DESIGN AND CONSTRUCTION

OF

1KVA INVERTER (DC - AC)

EGBUNU A. MURTALA

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DEDICATION

This project is dedicated to Almighty Allah for His infinite mercy, guidance and protection.

DECLARATION

I (Murtala A. Egbunu) declare that this work was done by me and has never been presented anywhere for the award of a I also hereby relinquish the copy right to the Federal University Of Technology, Minna.

Murtala A. Egbunu

(Name of Student)

28/11/2007

Signature and Date

Mr. O.D Ahmed

(Project supervisor)

O. D. Ahmed 28/11/07

(Signature and Date)

Engr. M.B Abdullahi

(Head of Department)

(Signature and Date)

(External examinar)

(Signature and Date)

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ABSTRACT

Uninterrupted power supply (UPS) is one of the numerous applications of an inverter. In this project work an Astable multivibrator is used to generate the operating frequency of 50Hz through capacitors and resistors. The maximum power requirement is met with the use of power MOSFET (metal oxide semi-conductor Field Effect transistor) as switches. The current was tested after the final construction and the derivations were within the designed limit. The entire components and materials used were sourced locally, and were rugged and readily available. As usual, problems were encountered and solved in the course of this project design.

This project was well researched, criticized, analyzed, designed and constructed to the given specifications as the output can be compared favourably with the existing UPS in the market.

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CHAPTER ONE

1.0 INTRODUCTION

Utility electric power system in Nigeria, (PHCN) have evolved to supply bulk electric energy to domestic, commercial and industrial customers. [1]

Statistics have shown that power failures are rare in some countries, but in a country like ours, it is a frequent occurrence.

Power outages are the most troublesome utility many companies are faced with problems. These result mainly from faults. Such outage generally takes from some few minutes to sometimes, some sustained period of hours or even days. These always creates significant negative effect on the productivity of an industry or company. For instance, a data company can suffer a great loss of data that may take hours or days to rebuild. In the area of transportation where use is being made of Electric trains, tramps, lifts, etc, power outage can be dangerous. In medical area, this could be life threatening. These and several other factors call for the use of a stand-by power unit to safeguard the losses.

An uninterrupted power supply (UPS) is one of the solution to power outages. The UPS is basically an application of an AC/DC/AC inverter. It is a power supply system connected between the user equipment with or without outages. Apart from the above, the supply is also free from frequency variations, spikes and transients.

Uninterruptible power supply system fall into the family of equipment termed 'Emergency/Standby system'. It development can be traced back to the beginning of computer age in the 1950's. The diagram in fig 1 below illustrates the relationship between UPS and Emergency/Standby systems.

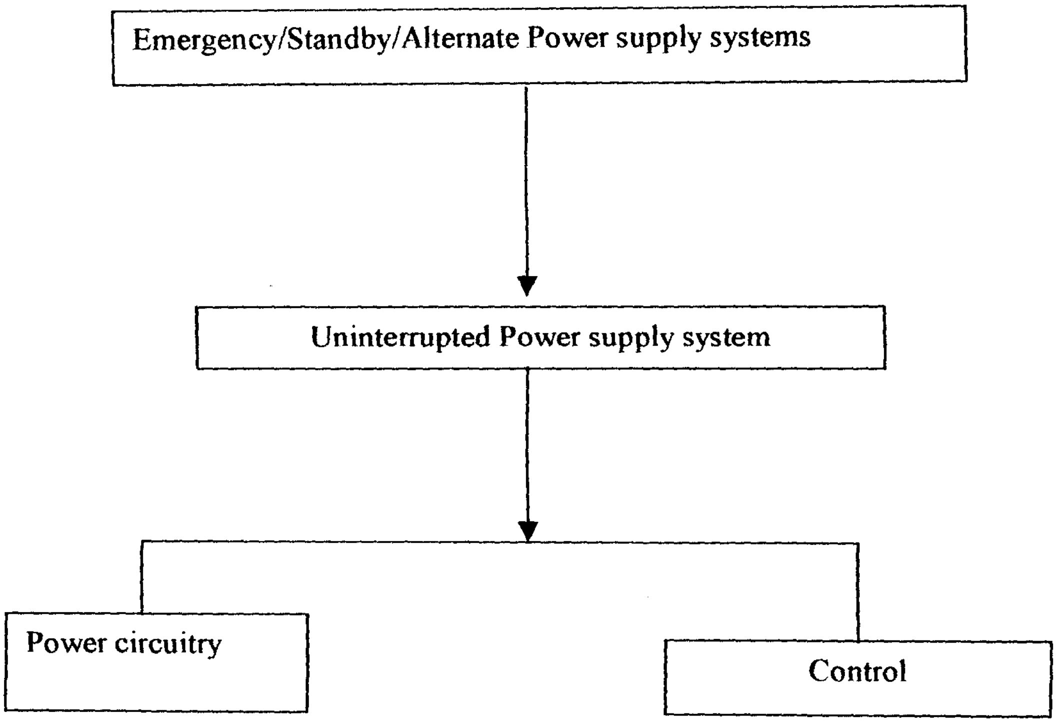


Fig. 1:1 Relationship Between UPS And Emergency Power Supply System.

1.1 AIMS AND OBJECTIVE

This project aims at designing and constructing a 1KVA capacity inverter (UPS) with an automatic battery charging unit.

The objective is to use a unique and simple means to achieve a better result taking into consideration the cost implication.

1.2 SIGNIFICANCE OF STUDY

This project has a significance role to play in proffering a lasting solution to losses incurred by industries in particular and the general society at large during possible power outages. Though, there has been in existence various types of UPS, this application is unique in the sense that it combines the attribute of cold starting with the use of the HEXFET III POWER MOSFET equipment with an integral body diode as the switching device thereby prolonging the lifespan of the system. It has a very high overload capacity and latest design in the market which reduce the cost of the entire circuitry.

1.3 SCOPE OF THE STUDY

The scope of this project is limited to load up to 1KVA capacity. This means that it can serve loads like personal computers (PCs) and several other electronics gadgets like T.V, Video player, Video CD players and some electrical appliances like standing/table fans, florescent lamps, etc which are not more than 1KVA.

1.4 METHOD OF STUDY

The method used in this study is by consulting several textbooks, journals, data books, various designer manuals and consultations with learned individuals with vast practical experience.

In the construction, HEXFET III (a specially and recently modified power MOSFET) has been used as the switching device because of its vast advantages over other electronic switching devices such as thyristors and transistors. In addition to the above, the advantage of the HEXFET body diode was also exploited.[2]

CHAPTER TWO

2.0 LITERATURE REVIEW

As has been mentioned earlier on, utility electric power systems have evolved to supply bulk electric energy to customers for loads such as lighting, heating, motors and other equipment that can tolerate momentary and long interruptions without damage and with incidental conveniences. To supply such loads to meet their concept of reliability, utility companies employ feeder and capacitor switching, step feeder regulators, voltage reduction measures, and occasional complete interruption for critical maintenance work.

However, a small fraction of the total consumer load consisting of emergency lighting, medical facilities, transportation, data processing and communication centre cannot tolerate utility quality power. As a result, a family of equipment termed emergency/Standby systems has been developed to provide high quality power for that of the customer load, which requires it.

An Emergency power system is defined as an independent reserve source of electric energy, which upon the failure of the normal source, automatically provides reliable and steady electric power within a specified time to critical devices and equipment whose failure to operate satisfactorily would jeopardize the health and safety of individuals or result in damage to property.

A one line diagram for a system in which a state (Solid-state) UPS provides the Emergency power is shown in fig. 2. The UPS module consists of a charger, a battery and an inverter. The module is usually provided with a bypass circuit that transfer the Emergency load to the normal source either automatically if the UPS fails or normally to isolate the UPS for maintenance. The high-speed static switch closes first, followed by the closing of the bypass circuit breaker (CB) and opening of the output CB. The UPS operates to supply the emergency load continuously; it does not operate in a standby mode. But this project operate in a standby mode (i.e. cold start)

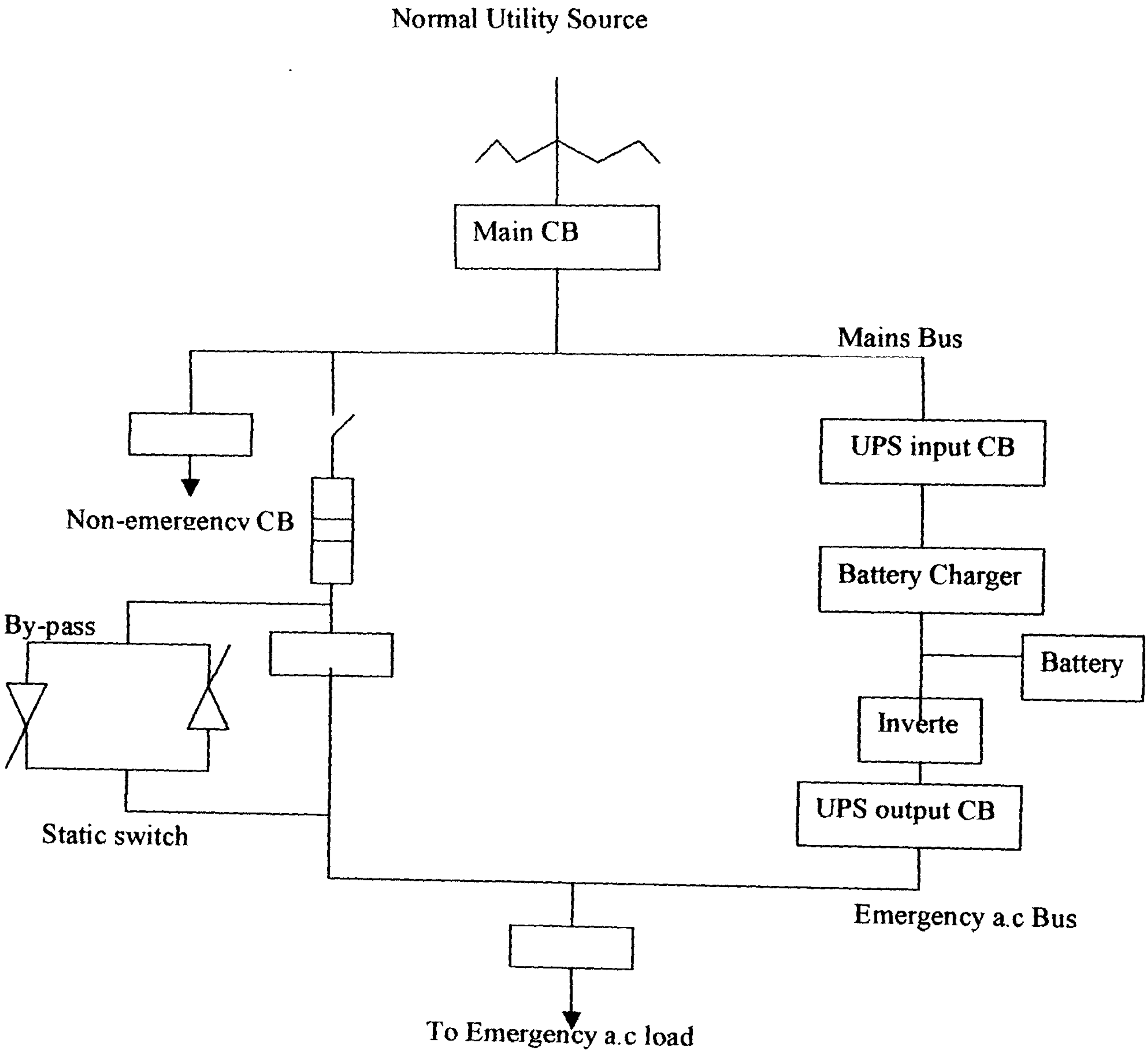


Fig. 2:1 Emergency System With Static UPS [3]

The earliest inverters developed used the conventional thyristor because that was the only device available. This version requires extensive commutation networks using capacitors, and inductors to bring about turn-off, which is a disadvantage and the need to include inverse parallel connected feedback diodes was not possible with the thyristor.

The recent development of the transistor solved these problems enumerated with the thyristor version as they are now widely used and they have the added advantages of faster switching speed with less losses.

The most recent development in switching devices was the HEXFET III power MOSFET developed in 1979, which is by far, the fastest switching device yet. It is a voltage-controlled device, which is suitable for this particular project. They offer many advantages over the thyristor and transistor models, in both linear and switching applications.

These advantages include; very fast switching, absence of second breakdown, wide safe operating area, and a very high, almost infinite, d.c gain. They require no scrubbers and have low switching losses. They can be driven direct from buffer logic and the design can be used for different power ratings unlike with other devices. The HEXFET III power MOSFET have very high overload capacity (about 1200%) and have avalanche capacity, which is lacking in other devices.

2.1 UPS SYSTEM STRUCTURE

The basic functional component of the UPS can be grouped into two main area:

(i) The power circuitry, which consists of input transformer, rectifier, battery bank, the inverter, the switching unit and the output transformer.

(ii) The UPS control is made up of the following: rectifier control, control relay, inverter control and the charger's control.

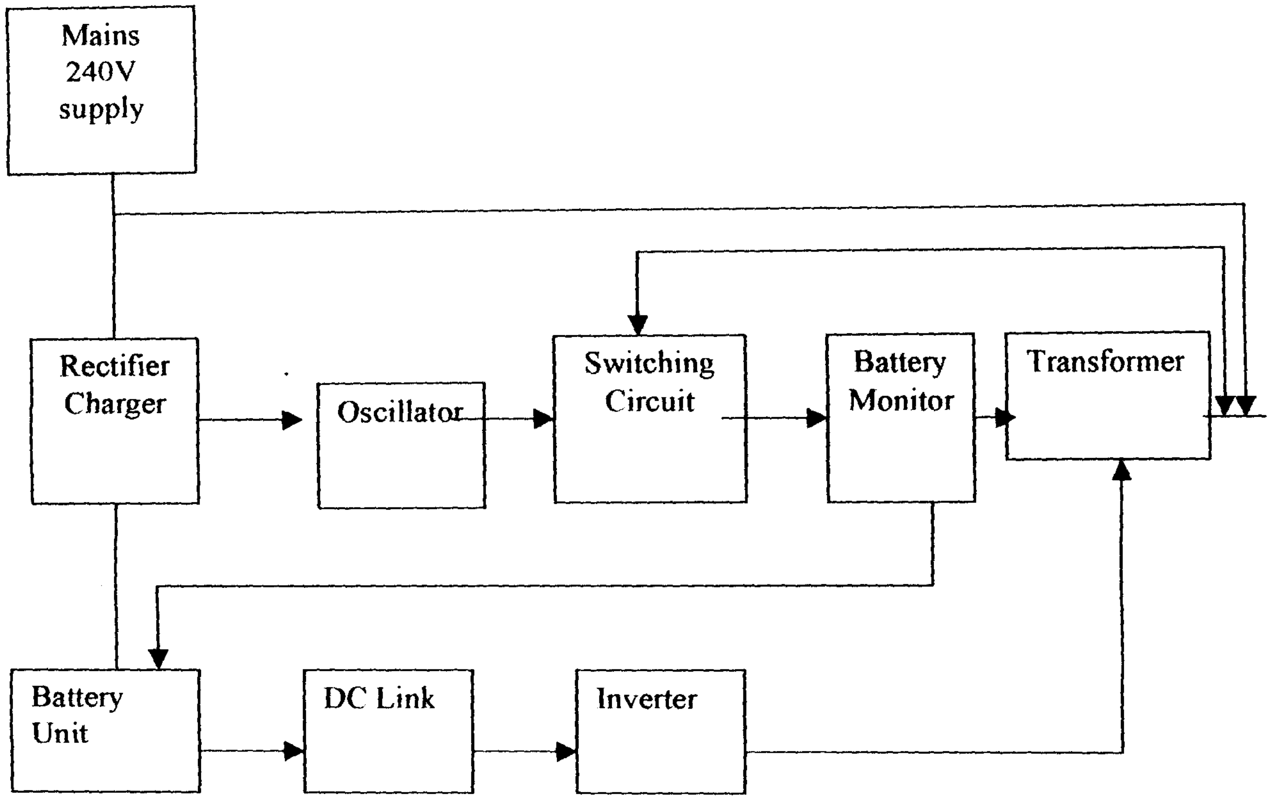


Fig. 3.0: Block Diagram of the UPS

2.2 THE AC-DC-AC INVERTER CIRCUIT

The heart of the UPS is the rectifier-inverter unit that accepts a.c line power and delivers a transient free a.c power to the critical load.

The inverter may receive its D.C power from battery when the a.c line power source is interrupted up to several minutes, but in most industrial applications, a rectifier feed it. This configuration is classified as D.C converter because it is a two stages static frequency converter in which a.c power at network frequency is rectified and then filtered in the D.C

CHAPTER THREE

3.0 DESIGN STRATEGY AND PRINCIPLE OF OPERATION

The design of an inverter/uninterrupted power supply (UPS) unit is such a task

link before being inverted to a.c at an adjustable frequency. Rectification and inversion are performed by discrete standard diodes and transistor a stable multivibrator circuit.

Inverters can be classified as voltage source or current source. But only the former will be discussed being the method adopted in this project.

2.3 THE IMPORTANCE OF INVERTION

As has been enumerated earlier, the need for an alternate a.c power source becomes imperative with an unreliable and unsteady utility power regime as ours. Therefore, comes in the inversion system.

Inversion simply means the method of changing a readily available d.c source to an a.c source of varying or steady frequency and voltage. [4]

2.4 APPLICATION OF INVERTERS

These are listed below:

(a) Generation of 50/60Hz, fixed voltage a.c from d.c source such as d.c obtained in wind power, solar generation, or from battery.

(b) Speed control of three-phase induction and synchronous motors.

(c) Uninterruptible power supply system (UPS)

(d) Induction heating

(e) Standby power supply.

The transformer laminations are cut out from silicon steel sheet of 0.5mm thickness. It is rectangular in shape. The central limb is chosen to 29mm wide.

Working with the fore mentioned parameters, the cross-sectional area, of the magnetic path, Ai, can be calculated thus

Lamination thickness = 0.5mm

Number of laminations = 63

Stock of laminations = 0.5 x 63 = 31.5mm

Width of outer lamination limb, a = 14.5mm (½ of 29)

Width of the central limb, b = 29mm

Gross core area = 31.5mm x 29mm = 913.5mm^2

Net area of iron (staking factor) of 0.9

Ai = 0.9 x 31.5mm x 29mm = 822.15 x 10^6

To calculate the voltage per turn, Vt we use the transformer equation given thus:

Vt = 4.44F Bmax AiN..(2)

Where F = 50Hz (Supply frequency)

B_{max} = maximum flux density = 1.35T (Assumed)

A_i = Calculated

To find the primary and secondary number of turns N1 and N_2 respectively.

N_1 = 240 x 4.055 = 973.2 + 5% tolerance

= 1033 turns

For the secondary side N_2'

$N_2 = 17 \times 4.055 = 68.935 + 5\%$ tolerance

72turns.

The sizes of the copper wire for the primary and secondary windings of the transformer are calculated thus

Let δ (the standard wire sire size current density) for copper wire = $3A/mm^2$

To find the copper wire size for the primary winding

$$\delta = \frac{Ip}{Ap} \quad \text{.....(3)}$$

Wherw

$$Ap = \frac{Ip}{\delta} = \frac{0.6}{3} = 0.2mm^2$$

Knowing that

$$A = \frac{\Pi d^2}{4} \quad \text{.....(4)}$$

$$where\, \Pi = 3.142$$

$$d = \sqrt{\frac{4A}{\Pi}} \quad \text{.....(5)}$$

$$Where\ d = Diameter of\ wire$$

$$dp = \sqrt{\frac{4 \times 0.2}{3.142}} = 0.4mm$$

For the secondary winding

$$ds = \sqrt{\frac{4 \times As}{\Pi}} = \sqrt{\frac{4 \times 2.7}{3.142}} = 1.8mm$$

From table $9D_3$ of the fifteenth edition of IEE Regulation, the following size of wires for both primary and secondary windings were chosen to be SWG 25 and SWG 15 respectively.

The diagram of the shell type is shown below:

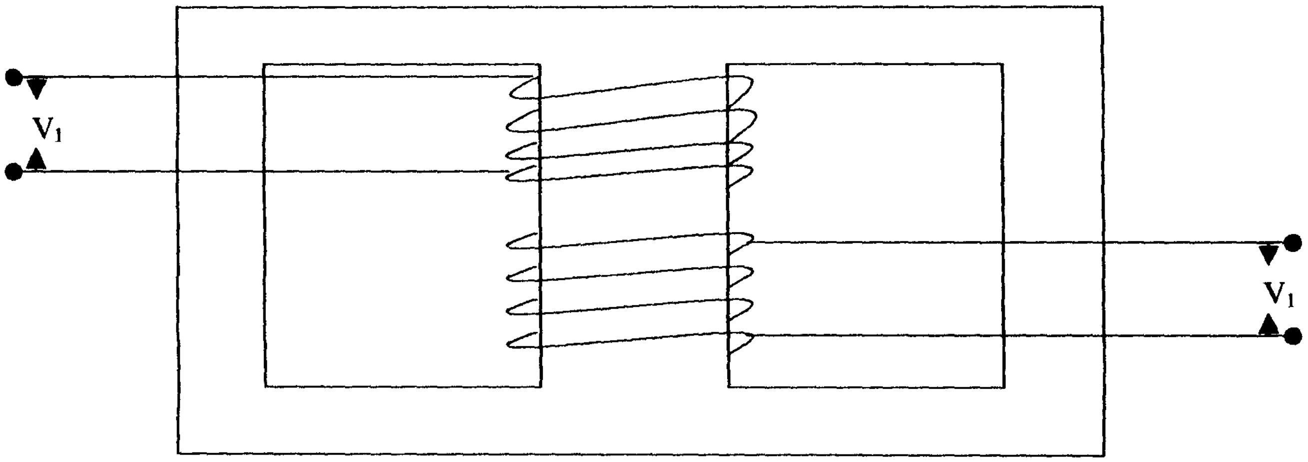


Fig. 3.1 Circuit Diagram of Shell Type Transformer

3.1.1 WORKING PRINCIPLE OF THE TRANSFORMER

The physical basis of the transformer is by induction. It can raise or lower the voltage in a circuit but with a corresponding increase or decrease in current. This particular transformer lowers the voltage at the secondary end from the high voltage fed into it from the primary side.

So it is referred to as a step down transformer. It consists of two inductive coils which are electrically separated but magnetically linked through a path of low resistance, if one coil is connected to source of alternating voltage, an alternating flux is set up in the laminated core, most of which is linked with the outer coil in which it produces mutually – induced e.m.f (according to faraday's law of electromagnetic induction e = mdl/dt)

If the second coil circuit is closed, a current flows in it and so electric current is transferred (entirely magnetically) from the first coil to the second coil. The first coil, in which electric energy is fed from the a.c supply mains, is called 'primary winding' and other from which energy is drown out is called 'secondary winding'.

3.2 THE FULL WAVE BRIDGE RECTIFIER

It is the most frequently used circuit for electronic D.C power supplies. It requires four diodes as the transformer used is not centre tapped and has a maximum voltage of Vsm (maximum value of transformer secondary voltage).

The full wave bridge rectifier is available in three distinct physical forms. [6]

1. Four discrete diodes
2. One device inside a four terminal case
3. As part of an array of diodes in an a.c.

   Four discrete power diodes were chosen for this project and all four were mounted on heat sinks.

   The diagram is as shown below.

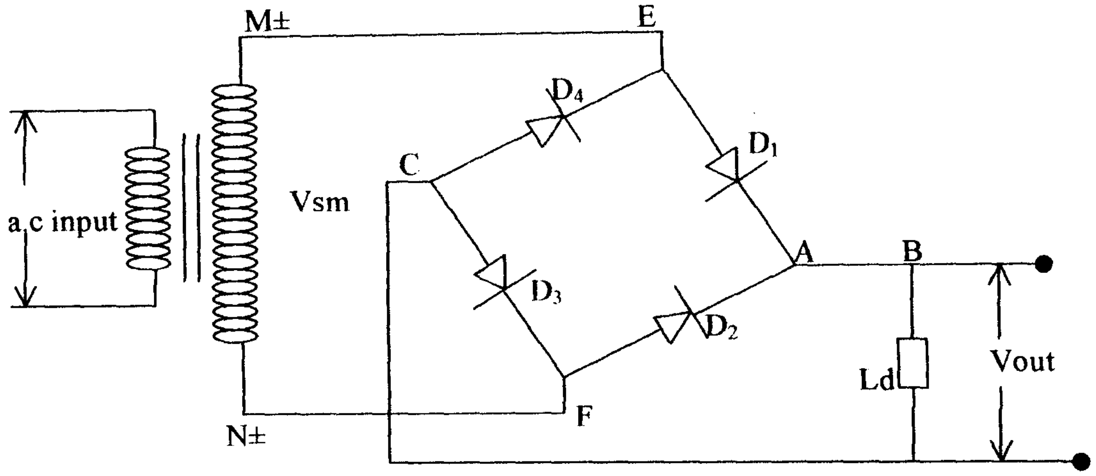


Fig. 3.2 The Circuit Diagram of Full-Wave Bridge Rectifier

Each diode chosen can handle 8A in the forward direction as the initial charging current from flat battery is about 4A so as not to destroy the diode.

The PIV (peak inverse voltage) of each diode should be able to handle the entire voltage across the secondary of the transformer. The part number of the diodes used is IN3883R with PIV of 50V and forward current of 8A at temperature of 100^0c.

3.2.1WORKING PRINCIPLE

Using fig. (3.2) ,during the positive input half-cycle, terminal M of the secondary is positive and N is negative. Diodes D_1 and D_3 become forward biased (ON) whereas D_2 and D_4 are reversed biased (OFF) Hence, current flows along MEABCFN producing a drop across R_L in the same direction AB during both half-cycle of the a.c input supply. Consequently, point A of the bridge rectifier always acts as an anode and point C as cathode. The output voltage across R_L is as shown below, it's frequency is twice that of supply frequency.

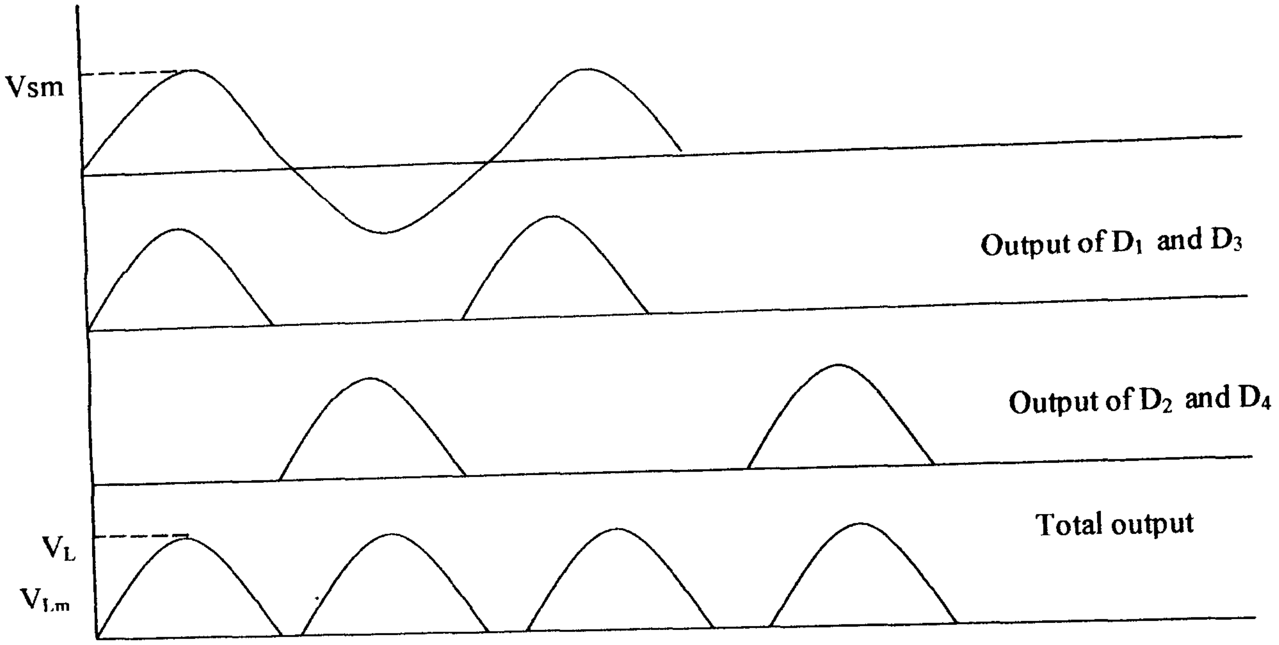


Fig. 3.3 The Rectifier Output Wave Form

Where

Vs = 17rms

Vrms = 0.707Vmax

Vmax = 17/0.70

Vdc = 0.636 x Vmax

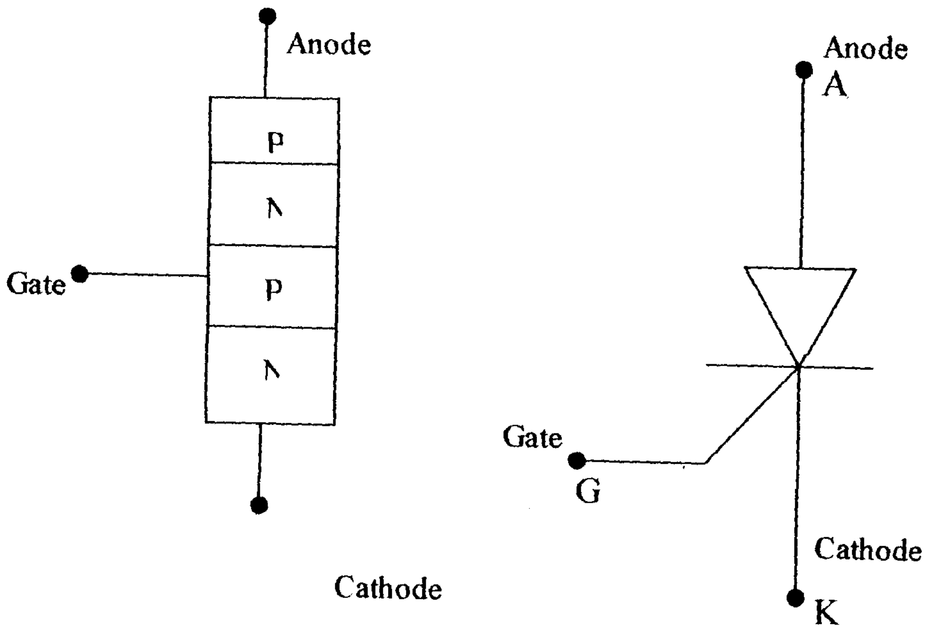
Vs Vdc = 15.3V

3.3 SILICON CONTROLLED RECTIFIER (SCR)

This is a four- layer (PNPN) semi-conductor device formally called a thyristor. It has three terminals, labeled anode, cathode and gate. The anode and cathode of the SCR are similar to that of ordinary semi-conductor diode. The gate serves as the control terminal of the SCR, hence SCR also conducts in one direction.

It differs from the ordinary semi-conductor diode in that it will not pass significant current, even when forward biased, unless the gate voltage is applied or the anode voltage equal or exceeds the forward break over voltage. However when forward break over voltage is reached, the SCR switches ON and becomes highly conductive. The SCR is unique because the gate current is used to reduce the level of break over voltage necessary for the SCR to fire. It is basically used as a switch but not as OFF and ON switch because output power is controlled from about 50% full power to zero power. The switching action is usually used to control the power to a piece of equipment.

The OFF state is also referred to as the forward blocking state and the ON state called the forward conducting state.



(b) Circuit symbol

(a) Simplified model of SCR

Fig. 3.4 Model And Circuit Symbol of SCR

3.4 THE CHARGER/REGULATOR UNIT

This is an automatic battery charger/regulator. It comprise wholly of electronic circuitry such as thyristors, resistors capacitors, zener diode and LEDs.

It is basically a voltage divider network. The rectifier provides a full-wave rectified signal Across SCRI and the 12V battery to be charged as shown below:

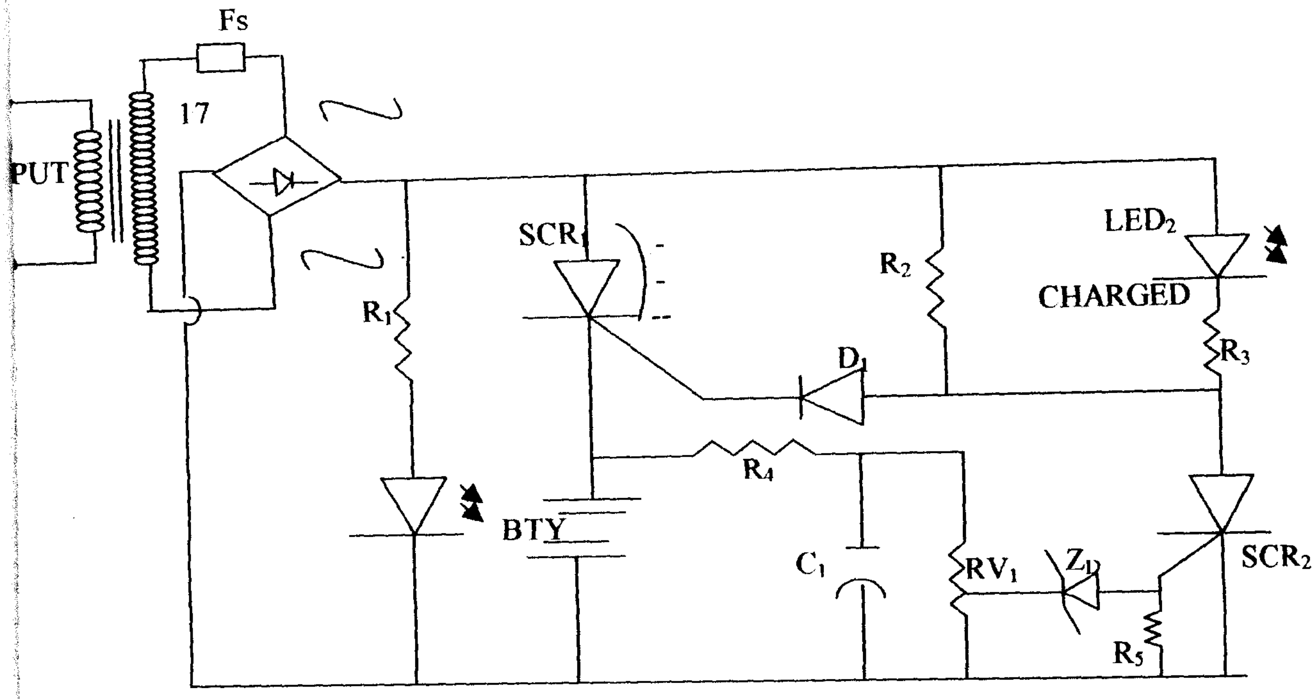


Fig 3.5 Circuit Diagram Of Automatic Battery Charger [7]

The SCR$_1$ and the battery circuit, which are in series, are gated 'ON' via the R$_2$ – R$_3$ – LED$_2$ network.

This network can be disabled by gating 'ON' SCR$_2$. The battery terminal voltage is monitored by the R$_4$ – C$_1$ – RV$_1$ – ZD$_1$ networks and turns 'ON' SCR$_2$ when the terminal voltage exceeds a value pre-set by RV$_1$. When a ' flat' battery is first put on charge, its terminal voltage is low . under this condition, SCR$_2$ is cut off and SCR$_1$ is gated ON in each half-cycle via the R$_2$ – R$_3$ – LED$_2$ network. SCR$_1$ acts as simple rectifier under this condition and the battery charges at maximum rate of about 4A.

the forward voltage drop of SCR_1 is only a few hundred millivolts and is insufficient to turn LED_2 'ON'. As the battery charges up , its terminal voltage rises. If the terminal rises above the trip level pre-set by RV_1, SCR_2 is gated 'ON' via ZD_1. under the condition, SCR_2 removes the gate drive from SCR_1, which turns 'OFF' and no longer passes a charge current to the battery . LED_2 is now turned 'ON' via SCR_2 and R_3 indicating that the battery is fully charged.

In practice, the terminal voltage of the battery depends on both the battery state and the magnitude of the charging current and decreases when the charging current is removed. Consequently the circuit does not abruptly stop providing a charging current when the battery is fully charged, but goes into a progressive skip-cycling mode, which progressively produces the mean charging current to a low trickle value. This action automatically maintains the battery in a fully charged (but not over charged) state.

The current setting of pre-set pot RV_1 is established initially by charging the battery up in the conventional manner until it reaches the fully charged state. RV_1 is then carefully set so that the charger goes into skip-cycling or trickle-charge mode. Under this condition. The RV_1 setting is then valid for all subsequent automatic recharging actions through the lifespan of the charger.

If RV_1 is correctly set, it will be found that on subsequent charges, LED_2 will first start to flicker or will alternatively cut 'ON' and 'OFF' as the fully charged state is maintained.

3.4.1 CIRCUIT CALCULATION

To find values of R_1 and R_3 to maintain the LEDs longer life I assumes the dc current (Idc) for each LED as 30mA

$$R = \frac{Vdc - 2}{Idc} \quad \text{..........(6)}$$

Where 2 is the rated voltage drop across a LED

$$R = \frac{153 - 2}{30 \times 10^{-2}} = 443\Omega$$

D_1 which was the phase control for SCR_1, was chosen to be IN4001, based on the Vrms of the secondary side of the transformer which is

Vrms = 17V

PIV = Vrms = 17V

Applying a safety factor of 2

Diode rating = 17 x 2 = 34V standardized to 50V (IN4001) which is a universal diode and can handle up to 1A.

To select SCR_1, cognizance is taken of the initial high charging current it should handle which is about 4A therefore any thyristor capable of handling that current or higher, can be chosen and should be mounted on a heat sink..

SCR_1 was chosen to be BTY79 which has the following characteristics:

Frequency: 50Hz

Forward voltage = 1000V

Forward current = 10A (at 85^0c)

For SCR_2 (silicon control rectifier), since it is gated 'ON' or 'OFF' through $R_4 - C_1 - RV_1 - ZD_1$ network which monitors the battery's terminal voltage, it is not required to handle much current value. So any 50Hz, low – current SCR can do the job. C106D was chosen and its parameters are:

Frequency: 50 Hz

Voltage: 400V

Current: 2.2A

To find R_4 we must first chose the value of ZD_1 to be used in gating SCR_2, then ZD_1 is chosen to be 6.8V

To get R_4

Where $V_{i(min)} = 12V$

VZ = 6.8V

VImax = 4A

It is necessary to point out at this point that $R_4 < R_{4(max)}$.

since the current is not in milliamps, it is necessary to multiply the final value by 1000

$R_{4(max)} = 1.3k\Omega$

Since $R_4 < R_{4(max)}$, R_4 was chosen to be 1.2 kΩ. C_1 is chosen to be between 50μF and 100μF and the voltage value should be twice the terminal voltage.

C_1 was chosen to be 1000μF, 25V

The value of R_5 is necessary to be high to prevent any accidental triggering of the SCR_2 so R_5 was selected to be 10 kΩ. the value of RV_1 was chosen to be 4.7 kΩ

The component values for the charger control/regulator unit are thus.

Resistors

$R_{1,2,3}$ - 470Ω

R_4 – 1.2 kΩ

Potentiometer: RV_1 – 4.7 kΩ

Capacitor:

C_1 = 1000 μF, 25 V (electrolytic)

Semiconductors

SCR_1 – BTY79

SCR_2 – C106D

D_1 – IN4001

ZD_1 – 6.8V, 400MW

$LED_{1,2}$ – TIL 220

3.5 THE OSCILLATOR /DRIVE STAGE

The is the pulse generating unit. Astable oscillator was chosen for this project due to its simplicity and ease of construction. It consists basically of two transistor amplifier stages.

An oscillator may be defined in any of the following ways:

a. It is a circuit which converts d.c energy into a.c energy at a very high frequency.

b. It is an electronic source of alternating current (a.c) or voltage having sine, square or saw tooth or pulse shapes.

c. It is a circuit that generates an a.c output signal without requiring any externally applied input signal.

d. It is an unstable amplifier.

This definition excludes electronic chemicals alternators producing 50Hz a.c power or other devices that convert mechanical or heat energy into electrical energy.

There are basically two classes of oscillators namely

(i) Sinusoidal (or harmonic) oscillators – which produce an output having sine wave form.

(ii) Non – sinusoidal (or relaxation) oscillators – they produce an output which has square, rectangular or saw tooth wave form or pulse shape.

The Astable oscillator chosen, belongs to the later group as it produces square waveform output.

Whatever oscillator is adopted, it is important that the frequency of the oscillation remain within prescribed limit and the output voltage must also be stable.

The diagram below shows the circuit diagram of an Astable multivibrator.

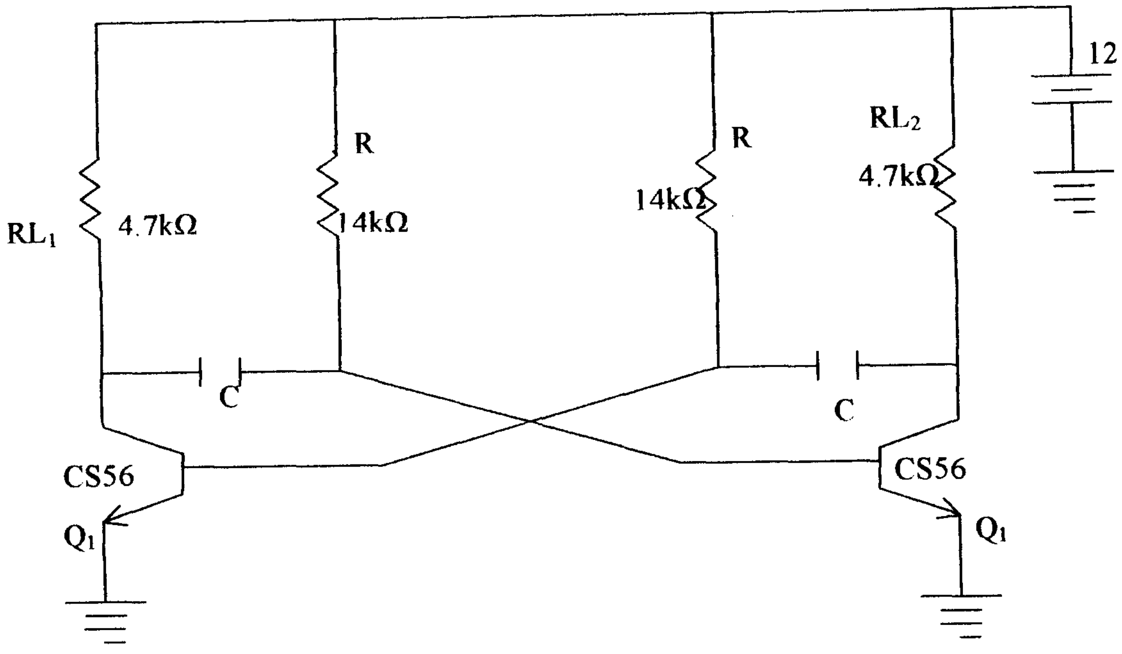


Fig 3.6 Circuit Diagram Of Astable Oscillator

3.5.1 TRANSISTOR CS5609 PARAMETERS

It consists of two common emitter (C.E) amplifier stages, each providing a feedback to the other. The feedback ratio is unity and positive because of 180^0 phase shift in each stage. Hence the circuit oscillates due to the very strong feedback signal, the transistors are driven either to saturation, or to cut – off (they do not work on their linear region of their characteristics).

The transistor Q_1 is forward-biased by Vcc and R_1 as Q_2 is forward biased by Vcc and R_2. The collector emitter voltages of Q_1 and Q_2 are determined respectively by RL_1 and RL_2 together with Vcc. The output of Q_1 is coupled to the input of Q_2 by C_2 whereas output of Q_2 is coupled to Q_1 by C_1. the output are taken from points A and B, which would be phase-reversed with respect to each other.

3.5.2 CIRCUIT OPERATION

The circuit operation will be easy to understand if it is remembered that due to feedback, Q_1 is ON when Q_2 is OFF and when Q_2 is ON, Q_1 is OFF.

When the power is switched ON by closing switch S, one of the transistors will start conducting before the other does (or slightly faster than the other). It is so because no characteristics of the two 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:

a. Since Q_1 is in saturation, the whole of Vcc drops across RL_1. hence $Vc_1 = 0$ and point A is at zero or ground potential.

b. Since Q_2 is in cut-off, there is no drop across RL_2 Hence point B is at Vcc.

c. Since A is at OV, C_2 starts to charge through R_2 towards Vcc.

d. When voltage across C_2 rises sufficiently (i.e. more than 0.7V), it biases Q_2 in the forward direction so that it starts conducting and is soon driven to saturation.

e. Vc_2 decreases and becomes almost zero when Q_2 gets saturation. The potential of point B decreases from Vcc to almost 0V. this potential decrease (negative swing) is applied to the base of Q_1 through C_1. consequently, Q_1 is pulled out of saturation and is soon driven to cut-off.

f. Since now, point B is at 0V, C_1 starts charging through R_1 toward the target voltage Vcc

g. When voltage of C_1 increase sufficiently, Q_1 becomes forward-biased and starts conducting. In this way the whole cycle is repeated.

It is seen that the circuit after alternates between a state in which Q_1 is ON and Q_2 is OFF and a state in which Q_2 is OFF and Q_1 is OFF and Q_2 is ON.

The time in each state depends on RC values. Since each transistor is driven alternatively, into saturation and cut-off, the voltage waveform at either collector (point A and B) is essentially a square waveform with peak amplitude equal to Vcc.

3.5.3 CALCULATION OF COMPONENT VALUES FOR OSCLILLATOR

Since it has been proved that the off-time for Q_1 is $T_1 = 0.69\ R_1\ C_1$ and that of Q_2 is $T_2 = 0.69\ R_2\ C_2$ hence the total time period of wave is $T = T_1 + T_2 = 0.69(R_1\ C_1 + R_2\ C_2)$ if $R_1 = R_2 = R$ and $C_1 = C_2 = C$ (i.e the two stages are symmetrical), then $T = 1.38\ TC$ and since the frequency of operation is given by the reciprocal of time period.

$$F=\frac{1}{T}=\frac{1}{1.38RC}=\frac{0.7}{RC}\text{...}(7)$$

In this project, the frequency of operation was chosen to be 50Hz (supply frequency), while C the capacitor value was chosen to be 1μF, we now calculate the value of R, the resistor

$$F=\frac{0.7}{RC}\text{...}(8)$$

$$50=\frac{07}{R\times 10^{-6}}$$

$$R=\frac{0.7}{R\times 10^{-6}}=14k\Omega$$

$$RL_1=RL_2=4.7k\Omega(chosen)$$

MINIMUM VALUE OF B

To ensure oscillations, the transistor must saturate for which minimum values of β are as under.

$$\beta = \frac{R}{RL_1} \text{..} (9)$$

$$\beta = \frac{R_2}{RL_2} \text{..} (10)$$

If $R_1 = R_2 = R$ and $RL_1 = RL_2 = RL$ then

$$\beta mm = \frac{R}{RL} \text{..} (11)$$

In this project

$$\beta mm = \frac{14,00}{4,700} = 3$$

The transistor chosen is CS5609 which is an NPN silicon transistor for switching application.

Table 3.1 TRANSISTOR CS5609 PARAMETERS

IC	Bv CBO	Bv CEO	Bv EBO	Hfe	P.O	fr
Maximum collector current (A)	Collector to base (V)	Collector to emitter (V)	Emitter to base (V)	Typical forward current gain 100mm	Maximum collector power dissipation (W)	Typical frequency (MHz)
0.8	50	50	5	100MIN	0.625	100

3.6 POWER MOSFET

Power MOSFET offer many advantages over conventional bipolar transistors, in both linear and switching applications. These advantages include very fast switching, absence of second breakdown, wide safe operating area, and extremely high gain. Typical applications are high frequency switching power supplies, chopper and inverter systems for DC and AC motor speed control, high frequency generators for induction heating, ultrasonic generators, audio amplifiers, AM transmitters computer peripherals, telecommunication equipment and a host of special military and space needs.[8]

When handling or using power MOSFET, beware of unexpected Gate-to-source voltage spike. Excessive voltage will punch through the gate-source oxide layer and result in permanent damage.

Being a power device is thermally limited. It must be mounted on an heat sink that is adequate to keep the junction temperature within the rated T(max) 150^{0}C under the worst case condition of maximum power dissipation and maximum ambient temperature. [9]

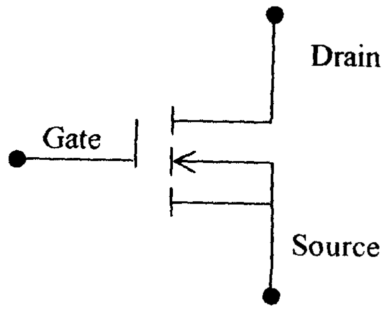


Fig 3.7: Circuit Symbol of MOSFET

With the use of the astable multivibrator with two alternating outputs, each of the MOSFET switches will handle half of this input current.

CALCULATION OF INPUT POWER (P_{in})

With specification of 1KVA expected rating of the design, some assumptions are made such as:

Specification = 1KVA, V_{out} = 220-250V, V_{dc} = 12V, P_{in} = KVA = 1000VA

CALCULATION OF THE INPUT CURRENT (I_{in})

From the fundamentals, it is well known that:

$P = IV$, where P = power rating,

I = input current and

V = input Voltage

$I = P/V$

Hence, $I_{in} = P_{in}/V_{in}$

Since V_{dc} to the inverter is 12V from the battery, and a direct current, there is no presence of phase angle, therefore Cosφ = 1. Hence, the above formula holds. It is inevitable that there must be some sort of voltage drops possible due to the internal resistance of the battery cells. This drop at its maximum can be taken to be 0.5V since the maximum gate to source voltage specification of most MOSFET is = ± (20V). Assuming a maximum V_{in} of 11.5V, recall $Vdc > V_{in}$ from the above,

$$I_{in} = 1000/11.5 = 87A$$

Each of the MOSFET switches will handle half of this input current; which implies that

$$I = 87/2 = 14.5A$$

In order not to overstress a single device and also due to the fact that high current is involved, each switching segment is made to have three MOSFETS in parallel to share the current given by

$$I_{sp} = 43.5/3 = 21.8A.$$

Also, it is understood that in such an arrangement, the switch has to be able to handle the voltage given by

$$V_{sw} = 2\sqrt{2}\times V_{dc}$$

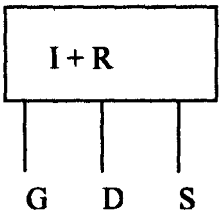
$$= 2\sqrt{2}\times 12$$

$$= 24V$$

As a result of this, the switching device chosen to be used is HEXFET III POWER MOSFET IRFP250. this is due to the ease of paralleling the single gate driver required.

The MOSFET characteristic is given below:

Table 3.2 The MOSFET characteristics

Port number	B_{VDSS} Drain source voltage (Volts)	R_{DDS} (ON) state resistance (Ω)	Dmax Contineous Drain Current	Case Style
IRFP 250	200	0.085	30	

The low RDSC (ON) helps in reducing the conduction lose.

The circuit of the IRFP 250 power MOSFET switch is as shown below. It is an N-channel enhancement-mode MOSFET.

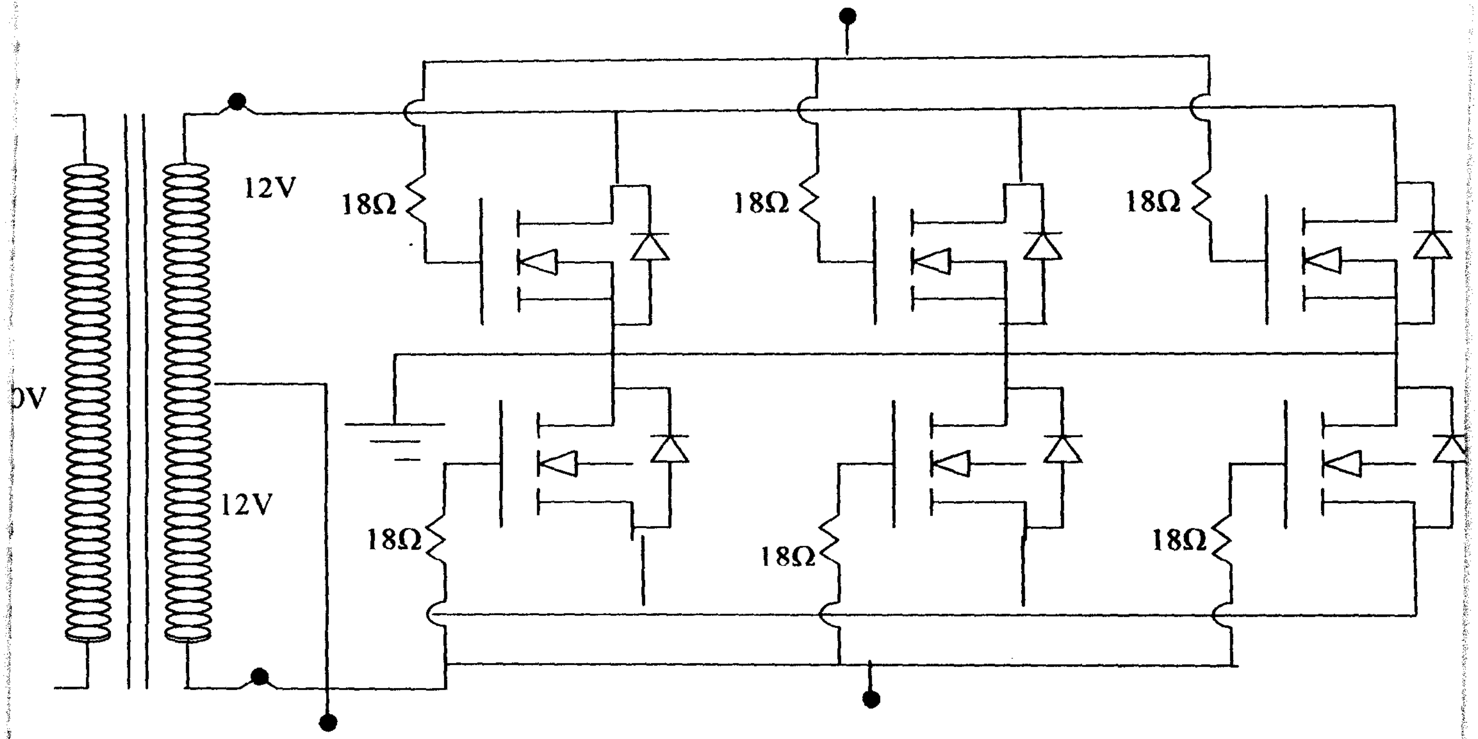


Fig 3.8 The Switch Circuit Using The IRFP250 HEXFET Power MOSFETS in Parallel [10]

Due to the allowance given in the data book that oscillation can be prevented with parallel MOSFET by using a high value of resistor in series with the gate a value of 1000Ω chosen as shown above.

3.7 THE INVERTER/OUTPUT TRANSFORMER

This inverter/output transformer is a step up and centre tap transformer. This is because the 12Vdc supply from the battery and the outputs from the inverter section are fed to it through the high speed power MOSFETS switches. It therefore, steps up the alternating inputs to about 250Vac for the load end.

Its principle of operation is similar to the input transformer earlier discussed, with the exception that this one now steps up the voltage unlike in the former case which steps down the voltage.

3.7.1 CONSTRUCTIONAL DETAILS

A step-up transformer that steps-up voltage from 12ac to between 240 and 250ac, 50Hz with a primary current of about 87A maximum and maximum primary current of 5A is needed. It is a 12V centre-tap, step-up transformer.

$E_2/E_1 = N_2/N_1 = k$..(12)

Where K (the constant) is known as the voltage transformer.

But if $N_2 < N_1$ i.e. $k > 1$, then the transformer is called step down t6ransformer. For this design

$E_1 = 12V$

$V_2 = 250V$

$E_2/E_1 = 250/12 = 20.8$. where $K = 20.8$ and shows that the transformer will function effectively.

A shell type transformer was also utilized for this transformer because of the advantages enumerated earlier. In this project, both input and output transformer i.e single transformer is used for charging and investing unit. Therefore the transformer lamination is still 0.5mm, the core is rectangular in shape, the central limb is 29mm wide and the outer limb 14.5mm.

Since the power rating of the inverter has been given to be 1KVA

$P = 100VA$ from the formula, $P = IV$

To find the current input Ip

Ip = Pout/Vin = 1000/11.5 = 87A

Vin was chosen to be 11.12V instead of 12 V arising from losses from the battery and to also ensure maximum rated voltage output. Since one single transformer is used for charging and inverting unit, the cross section area of the magnetic path Ai remains the same i.e Ai = 822.15 x $10^{-6}m^2$

To find the primary and secondary number of turns N_1 and N_2 respectively,

Vp = primary voltage =11.5 (chosen)

Vs = secondary voltage = 220V supply voltage

N_1 = primary number of turns

N_2 = secondary number of turns = 1022 turns

V_1/V_2 = Vp/Vs = N_1/N_2

N_1 = Vp/Vs x N_2 = 11.5/220 x 1022 = 53 turns

With the value obtained for current at the primary winding, we can now calculate the size of wire for the primary winding .

δ = 3A/mm^2 = the standard current density for cupper.

δ = I/A where A = cross sectional area of the winding

Ap = Ip/ δ = 87/3 = 29mm^2

To find the diameter of the copper wire

$$A = \frac{\Pi d^2}{4} \quad \text{.......} (13)$$

$$Dp = \sqrt{\frac{4A_p}{\Pi}} = \sqrt{\frac{4 \times 29}{3.142}} = 6.08mm$$

From the IEE regulation table 903 of the fifteenth edition the following size was chosen for the primary winding

S.W.G (Standard wire gauge) 8 in parallel.

3.8 THE INTERPHASE RELAY

This relay provides the actual interface switching between the mains voltage and the inverter d.c voltage.

The relays are so connected in such a way as to isolate the inverter section when there is mains supply and to also instantly cut-in the inverter circuit immediately there is power outage.

Taking into cognizance the high voltage needed at the inverter primary , and the charging current to the battery , the relay selected is R.F.T – TGL 200 – 3799.

They have the following parameters.

Coil resistance - 430Ω [5b]

Voltage to operate coil (DC) 12 – 24V [5c]

Contact handling capacity:

15A – 240Vac

30A – 12 – 24Vdc

III. CHAPTER FOUR

4.0 CONSTRUCTIONS, DISCUSSION OF RESULT AND TEST

4.1 CIRCUIT CONSTRUCTION

The circuit construction started with the metric layout of components on paper, which was carefully cross-checked for flaws before being transferred to the breadboard for initial testing. This was done in stages to avoid wiring errors. This started with the power supply components down to the output transformer. After certifying the output performance, the components were transferred to the Vero board for final soldering.

4.1.1 VERO BOARD

The Vero board is the material used for permanent soldering of the tested components. Before being used, it was thoroughly cleaned of dust using emery cloth. The respective slots for each component were then marked out before placing the components in their respective slots.

A 40-watt soldering iron was used so as not to over-heat the components during soldering, thereby ensuring that they are not damaged by excessive heating. Since the copper paths that were earlier cleaned are continuous from end to end on the Veroboard all sections were isolation is required are identified and marked out.

4.1.2 TRANSFORMER CONSTRUCTION AND TESTING

The transformer, which will carry the two coils, is constructed from the tesolite.

The lamination is then cut out in the shapes of 'E's and 'I's. These are then inserted one after the other alternatively on either side of the former. A wooden mallet is then used to tap in the lamination properly to close up the entire air gap.

This is usually done after the primary and secondary copper wires have been wound on the former, moving in cyclic direction and at the end, it was separated from the beginning of the secondary winding with transformer insulating paper. After this, the secondary winding was wound on top of the primary winding and all taping were brought out.

When the lamination have been inserted properly, the whole wound coil of the transformer was immersed in a container of varnish and later brought out to dry in sun for about three hours. Covering the entire coil with impregnated paper to provide mechanical protection against damages followed this. Bolts and nuts were then used to hold the laminations firmly into place, before any test is carried out.

A. 4.1.3 TESTING

Tests like continuity test of all the coil sections of the transformers were performed, including insulation resistance tests between primary and secondary windings, between the windings and the core using a multimeter. The transformer was then powered and using a variac with range 0 – 260V, the desired and calculated values was obtained. This transformer was then loaded and the losses were discovered to be minimal and negligible

.4.1.4 TESTING OF OSCILLATOR UNIT

After the oscillator section has been soldered, it was tested by feeding voltage into it, and an oscilloscope used to monitor the wave form. The figure 4.1 below was the waveform observed.

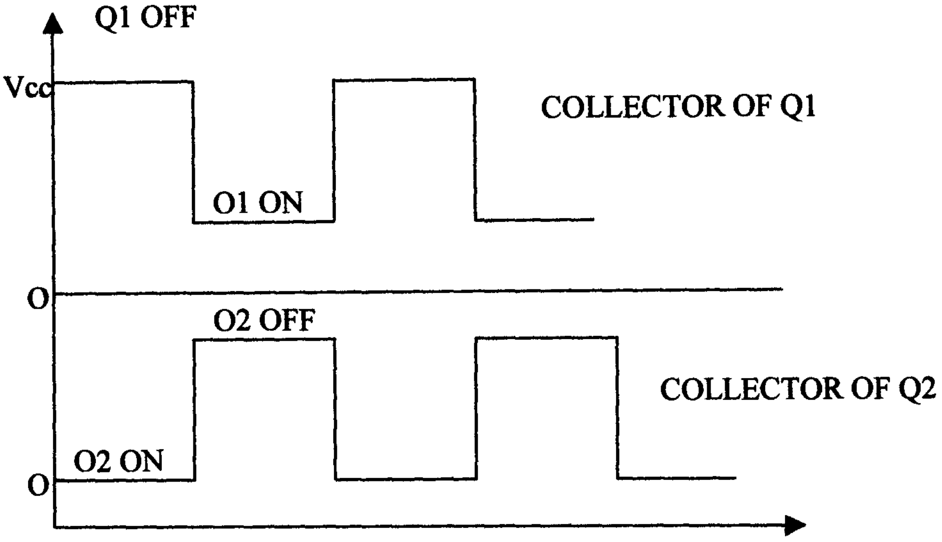


Fig. 4.1 Output Wave Form Generated by Oscillator Circuit[8]

4.4 TESTING OF SWITCHING UNIT

After mounting all six MOSFET on heat sinks, they were then properly soldered using thick gauge wires for the drain and source as they intended to handle high current values. They are then connected to the oscillator unit and the output transformer and it was observed that it worked perfectly without heating up after twenty minutes, showing clearly that there was no problem with the design. The results obtained also implied that the design parameters were adhered to.

4.5 PRECAUTIONS OBSERVED

The following were the precautions that were taken in the cause of this project design and construction.

- The power MOSFETS were left in anti-static slupping bags, until required for testing or soldering
- A 40-Watt soldering iron was used so as not to overheat the component and was also grounded
- Ensured all components were connected in conformity with their polarity before testing and soldering
- The power supply was always turned off when not in use
- Off-target solder splashes were carefully removed to avoid short-circuit
- The transformer was grounded
- The casing was earthed

4.6 AREA FOR FURTHER IMPROVEMENT

It is possible to improve upon the over all performance of this design as thus:-

Using an IC (integrated circuit) at the oscillator stage instead of transistor which reduce the level of distortion and also the cost

Also incorporating an over-voltage protective circuit will further improve the performance of the design and including a cooling fan for the system will in no small way increase the life span of all the circuit components.

4.7 CONSTRUCTION OF CASING

The casing is constructed from miled steel sheet of gauge 22 (0.71mm thick). It is rectangular in shape and perforated at the size to facilitate effective ventilation. Some holes were evenly drilled out at the front and the back of the casing for the LEDs, the power switch, the voltmeter, toggle switch, the 5A fuse, the socket output, the cables for the battery terminals and the input main cable.

4.8 RELIABILITY

Reliability [11] can be defined as the probability that a device or system such as the project design will perform optimally within a given time frame without failure.

This depends on the number of factors such as;

- The reliability of components used
- Care and precautions taken, during and after fabrication
- The operating environment

Each of the factors is discussed briefly: -

The Reliability Of Components Used

About 90% of the components used in this project design are electronic components, which are robust, rugged and can withstand stress and are noted for their long life. Therefore, under normal condition, this device has a long life guarantee.

Care And Precautions Taken, During And After Fabrication

To enhance the reliability of the device, the components chosen and used were above their rated values, thereby enabling them to withstand abnormal conditions

The Operating Environment

The Operating/working Environment of any electrical/electronic device is always very important. Even though this system is expected to work when subjected to very harsh condition, operating environment with a resultant of over sustained abnormal temperature condition may affect the system adversely

1. CHAPTER FIVE

5.0 PROBLEMS, CONCLUSION AND RECOMMENDATIONS.

In every endeavours of life, there must be problems. The important aspect of such endeavours is how those problems are solved. I encountered some in the cause of this project

The first was how to come out with a fissible circuit design, most effort was channeled towards the course and I finally triumph with the help of some people including my project supervisor.

The second was in procuring the transformer lamination to produce the transformer's core. I finally succeeded but not without a lot of effort.

Another problem was in realizing the needed output voltage from the output inverter's transformer and loading the transformer the voltage will drop significantly. Designing for 250V output instead of 220V finally solved this problem. Other problems, such as over heating of the power MOSFETs, switching irregularities, open circuits, etc were encountered but at the end of the day they were all solved.

5.1 CONCLUSION

The aim of this project is to design and construct a 1KVA inverter (DC- AC). This was satisfactorily achieved. My greatest satisfaction is being able to come up with such a device that is almost indispensable in our peculiar environment as it can be used in both rural and urban areas. Most of the UPS in the markets today, if I must say, are not reliable and durable as this particular one; as the oscillators and switching devices are the latest in the market. The inverter is protected against over current by a

5A fuse. The output voltmeter helps to indicate the output voltage range thereby making it easy to monitor the respective voltage output.

5.2 RECOMMENDATION

In both rural and urban areas, consumer suffers untold hardships due to incessant power outages. I would strongly recommend that PHCN be adequately funded to improve its power supply. There is also the need for government to support our tertiary institutions financially and encourage the various departments of electrical computer engineering to go into production of such devices that will benefit the country in general.

As a result of insufficient transformers in the cities, rural and urban areas, consumers at the far end of the distribution lines in their areas suffer from acute low voltage or epileptic power supply. This inverter although for a frequency of 50Hz, is very rugged and stable compare to the various types in the market. I therefore recommend it for production by the department of electrical/computer of Federal University of Technology, Minna and other business organizations.

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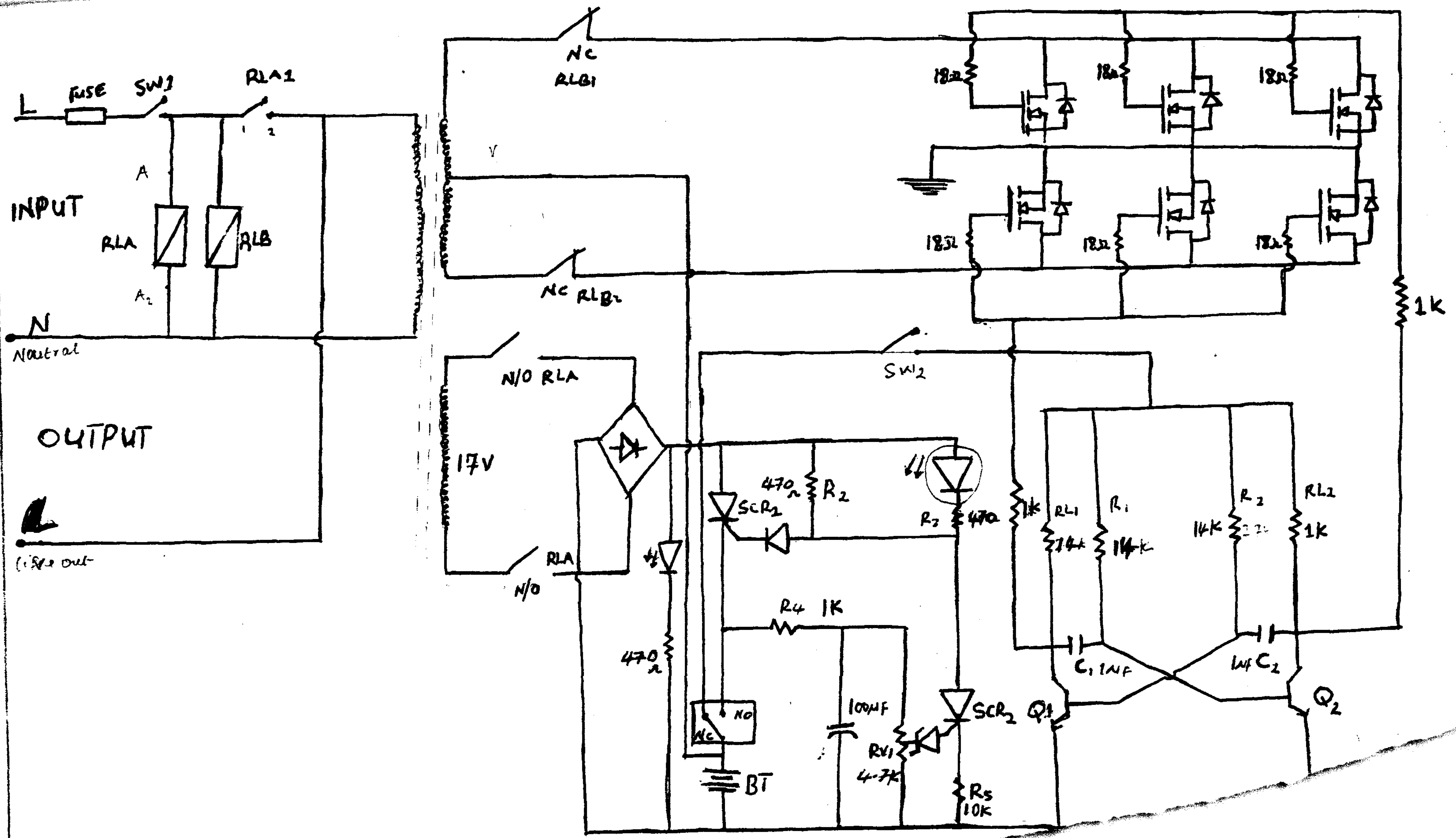

COMPLETE

UNTERRUPTED POWER SUPP

DESIGN AND CONSTRUCTION OF A 1 KVA INVERTER

MANUAL

This project is designed for a load that is not more than 1 kVA. You can power it up with minimum of 220V input supply (a.c.) which is sufficient to charge 12V (d.c.) battery and at the same time serving the load at the output end. There are two cables for charging battery; the red is to be connected to the positive terminal and the black to the negative terminal, each of the cable has open-able clip to grasp the battery electrode.

Two LEDs are used to serve as indicator; the red LED is for input power and green LED is on when the battery is fully charged. Three pins socket outlet is used to plug the load. It is highly recommended to use an automatic voltage regulator for effectiveness and durability of the project. It also has two switches; the red plastic switch is for ON and OFF input supply and the ON and OFF iron switch is for inverter unit.

Note, wrong connection of battery terminal can damage the system.