DESIGN AND CONSTRUCTION OF 1.5KW INVERTER

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TITLE PAGE

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BEING A THESIS SUBMITTED TO THE ELECTRICAL ELECTRONICS ENGINEERING TECHNOLOGY
NUHU BAMALLI POLYTECHNIC P.M.B 1061
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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF HIGHER NATIONAL DIPLOMA IN ELECTRICAL ELECTRONIC ENGINEERING TECHNOLOGY

DECEMBER, 2010

DECLARATION

I declare that the work carried on this project was done by me and to the best of my knowledge, no such work of this manner has been submitted any where for the award of a Higher National Diplom. All sources of information were been duly referred, and for any lapses, I accept the blame and offer apology.

05/12/2010

Mohammed Abubakar Umar **Date**

CERTIFICATION

This project has been duly certified by the Department of Electrical Electronic Engineering Technology, Nuhu Bamalli Polytechnic Zaria so satisfy the requirement for the award of a Higher National Diploma in EEET.

6/12/10 ______________________ 6 DEC, 2010.
Mal. Aliyu Agum Date
(Project Supervisor)

______________________ ______________________
Mal. Muhammud A. Fanti Date
(Project Coordinator)

______________________ ______________________
Mal. Mohammed Garba Date
(Head of Department)

DEDICATION

This project is dedicated to all members of my family.

ACKNOWLEDGEMENT

Alhamdulillah, I would like to thank Almighty Allah, for his mercy, support and guidance over me and for making this project possible.

My heart is full of gratitude to my Late Father, Mal. Abubakar Umar and my mother Saratu Abubakar, my brothers and sisters, Ibrahim, Musa, Yusuf Aminu Hadiza, Aisha, Hauwa'u and to those that I did not mention here for their love and sacrifice.

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ABSTRACT

The project is all about the development of 1.5KVA DC/AC Inverter. The circuit converts DC supply into AC stepped up voltage. It comprises of six units. These are the Oscillator unit which produces an alternating signal for driver. The driver is a buffer IC (CD 4050) to supply the dual alternating outputs responsible for switching on and off of the power transistor, the switching unit uses six power MOSFETs to switch on and off the DC voltage to be inverted, the transformer unit which is use to couple the voltage swings due to switching of the transistors at its primary center tap to a square wave. The low battery unit is used to monitor the battery voltage, the change over unit which changes the output supply from the inverter to mains supply and finally the charging system which charges the battery. The result is an input DC voltage inverted to an AC stepped up voltage.

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CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

The most common type of inverter is the DC to AC inverter. This takes in DC signal and produces an AC output. The conversion process can be on a ratio, an amount that defines the multiplying factor between the input and the output voltages. In this way the inverter can be operating in step down mode, where the output signal is at lower level compared to that of output signal; or step up mode with the output being much more compared to the input signal level. The latter is the most common mode of inverter operation. Here, a small DC voltage say 12V is fed into the system to produce a 220V or 230V AC output as desired. The AC output voltage from the inverter is used to drive ac appliances. Depending on the load requirement, the inverter must meet the necessary power to drive the load. Likewise the dc source must have the capacity to supply the necessary power for the whole conversion process.

There are basically two types of dc to ac inverters base on their output voltage waveforms. These are pure sine waves and square wave inverters. Another form of the latter is modified square wave inverter, this is the cheapest commercially available inverter in the market. This usually has limitations as to the type of load the unit should power — it is not good for inductive loads. The pure sine wave is expensive because it is universally adaptable to any load type. The modified square wave technology is employed in the production of the most UPS in market today [6].

1.2 PROJECT MOTIVATION

For ages, life in this country has been difficult for the majority of its populace. The people are used to hardships and inadequate social amenities such as education, water supply and electricity. It is rather unfortunate that people are so much used to black outs that they tend to raise eyebrows just for a constant power supply from Power Holding Company of Nigeria plc (PHCN), for a supply of more than 24 hours at a stretch: People resolve to alternative sources of power supply available and affordable, while the PHCN supply serves as only a standby instead of the other way round.

With the level of unemployment of the youth in the country, increasing with an alarming rate every day the intention is to use the knowledge acquired from electrical engineering in contributing towards the reduction of the hardship, by providing not only a job for the unemployed, but also a level of satisfaction for those seeking power supply alternative.

1.3 PROJECT AIM AND OBJECTIVES

The economy in manufacturing, operation and running cost of equipment should be kept in view at the design stage. One of the important criteria in good design is to get the minimum losses for a given total cost. If only initial cost is considered and we try to minimize it, this could result in equipment which may be expensive for operation and maintenance; the losses may be more and if we try to minimize the losses to get maximum possible efficiency from the equipment it may turn out to be costlier. There has therefore, to be a balance between the losses and the cost. Hence the aim of this project is to present the basic design as per required specification for a given total cost.

1.4 PROBLEM DEFINITION AND METHODOLOGY

Building electrical equipment as economical as possible which will be suitable for the intended application and will meet the performance expectation is paramount importance to manufactures the electrical apparatus.

The methodology used in the design of this electrical apparatus is;

The appropriate DC to AC supply system, which involves the choice of its basic units such as;

I. The low battery unit

II. The oscillator unit

III. Power amplification

IV. The transformer unit

V. The charging unit

1.5 SCOPE AND LIMITATION

The first problem encountered was in obtaining the exact 50 Hz frequency from the oscillator. One of the major setback encountered was the long time industrial strike action embarked upon by the nonacademic staff which made it impossible for me to use the electronic lab to carry out test. The test was carried out in Kadpoly electronic lab.

Consistent power failure was also a major setback in my effort. Another limitation of this work is that the output waveform of the system is not sinusoidal and the system would not be suitable for running inductive load.

1.6 THESIS OUTLINE

Chapter one; Introduces the project and it is made up of aim and objectives, project motivation, problem and methodology, literature review and thesis outline. Chapter two contains the theoretical background discussing the various components involve in the design work. Chapter three is on design procedure. Chapter four covers the construction and testing of the thesis. Finally chapter five consists of limitation, conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

The major components used in the design are detailed in this chapter. Each constituent of the design is explained based on their configuration and mode of operation.

2.1 LITERATURE REVIEW

Inverter circuit was developed or introduced by heart interface, based in America in 1983[4]. In 1994, there was an improvement in the inverter technology, as the MOSFET was then introduced for the main power output. The power MOSFET was used so that it could make design smaller to switch larger current.

Work has been done on this project and is still in the experimental stages, where it started from the work of Shattuck, who describes the inverter output wave-shape to the techniques for realizing uninterrupted power supply, as describe by Haiden M E. A design was also of a UPS, as a wave form signal generator.

An improvement of the inverter output wave using filters was designed by Ihuoma J.U of Ahmadu Bello University Department of Electrical Engineering in 2002. Similar work was done based on the online UPS principles, which modify the main supply before it goes out to the attached load and continues to provide power in case of mains power failure. Zakari M. of Ahmadu Bello University Department of Electrical Engineering in 1998 uses the principles of rectification and inversion to design an online uninterrupted power supply.

All that has been done in this field is a demonstration of the basic principle of operation of the inverting system. This project set out to determine the requirement and fact (practical tips) about constructing a DC - AC inverting system, based on the load demand making use of the available and affordable.

2.2 HISTORY BACKGROUND OF THE STUDY

The IC chosen as the oscillator is the SG3524. This is a 16 pin integrated circuit. The SG3 524 is a fixed frequency pulse width modulator (PWM) voltage regulator circuit. Pulse width modulator is achieve by having a feedback system which sense the inverter's output voltage or load current. When this feedback senses that the load on the inverter's output has increased, the inverter's control circuitry acts to increases the width of the pulses which turn on the MOSFETs. So the MOSFETs turn on for longer each half cycle, automatically correcting the RMS value of the output to compensate for any drop in peak-to-peak output. The resulting regulation is usually capable of keeping the RMS value close to constant, for loads up to the inverter's full rated output power. However this approach does have limitations, mainly because it can generally only increase the pulse width to a certain point. In the extreme, the output voltage becomes a square wave.

2.2.1 DESCRIPTION

The SG3524 incorporates on a single monolithic chip all the functions required for the construction of regulatory power supply inverters or switching regulators. They can also be used as the control element for high power-output applications. The SG3524 family was designed for switching regulators of either polarity, converter applications employing fixed frequency, pulse-width modulation technique. The dual alternating outputs allows either single-ended or push-pull applications. Each device includes an on-chip reference, error amplifier, programmable oscillator, pulse-steering flip flop, two uncommitted output transistor, a high gain comparator and current limiting and shut-down circuitry.

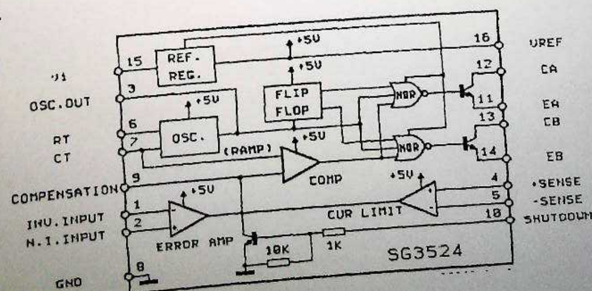


Fig 2.1 The SG 3524 internal circuit

R_T = Timing resistor

C_T = Timing capacitor

EA= Emitter A

CA = Collector A

EB = Emitter B

CB = Collector B

CHAPTER THREE

SYSTEM DESIGN

3.0 INTRODUCTION

In this chapter, detailed procedure of the design of 1.5KVA square wave inverter is presented. By knowing designed specification and available input parameters, we can have an accurate and simple relationship between the input and output to perform the require task.

Designed specifications are as follows:

a) Input DC supply = 12v

b) Frequency of operation = 50 Hz

c) Output AC voltage = 240 V

d) Output power = 1.5KVA

3.1 PRINCIPLE OF OPERATION

The regulator operates at a frequency that is programmed by one timing resistor (R_T) and one timing capacitor (C_T). R_T establishes a constant charging current for C_T. which is fed to the comparator providing linear control of the output pulse width by the error amplifier. The SG3524 contains an on-board 5V regulator that serves as a reference as well powering the SG3524's internal control circuitry and is also useful in supplying external support functions. This reference voltage is lowered externally by a resistor divider to provide a reference within the common mode range, the error amplifier or an external reference may be used. The power supply output is sensed by a second resistor divider network to generate a feedback signal to error amplifier. The amplifier output voltage is then compared to the linear voltage ramp at C_T. The resulting modulated pulse out of the high-gain comparator is then steered to the appropriate output pass transistor (Q_A or Q_B) by the pulse-steering flip flop, which is synchronously togged by the oscillator output. The oscillator output pulse also serves as a blanking pulse to ensure both outputs are never on simultaneously during the transistor times. The width of the blanking pulse is controlled by the value of C_T. The output may be applied in a push-pull configuration in which their frequency is half that of the base oscillator. The output of the error amplifier shares a common input to the comparator with current limiting at shutdown circuitry and can be overridden by signals from either of these inputs. The common point is also available externally and may be employed to control the gain of, or to compensate the error amplifier, or to provide additional control to the regulator.

3.2 TYPICAL APPLICATION DATA

OSCILLATOR

The oscillator controls the frequency of SG3524 and is programmed by C1 according to the approximate formula

$$f = \frac{0.73}{R_T C_T} = 50Hz$$

Where

C_T is in nf

f is in Hz

A practical value of C_T is 100nf.

3.3 THE UA741 OPERATIONAL AMPLIFIER

3.3.1 DESCRIPTION

The UA74 1 as a general purpose operation amplifier featuring offset-voltage null capability the high common-mode input voltage range and the absence of latch up make the amplifier ideal for voltage-follow applications. The device to short circuit protected and the internal frequency compensation ensures stability without external component.

3.3.2 COMPARATOR

The operational amplifier UA 741 is used in this project as a comparator. A comparator is a circuit that compares an input voltage with a reference voltage. The output of the comparator then indicates whether the input signal is either above or below the reference voltage. This depend on where the input is inserted (+ or -) and where the reference voltage is applied (+ or -) terminals. The output polarity of the op-amps switches from positive to negative, it is convenient to keep reversing the voltmeter leads to keep polarity correct. One way to overcome that problem is to use an indicator light to tell the output state

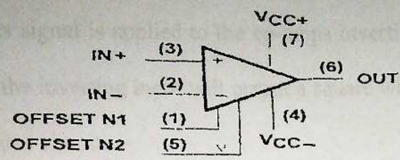


Fig 2.2 Op- amp pin configuration

3.3.3 DEFINITION OF UA741 PIN FUNCTION

Pin 1 (Offset null) since the op-amps is the differential type input offset voltage must be controlled so as to minimize offset. Offset voltage is nulled by application of a voltage of opposite polarity to the offset.

Pin 2 (Inverting input): All input signal at this pin will be inverted at output pin 6. Pins 2 and 3 are very important to get correct output signal or the op-amp cannot do its work.

Pin 3 (Non-inverting input): All input signals at this pin will be processed normally without inversion. The reset is the same as pin 2.

Pin 4 (Negative pin): All negative pin supply voltage terminal supply voltage operating range for the 741 is -4.5V (mm) to - 18V (max), and it is specified for device will operate essentially the same over this range of voltages without change in timing period. Sensitivity of time interval to supply voltage change is low.

Pin 5 (Offset Null): Same as pin 1

Pin 6 (Output): Output signal polarity will be the opposite of the inputs when this signal is applied to the op-amps inverting input for example, a sine-wave at the inverting input will output a square wave in the case of an inverting comparator circuit.

Pin 7 (Positive pin): The positive pin is the positive supply voltage terminal of 74 lop-amp IC. Supply voltage operating. Range for the 741 is +4.5V (mm) to +1 8V (max), and it is specified for operation between +5V and +15V dc. The device will operate essentially over this range of voltages without change in timing period.

Pin 8 (N/C): The "N/C" stands for "not connected" there is no other explanation there is nothing connected to this pin, it is just there make it a standard 8-pin package.

3.4 MOSFET

Metal oxide semi-conductor field effect transfer (MOSFET) is a device that control a current between two contacts (source and drain) using a voltage contact (Gate). The type of MOSFET used in this project is power MOSFET IRFP 150

3.5 INTRODUCTION

The high voltage power mosfets that are available today are N-channel, enhancement mode, double diffused, metal oxide silicon, field effect transfers. They perform the same function as N-P-N Bipolar Junction Transistor except the former are voltage controlled in contracts to the current controlled bipolar devices. Today power MOSFET owe their ever-increasing popularity to their high input impedance and to the fact that being a majority carrier device, they do not suffer from minority carrier storage time effects, thermal run away.

3.5.1 MOSFET OPERATION

An understanding of the operation of mosfet can be best be gleaned by first considering the later mosfet as shown in the figure 2.3

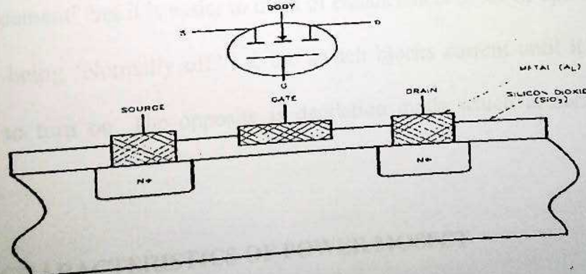


Fig 2.3 Lateral N-Chanel MOSFET cross section

With no electrical bias applied to gate G, no current can flow in either direction underneath the gate because there will always be a blocking PN-

Junction. When the gate is forward biased with respect to the sources as shown in fig 2. The free hole carrier in the p-epitaxial layer are repelled away from the gate are creating a channel which allows electrons to flow from the source to the drain.

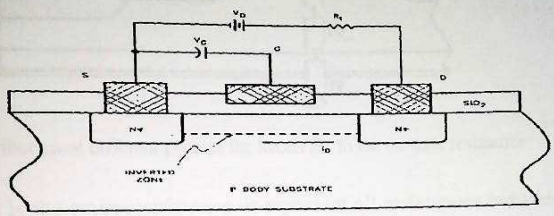


Fig 2.4 Lateral MOSFET transistor Biased for forward current conduction

Note that since the holes have been repelled from the gate channel, the electrons are the 'majority carriers" by default. This mode of operation is called 'enhancement" but it is easier to think of enhancement mode of operation as the device being 'Normally off" i.e, the switch blocks current until it receives a signal to turn on. The opposite is depilation mode which is normally "on" device.

3.5.2 CHARACTERISTICS OF POWER MOSFET

i. ON STATE CHARACTERISTICS

On-state Resistance: when the power mosfet is in the on state, it inhabits a resistance behavior between the drain and source terminal. It can be seen in the below that this resistance (Called Rison for "drain to source resistance in on state") is the sum of many elementary contributions.

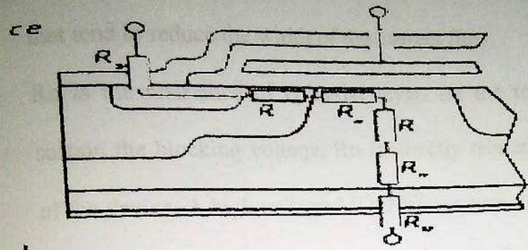


Fig 2.5 Contribution of different parts of the MOSFET to the on state resistance

- Rs is the source resistance, it represent all resistances between the source terminal of the package to the channel of the MOSFET resistance of the wire bond, of the source metallization and of the N wells,
- Rch: this is the channel resistance it is directly proportional to the channel width for a given die size to the channel density the channel resistance is one of the main contributors to the RDson of low voltage MOSFETs, and intensive work has been carried out to reduce their cell size in order to increase the channel density.
- Ra: is the access resistance, it represents the resistance of the epitaxial zone directly under the electron where the direction of the current changed from horizontal in the channel to vertical (to the drain contact).

- RJFET: Is the determinant effect of the cell size reduction mentioned above. The P implantations from the gate of a parasitic JFET transistor that tend to reduce the width of the current flow.
- Rn is the resistance of epitaxial layer. As the role of this layer is to sustain the blocking voltage, Rn is directly related on the voltage rating of the device. A high voltage MOSFET requires a thick, low doped layer (i.e Less Resistance) as a result; Rn is the main factors responsible for the resistance of high voltage MOSFETs.
- R_D is the equivalent of rs for the drain. It represents the resistance of the transistor substrate and of the package connections.

ii. **BREAK DOWN VOLTAGE OR ON STATE TRADE OFF**

When in the off-state, the power mosfet is equivalent to a P/N diode (Constituted by the P Diffusion, the N^-Epitaxial layer and the N substrate). When this highly symmetrical structure is reverse-biased, the space charge region extends principal on the height doped side i.e over the N' layer. This means that this layer has to withstand most of the MOSFETs off state drain-to-service voltage.

However when the MOSFET is in the On-state this N' layer has no function furthermore, as it is a highly doped region, its intrinsic resistivity is non-negligible and adds to the MOSFET On-state drain-to-source resistance (RDson).

Two main parameters govern both the break down voltage and the RDson of the transistor, the doping level and the thickness of NEpitaxial layer. The thicker the layer and the lower the doping level. The higher the breakdown voltage. On the contrary, the thicker the layer and the higher the doping level, the lower the Rdson (and therefore the lower the conduction losses of the MOSFET). Therefore it can be seen that there is a trade —off in the design of a MOSFET, between it voltage rate and it's in state resistance.

(iii) SWITCHING OPERATION

Because of their unipolar nature, the power MOSFET can switch at very high speed. Indeed, there is no need to remove minority carries as with bipolar devices. The only intrinsic limitation in commutation speed is due to the internal capacitance of the OSFET as shown below.

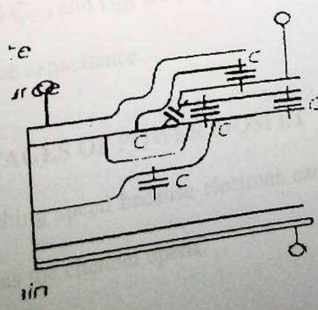


Fig 2.6 Location of the intrinsic capacitances of power MOSFET

These capacitances must be charged or discharged when the transistor switches. This can be a relatively slow-process because the current that flows through the gate capacitance is limited by the external driver circuit. This circuit will actually dictate the commutation speed of the transistor.

3.5.3 CAPACITANCES

In MOSFET data sheet, the capacitances are often named Ciss (Input capacitance, drain and source terminal shorted) Coss (Output capacitance, gate and source shortened) and Crss (Reverse capacitance, gate and source shortened). The relationship between this capacitance and those described below is:

$Ciss = C_{GS} + C_{GD}$

$Coss = C_{GD} + C_{DS}$

$Crss = C_{GD}$

Where C_GS C_{GD} and C_{DS} are respectively the gate to source, gate to drain and drain to source capacitance.

3.5.4 ADVANTAGES OF POWER MOSFET

i. Fast switching speed because electrons can start to flow drain to source as a soon as the channel opens.

ii. Low gate signal power requirement no gate current can flow into the gate after the small gate oxide capacitance has been charged.

3.6 RELAY

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contact. Mechanical relays have two switch position and they are double throw (change over) switches.

3.6.1 MODE OF OPERATION

A relay consist of two parts, a coil and a magnetic switch when a electric current is passed through a coil, the resulting magnetic field attract the armature, and the consequent movement of the movement of the movable contact or contacts either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movements open the contact and break the connection and vice-visa if the contact were open. When the current in coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to it released position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters.

If the coil is energized with DC, a diode is frequently installed across the coil to dissipate the energy from the collapsing magnetic field at deactivation which would otherwise generate a voltage spike dangerous to circuit component. Since relays are switches, the terminology applied to switches is also applied to relay. A relay will switch one or more poles, each of whose contacts can be thrown by energizing the coil in one of three ways:

- Normally-Open (NO) contacts connect the circuit when the relay is activated, the circuit disconnected when the relay is inactive. It is also called an form A contact or "make" contact.
- Normally-Closed (NC) contact disconnect the circuit when the relay is activated, the circuit is connected when the relay is inactive. It is also called a form B contact or "break" contact.
- Change-Over (CO), or double-throw (DT), contact control circuits: one normally-open contact and one normally-closed contact with a common terminal. It is also called a form C contact or "transfer" contact ("break before make"). If this type of contact utilizes "make before break" functionality, then is called a form D contact.

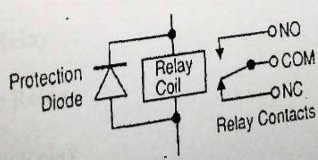


Fig 2.7 Relay circuit line diagram

3.6.2 PROTECTION FREE-WHEELING DIODE FOR RELAYS

Transistors and its ICs must be protected from the brief high voltage produced when a relay coil is switched off. Fig. 2.7 shows how a signal diode (eg 1N4 148) is connected "backwards" across the relay coil to provide this protection.

Current flowing through a relay coil creates a magnetic field which collapse suddenly when the current is switched off. The suddenly collapse of the magnetic field indices a brief high voltage across the relay coil which is very likely to damage transistors and ICs. The protection diode allows the induced voltage to drive a brief current through the coil (and diode) so the magnetic field dies away quickly rather than instantly. This prevents the induced voltage becoming high enough to cause damage to transistors and ICs.

There are different types of relays which include:

i. Latching relay

ii. Read Relay

iii. Polarize Relay

iv. Contactor Relay

v. Solid state Relay

vi. Over load protection Relay e.t.c

ADVANTAGES OF RELAY

i. Relays can switch AC and DC.

ii. Relays can switch high voltages.

iii. Relays are better choice of switching large currents (> 5 A).

iv. Relays can switch many contacts at once.

DISADVANTAGE ES

i. Relays require more current than many Ics provide.

ii. Relays use more power due to the current flowing through their coil.

iii. Relay cannot switch rapidly (Except read relay).

3.7 TRANSFORMER SELECTION

The specifications of the transformer are:

I. Input power = Output power

II. Input voltage = 12 V

III. Output power = 1.5KVA

The transformer is saddled with the responsibility of coupling two alternating swings from the switching transistors as its centre-tap. This in turn from a low voltage DC at the primary which then step up low Voltage, that is 12V to 240V at the secondary. The major determinants that suggest the power handling capacity of the transformer are its size and coil gauge.

The core area of the transformer is given by

$A_i = K\sqrt{(rating)}$ 3.1

Where k is a constant which depend on type of transformer.

The rating is 1.5KVA = 0.0015MVA

As the transformer is a shell type, then k = 0.05 7

$A_i = 0.0022076m^2$.

The secondary current is obtain from the relation

Transformer rating = VI_s

Where I_s = secondary current

Hence, $I_s = 1500/240 = 6.25A$ 3.2

Since the input power = output power

$1500 = 12I_p$

$I_p = 1500/12 = 125A$

From the faraday law of electromagnetic induction

$\varepsilon = N^{d\phi/dt}$ 3.3

Where

ε = Induction emf

N = Number of turns

$d\phi/dt$ = rate of change of flux density

But $\phi = \phi m \sin wt$

Where ϕm = max flux

$$W = 2\pi f$$

$$\varepsilon = 2\pi f N\phi_m \cos wt = \sqrt{2}\ V\cos wt \quad \text{.......... 3.4}$$

$$\text{Hence } V = 4.44fN\phi_m \quad \text{.......... 3.5}$$

$$\phi_m = B_m * A_i$$

B_m = maximum flux density

$$V/N\ 4.44\ fB_mA_i \quad \text{..........3.6}$$

This is an expression for obtaining the voltage per unit turn of the transformer, hence

$$V_1/N_1 = 4.44 \times 50 \times 1.51 \times 0.0022076 = 0.740$$

Since the voltage per unit turn is constant then

$$V_1/N_1 = V_2/N_2$$

For the primary winding,

$$V_1/N_1 = 0.740$$

but $V_1 = 12$

$\therefore N_1\ 12/0.740 = 17$ turns

For the secondary winding, $V_2/N_2 = 0.740$

Hence, $N_2 = 240/0.740 = 325$ turns

3.8 SIZE OF THE WINDING CONDUCTOR

Primary wire gauge

$$r_p = \sqrt{\frac{I}{\pi J}} \quad \text{.......... 3.7}$$

Where I_p = primary current

$\pi = 3.14$

J = current density per square inch

But $I_p = 125A$

$$r_p = \sqrt{\frac{125}{3.14 \times 2000}} = 0.14 \text{ inch}^2 \text{ (SWG 14 will be used)}$$

Secondary wire gauge

$$r_s = \sqrt{\frac{I}{\pi J}}$$

Where $I_s = 6.235A$

$$r_s = \sqrt{\frac{6.235}{3.14 \times 2000}}$$

$$r_s = \sqrt{0.000993}$$

$= 0.032 \text{ inch}^2$ (SWG 16 will be used)

3.8 SIZE OF THE WINDING CONDUCTOR

Primary wire gauge

$$r_p = \sqrt{\frac{I}{\pi J}} \quad \text{.......} \quad 3.7$$

Where I_p = primary current

$\pi = 3.14$

J = current density per square inch

But $I_p = 125A$

$$r_p = \sqrt{\frac{125}{3.14 \times 2000}} = 0.14 \text{ inch}^2 \text{ (SWG 14 will be used)}$$

Secondary wire gauge

$$r_s = \sqrt{\frac{I}{\pi J}}$$

Where $I_s = 6.25A$

$$r_s = \sqrt{\frac{6.25}{3.14 \times 2000}}$$

$$r_s = \sqrt{0.000995}$$

$= 0.032 \text{ inch}^2$ (SWG 16 will be used)

3.9 THE OSCILLATOR CIRCUIT DESIGN

The SG 3524 is an hybrid oscillator that is used as the control element of the system and intelligent regulating unit of the inverter. This configuration gives the desired signal wave form. The frequency required is 50Hz. The 50Hz is attained by configuration of external timing resistors and capacitors. The calculations were made to achieve a square wave of 50Hz.

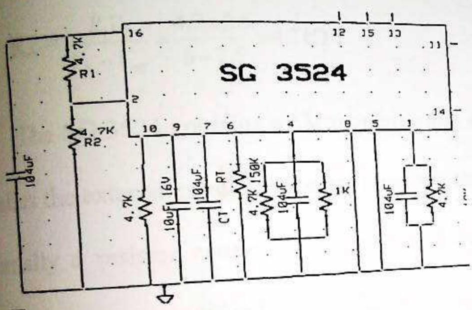


Fig 3.1 Oscillator circuit

R_T and C_T are the frequency determinant component of the SG 3524.

Thus 3.8

$f = 0.73/R_TC_T$ ...

Therefore selecting C_T to be 100nf the value of R_T can be calculated

$R_T = 0.73/f\,C_T$

$$R_T = \frac{0.73}{50x100E-9} 146\,k\Omega$$

But a 1 50kΩ resistor was used as the timing resistor. Also given that V_{ref} pin 16 is 2.5V and V pin 2 is 5V and assuming R_1 to be 4.7kΩ, the value of R_2 can be calculated.

$$V_2 = \frac{R_2 V_{ref}}{R_1 + R_2}$$

Therefore

$$R2 = \frac{R_1 V_2}{V_2 - V_{ref}} = \frac{4.7 \times 2.5}{5 - 2.5} = 4.7k\Omega$$

The SG 3524 contains a 5V regulator that serves as a reference and also supplies the external regulator control circuitry, this reference voltage is divided externally a resistor network to supply a reference within a common mode range of the error amplifier (1.8V to 3.4V).

3.10 SWITCHING UNIT

This unit consists of two modules of MOSFETs. Each module has 3 MOSFETS screwed firmly and arranged on a heat sink. Diodes are connected across the drain and each sources of each MOSFET. The sources of the two modules (i.e all the MOSFETs) are connected together by means of 10mm wire linking the sources the two modules and then connected to the ground. The drains of the modules are connected to the primary windings of the transformer.

It is in this unit of the inverter that the de voltage from the battery is been switched to• obtain its ac equivalent.

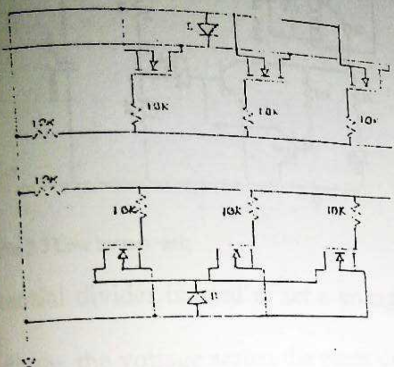


Fig 3.2 Bank of MOSFETS

As shown above six N-MOSFE1s IRFP 150 are used to achieve switching and the current requirement to carry the load. They have lie following specification.

- Drain to source voltage (max) V_{ds} = 100V
- Gate to source voltage (max) V_{gs} = 20V
- Drain current (max) I_d = 40A
- Power dissipation (max) = 180W

It should be noted that a 10kΩ resistor to the each gate of the MOSFT, this is used to limit the current at the gate. Another 10kΩ is connected from the gate to the ground, this is used to switch off the gate of the MOSFET after they are switched on.

3.11 LOW BATTERY INDICATOR DESIGN

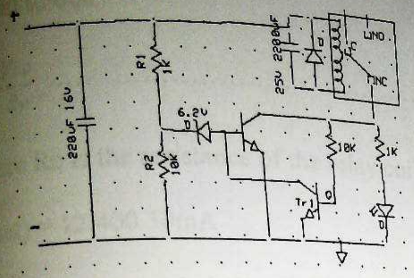


Fig 3.3 Low battery unit

A potential divider is used to set a voltage to the zener diode. Choosing 6.2V zener diode, the voltage across the zener diode will be

$$V2 = \frac{R_2V_1}{R_1 + R_2} \quad \text{......} \quad 3.10$$

The minimum input voltage is 10V

i.e $V_1 = 10V$

$V_2 = 6.2V$

Choosing $R_1 = 1k\Omega$

Therefore $R_2 = \frac{R_1V_1}{R_1 - V_2}$

$R_2 = \frac{1000 x 6.2}{10 - 6.2} 2.3k\Omega$

We are going to use 10kΩ potentiometer as R_2.

The transistor selected to switch the relay is C9014. The transistor has the following specification.

Collector current I_c (max) = 150mA

h_{fe} 200 to 600

$$I_c = \frac{Vcc}{Rc} \quad \text{.......... 3.11}$$

Where Rc is the resistance of the relay coil

I_c (sat) = 12/400 30mA

When the voltage is below I OV transistor T11 will switch on and the relay will switch off and the LED will turn on.

3.12 THE DESIGN OF THE BATTERY CHARGING UNIT

This unit of the inverter circuit deals with automatic charging system, where operational amplifier (Op-amp UA 741) is used as a voltage comparator, to compare two different voltages levels and determines which one is larger of the two between pins, the inverting and non inverting inputs (i.e pin 2 and pin 3).

From fig 3.3 at pin 3 of the IC (UA 741) there is always a reference voltage 12V, with respect to the inverting input which can be regulated with 10kΩ variable resistor. If pin 3 voltage is higher than that of pin 2 the output of Op-amp will be positive which allows the two transistors in the charging circuit to saturates which in turns gives a positive voltage at the gate of the MOSFET which cause negative voltage to pass through the mosfet source to the drain terminal and charge the battery.

If the voltage at pin 2 begins to increase continuously and exceeds that of pin 3, this will reverse the output of the op-amp (i.e from positive to negative) and this will change the operation of the transistors in the circuit and this will also changes the positive voltage of the MOSFET gate to negative and as a result of this it stops the charging of the battery.

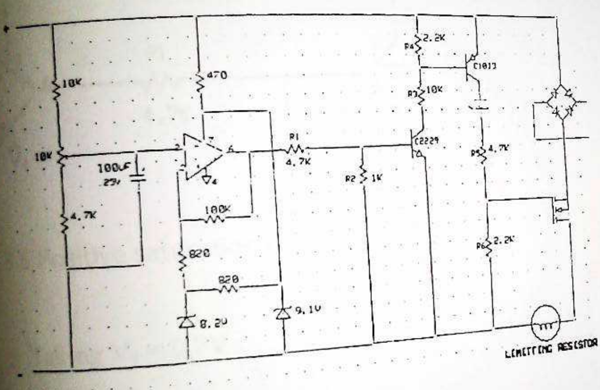


Fig 3.4 Charging circuit

If both inputs of an op-amp are use simultaneously, then the output voltage is given by

$V_0 = A_0 (V_3 - V_2)$

Where V_2 is the inverting (negative) input, V3 the non inverting (positive) input and A_0 the open loop gain.

When $V_2 < V_3$, V_0 is positive, its maximum value being the positive supply $+V_s$, which it has when

$V_3 - V_2 = V_s / A_0$

The op-amp is then saturated.

When $V_2 < V_3$, V_0 is negative and saturated, occurs if V_2 exceed V_3 by V_s/A_0.

From the charging circuit

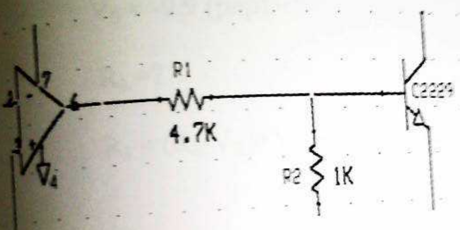


Fig 3.6 Positive saturation Op-amp

Taking $V_1 = 0.7V$

$V_s = 9.1V$

$R_2 = 1k\Omega$

$R_1 = ?$

$$R1 = \frac{R_2 V_1}{V_s - V_1} = 4.7k\Omega$$

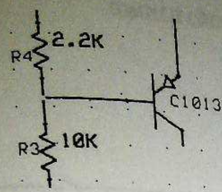


Fig 3.7 Potential divider

Taking Vcc = + 12V

$R_4 = 2.2k\Omega$

$V_B = -0.9$ (pnp)

$R_3 =?$

$R_3 = (R_4 - V_B)/(Vcc - V_B) = 10k\Omega$

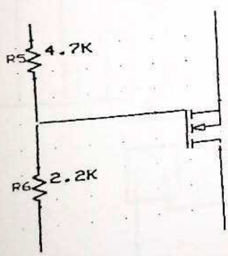


Fig 3.8 Potential divider

Taking $V_G = 8.2V$

Vcc = +12v

$R_6 = 2.2k\Omega$

$R_5 =?$

$R_5 = (R_6 V_G)/(V_{cc} - V_G) = 4.7k\Omega$

COMPLETE CIRCUIT DIAGRAM OF THE DESIGN

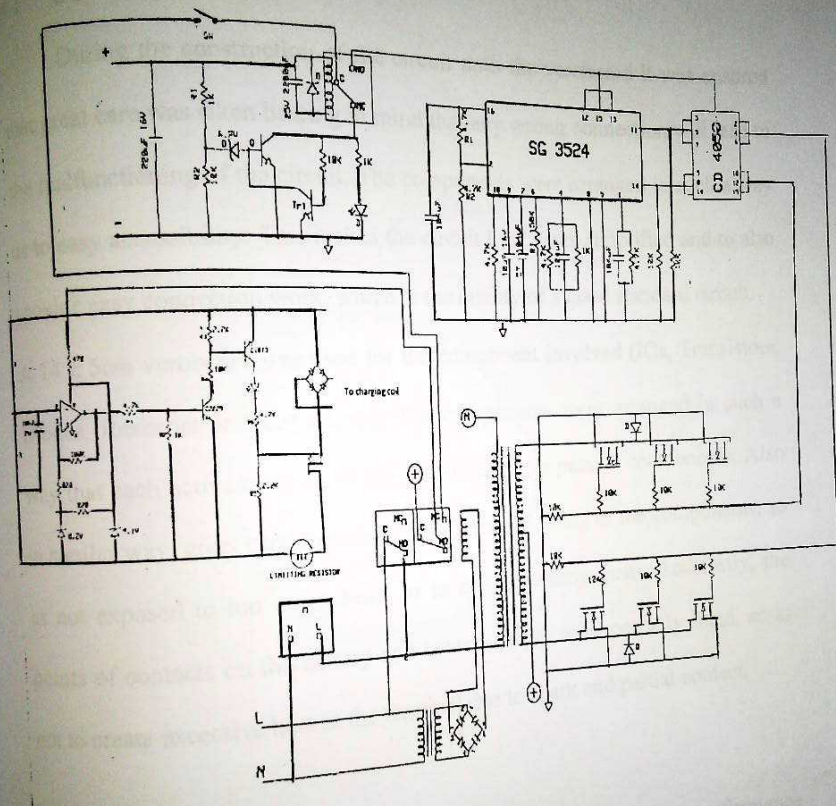


Fig 3.5 Complete circuit diagram

CHAPTER FOUR

CONSTRUCTION, CASING AND TESTING

4.1 CONSTRUCTION

During the construction of the circuit onto the veroboard it was ensured that great care was taken bearing in mind that any wrong connection will lead to the malfunctioning of the circuit. The components were arranged in such a way as to easy accessibility. This makes the circuit look more simplified and to also provide easy connection work, which is the quality of a good standard circuit.

A 14 x 5cm veroboard was used for the component involved (ICs, Transistors, Diodes, Resistors and Capacitors). The components were arranged in such a way that each active component is located beside its passive components. Also in similar way, great care was taken during the soldering of the components, so as not exposed to too much heat, so as not to destroy them. And lastly, the points of contacts on the battery and source supply were properly fixed, so as not to create excessive heat at the terminal due to spark and partial contact.

4.2.0 TESTING

The following test were carried out to ascertain the performance specification of the system; frequency test, current on no load test, current on load test, voltage on no load test, voltage on load test.

- Current on no load is 2.0 A

- Voltage on no load is 243 V
- Frequency test

The inverter output was connected to the input of the oscilloscope through its input and the ground probes. When the ac/dc switch was switched to ac position and current/time switch was set to display a Quasi waveform displayed on the screen.

The frequency of operation is 50 Hz, and the wave form of the system output is shown in figure below.

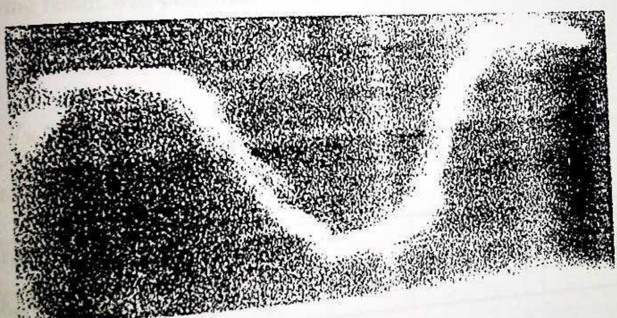


Fig 4.1 System output wave form

- Currents / voltages on different loads

Here the loads are varied and a multimeter was used carry out the corresponding reading of both the dc current and the output voltage respectively is shown below.

Table 1: Current and voltage on varying load.

S/N	LOAD (W)	CURRENT (A)	VOLTAGE (V)
1	100	0.45	220
2	200	0.93	215
3	300	1.43	210
4	400	1.93	207

- Efficiency Test

Efficiency of the system was system tested by varying the load. The following result was obtained.

Assuming unity power factor

$P_{in} = I\ V\ COSØ$

Table 2: Input and output power

P_{in} (W)	142.6	286	429	572.9
P_{out} (W)	100	200	300	400

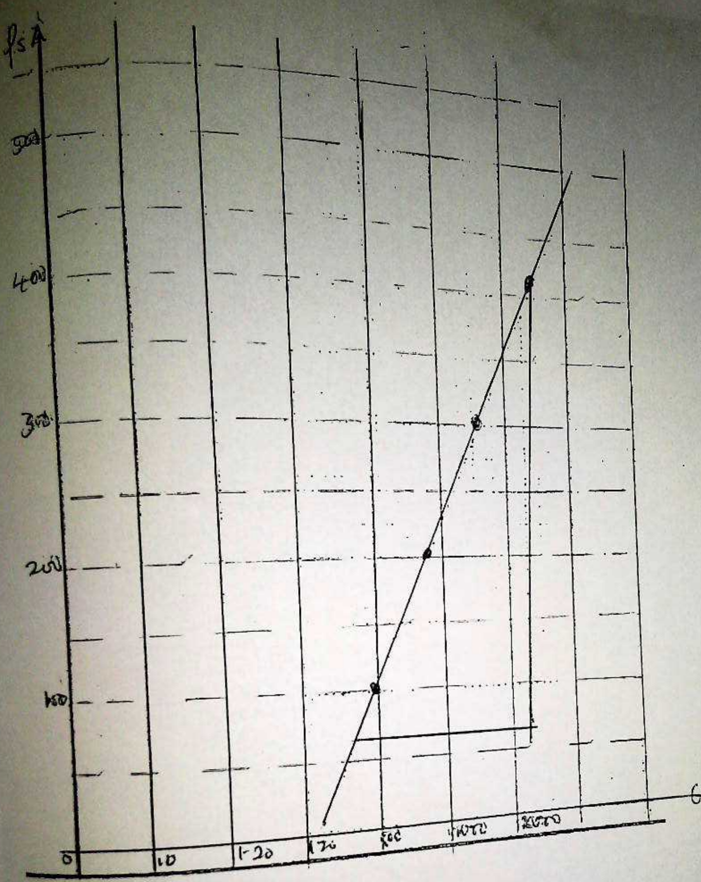


Fig 4.2 Graph of output vs input power

Efficiency = P_{out}/P_{in}

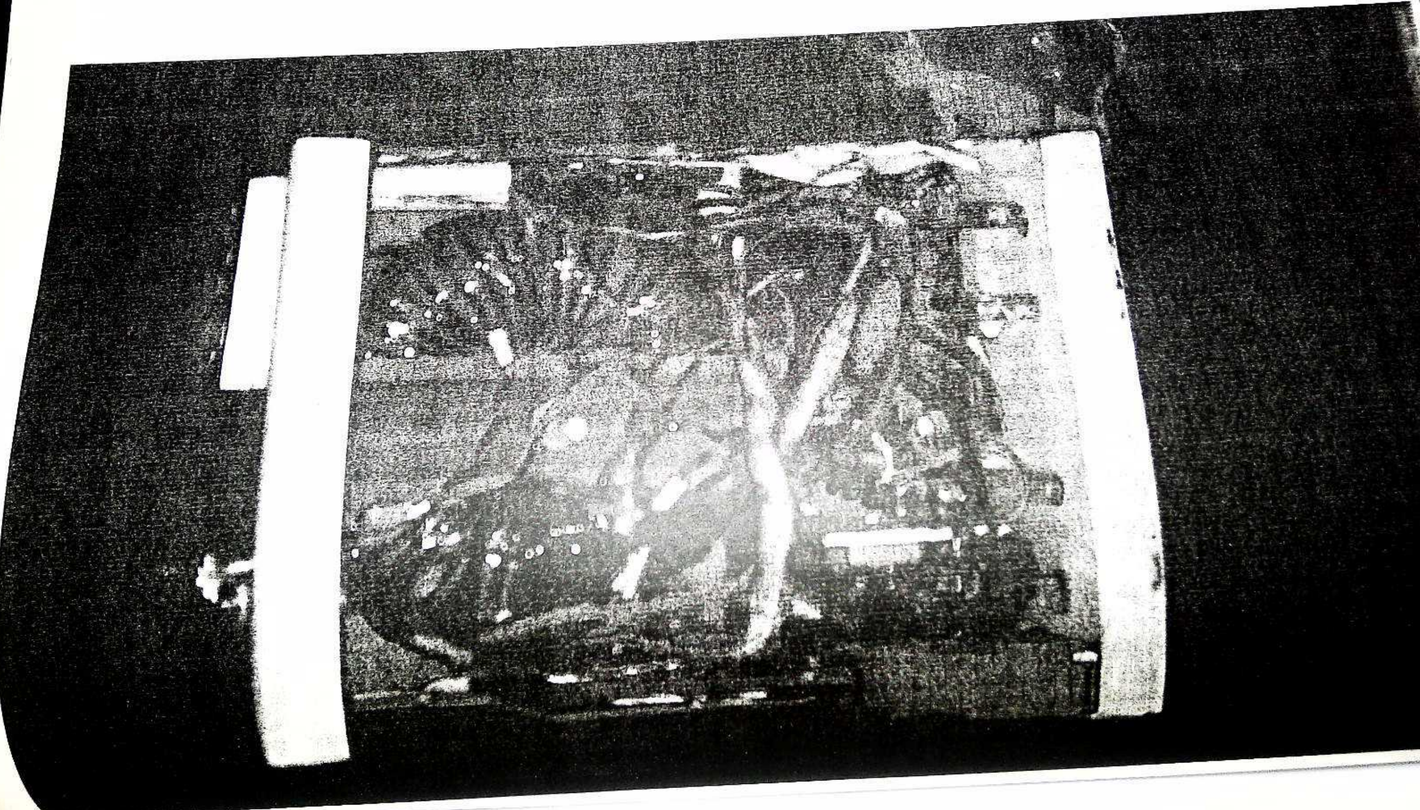
Slope = $(Y_2 - Y_1) / (X_2 - X_1)$ = Efficiency = P_{out} / P_{in}

$= (393 - 78) / (1220 - 770)$

$= 315/450$

$= 0.70$


15KW
INVERTER
BY
MUHAMMAD



CHAPTER FIVE

LIMITATIONS AND RECOMMENDATIONS

5.1 CONCLUSION

The circuit was designed, built and tested; it was found to be working according to specification.

Based on locally available components and the inverter system basic operating principle the self commutated inverter system was realized using fundamental electronic concepts. The system had a maximum power output capacity of 1300W when operating under the conditions of fully charged battery. This particular inverter can be used for domestic application but cannot be used in industrial application where high current is required. Hence the design objectives were met.

5.2 DIFFICULTY ENCOUNTERED

The first problem encountered was in obtaining the exact 50Hz frequency from the oscillator. The second is for testing the relay because it requires more current than many ICs provide so that the test was carried out in electric lab.

5.3 ACHIEVEMENT

It is to convert DC signal and produces an AC output, and also a small DC voltage say 12V is fed into the system to produce a 220V or 230V AC output as desired.

5.2 RECOMMENDATIONS

Even though the circuit design and construction is completed successfully. Modification of the circuit can be done to improve its efficiency and capacity so as to make the inverter system practically applicable to supply power for more electrical load. In other to increase the power output, the power transistor (Mosfet) has to be increase in number and transformer with greater rating should be used.

It is also required to include photovoltaic solar cells to work alongside with batteries. This way the system will become fully independent of AC mains supply. This will surely improve the performance of the system and make it really a reliable electricity source for rural area.

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