Design and Construction of 1kVA Uninterruptible Power Supply (UPS)

Musa B. Musawa

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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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DEDICATION

This project is dedicated to God Almighty for sustaining me before, during and also after the completion of this work and to my parent late Alhaji Musa Musawa and Hajiya Fatima Musa.

Declaration

I, Musa B. Musawa, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also relinquish the copyright to the Federal University of Technology, Minna.

Musa B. Musawa

21/12/2009

Signature and date

Mr. J.A. Ajiboye

Supervisor

21/12/09

Signature and date

for Dr. Y.A. Adediran

H.O.D

(May 6, 2010)

Signature and date

External supervisor

9/03/10

Signature and date

ACKNOLEDGEMENT

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ABSTRACT

Regular power supply is one of the factors that contribute immensely to the economic growth of a nation. This project report examines the possibility of creating alternatives source of energy utility by means of low power electronics interface (DC-AC) conversion. The UPS operate in two modes: Normal mode and Backup mode. in the normal mode the power supply from the a.c mains is deliver directly to the load and charges the battery as well, while in the backup mode, the DC voltage from the battery is inverted by an inverter into an AC output voltage approximately the same as that of the AC input voltage. A transfer switch is provided to selectively control which AC output voltage is delivered to the load, the AC input supplied by the utility, or the AC output waveform from the inverter. The design and construction are carried out in modules, the modules were assembled together after construction to form the complete circuit.

List of Figures

TABLE OF CONTENTS

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

The inconsistency in the supply of utility power in Nigeria has been the cause of great damage to most of our electrical and electronics appliances. In addition, the country economy has lacked a rapid and steady development. However in bid to be among the industrialized country by the year 2020, there is need for an alternative power supply sources which serve as a backup to unpredictable power disturbances from the mains. The Uninterruptible Power Supply (UPS) offer users extended period of backup power during which they can continue to use electronics equipment such as personal computer. The UPS is a device that converts direct current (DC) to an alternating current (AC) energy, the UPS uses a conventional battery 12V or 24V (terminal voltage) at a specified current (commonly 100AH or 200AH) taking into account the amount of power required since power is a function of voltage and current (P=IV)[1].

The composition of UPS is rectifier circuit, storage batteries, switchover circuit and inverter (DC to AC). The action of the inverter circuit gives an alternating voltage to the load. In general, the UPS works on the following principle: during normal operation, the line power from the AC mains is delivered to the load as if the load was plugged directly into the AC mains. If a parameter of the line power, whether voltage or frequency, falls outside a tolerable limit for that parameter, the control circuitry reacts to this condition and generates an AC voltage waveform from a battery [2]. The DC battery voltage is inverted which is then filtered with a low-pass filter to remove the switching harmonics.

1.2 Aims and Objectives

The main aim is to Design and Construct a 1KVA UPS to provide a low cost alternative source of electric power which may be used in small commercial outfit. The objectives are as follows;

- ✓ Detect the occurrence of a power outage and transfer the load from utility power to backup power rapidly enough to prevent loss of unsaved data on a PC.
- ✓ Synchronize phase of backup power with that of utility power if the utility power is restored while backup power is being supplied.
- ✓ Warn a user of an impending expiration of the backup power during a power outage.

1.3 Methodology

The methodology used in this project entailed paper design initially, after which a simulation was done using Electronic Workbench software. The designed circuit was then put on a bread board to allow for placement adjustments, and then on the actual soldering unto a Vero board. The top down design approach was also employ in the design of the UPS.

1.4 Scope of work

The design of the project is based on the Offline or Standby system. It involve powering the load directly by the input power and when the utility power fails, the backup power circuitry DC/AC inverter is automatically switched to supply power to the load.

1.5 Sources of materials

The components used for the construction of the project were gotten from a recommended electronics shops in accordance with correct specification and ratings of the components.

1.6 Limitation

The system designed is expected to operate at a maximum power rate of 1000VA, 230V a.c at 50Hz frequency.

1.7 Project layout

The general introduction, aims/objective and methodology are contained in the Chapter One.

Chapter two contains the literature review, theoretical background: Inverter, batteries, relay and types of UPS.

Chapter three, deals extensively with the circuit design and analysis, the block diagram and the circuit diagrams of the Uninterruptible Power Supply and the function units of the system.

A review of how the construction was achieved is given in chapter four, while chapter five the last chapter, concludes the project report. References are provided at the last page of the report.

CHAPTER TWO

LITERATURE REVIEW

The discovery of electricity has brought about rapid development to all area of human life. The importance of good reliable source of electrical power cannot be over-emphasized when considering some processes which cannot be stopped due to high cost of equipment downtime and irreparable damage that may be done.

In 1882 in New York, Thomas Edison laid the foundation of modern electric power transmission by building a DC pearl street station which generates a radial live transmission primary for lighting. Therefore, the development of AC transmission in USA begins in 1885 when George Washington bought the patent for AC system development by L. Gaulard and J.D Gibbs of France [3].

In 2003, engineers at the University of Aberdeen in Scotland design and construct an inverter in which a Darlington pair is used in the driver stage of the stage of the device. The transistor of the Darlington pair are basically two Bipolar Junction Transistor(BJT) devices with the emitter of the first connecting the base of next while the collector joined together, thus help in producing a gain value(beta) that is the product of both transistor. Darlington pair is used here to achieve high gain for the inverter circuit. The output of the multivibrator is fed into the Darlington pair which consist of 2N6107 and BD140 transistor(PNP) that is connected to the output of the frequency generator(multivibrator).The output of the of the darling ton pair arrangement is used to drive push pull NPN power transistor 22ohm ,15w each. The bank of transistors consist of four NPN(BD508A) each connected to the output of the power resistor used, which taps it input from collector to collector of the Darlington pair [4].

In recent years, fuel cell UPS have been developed using hydrogen and a fuel cell as a power source potentially providing long runtimes in a small space internal UPS, it is a group of Interruptible Power Supplies (UPS) designed also to be placed inside a computer chases. There are two types of internal UPS, first type is miniaturized regular UPS that are made small enough to fit into 5.25 CD ROM slot bay of a regular computer chassis. The other is re-engineered switching power supplies that utilized dual power source of AC and/or DC as power input and have an AC/DC built-in switching management control units [5].

To ensure a reliable power supply, UPS was developed to provide power by conversion of DC to AC whose magnitude and frequency are controllable. The general categories of modern UPS system are on-line, line interactive and standby.

2.1 Types of UPS

2.1.1 Online UPS

The Online UPS are designed so that the inverter is connected in series between the AC line Power input and the load. The inverter is operational regardless of whether line power is available. When line power is available, the AC input voltage waveform is rectified, the rectified DC waveform is inverted, and the inverted AC waveform is then supplied to the load. If the line power is disrupted, or otherwise falls outside of the tolerable limits of the load, the battery power is inverted and supplied to the load. Since the battery is parallel with the line-power input, the transition from line power to backup power is seamless.

Additionally, there is a static bypass switch that allows line power to bypass the inverter and be delivered directly to the load as desired [6].

The online UPS has the following advantage

- ✓ It offers isolation to the load from upstream voltage disruptions in the AC input voltage waveform. Thus, voltage spikes and over voltages in the AC input waveform are not transmitted through to the load.
- ✓ Also, since all AC output voltage waveforms (during normal operation) are generated by the inverter, this method allows for precise control and fine tolerances. For these reasons, the online UPS is used almost universally for critical and high-power-rating applications requiring 10 kVA and up.

The online UPS has the following disadvantage

- ✓ They are relatively complex and more expensive.
- ✓ Consume more electricity and is less efficient.

2.1.2 Line-Interactive UPS

The Line-Interactive UPS are designed so that the inverter is connected to the load parallel to the AC input voltage from the utility. When line power is being delivered, the inverter is also operational to charge the battery and to condition the line power. If a disruption to the line power occurs, the battery/inverter combination maintains continuity of power to the load. Once this occurs, the static transfer switch is opened to prevent power from the inverter from being introduced to the line-power distribution system [6].

The Line-Interactive UPS has the following advantage.

- ✓ The transfer of load from line power to backup power is almost instantaneous since the backup power is generated in parallel with the line power.
- ✓ It provides better filtering than a standby unit because the inverter is always connected to the load.

The Line-Interactive UPS has the following disadvantage.

- ✓ It suffers from a lack of isolation of the load from the line power, including all spikes and overvoltage.
- ✓ There is no regulation of the output frequency since the output frequency depends on the frequency of the line power, which is a primary reason why this type of UPS is typically not used for sensitive loads with high power ratings.

2.1.3 Standby (Offline) UPS

Basically, the passive-standby UPS supplies the AC input voltage directly to the load when it is available, bypassing the backup power portion of the UPS. When a disruption of the AC input voltage occurs, the DC voltage waveform from the battery is inverted by an inverter into an AC output voltage waveform approximately the same as that of the AC input voltage. A transfer switch is provided to selectively control which AC output voltage waveform is delivered to the load: the AC input supplied by the utility, or the AC output waveform from the inverter [6].

The Standby UPS has the following advantage.

- ✓ It offers a simple design, relatively small size and low cost.
- ✓ It allows tight output voltage regulation to be obtained.
- ✓ It allows automatic load transfer.

The Standby UPS has the following disadvantage.

- ✓ Isolation of the load from the upstream distribution system and line power is limited at best, and should only be used for applications with power ratings less than 2 kVA.
- ✓ It can't run for a very long time on inverter after loosing a utility power because the battery has it limit to which it can be drained.

The advantage of this type of UPS (standby) being the cheapest and also having the ability to eliminate power outage and its consequences was a pre-requisite in the selection of the UPS type for the purpose of this project design.

The importance of UPS is also found in the following problem they rectify:

- ✓ Power Failure: - Total loss of utility power, cause electrical equipment to stop working.
- ✓ Over- Voltage: - Increased voltage for an extended period of time causes light bulbs to fail.
- ✓ Under-Voltage:- Low line voltage for an extended period of time resulting in Overheating.
- ✓ Frequency Variation: - Deviation from normal frequency (50 or 60Hz) causes motor to increase or decrease speed.
- ✓ Line Noise:- Distortion superimposed on the power waveform which causes electromagnetic interference.

2.2 THEORETICAL BACKGROUND

The design and construction of this project is achieved by the use of electronic components which serve as the mechanism behind the operation of the 1kVA UPS. The theoretical background of each element is extensively dealt with.

2.2.1 Power Supply

Power supplies are an essential part of all electronic systems from the simplest to the complex. A basic power supply consists of a transformer, a rectifier, a filter and a regulator .A power supply filter greatly reduces the fluctuation in the output voltage of a half-wave or full-wave rectifier and produces a nearly constant-level dc voltage. Filtering is necessary because electronic circuits required a constant source of dc voltage and current to provide power and biasing for proper operation. Filtering is accomplished using capacitors, as you will see in the next chapter. Voltage regulation is usually accomplished with integrated circuit voltage regulators. A voltage regulator prevents changes in the filtered dc voltage due to variation in line voltage or load [7].

2.2.2 INVERTER

An inverter is a device that changes dc power into ac power. The inversion process can be achieved with the help of transistor, SCR etc. [8]. An inverter is used to produce an un-interruptible 230V AC supply to the device connected as the load at the output socket. The inverter gives constant AC voltage at its output socket when the AC mains power supply is not available. It consists of oscillator stage and driver stage.

2.2.2.1 Oscillation Stage

This stage consists basically of two NPN transistor connected in astable mode. As table multivibrators or free running relaxation oscillator has no stable state but only two quadstable (half-stable) states between which it keeps oscillating continuously of its own accord without any external excitation. In the circuit neither of the two transistors reaches a stable state. When one is ON, the other is OFF and they continuously switch back and forth at a rate depending on the RC time constant in the circuit [9]. It has two energy storage element (capacitors) the oscillator stages determine the frequency of the output voltage. The circuit diagram of astable multivibrators is shown in chapter 3.

2.2.2.2 Driver stage

This stage consists of centre tap step up transformer with two pair of MOSFET connected in parallel. MOSFET have unique features that make them potentially attractive for switching applications. They are essentially voltage-driven rather than current-driven devices, unlike bipolar transistors. The gate of a MOSFET is isolated electrically from the source by a layer of silicon oxide. The gate draws only a minute leakage current on the order of nanoamperes. Hence, the gate drive circuit is simple and power loss in the gate control circuit is practically negligible. The MOSFET is turn ON when the gate-source voltage is sufficiently large and turns OFF when the gate-source voltage is below the threshold value. MOSFET requires the continuous application of a gate-source voltage of appropriate magnitude in order to be in the ON-state. The switching times are very short, being in the range of a few tens of nanoseconds to a few hundred nanoseconds depending on the device type. MOSFET are easily paralleled because their ON state resistance has a positive temperature coefficient. This ensures that paralleled devices will share the total current equally [10].

This inverter performs two main functions in the following situation.

- ✓ When the AC mains power supply is available.
- ✓ When the AC mains power supply is not available.

When the AC mains power supply is available.

When the AC mains supply is available, the AC mains sensor senses it and the supply goes to the relay and battery charging section of the UPS. AC main sensor activates a relay and this relay will directly pass the AC mains supply to the output socket. The load will be driven by the line voltage in this situation. Also, the line voltage is given to the battery charging section where the line voltage is converted to a DC voltage (12V DC), then regulated and battery is charged using it.

When the AC mains power supply is not available.

When the AC mains power supply is not available, an oscillator circuit inside the inverter Produces a 50Hz MOS drive signal. This MOS drive signal will be amplified by the driver Section and sent to the output section. MOSFETs are used for the switching operation. These MOSFETs are connected to the primary winding of the inverter transformer. When these Switching devices receive the MOS drive signal from the driver circuit, they start switching between ON & OFF states at a rate of 50 Hz. This switching action of the MOSFETs cause a 50Hz current to the primary side of the inverter transformer. This results in a 230VAC at the

Secondary of the inverter transformer. This secondary voltage is made available at the output socket of the inverter by a changeover relay.

2.2.3 BATTERY

A battery consists of two or more cells connected together with the aim of obtaining higher current, voltage or both. Primary Cells are cells whose chemical reaction during discharge is not reversible, therefore not rechargeable e.g. flash light cells. While Secondary Cells are cells that may discharge and be recharged several times, the charge-discharge reaction are chemically reversible e.g. 12V automotive battery[11]. The battery used in this design is the sealed lead acid type with voltage rating of 12V 100Ah.It was choosing because of its ability to retain its stored charge for a very long period of time after charging has ceased.

The electrochemical reaction that takes place in a lead acid battery is summarized below:

Lead dioxide + Sulphuric acid + Lead + Lead sulphate + Water [12]

However in this design, the UPS has been made to accommodate virtually any lead acid battery rated 12V irrespective of size. A common measure of capacity is the AMPERE-RATING. It is the product of current (in amperes) and the time to discharge (in hours) [11].

2.2.4 RELAY

Relays are electromagnetically operated switches. It basically consists of an electromagnet which operates a pair of electrical contacts. It requires just a small amount of current to energize the electromagnet which causes the movement of the armature, and hence the closure of the contacts [11]

2.2.4.1 Relay Designed ID

Relay are either Normally Open (NO) or Normally Closed (NC). Normally Open relay have switch that remains open until energized (ON) while normally closed relays are closed until energized. Relays are always shown in the de-energized position (no current flowing through the control circuit –OFF).

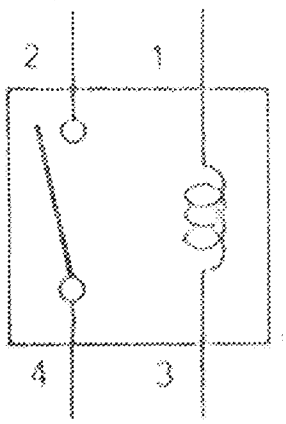


Fig2.1 Normally Open Relay

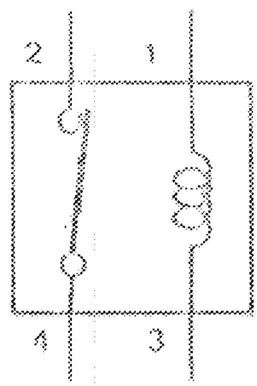


Fig2.2 Normally Closed Relay

2.2.4.2 Relay Operation

When no voltage is applied at pin1, there is no current flowing through the coil. No current means no magnetic field is developed, and the switch is open as shown in figure 2.3. When voltage is applied to pin 1, current flow through the coil creates the magnetic fields needed to close the switch allowing continuity between pin 2 and 4 as shown in figure 2.4.[13].

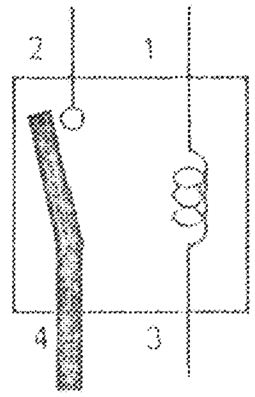


Fig2.3Relay De-energized (OFF)

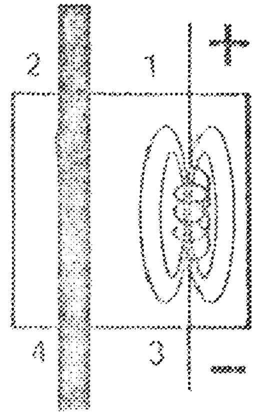


Fig2.4 Relay Energized (ON)

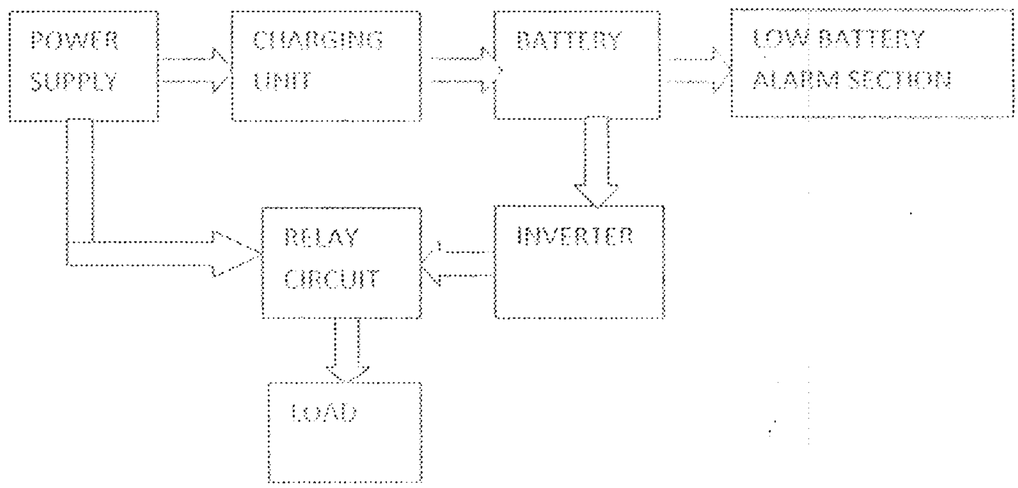


Fig2.5 Block Diagram of Uninterruptible Power Supply (UPS)

CHAPTER THREE

DESIGN AND IMPLEMENTATION

For easy design and realization of the set objectives, top-down design method was used. This involves breaking the whole-conceived idea into manageable pieces. Hence, the project design was broken into sub units. These units are:

(1) The power supply unit/Charging unit.

(2) Battery Back-Up Capacity.

(3) Low Battery Alarm Section.

(4) Automatic Relay Circuit.

(5) Inverter Unit.

3.1 POWER SUPPLY UNIT/CHARGING UNIT

The power supply unit is the basic unit that is responsible for the supply of power required at the load section/socket outlet and to charge the battery. The regulated D.C supply consists of the step-down transformer (230v/15v), a rectifier circuit (Bridge rectifier), a filtering capacitor and a regulator. This is shown on the diagram below.

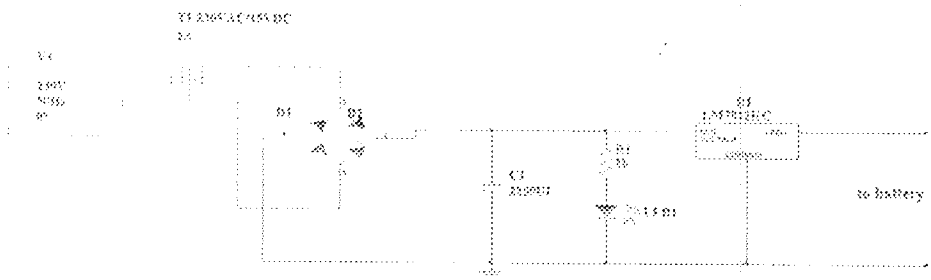


FIG. 3.1 Circuit Diagram of a regulated D.C Power Supply.

3.1.1 TRANSFORMER

Transformer is an electrical A.C component or equipment which consists of two or more coils that are linked together by mutual inductance. It is used to transfer electrical power from one coil to another. It can be used to change voltage, current or impedance from one value to another [11]. A 230V (r.m.s)/15V 2A step-down transformer was used to reduce the 230 A.C from the main supply to 15V which is rectified to give the required DC voltage.

3.1.2 RECTIFICATION

Rectifier is a circuit that employs one or more diodes to convert alternating current/voltage into pulsating direct current/voltage [7].The component selected for the rectification is the diode. It was used to rectify the output voltage from the transformer as well as the type of rectification used, i.e. whether half wave, full wave or bridge rectification. Below is the circuit diagram of the bridge rectification.

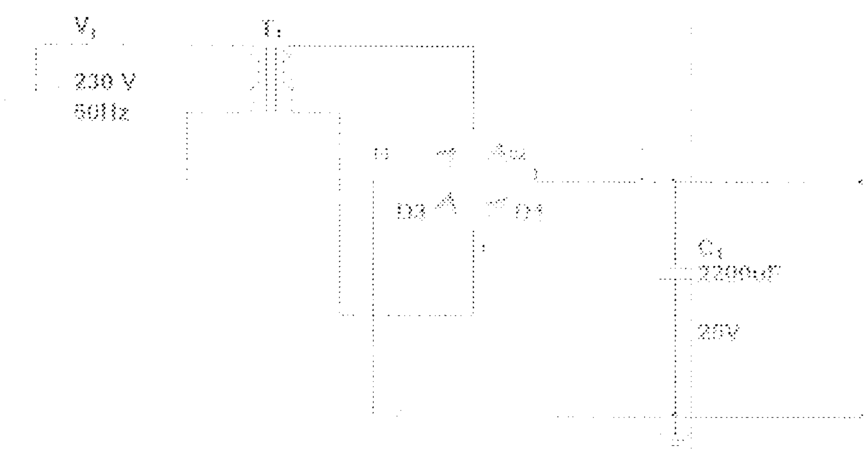


FIG. 3.2 Bridge Rectifier

$V_2 = 15V$

$$V_{out(peak)} = V_{2(peak)} = \frac{V_2}{0.7071} = \frac{15}{0.7071} = 21.2V$$

$$V_{(d.c)} = \frac{2V_{out}}{3.142} = \frac{42.4}{3.142} = 13.5V$$

During the positive half cycle of the secondary voltage, diode D2 and D3 are forward biased and current flows through the load. In the negative half cycle of the secondary voltage, diodes D1 and D4 are forward biased therefore current flows through the load as well. Since the load current is in the same direction, the full wave rectified signal appears across the load as seen in the figure below.

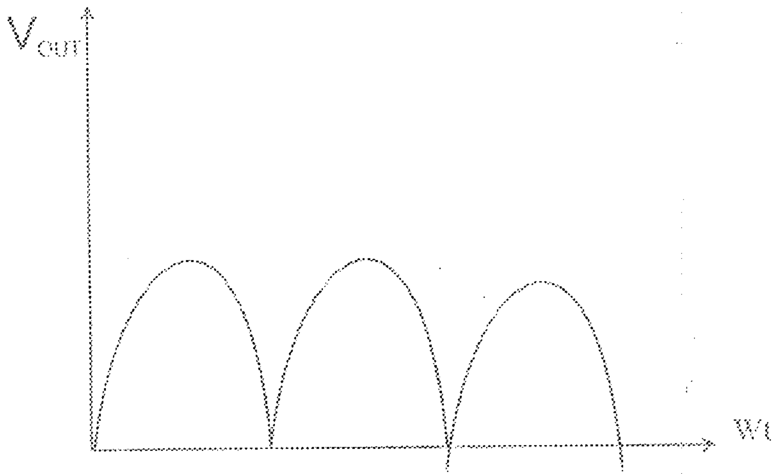


FIG.3.3 Full wave rectified output

The bridge rectification was chosen for the design because the frequency F at the output of a half wave rectifier is the same as the line input frequency where as that of the bridge and full wave rectifier is twice the line input frequency thereby reducing the ripple. Also the half wave rectification uses only the positive half cycle but it was desired that both the positive and the negative half cycles be used. For this reasons the half wave rectification was not used. The ripple voltage is calculated thus;

$$V_{(ripple)} = \frac{I}{FC} \quad (3.1)$$

I = D.C. load circuit

F= ripple frequency

C= capacitance

For half wave rectification $V_{(ripple)} = \frac{I}{FC}$

For bridge and full wave rectification $V_{(ripple)} = \frac{I}{2FC} = \frac{0.5I}{FC}$

This shows that V_{ripple} is smaller for bridge and full wave rectification than for half wave rectification and the smaller the ripple the better.

3.1.3 FILTERING

The filtering stage comprise of capacitance in parallel, the purpose of the shunt capacitance is to provide a very good smoothing of the AC ripples from the output of the rectifier. The equation governing the choice of capacitance is given in the following expression.

$$Q = CV \quad (3.2)$$

$$Q = It \quad (3.3)$$

From above, equation (3.2) is equal to equation (3.3).

$$CV = It \quad (3.4)$$

$$C\Delta V = I\,\Delta t \quad (3.5)$$

Where C = value of capacitance connected across the DC unit.

ΔV = AC ripple on the DC supply

I = current of the regulator going through to the circuit

Δt = time of regulation, which is a constant

From the expression above,

$C = \frac{I\Delta t}{\Delta v}$

$\Delta t = \frac{1}{2F} = \frac{1}{2\times50} = 0.01\text{sec.}$

$\Delta v = 25\% \text{ of } V_{2(ripple)} = \frac{25}{100}\times 21.2 = 5.3V$

I = 1A

$C = \frac{1\times0.001}{5.3} = 1.8868e\text{-}3$

C = 1886.8e-6 ≈ 2000μF

A value of 2200μf 25V was used as the capacitance, which was deduced from the previous calculation, this is only the minimum capacitance required to keep the system specification from falling below the projected value. A 12V regulator, LM7812 1A was used to obtain a 12V output which is used to charge a 12volt lead acid secondary cell on the unit.

A charger on indicator is connected to indicate when the power is supplied to the charging unit. It is made up of a resistor and LED.

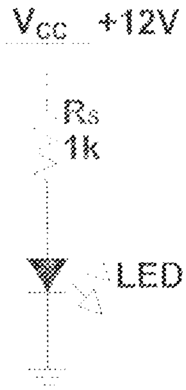


FIG.3.4 Charger ON indicator

The current timing resistor was deduced from:

$$R_s = \frac{V_s - V_{led}}{I_{led}} \tag{3.6}$$

V_{led} = 1.7V

I_{led} = 10mA

$R_s = \frac{12 - 1.7}{10m} = 1030\ \Omega$

A 1kΩ resistance was used instead.

3.2 BATTERY BACK-UP CAPACITY.

The battery being the sole energy source is a critical aspect of this design. The battery used in this design is the sealed lead acid type with voltage rating of 12v a 100Ah, it was choosing because of its ability to retain it stored charge for a very long period of time after charging has ceased. To charge the battery appropriate charging current must be applied. For a lead acid battery with rating of 12V at 100Ah if the charging time is to be 24hours from complete discharge, then the initial charging current to be made available should be about

$I_{charging} = \frac{66}{24} = 2.75$ amperes/hour

Voltage Utilization per unit time is given as

$$T = \frac{Q \times V}{P} \quad (3.7)$$

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 100Ah for a lead acid Battery).

$T = \frac{66 \times 12}{1000}$

$T \approx 47$ minute

Hence, on maximum load and full charge on battery, the operating time of the inverter will not exceed forty seven minute. This time can however be exceeded if only inportant work would be carried out using the necessary appliances while others are switched off.

3.3 LOW BATTERY CUT-OFF UNIT

This consist of op-amp (LM741) used as comparator and an 8V voltage regulator (LM 7808) as shown below.

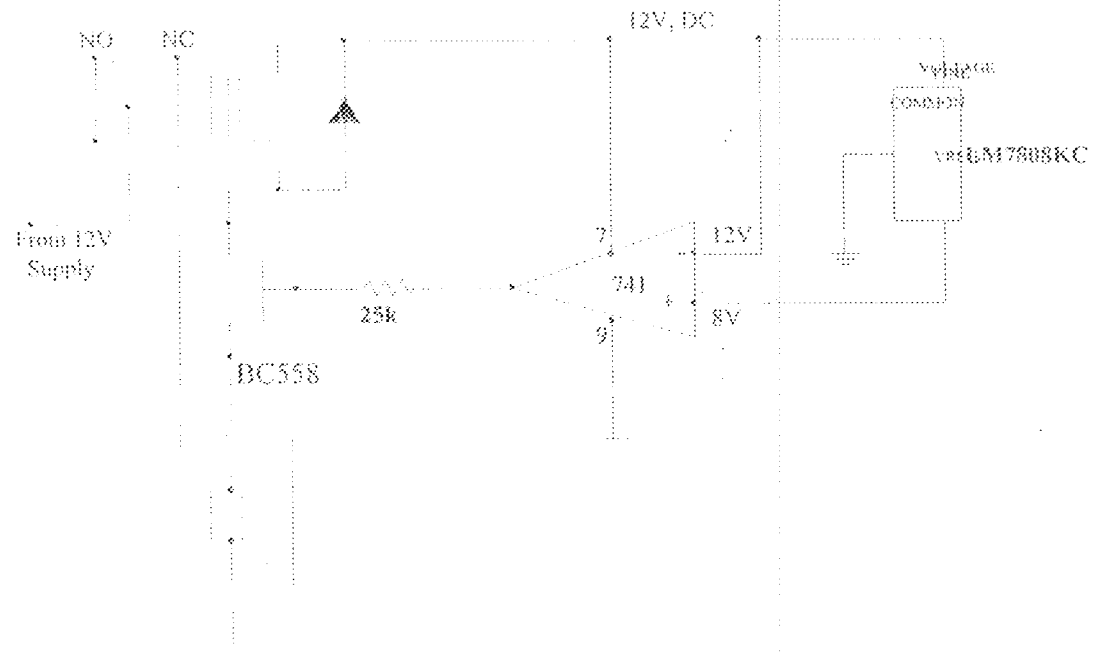


FIG.3.5 Low battery Alarm Section

In this circuit, a LM741 is used as voltage comparator. The voltage (input) at the non-inverting (+) terminal is fixed at 8V while the 12V from battery is applied directly to the inverting (-) terminal. As the voltage at the inverting terminal drop down up to 8V, the op-amp will give a high output which was formerly low goes high, this will apply a high voltage to the base of the transistor thereby causing the transistor to conduct and then trigger the relay, which causes the buzzer to make a sound indicating that the battery voltage is low.

The Base Resistor (R_B) was deduced from:

$$V_{cc} = I_c R_c \qquad (3.8)$$

V_{cc} is supply voltage =12V

R_c = Collector resistance =200 Ω

I_c = Collector current

$I_c = \frac{V_{cc}}{R_c}$

$I_c = \frac{12}{200} = 0.06A = 60mA$

But h_{fe} of BC108 = 300, from the datasheet, choosing h_{fe} = 224

$I_c = I_b h_{fe}$

$I_b = \frac{I_c}{h_{fe}}$ = 0.06 / 224 =2.679e-4A

V_{be} = 0.7V

$$V_{in} = I_b R_b + V_{be} \qquad (3.9)$$

$R_b = \frac{V_{in} - V_{be}}{I_b}$

$R_b = \frac{12-0.7}{0.000268} = 42K\ \Omega$

A 25K Ω resistance was used instead.

3.4 AUTOMATIC RELAY CIRCUIT.

A relay is an electromagnetic device or solid state device operated by varying the input, which in turn is used to control other device connected to its output. The relay used in this design is 24V 10Amps dual pole, double throw relay.

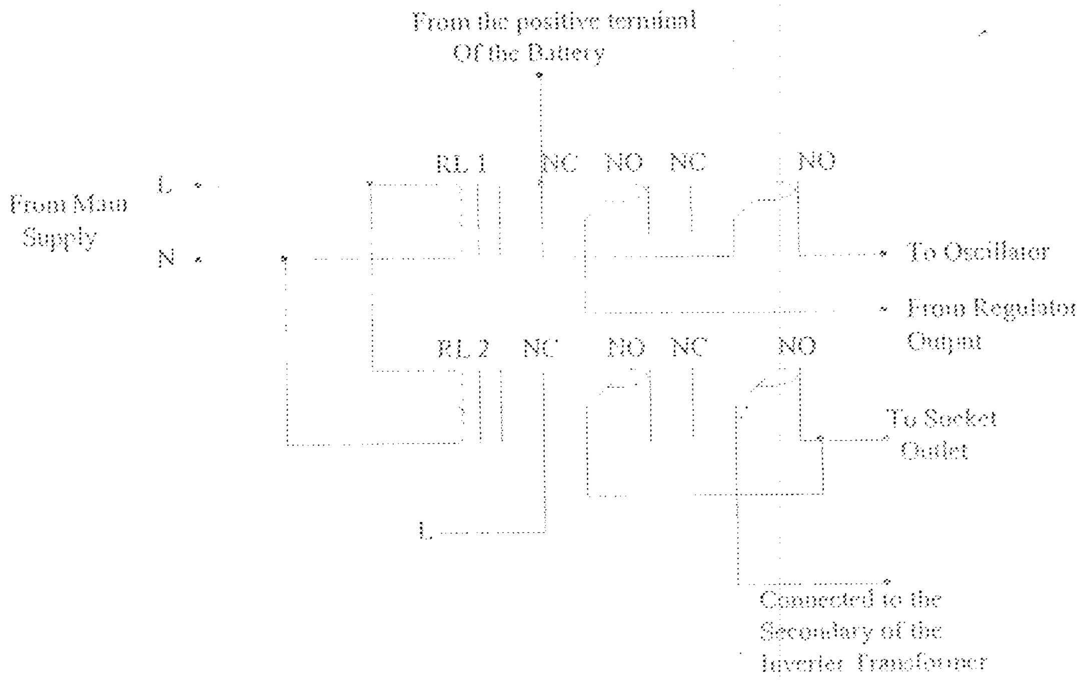


FIG.3.6 Circuit diagram of Relay

When there is power supply from the AC mains, both relays 1 and 2 are energized. The normally open (NO) contacts becomes closed, Relay 1(RL_1) automatically connects the ac mains input to the charging unit of the battery and at the same time disconnect power supply from the battery to the oscillator while relay 2 (RL_2) is used to disconnect the secondary of inverter transformer from the socket and at the same time connect AC power source to the socket.

In the event of AC mains failure, both relays revert to their normally open contacts, thus relay 1 is used to make contact for the battery to supply power to the oscillator and result to an AC output at secondary of inverter transformer (T_2). this can happen only if switch1 (S_1) is closed while at the same time relay 2 now connect the secondary AC output of T_2 to the socket.

3.5 INVERTER UNIT.

This is the sub-circuit that converts direct current (DC) voltage to alternating current (AC) voltage which determines the magnitude and the frequency of the voltage. The inverter consists of the oscillator stage, driver stage and step-up transformer.

3.5.1 OSCILLATOR STAGE

This stage basically consist of two NPN transistor connected in astable mode. The oscillator stage determines the frequency of the output voltage and the frequency of oscillations is dependent on the values of resistors R_2, R_3 and capacitors C_1, C_2.

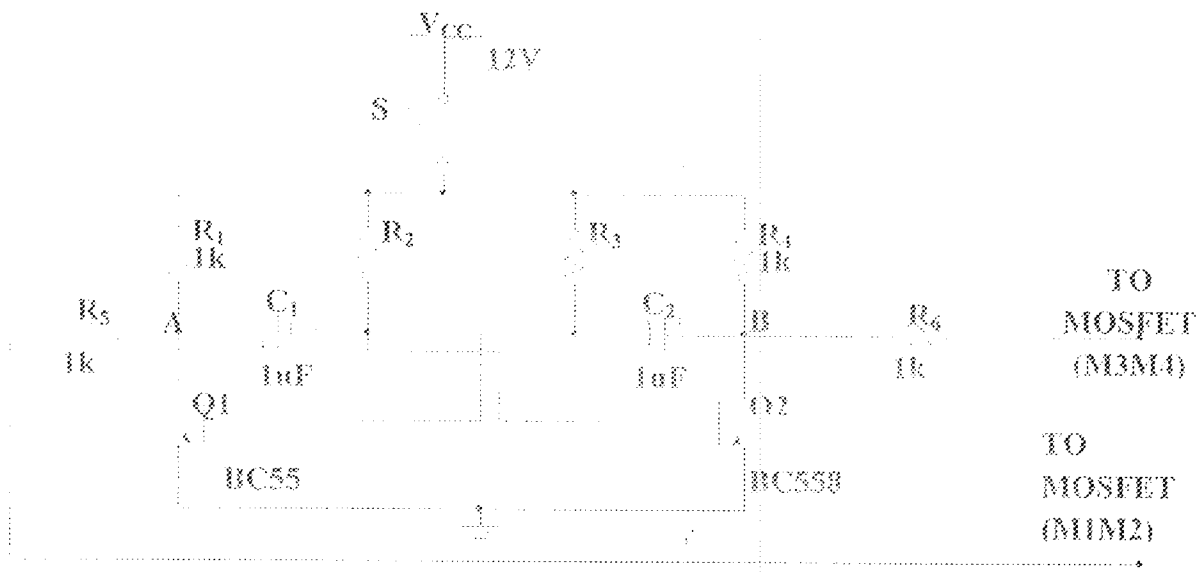


FIG.3.7 Circuit Diagram of an Oscillator

When the power is switched on by closing S_1, one of the transistors will start conducting before the other does. It is so because characteristics of no two seemingly similar transistors can be exactly alike. Suppose that Q_1 starts conducting before Q_2 does, the feedback system is such that Q_1 will be very rapidly driven to saturation and Q_2 to cut-off.

The following sequence of events will occur:

- ✓ Since Q_1 is in saturation, the whole of V_{cc} drops across R_1, hence Vc_1=0 and point A is at 0V.
- ✓ Since Q_2 is in cut-off, there is no drop across R_4, hence point B is at V_{cc}.
- ✓ Since A is at 0V, C_1 starts to charge through R_2 towards V_{cc}.
- ✓ When voltage across C_1 rises sufficiently, it biases Q_2 in the forward direction so that it starts conducting and soon driven to saturation.
- ✓ Vc_2 decreases and becomes almost zero when Q_2 gets saturated. The potential of point B decreases from V_{cc} to almost 0V.
- ✓ Since now point B is at 0V, C_2 starts charging through R_3 towards the target voltage V_{cc}
- ✓ When voltage across C_2 increases sufficiently, Q_1 becomes forward biased and starts conducting. In this way, the whole cycle is repeated.

The circuit alternate between a states in which when Q_1 is ON, Q_2 is OFF and they continuously switch back and forth at a rate depending on the RC time constant in the circuit [8].

From basic analysis

$$t_1 = 0.69C_1R_2 \qquad (3.10)$$

Similarly, the time t_2 for which Q_2 remains in conduction is given by:

$$t_2 = 0.69 C_2 R_3 \qquad (3.11)$$

$$T = t_1 + t_2 = 0.69(C_1 R_2 + C_2 R_3)$$

If the circuit is symmetrical, $C_1 = C_2 = C$ and $R_1 = R_2 = R$,

$$T = 1.38RC$$

The frequency of the rectangular wave is:

$$F = \frac{1}{T} = \frac{1}{1.38RC} \qquad (3.12)$$

The Base Resistor (R_b) was deduced from:

$$V_{cc} = I_c R_c \qquad (3.13)$$

$$12 = I_c \times 100$$

Let $R_c = 100\ \Omega$

$$I_c = \frac{12}{100} = 0.012\text{A}$$

From the datasheet, h_{fe} is 100, choosing $h_{fe} = 12.2$

$$I_c = I_b h_{fe}$$

$$I_b = \frac{I_C}{h_{fe}} = \frac{0.012}{12.2}$$

$$I_b = 0.0009861\text{A}$$

$R_b = \frac{V_{cc}}{i_b}$

$R_b = \frac{12}{0.0009861}$

R_b= 12.2K Ω

Choosing the capacitance C to be 1μF

$F = \frac{1}{1.38RC} = \frac{1}{1.38 \times 12.k \times 1\mu}$

F = 59Hz

R_b=R_2=R_3= 12.2K Ω

C_1=C_2 = 1μF

3.5.2 DRIVER STAGE

This stage consists of a centre tap transformer with two pairs of enhancement MOSFET IRF3205 connected in parallel, this does not help to increase the power but divide the current into two equal part so that maximum of 50A flow through each MOSFET. Each pair is connected to primary side of the transformer and each pair of MOSFETS supplies current to the transformer at different period of oscillation supplied by the oscillator as shown below.

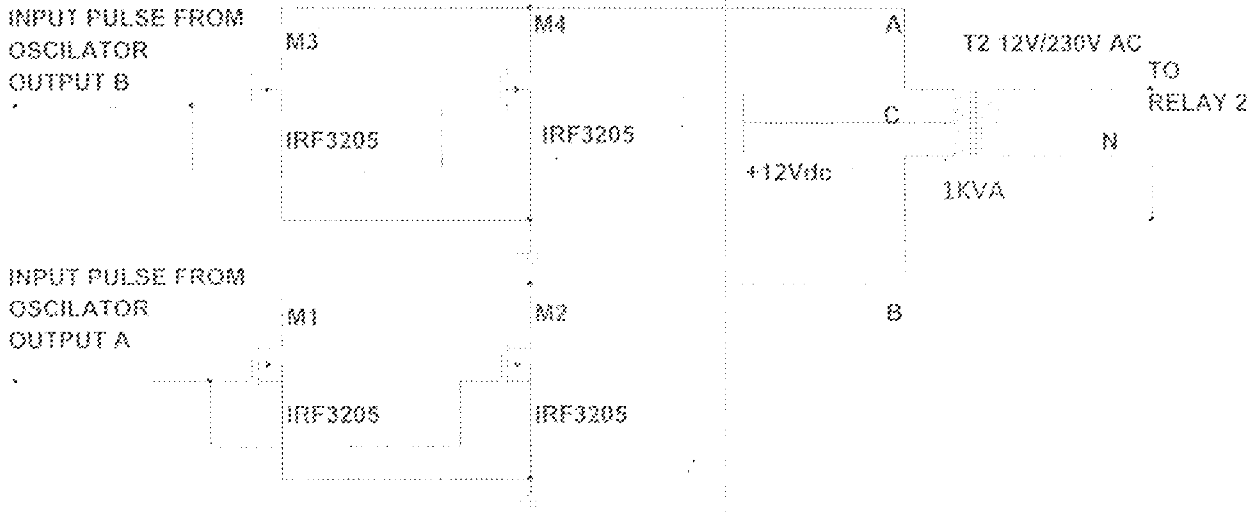


FIG.3.8 Circuit Diagram of the driver stage

When the output from point A of the oscillator is high, M1 and M2 are in the ON condition while M3 and M4 are in the OFF condition, the electric current flows in the direction of CB of the primary side of inverter transformer (T_2). When the output from point B of the oscillator is high in the second period of oscillation, M3 and M4 are in the ON condition, hence electric current flows in the direction of AC of the primary side of inverter transformer (T_2). Therefore, by switching the pair of MOSFET ON and OFF alternatively, current is made to flow in first half of the primary of the inverter transformer and then in the other, producing an alternating magnetic flux in the transformer core. As a result a corresponding AC voltage (230V) is induced in the transformer secondary winding with switching frequency determined by the frequency of the oscillator. A 5v is achieved at point A and B which is enough to drive the MOSFET.

The gate resistors R_5 and R_6 are required to prevent static charge that builds up at the gate which may result to damage of the MOSFETS.

The IRF3205 was used as a power switch for the following reason:

- ✓ High frequency response
- ✓ Low noise
- ✓ High input impedance
- ✓ Long life
- ✓ Positive temperature coefficient [14].

3.5.3 INVERTER TRANSFORMER DESIGN

For a D.C to A.C inversion, a special type of transformer is required. The steroidal type of core transformer is used in this design because of its ease of winding. The following condition was noted before choosing the transformer.

I. Power Rating

II. Current Rating

III. Voltage Ratio

POWER RATING

The sole determinant of a transformer power rating is the core, the larger the coil, the less the number of winding required and the higher the power rating. The material the core is made up of also determines its efficiency, for this project design an iron core rated at 10,000AT/M was choosing for the inverter transformer core.

CURRENT RATING

The current rating will determine the type of D.C source to acquire. The winding gauge wire used is sufficiently thick in order to minimize I^2R losses especially in the primary side which conduct a higher current. To calculate the number of turns in both the primary winding and secondary winding, the following data is required

D.C input switching voltage = 12V

Required A.C output voltage = 230V

From the above data

Required Transformer Ratio = $\frac{Average\ peak\ A.C\ output\ voltage}{D.C\ input\ voltage} = \frac{300}{12} = 25$

Output current $I_{out} = \frac{1000}{230} = 4.35A$

$I_{in} = 105A$

The gauge of the wire is 19 (g=19)

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

No. of secondary winding will be

$$\frac{I_{in}}{I_{out}} = \frac{N_2}{N_1} \quad (3.14)$$

$N_2 = 605$turns

VOLTAGE RATIO

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

Voltage Ratio = $\frac{300}{12} = 25$

3.5.4 SELECTION OF HEAT SINK

The power MOSFETS which are connected in parallel at maximum handling current of 110A, each pair of MOSFET will draw about half the total current i.e. 42A.

From the datasheet of IRF3205

$I_D = 110A$

$V_{DS} = 60V$

$P_D = 200W$

R_{DS} = 8.0m Ω [15]

Voltage drop across device = $I_D R_{DS}$=110 × 0.08= 8.8V

Power dissipated across the device = $I_D \times V$ = 110 × 8.8 = 968W

The above calculation shows that a heat sink of about 968 watt minimum for each pair of MOSFET suitable enough to dissipate the generated heat.

3.6 SYSTEM MAXIMUM POWER RATING

The system designed is expected to operate at a maximum power rate of 1000VA, 230V a.c at 50Hz frequency. The specified power rating is for a system that is 100% efficient. The following assumptions were made:

- ✓ Let the transformer used for the design be 90% efficient.
- ✓ The use of resistive loads was for testing (power factor for resistive loads is 1).

Power equation = $Currnt \times Voltage(in\ VA)$

Also $P = VI\cos\emptyset$

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

But for a 90% efficient system

$$P_{in} = \frac{90}{100} \times 1000 = 900W$$

But at the output, V=230V $a.c$

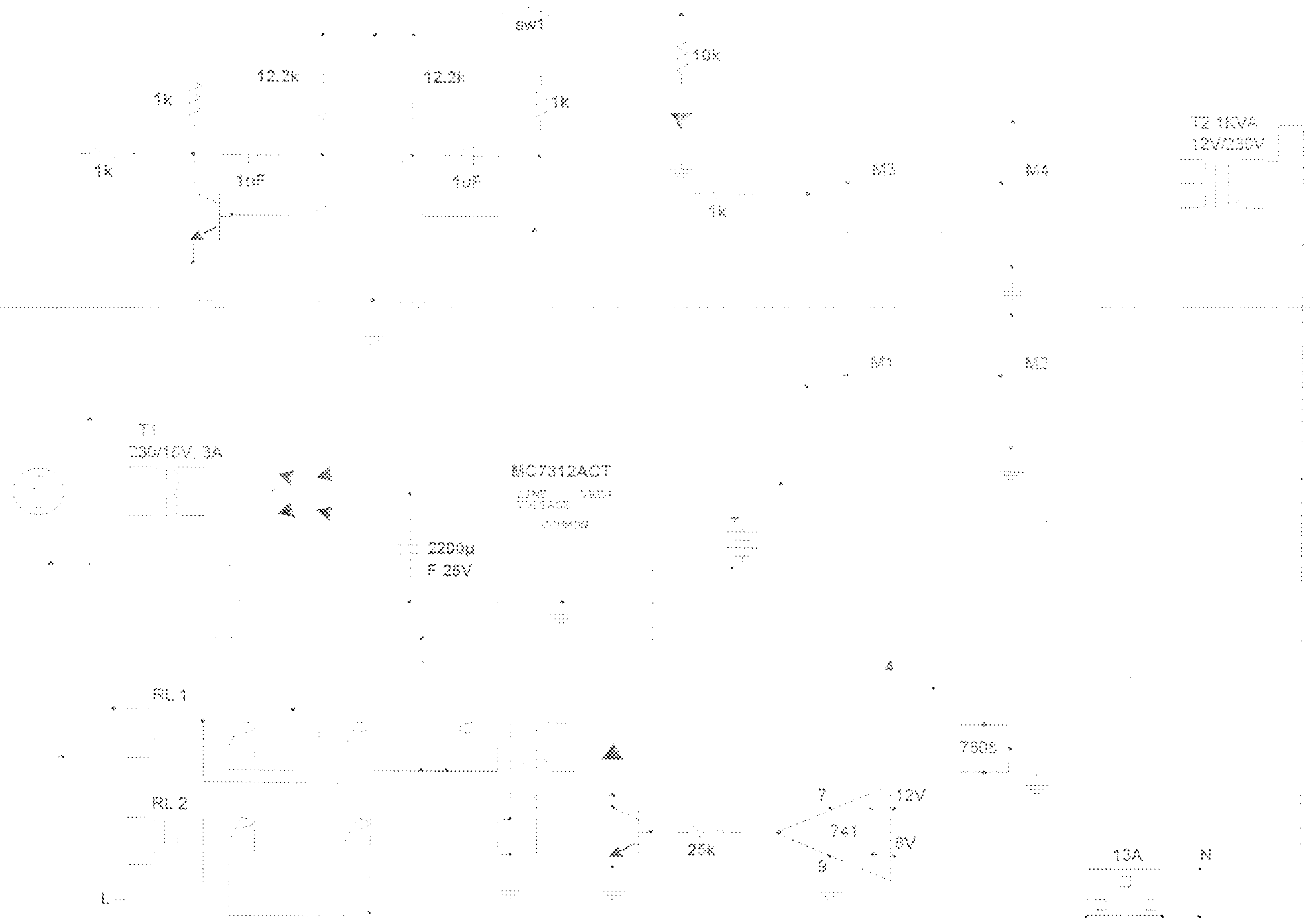
$VI\cos\emptyset$= 900W

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

$$I_{out} = \frac{\quad}{230} = 3.9A$$

$$I_{in} = \frac{900}{12} = 83.3A$$

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


sw1
10k
12.3k
12.3k
1k
1k
1k
1uF
1uF
1k
T2 1KVA
12V/230V
M3
M4
M1
M2
T1
230/15V, 3A
MC7312ACT
2200μ
F 25V
4
7805
RL 1
RL 2
7
12V
741
8V
6
25k
13A
N
L

CHAPTER FOUR

CONSTRUCTION, TESTS, RESULT AND DISCUSSION

4.1 CONSTRUCTION

Construction is the process of putting the various components together on a Vero board. In constructing the system, the various units that made up the system were followed in proper order, starting from the power supply unit, low battery alarm unit, automatic relay unit and inverter unit. Initially, most of the stages of the project were tested on the bread board before transferring them to the Vero board for soldering and all the stages worked properly both on the bread board as well as the Vero board.

An old stabilizer metal casing was used to case the project and sprayed with black car paint to give its aesthetic beauty.

4.2 TESTING

On successful completion of the construction, the first thing that was done was to carry out a thorough test of the circuit to make sure that there was no misconnection resulting in short circuit or bridging components before it is powered. Other tests were still carried out after powered to ascertain the proper operation of the system. This test involves a number of different procedures ranging from visual to equipment checks to cater for a perfect working condition. The visual checks were performed before power was connected to the circuit while the equipment checks were performed when power was connected to the circuit.

The oscillator stage and inverter output were tested with a multimeter and values obtained were recorded. The 12V sealed acid battery used was tested with a multimeter and the rated voltage was confirmed.

Eventually the system was powered from the mains, the red LED_1 came ON indicating that the battery was being charged, the green LED_2 came ON indicating that any appliance connected to the UPS was making use of public power supply. With the 12V battery still connected, the power plug was disconnected from the public power supply; LED_3 (red) became lit while LED_1 (red) and LED_2 (green) go OFF. This indicates that the UPS was now on standby mode and any appliance connected to it was making use of battery power. The output voltage from the UPS and battery was measured and recorded. There was a little humming sound from the system, this did not come from the design itself but from one of the components (step up transformer) used in the design. The audible hum is as a result of the 50Hz AC signal (which falls within the audio frequency range) causing the laminations of the step up transformer to vibrate or resonate which could be as a result of improper fastening or alignment of the transformer lamination.

4.3 RESULTS

The following results were obtained from the test carried out.

Output Voltage from the battery	12V
Output Voltage from the inverter when the battery is fully charged	230
Output Current from the inverter	4.3A

Output Frequency of oscillation	56Hz

4.4 DISCUSSION OF RESULT

The actual frequency of the output voltage was measured and found to be 56Hz, a 3Hz deviation from targeted 59Hz. This may be due to tolerance in the values of capacitors and resistors used to determine the frequency of the astable circuit.

The UPS was tested on different electronic loads such as TV, Radio, soldering iron and electric bulb the output voltage began to drop when the load connected across the UPS was increased to a certain level. It drops to about 120V when a load of about 800W was connected making a buzz sound indicating that the battery is low. This drop can be explained from the point that the step up transformer is rated in KVA which is the usual rating for an inductive load operating ac signal.

Actual power in watts = KVA power rating * power factor (P.F)

4.5 COST ANALYSIS

Cost plays a vital role in any engineering design and construction. The cost of any project determines how prosperous that particular project is going to be used. In view of this, the cost estimation of 1kVA UPS is shown in the table below:

Table 4.1 Cost Estimation of the System

S/No	ITEMS	QUANTITY	COST (₦)
1	240/15V 3A Transformer	1	300
2	Bridge Rectifier	1	150
3	Capacitor	6	100
4	Regulator	3	120
5	Resistors	10	50
6	Transistor	3	120
7	Relays	2	900
8	12V 66AH lead acid battery	1	4000
9	Vero board	1	150
10	Lead	1	300
11	12V/230V Inverter Transformer	1	3000
12	RF3205	4	900
13	Regulator 7812 and 7808	1 each	200
14	Casing	1	300
15	AC Meter	2	300
16	LM741	1	450
17	LED indicator	5	50
18	Socket	1	250
	Total		N12,500

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The aim of this project is to design, construct and test a 1KVA UPS, which have been achieved. The system was tested and the desired result was obtained, the system can be easily maintained and not so expensive to construct in terms of purchasing components.

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

5.2 RECOMMENDATION

Most of the project designs implemented so far is mainly on the offline operating made type, therefore I recommend that the next project on this topics be on the Online operating mode type, which I want to recommend that a higher capacity inverter circuit capable of handling battery voltage of about 24V instead of normal 12V be designed.

Also, after the completion of this project work, I would recommend that students should be made to embark on at least three project designs before graduation. Also, the students should be made to understand the use of simulators in this computer age to ease workability and construction.

5.3 PROBLEM ENCOUNTERED

- ✓ Non-availability of some components.
- ✓ 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.
- ✓ The inverter transformer was difficult to source but was later constructed.
- ✓ Finance

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