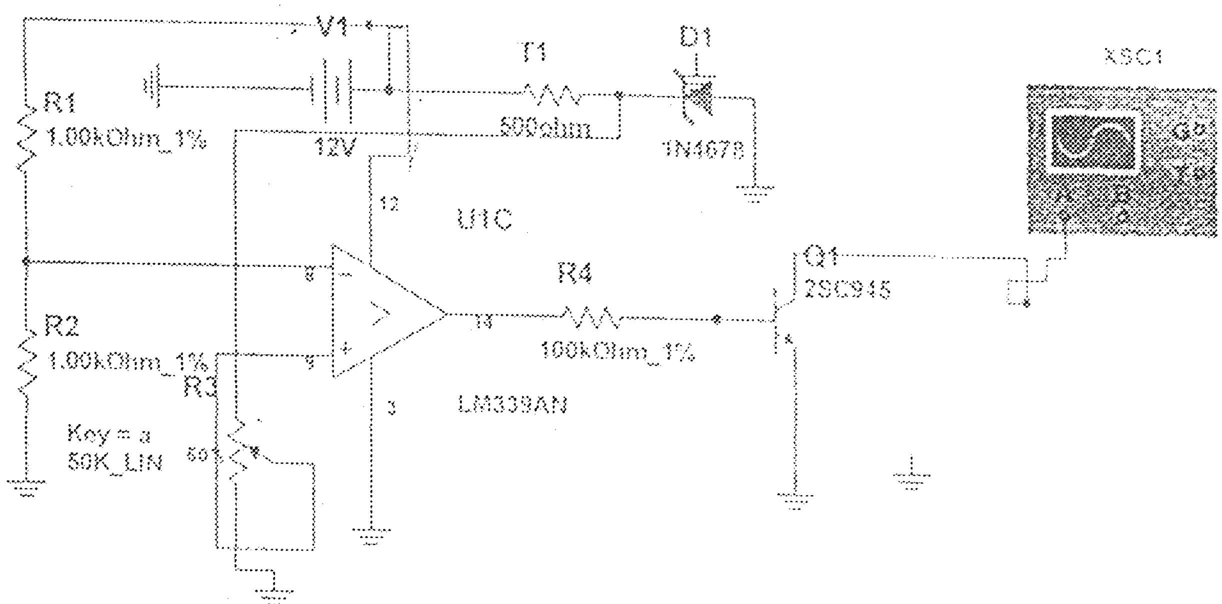


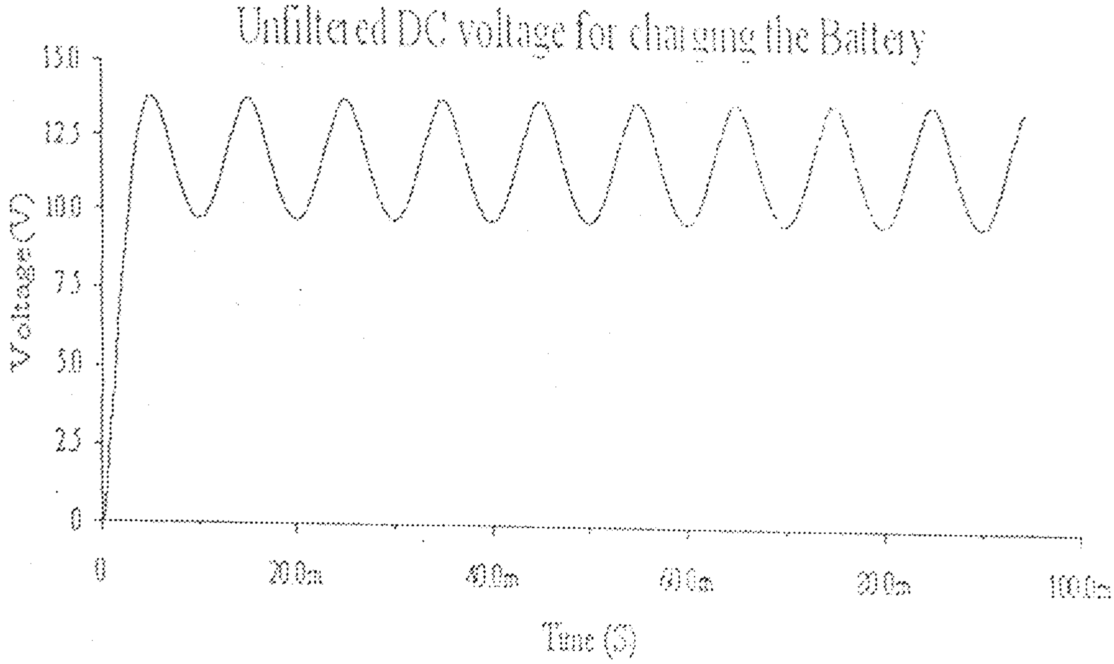
Comparator output waveform without Transistor
15.0
12.5
10.0
7.5
5.0
2.5
0
Channel_A Voltage(V)
0
20.0m
40.0m
60.0m
80.0m
100.0m
Time (S)

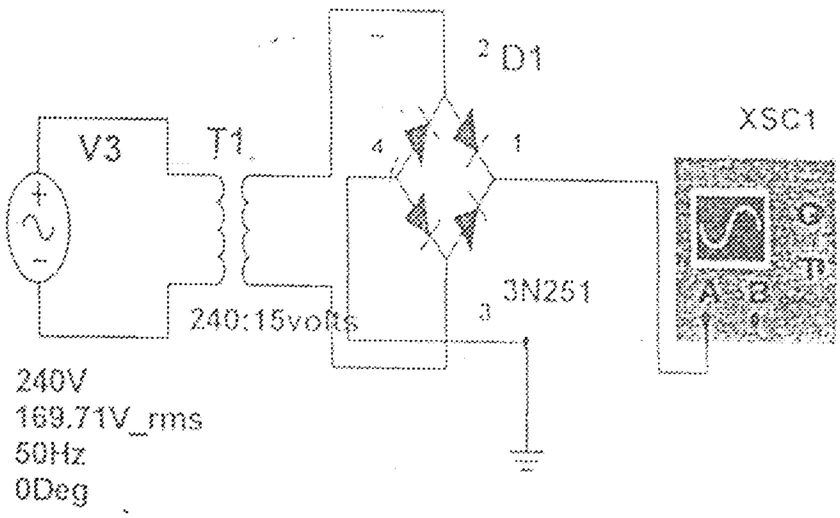


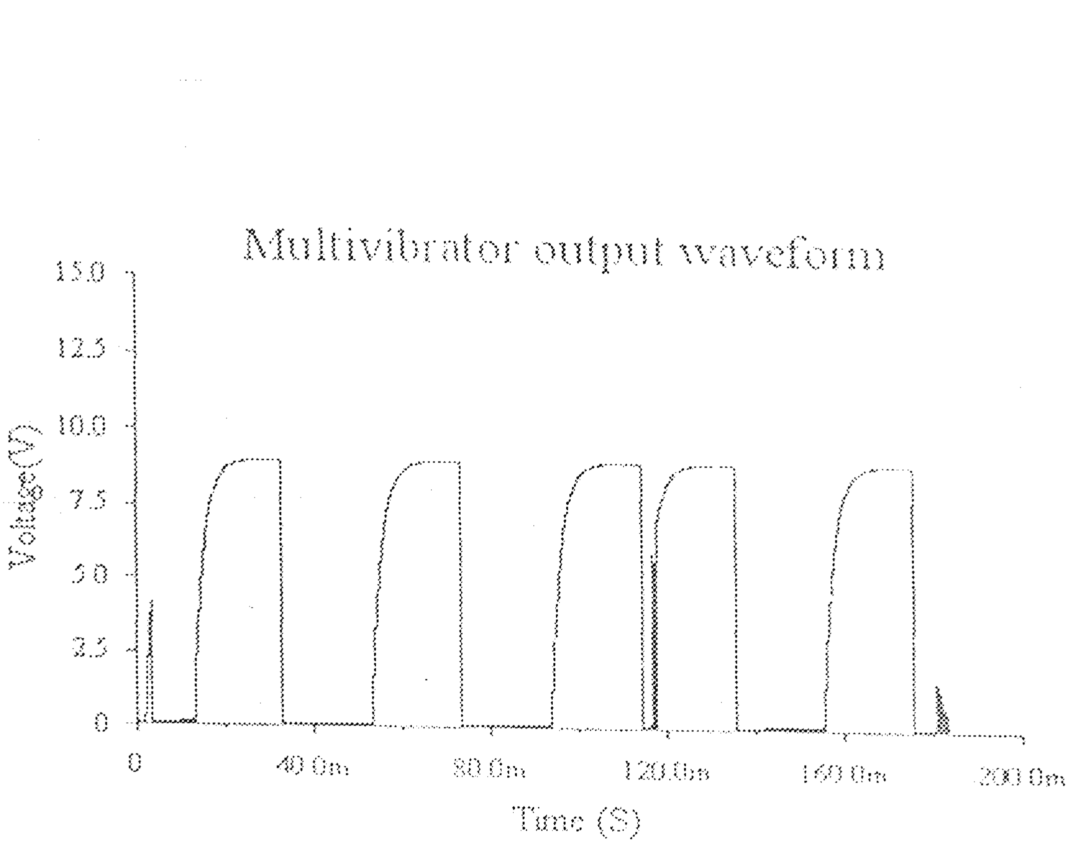
V1
12V
T1
500ohm
D1
1N4734A
R1
1.00kOhm_1%
R2
1.00kOhm_1%
Key = a
50K_LIN
50%
R3
U1C
LM339AN
12
3
XSC1

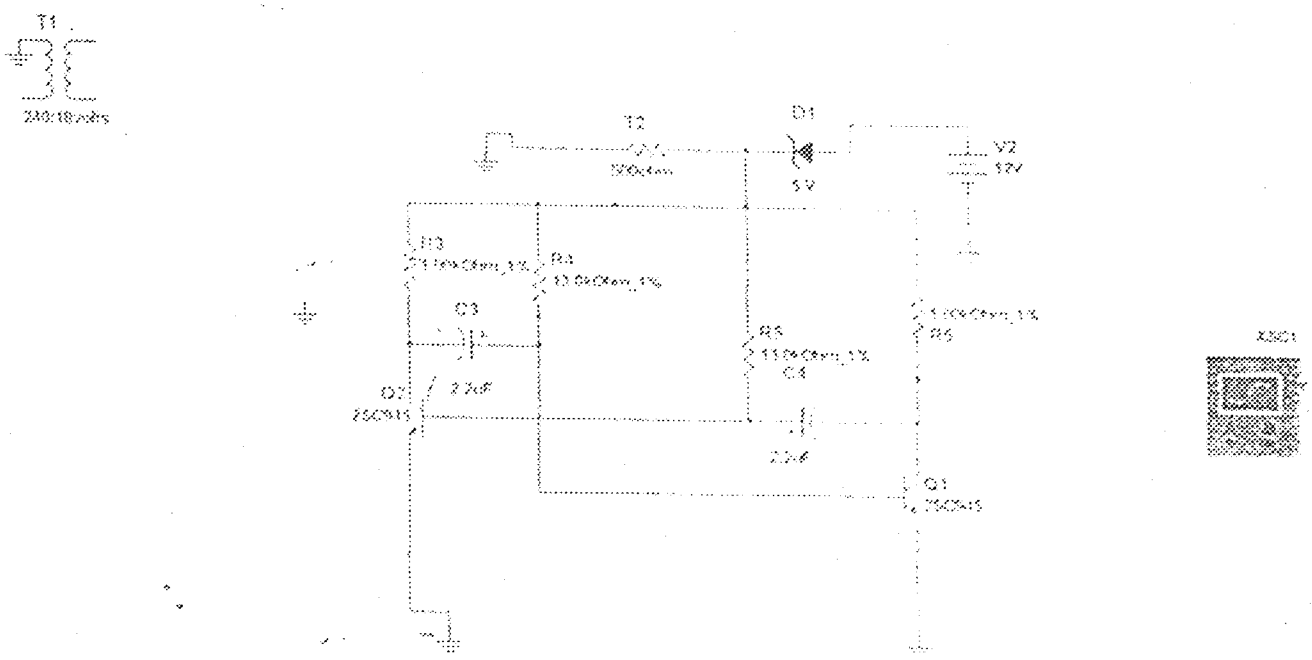

Comparator complete output waveform
Voltage(V)
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
0
20.0m
40.0m
60.0m
80.0m
100.0m
Time (S)

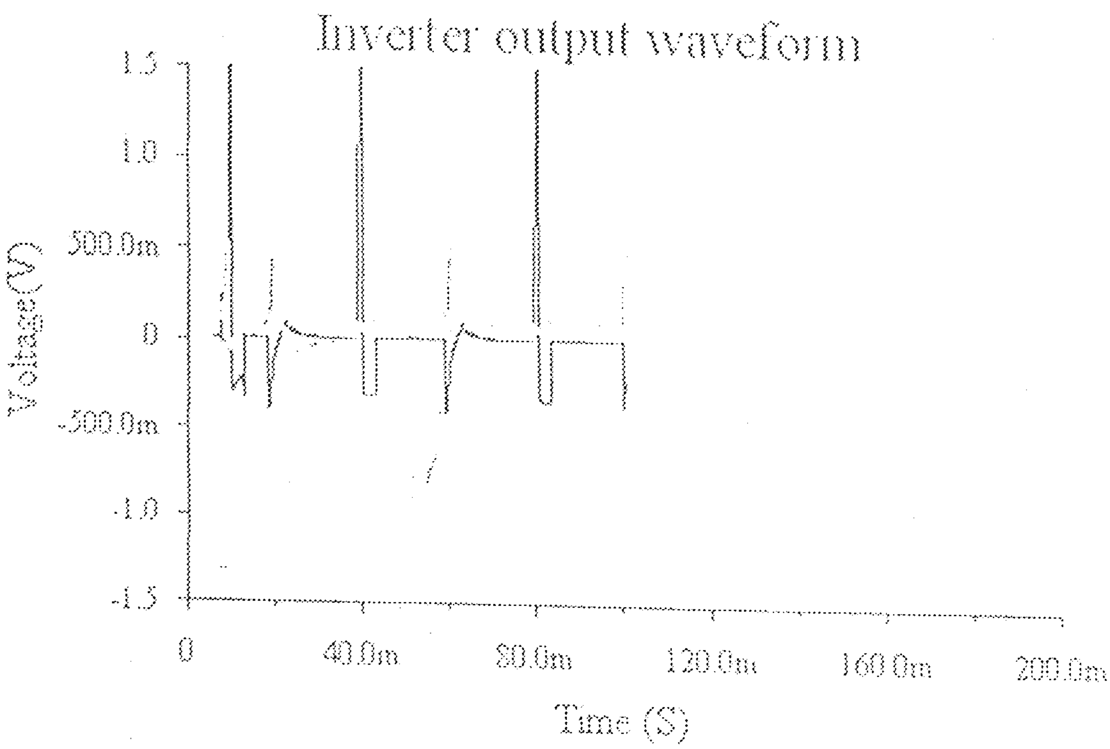

V1
12V
T1
500ohm
D1
1N4678
XSC1
R1
1.00kOhm_1%
R2
1.00kOhm_1%
R3
Key = a
50K_LIN
U1C
LM339AN
R4
100kOhm_1%
Q1
2SC945

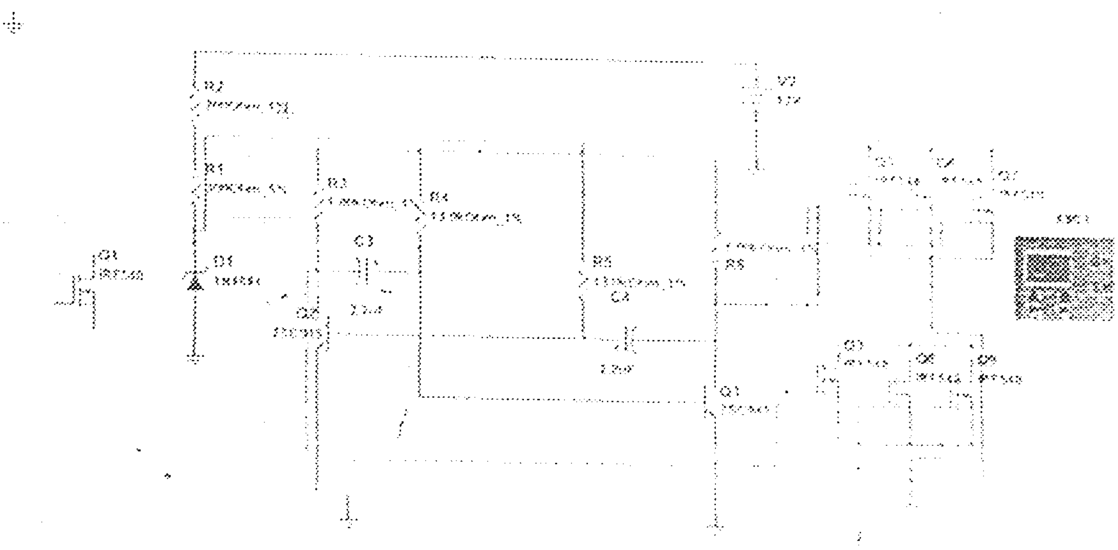

Unfiltered DC voltage for charging the Battery
Voltage (V)
150.0
125
100.0
75
50
25
0
0
20.0m
40.0m
100.0m
Time (S)

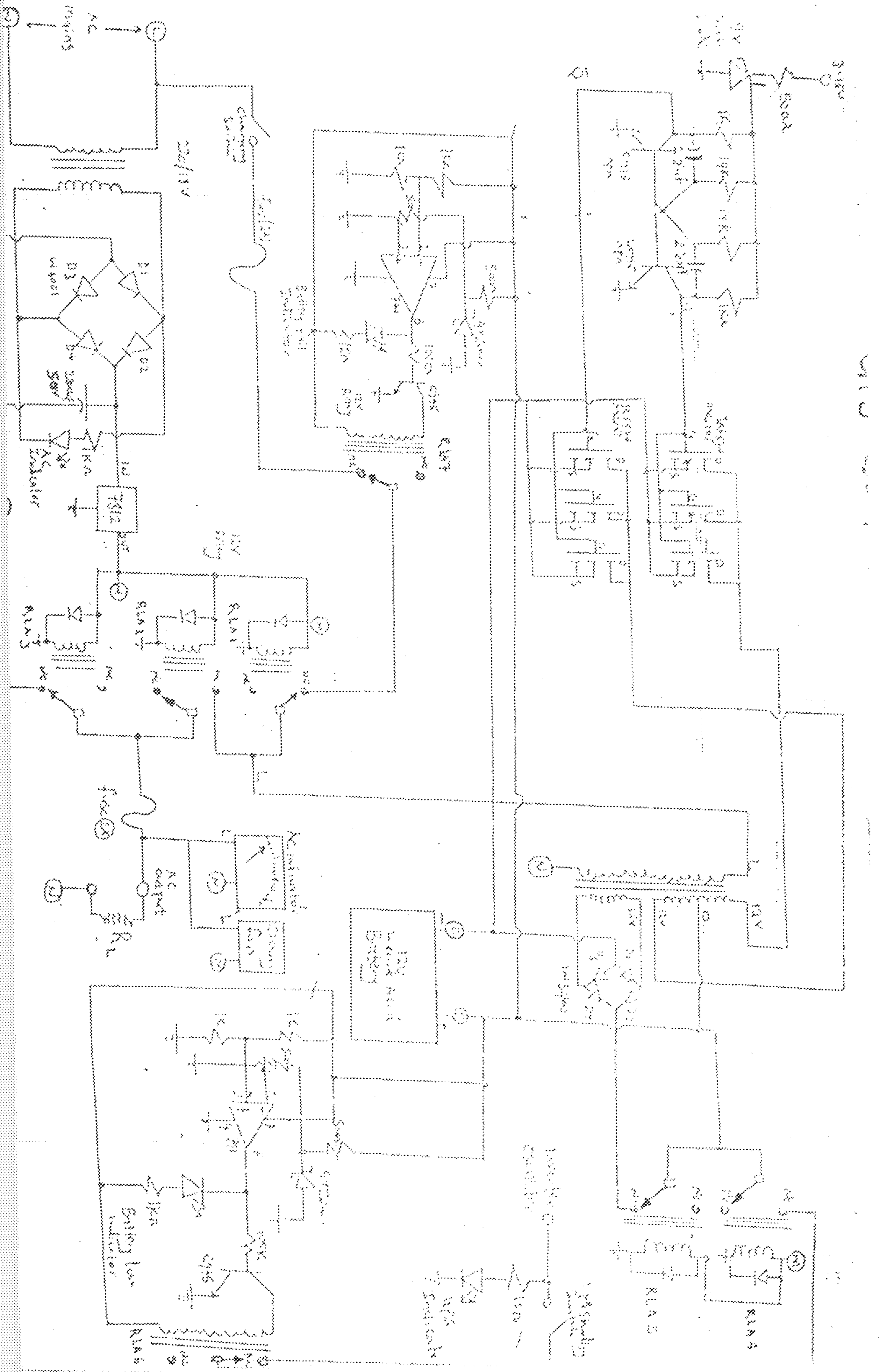

V3
T1
240:15volts
240V
169.71V_rms
50Hz
0Deg
D1
3N251
XSC1
A
B


Multivibrator output waveform
15.0
12.5
10.0
7.5
5.0
2.5
0
Voltage(V)
0
40.0m
80.0m
120.0m
160.0m
200.0m
Time (S)


T1
T2
D1
V2
12V
C3
Q1


Inverter output waveform
1.5
1.0
500.0m
0
-500.0m
-1.0
-1.5
Voltage(V)
0
40.0m
80.0m
120.0m
160.0m
200.0m
Time (S)





AC Mains
Charging Switch
7812
AC Indicator
Battery low Indicator
AC output
12V Lead Acid Battery
RLA1
RLA2
RLA3
RLA4
RLA5
RLA6
RLA7

CHAPTER FOUR

TESTING AND CONSTRUCTION

4.0 TESTING

The physical realization of the project is very vital. This is where the fantasy of the whole idea meets reality. The designer will see his work not just on paper, but as a finished hardware system.

After carrying out all paper design and analysis, the project was implemented and tested to ensure of its working capability, finally it is constructed to meet the desired specification. The process of testing and implementation involves the use of some equipment as listed below.

(i) **BENCH POWER SUPPLY:** This was used to supply voltage to the various stages of the circuit during the bread boarding and soldering. The bench power supply was also used to calibrate the charger simulations by setting the charged and discharged voltage conditions of the Battery.

(ii) **OSCILLOSCOPE:** The oscilloscope was used to observe the ripple in the power supply waveform and also to check the oscillator waveform as well as the oscillator frequency.

(iii) **COMPUTER AIDED CIRCUIT DESIGN (CAD).** The particular product used in this design was the MULTISM. This was used to analyse various sections of the UPS output voltages, waveforms analysis and components abilities to withstand a particular amount of voltage impressed on them. The results of this aspect are attached to this project

(iv) **ANALOG MULTIMETER:** This basically measures voltage resistance, continuity, current, frequency, temperature and Transistor hfe. The process of implementation of the design on the breadboard required that the measurement of parameters like voltage, continuity, current and resistance value of components so as to test their status. Frequency measurement was used to check the frequency of the oscillator stage to confirm functionality. The ammeter in the digital multimeter was used to check the charging of the battery to confirm if the Battery was charging.

4.1 IMPLEMENTATION:

The implementation of this project was done on the breadboard. The power supply derived from the bench power supply in the laboratory (to confirm the workability) of the circuit before the power supply stage was soldered on the vero-board. Stage by stage testing was done according to the block representation on the breadboard before soldering of the circuit commenced on the vero board.

The driver and class B Amplifier stages were soldered directly due to the high current which they exhibit that could damage the breadboard.

4.2 CONSTRUCTION

The construction of the project was done in two different stages, the soldering of the circuits and the coupling of the entire project in the casing.

The soldering of the project was done on the vero- boards and a printed circuit board.

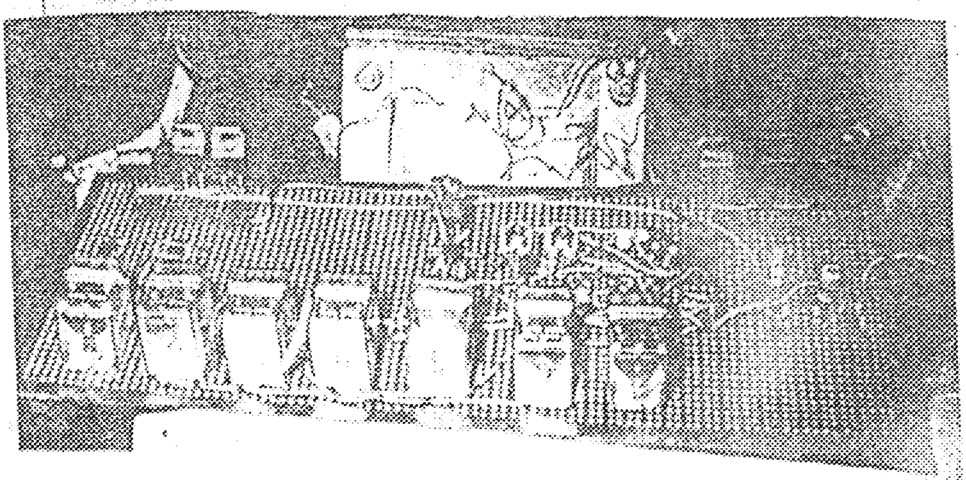


Figure 4.2.1 shows the picture of the vero board and the various components mounted.

The project was coupled to a metal casing. The casing material being a wrought metal and sprayed with car-paint to give its aesthetic beauty.

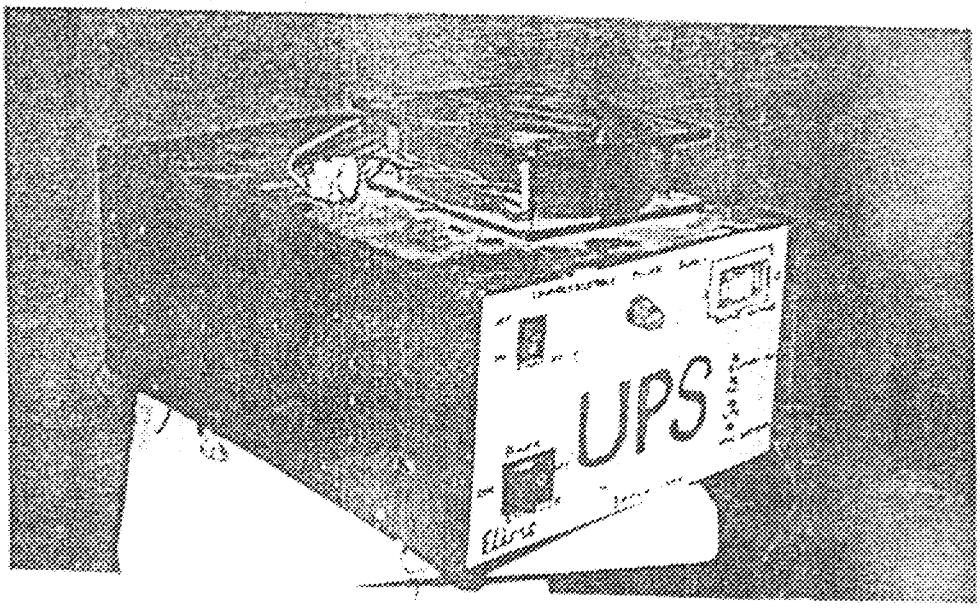


Figure 4.2.2 show the picture of the Isometric view of the casing

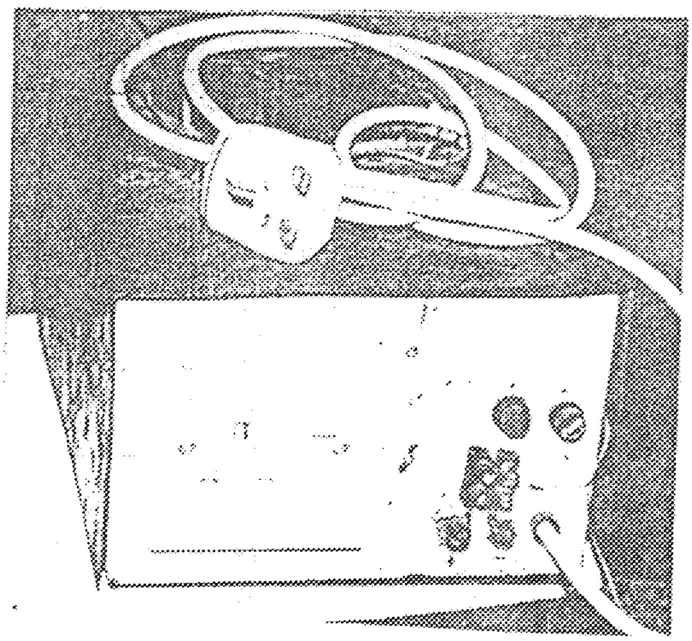


Figure 4.2.3 shows the back view of the casing

4.3 PROBLEMS ENCOUNTERED

In the course of implementation, testing and construction of the project, series of problems were encountered. They are as follows

(i) The efficiency of the system is about 70%. This means that in actual fact a 1KVA UPS was designed so that the efficiency losses would be compensated.

(ii) The Transformer was difficult to source but was later constructed by hand

(iii) The power MOSFETs were at a time dissipating a lot of heat, hence the use of heat sinks placed on each MOSFET to allow for proper heat dissipation.

(iv) The UPS output goes high when there is no load across its terminals. The problem could be solved by implementing feedback circuit to control the output.

4.3 PROBLEMS ENCOUNTERED

In the course of implementation, testing and construction of the project, series of problems were encountered. They are as follows

(i) The efficiency of the system is about 70%. This means that in actual fact a 1KVA ,UPS was designed so that the efficiency losses would be compensated.

(ii) The Transformer was difficult to source but was latter constructed by hand.

(iii) The power MOSFETs were at a time dissipating a lot of heat, hence the use of heat sinks placed on each MOSFET to allow for proper heat dissipation.

(iv) The UPS output goes high when there is no load across its terminals. The problem could be solved by implementing feedback circuit to control the output.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

The UPS project was designed considering some factors such as economy, availability of components, research materials, efficiency, compatibility, portability and also durability.

The performance of the project after test was satisfactory. The general operation of the project and to make human error such as Battery polarity being reversed, over loading e.t.c. However, there is provision for overload protection using a fuse at the output.

In addition, the construction was done in such a way that it makes maintenance and repairs an easy task and affordable for the user.

The project has really exposed me to both Analog and power electronics and practical electronics generally which is one of the major challenges to be met in this field in future. The design of the UPS was quite challenging.

I wish to thank the department, my supervisor and project co-ordinator for giving me the opportunity to carry out this project work. However, like every aspect of engineering, there is still room for improvement and further research on the project as suggested on the recommedation below.

5.1 RECOMMENDATION

I would recommend that the department should obtain more digital simulators and equipments to enable students to carry out their work on time without any unnecessary delay due to insufficient equipments.

5.2 REFERENCES

William H. Roadstrum and Dan Wolaver

Electrical Engineering for all Engineers p220 - 224

The Art of Electronics p92 - 98

Paul Horowithz and Winfield Hill

Electronics Principle p25 - 28

A.P. Malvino

A Textbook of Electrical Technology p1550 - 1557

B.L Theraja and A.K. Theraja

Electrical project section 2003/2004 p19 - 28

Matric No. 98/6814