DESIGN AND CONTRUCTION OF 1KVA VOLTAGE INVERTER WITH AUTOMATIC CHANGEOVER FOR REMOTE APPLICATION

BY

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2003/15391EE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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A Thesis submitted to the Department of Electrical and Computer Engineering, Federal University of Technology, Minna.

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DEDICATION

The project is dedicated to Almighty Allah for His sustenance and favour bestowed on me for successful completion of the degree program.

DECLARATION

I JIMOH TESLIM AYOTUNDE, declare that this work was done by me and has never been presented elsewhere for the award of degree. I also hereby relinquish the copyright to the Federal University of Technology Mina.

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critics must be acknowledged too because without them, my place of yesterday would have been the same as today. I love you all.

ABSTRACT

This thesis document outlines the research, design and implementation of a high power DC to AC inverter with particular focus on remote locations. The final design consisted of modulating module (DC – AC inverter stage) consisting of oscillator and a buffer. The step up stage. These two stages form the DC – AC inverting stage. Then the charger stage which carries the charging mode and the fully charged mode indicators. And the changeover stage; At this stage, continous power generation from the inverting system is ensured by the changeover. This is achieved by swapping two batteries between charging and discharging modes. It also supplies power to the charger from either the output of the inverter or the primary supply. The system was implemented and tested to generate 220V AC at 1000W.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE RESEARCH

An inverter is a device that takes a DC input and produces a sinusoidal AC output. It can also be defined as an electro-mechanical device that converts DC to AC. A high power inverter is one that can be used to power an entire home or workshop, from a battery bank-charged from a renewable energy source, or supply grid as in UPS application. Inverters are also used in a wide range of application from small switching power supplies in computers to large electric utility application that transports bulk power. An inverter used to be designed to handle the requirement of an energy hungry household or location as we have in Nigeria, where power is not efficient, consistent and even lack rapid and steady development, which damages most of our electrical appliances.

Inverters can be designed in a number of topologies depending on the situation and its requirements. The efficiency of inverters is highly dependent on the switching device, topology and switching frequency of the inverter. The inverter is so named because, early mechanical AC to DC converters were made to work in reverse and thus were ''inverted'' to convert DC to AC. The inverter performs the opposite function of a rectifier. The aim of this project is to produce efficient DC to single phase 220V AC inverter.

1.2 JUSTIFICATION

There are still a significant number of remote locations in Nigeria that are not connected to the national grid. Often, the cost of connecting these locations to the national grid far outweighs the initial expenditure required to setup some form of renewable energy source on location. The position is made more attractive with the introduction of high efficiency inverters. It also complement for the inconsistency in power supply. An inverter converts the DC electricity from source such as batteries, solar panels or fuel cells to AC electricity, which can in turn be used to operate AC equipment. This goes further to justify the importance of the inverter.

1.3 AIMS AND OBJECTIVES

The aim and objective of this project is to design and construct a 1KVA voltage inverting system, which may be used in a cottage industry (small scale commercial outfit) e.g barbing saloon, football viewing center etc. when utility power fails or in remote area away from the national grid. Both private and domestic power demand in Nigeria is increasing rapidly, especially the urban areas. The rate of power consumption is growing faster than our ability to supply power. Under this condition failure will occur unpredictably and without any warning due to the stress on the inadequate source of power. This brought about the need for alternative source of power, which will bridge the gap and cover for lapses of inadequate power supply. The usual choice of storage device is the rechargeable secondary battery. The device stores DC power and must therefore, be proceeded by a charging circuit which converts AC from the main supply to DC power, once utility power fails the AC power stored in the battery is inverted to AC through suitable circuit and amplified to deliver power to the load.

1.4 METHODOLOGY

In designing this inverter, a modular method was employed; each module was independently designed, constructed and tested. Upon testing, the modules were found okay. The casing was designed to accommodate the transformer, the inverting circuit, the charging circuit and the switching circuit (changeover circuit) carrying the relays. The system was tested again after the casing process.

1.5 APPLICATION AND IMPORTANCE

Inverters, due to the use of battery are capable of generating power for hours, even depending on the capacity and number of batteries used. This power is importance that cannot be overemphasised. In some industrial or organisational settings, a loss of power of up to 1 minute can cause heavy loss or damages. The ability of inverters to do some functions more intelligently and automatically gives it advantages over the engine drive generator.

It performs the work of an electric generator in refined and more friendly manner.

- No noise.
- No smoke.
- No pollution.

- No danger of fire accident.

» Inverters are cost efficient

- No diesel nor petrol
- No engine oil
- No mechanical maintenance cost
- No spare part cost

The ranges of heavy load inverters are specially designed to cope with long hours at heavy loads and have wide ranging application. Batteries with suitable ratings and durability are also used.

- Air conditioners
- Domestic light and electronics
- Fridges
- Computers, printer scanner and ATM machines
- Deep freezers, block making machine, cold rooms and mortuary cold rooms
- Bank branch
- Gas station pumps
- Computer servers
- Lifts
- Industrial drives and motors
- Operation theatre and ICU wards, and many more.

1.6 SCOPE OF THE PROJECT

The scope of this project entails the designing of 1000VA inverter to meet the design specifications and the respective areas of applications. This is achieved by using a modular approach; the construction of the inverting system, giving cognizance to the specifications and ratings from the data sheet. The charging system's components are to be able to withstand the voltage, current and heat generated in the course of charging. Components values are to be selected from calculation results. It takes its supply from either the primary supply or the output of the inverter. The changeover is to compare the voltage gap between two batteries and swap them from charging to discharging mode at certain voltage gap. This is done by the action of a comparator, relays and introduction of hysteresis to increase the voltage gap.

1.7 THESIS OUTLINE

Chapter 1 includes the introduction, aims and objectives of the project, the methodology, justification, and the importance and application areas of the project.

Chapter 2 began with a literature review on all relevant recent articles written on the Subject of both low and high power inverters and their control. Each module of this project was explained and the improvement in it was highlighted.

Chapter 3 will give a theoretical outline to all concepts behind the design and Implementation of the entire system.

Chapter 4 will list the results of testing on both stages of the inverter implementation, with particular focus on stability and efficiency.

Chapter 5 will include an analysis of data and attempt to draw appropriate Conclusions based on the experimentation. It will also look into future implications of his research.

CHAPTER TWO

2.1 LITERATURE REVIEW

There have been a large number of articles written concerning conversion in recent years. This can be attributed in part to the use popularity of high voltage DC transmission systems and their integration with existing AC supply grids. There is also a consistent demand for high efficiency inverter devices for lower power application like house, boats, caravans, UPS and remote area of the world. This chapter will discuss and contrast recent literature concerning high power inverter and their control [1].

From the nineteen century through the middle of the twentieth century, DC to AC power conversion was accomplished using Rotary converter or Motor generator sets (M-G sets). In the early twentieth century, vacuum tubes and gas filled tubes began to be used as switches in inverter circuits. The most widely used type of tube was the thyratron source of the term inverter. Early AC to DC converters used an induction or synchronous AC motor direct –connected reversed it's connection at exactly the right moment to produce DC. A later development is the synchronous converter, in which the motor and generator winding are combined into one armature, with slip rings at one end and a commutator at the other end and only one field frame. The result with either is AC- in, DC-out. With an M-G set, the DC can be considered to be separated generated from the AC; with a synchronous converter, in a certain sense. It can be considered to be ''mechanically rectified AC''. Given the right auxiliary and control equipment and M-G set or rotary converter can be ''run backwards'', converting DC to AC. Hence, an inverter is an inverted converter [2].

There are varieties of inverters depending on their orientation and application, listed below are some of the varieties.

- Solar inverter
- Grid tie inverter
- Push –pull converter
- Variable – frequency drive
- Static inverter plant
- Switched –mode power supply (SMPS)
- Pacific intertie HVDC power transmission line
- Uninterrupted power supply (UPS)
- Full sine –wave inverter
- Modified sine wave inverter.

2.2 DC-DC CONVERSION

DC-DC conversion involves around the conversion of a voltage V_d source to an acceptably ideal output voltage Vo. This can be performed in a number of both isolated and none chosen to be of isolated variety.

Various DC-DC converter topologies exist – each with their own particular advantages. Some simple circuit diagram of the basic types of high power isolated DC-DC converters are shown below.

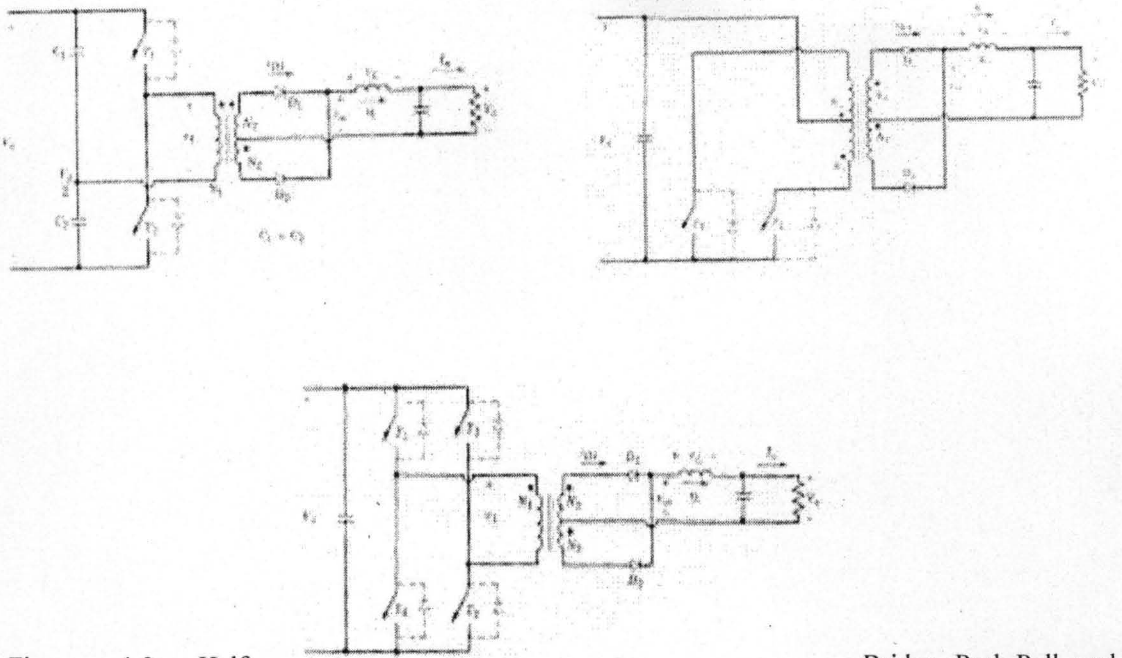


Figure 1.0 Half Bridge, Push-Pull, and Full Bridge DC-DC Converter (Clockwise)

DC-DC converter design tends to process of making tradeoffs between converter size, cost and performance and it is this procedure that tends to push the designer towards choosing a particular type of converter [1].

2.3 DC-AC INVERSION

In the scope of this project Dc – Ac inversion stage will be the most critical. The basic circuit of an inverter consists of power supply, switching circuit, step up transformer and oscillatory circuit. It will still have to cope with other issues such as reactive power correction and maintain a good level of voltage regulation in the most efficient manner possible [3].

2.4 POWER SWITCHING

Designing power inverters can be summarized into attempting to meet two primary objectives:

- Supply harmonic free electrical power at a constant voltage for a variety of loads and have the ability to cope with a non ideal supply.
- Supply this power as efficiently as possible with negligible electromagnetic interference.

The equations relating power losses;

Switching losses:

$$Ps = \frac{1}{2} V_s I_s f_s (t_{con} + t_{coff})$$

Conduction losses:

$$Ps = V_{on} I_{on} t_{on}/T_s$$

From these equations, it can be inferred that switching loss varies linearly with switching frequency and rise/fall times. Hence switching frequency can be increased provided devices with small rise and fall times are used.

Conduction loss is directly proportional to the on – state voltage. Clearly, a device need to be chosen that minimizes the on – state voltage (directly due to the MOSFET 'on – resistance') to reduce conductor loss.

Clearly often, the switching device chosen should meet the above criteria as closely as possible so as to maximize total efficiency of the device. The application of this theory to the choice of switching device will be explained in chapter four [1].

The switching circuit is designed from power transistors (MOSFETS) connected in parallel. The transistors' ability to act as switch has advantage of having no moving parts being able to operate ON and OFF at a very high rate of speed and requiring very low driving voltages and currents to trigger to switching action.

The ON – OFF switching appears to the transformer as an 'alternating DC' and since the transformer can only work with alternating signal, it converts it to AC at the output. The design of an inverter transformer is that of a step transformer. It increases the output of the switching circuit to the required value. For this project, it is 12V to 220V AC. Of course there are other ranges of 24V to 220V AC, 48V to 220V Ac etc [3], [4].

2.5 INVERTING CIRCUIT

This consist the 12V regulator, the oscillator, which can be designed for a multivibrator. It is the signal generator of an inverter. There are two major types of oscillator; sinusoidal oscillator produces a sine wave – shape output signal. Non sinusoidal oscillators produce waves other than sine – wave shaped waves, square wave, saw tooth waves and pulses. The oscillator or modulator modulates within the MOSFETS and the transformer as the inverting IC [4], [5], [6], [7], [8].

The 12V regulator (L7812) regulates the modification around the oscillator and the buffer IC to maintain 12V. It is essentially a three terminal positive regulator. It provides local on –card regulation, eliminating the distribution problems associated with single point regulation. It employs internal current limiting, thermal shut down and safe area protection, making it essentially indestructible. If adequate sinking (heat) is provided, it can deliver over 1A output current. Although designed primarily as fixed voltage regulator it can be used with external components to achieve adjustable voltage and currents [7].

Also in the inverting circuit is the buffer (CD4049UBC). It is used here as CMOS current driver, and at V_{DD} = 5V. It carries the modulated signal from the oscillator to the MOSFETS [9], [10]. It has many applications;

- CMOS hex inverter/buffer
- CMOS to DTL/TTL hex converter
- CMOS current 'sink' or 'source' driver
- CMOS HIGH to low logic level converter.

Its features;

- Wide supply voltage range: 3V to 15V
- Direct drive to two TTL loads at 5V over full temperature range.
- High source and sink current capability
- Special input protection permits input voltage greater than V_{DD}

2.6 CHARGING CIRCUIT

The charging stage comprise 15V 10A step down transformer; 15V transformer because a higher voltage is required to charge a battery. In this case 12V batteries are used so 15V transformer is needed to charge them one after the other. The rectifier rectifies the AC from the transformer which is filtered by the 50V 3300μF capacitor. The 1k resistor is responsible for limiting the current going into the OP –amp while the 6.8V Zener diode is the biasing diode. The OP – amp regulates the charging system and it is the comparator which compares the battery's nominal value and the charged value. It switches ON the charging transistor (TIP3055) which in turn turns ON the Red LED to indicate charging mode. And turns ON the NPN BC547 which also turns ON the green

LED, to indicate fully charged mode. At this stage the charging transistor is turned off. The two 6A1 diodes are the charging diodes and also protect the charging diodes and also protect the TIP 3055 from backward current/reverse voltage.

The 2Ω 10W choke resistor is limiting the current going into the TIP3055 and the second choke resistor 4700Ω 10W also limit current going into BC547B. The IN4001 is the calibrating diode for the reset resistor 10k. The negative terminal of the charging system is grounded while the positive terminal is connected to the 2 way 12 V Dc relay. The two other IN4001 supply positive and negative signals to the TIP3055 and BC547 respectively [3], [11], [12], [13].

2.7 CHANGEOVER CIRCUIT

This is made essentially of a 240V AC relay which switches between the primary supply and the output of the inverting system to power the charging system. A second relay, 12V Dc two–way relay with switches between the centre of the inverting transformer and the positive terminal of the output of the charging system. This switching selects one at a time of two batteries. The battery connected to the centre – tap of the inverting transformer is the discharging battery at that time, while the second battery connected to the position output terminal of the charging system to be in charging mode for that same time. After a certain voltage gap (difference) the batteries will swap. And this continues for as long as the whole system is in use. This switching is monitored and controlled by a comparator (LM358) which compares the two batteries for voltage gap. For example, if battery 1 is powering, starting at 12V after a while it would have discharged to about 9 – 8V. While the battery 2 would have charged to about 12V from 9V.

Hysteresis is introduced to prevent the LM358 from switching at very small voltage differences and is comprise of a reset resistor 10k and a Zener diode 3.3V for each battery.

In summary, the changeover is designed to achieve continuous running of the inverters system without fear of the battery going completely discharged. And continuous powering of the system is assured.

This project is designed to improve on the previous inverts by the introduction of a changeover system that assures continuous non – stop powering of the inverter system. Hence, can serve as long as it is needed when operated correctly.

CHAPTER THREE

DESIGN AND CONSTRUCTION

In electronic designs, functional or logical block diagrams are often used to represent systems. The block diagram for this system is shown in fig. 3.0

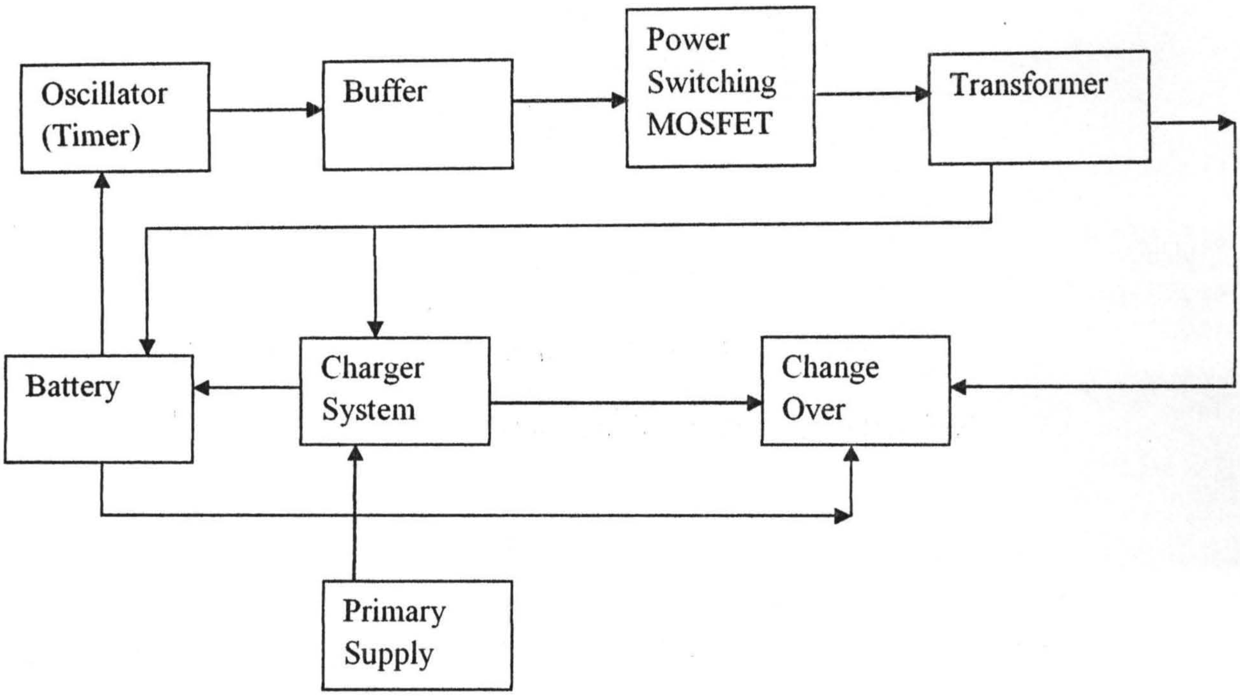


Fig 3.0 Block diagram

3.1 OSCILLATOR

Oscillator is the frequency generated per unit time. The oscillated frequency could be generated by monostable or stable device. Noted on the design is the astable multivibrator, because its self generated signal pulses. It has 50% duty cyclye on the oscillator output. It also has good stable frequency stability.

Under the oscillator generating circuit, certain pulse charateritICs are noted;

- Pulse repetitin frequency

- Pulse period
- Duty cycle
- Rise time
- Fall time

Pulse repetition frequency of a pulse wabve form is the number of pulse which occur in a given interval of time.

Pulse period of a pulse waveform is the time taken for one complete waveform of the pulse.

Duty cycle of a pulse wave form is the ratio of ON or high time to ON plus OFF (or low) times.

Pulse time of a pulse is the time intervals between the 10% and 90% amplitude point f the pulse.

Fall time of a pulse is the time interval between the 90% and 10% amplituide point of the pulse. Therefore the CD4047BC was used as an asatble generator possessing this charcateritICs which was capable of operating in either the non stable or astable mode. It requires an external capacitor between pin 1 and 3 and an external resistor between pin 2 and pin 3 to determine the output pulse width. The CD4047BC could go high or go low on the astable input. The output frequency on the biostable is determined by the timing component (RC)

Calculation

Pulse repetition frequency generated at the CD4047BC is noted in using the RC circuit

$$F = \frac{1.45}{(2R_1 + R_2)C}$$

$$F = \frac{1.45}{\left(2 \times 1 \times 10^{3} + 6 \times 10^{3}\right)4.8 \times 10^{-6} F}$$

$$F = \frac{1.45}{0.0288} = 50.35$$

F = 50Hz

Pulse period $= \frac{1}{\Pr f} = \frac{1}{50.35}$

T =0.0199sec $\approx$0.02sec

Therefore, it takes 0.02 seconds for a complete frequency of 50.35Hz

Duty cycle of the pulse wave form

$$= \frac{T_{ON}}{T_{ON} + T_{OFF}} \times 100$$

Therefore, the time ON = 0.693 (R_1 + R_2)C

$\therefore$= 0.693(1 x 10^3 + 6 x 10^3) x 4.8 x 10^{-6}

= 0.693 (6000) x 4.8 x 10^{-6}

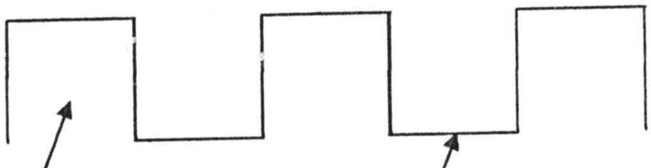
= 0.02 sec

Therefore, it takes 0.02 sec to ON with these paramneters of component. To achieve the time OFF in the system

$\Rightarrow$ 0.693 (R_2C) = 0.693 (1 x 10^3 x 4.8 x 10^{-6})

= 0.00333sec

Therefore, it takes 0.003 seconds to reach it OFF state.



Therefore the study cycle

$$= \frac{0.02}{0.02 + 0.003} \times 100 = 86.96\%$$

At 50.35Hz the voltage delivers 2V less than the rail voltage because of the operational amplifier incorporated on the IC timer (oscillator). Therefore, the comparator has 10,000 gain, but if it is not possible to increase the voltage to 10,000 supposing the input voltage is 1V, therefore it will only increase it to 2V less than the rail voltage because the voltage delivered to it is just 12V, and therefore the output voltage will be 10V. The 10V is delivered to the next stage. Here at the output, the frequency is specified at two phase at different time interval, one phase shift falling in the negative Point while at the other Output rising to the positive phase shift.

3.2 BUFFER

The buffer is the driver that drives the current to the input of the power switching MOSFET. The component used for the buffer (driver) is the CD4049UBC.

The CD4049BC inverted and non – inverted buffer is monolithic complementary MOS (CMOS) integrated circuit constructed with N and P channel enhancement mode transistor. The device feature logic level conversion using only one supply voltage (V_{DD}) the input signal at high level can exceed the V_{DD} supply voltage when this device is used for logic level conversion. This device is intended for use as hex buffer, and at V_{DD} = 50V, it can drive directly two DTL/TTL loads over the full operating temperature range or as CMOS current drivers.

3.2.1 THE FUNCTION OF THE BUFFER IN THE SYSTEM

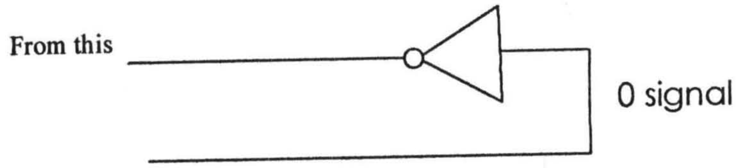
It gives out two different phase shift of pulses at different time intervals.

- To keep the input of the power switching MOSFET OFF at 0 and over at 1.
- To increase the current gain for the input of the switching MOSFET.
- To drain of excessive voltage from the input of the IC (4049) through the 6V Zener diode configured on the internal structure IC.

The Zener diode on the internal structure IC means that when excessive voltage is fed to the input of the 4049BC IC, the Zener diode will go into the state breakable voltage to leak of the excessive voltage until the voltage is less than 6V in which it become high resistance towards it to regulate the voltage to make sure that the input voltage remains at voltage less than 6V. In the internal structure it also composes of protective diode to protect it against surge.

3.2.2 STATE OF OPERATION

The 4049 operate in such a way that in the circuit, when two opposite pulses are fed to it, the output of the 4049 IC invert one phase of the signal, while the other output phase remain constant to make sure that the voltage fed to the switching MOSFET is either ON or OFF; voltage is 0 or 1. From the internal structure of the diagrams;



It will split code to 0 and 1 output. At the output we have

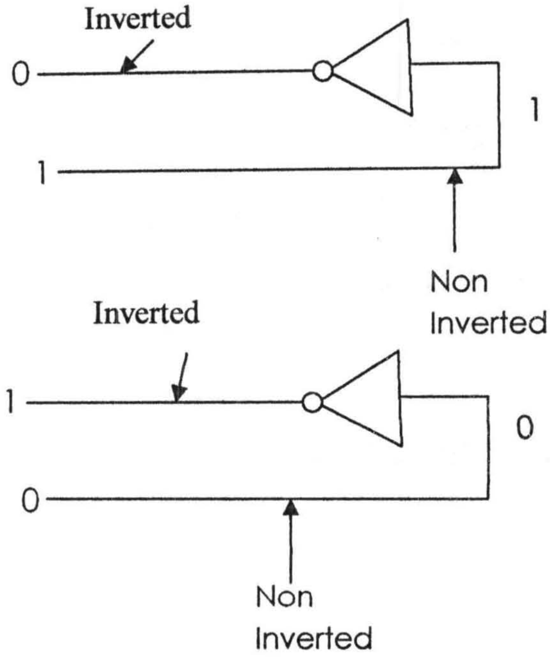


Fig 3.1 State of operation of the buffer

From the design of the component, the same input voltage will be the same as the output voltage. The only point noted was the inversion of the signal.

Note: - The internal structure of the buffer is like the emitter follower, where the input voltage is the same with the output voltage. $V_b = V_E$ because the gain is 1. Therefore only what was different is the 6V Zener diode which drain of 4V plus from the ten volt and leaving just 5V plus for the buffer feed the power MOSFET. Also noted on the structure, 4049BC component compose of N channel and P channel for proper inversion of the signal.

3.3 POWER SWITCHING MOSFET

MOSFETS are metallic oxide semi conductors in which the gate is completely insulated from the channel by a thin (about1dm) layer of silicon oxide. This permit operation with gate source or gate channel voltage above and below zero. The insulated gate of the MOSFET further reduces substantially the gate current, in which the gate current is less than one pico amp (pA).

On the design, the MOSFET receives 5V alternative voltage. Therefore for complete OFF the MOSFET – gate was negatively biased to avoid the damage of the component, because without the negative bias, the MOSFET will not completely OFF before the arrival of the other pulses which might damage the MOSFET. Therefore, 10Ω resistor was used to completely switch off the MOSFET. Furthermore, a diode was coupled across the drain to the source of the MOSFET to avoid surge at reverse direction which might also damage the MOSFET.

Calculation

5V was fed from the buffer to the switching MOSFET which makes

$V_{GS} = 0$ at self bias

$$I_G = \frac{V_H - V_{GS}}{R_b}$$

$$I_G = \frac{5-0}{100} = \frac{5}{100} = 0.05 \text{ Amp}$$

If $V_G = 5V$ at V_H

$\therefore$ Current drain = x

Since current drain = $\frac{V_{DD}}{R_D}$

$\therefore$ Since R_D = the reactance of the coil of the transformer. Therefore, we must achieve the reactance of the coil.

Since L (inductance) is not noted

$\therefore x_L = \frac{V}{I}$, V = 12 and I = ?

But power = 1kW = P = IV

1000 = 12 x I

$I = \frac{1000}{12}$=83.30 Amp

Therefore, the IRF150N has capacitance of 44Amp, therefore the MOSFET should be arranged parallel to compensate for the current.

$\therefore$If $X_L = \frac{V}{I} = \frac{12}{83}$=0.144Ω

⇒at 50Hz the reactance of the coil was noted to be 0.148Ω, hence R_D = 0.144Ω

Current drain = $X_L = \frac{N_{DD}}{R_D} = \frac{12}{0.144}$=83.3amps

3.3.1 POWER RATING DEVICE TEMPERATURE OF THE MOSFET

One of the main failure causes of power semi conductor is excessive heat at the function. Above certain temperature is largely a function of the material used. Silicon devices can operate at temperature up to about 175^0C to 200^0C. Therefore, IRF 150N was used in this design, it was power rating of 155watts, therefore, am using it for load of 0.144Ω, therefore the temperature will increase as power is dissipated.

⇒ Power dissipated from the MOSFET at 0.144Ω had will be = $\frac{(V_{DD})^2}{\pi^2 \times R_D}$ =

$$\frac{12^2}{(3.142)^2 \times 0.144} = 101.32\text{watt}$$

Therefore, when a load of 0.144Ω is coupled with the drain, 101.32watts heat is dissipated.

3.4 TRANSFORMER

The transformer is an inductive voltage device that can induce voltage in reponse to the ratio of coil as voltage rate runs throughout. Its voltage induction is proportional to the rise and fall of the magnetic field. The transformer is made up of the primary coil and the secondary coil. To achieve the impedance of the coil, the parameters are noted.

Primary coil turns = 500 + 50 turns ratio

Secondary coil turns = 30 – centre tap – 30 turns

Primary voltage =240V

Secondary voltage = 12V

Primary current = ?

Secondary current = 83A

The secondary current is obtained by the curent that runs through the source to the drain of the MOSFET. This help in powering the transformer, bceause the transformer is the R_L (Load resistor of the MOSFET).

∴ I_p (primary current) is given by

$$\frac{I_p}{I_s}=\frac{V_s}{V_p} \Rightarrow I_p=\frac{12\times 83}{240}=4.15\text{A}$$

$\therefore$ primary current = 4.15A

Power efficeincy = power input = power output

Power efficiency = 12 x 83 = 240 x 4.15

= 996W

If secondary reactance $X_{cp}=\frac{V}{I}=\frac{12}{83}=0.1446$

$\therefore$ inductance of the secondary coil

$X_L = 2\pi f L$

$= 0.1446$

$= 2 \times 3.142 \times 50 \times L$

$$L=\frac{0.1446}{2\times 3.142\times 50}$$

L = 0.000462H

L = 0.4×10^{-3}H

Inductance of the primary coil

$$X_L=\frac{240}{4.15}=57.8\Omega$$

$\therefore X_L = 2\pi f L$

$X_L = 2 \times 3.142 \times 50 \times L$

$$L=\frac{57.8}{2\times 3.142\times 50}$$

L = 0.18H

Therefore, the resonant factor = $\frac{\omega L}{R_{dc}}$

Where R_{dc} = dc pure resistivity

DC resistivity for primary coil is 1.6Ω

DC resistivity for secondary coil = 2.5Ω

$$\Rightarrow \frac{2\pi f L}{R_{dc}} = Q \text{ - for secondary coil}$$

$$\Rightarrow \frac{2 \times 3.142 \times 0.4 \times 10^{-3} H \times 50}{1.6} = 0.12$$

Q factor for primary coil coil

$$\Rightarrow \frac{2 \times 3.142 \times 0.18 \times 50}{2.6} = 21.8$$

Hence, impedance for secondary coil;

R = Q x X_L

R = 0.12 x 0.144

R = 0.0174Ω

Impedance for primary coil

= Q x X_L

= 0.18 x 57.8 = 10.404Ω

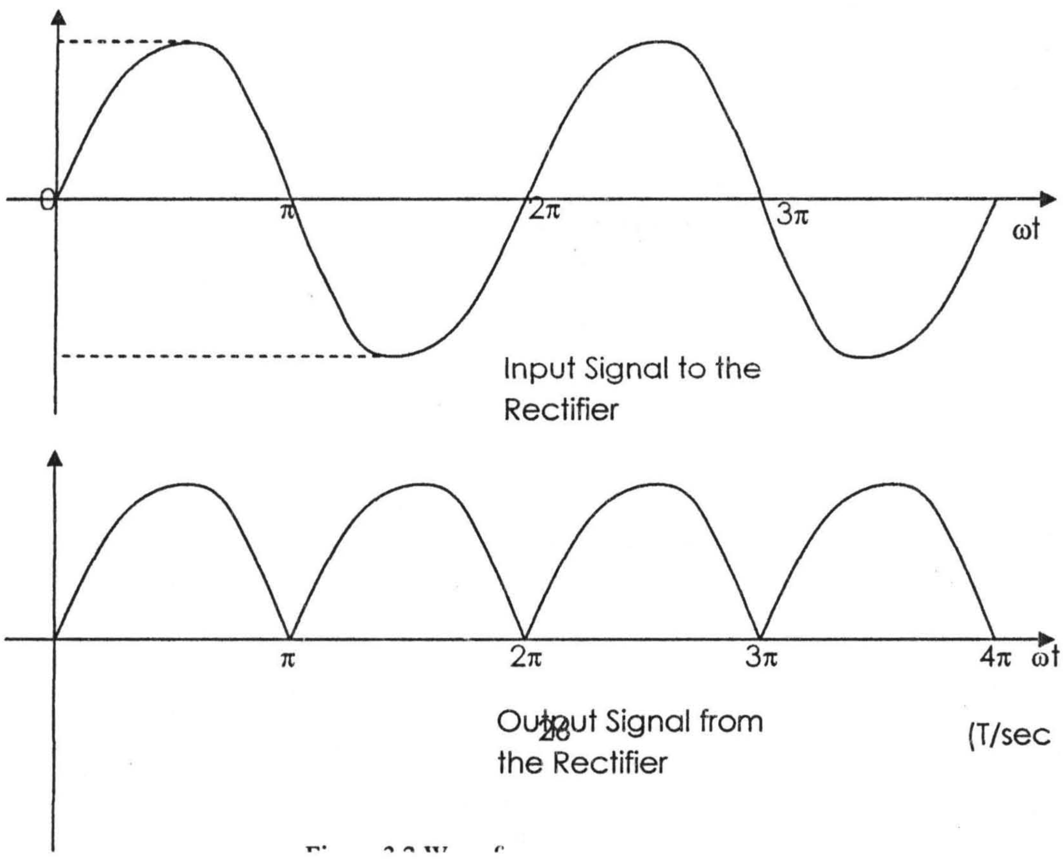
3.5 BATTERY CHARGER AND INDICATOR

This compose of the rectifier, filter and the indicator;

3.5.1 THE RECTFIER

This belong to the class of wave shapping circuit, whose pimary purpose is to convert AC voltage to DC voltage. The rectifier used in this circuit is called the bridge rectfier for full wave rectfictation.

The bridge rectifier is there to produce a full wave rectified wave form without using a centre tap transformer,. The bridge rectifier output is completely independent. There are two DC terminals, neither is common to the AC voltage with the circuit, both negative or positive DC supply voltage with respect to the ground can be produced. Connecting the positive terminal to the ground yield a negative supply while connecting the negative DC terminal to the ground yield a positive supply.



3.5.2 OPERATION OF THE CIRCUIT

For the time segment t_o to t_1, during the time interval, the ploarity of the AC voltage is such that it make AC, positive and AC_2 negative. This polarity turns D_1 and D_3 ON (forward biased) and D_2 and D_4 OFF. (reversed biased). As a result, trhe current I_1 through D_1 has the direction from +DC to – DC. Therefore, 15V, 10A transformer was used to charge the charge up the battery.

∴ the load resistance $15/10 = 1.5\Omega = E_m$

E_m = max voltage

Hence, the transformer input voltage = $240V_{rms}$, which is 20 times $\Rightarrow 12V_{rms}$ x $\sqrt{2}$ =16.97

≈17 peak to peak

Voltage DC = $\frac{2}{\pi} \times E_m$ = 0.637 Dc voltage as the rectifier voltage

$$\therefore I_{dc} = \frac{V_{dc}}{0.144}$$

Where V_{dc} = direct voltage

$$I_{dc} = \frac{V_{dc}}{0.144} = \frac{10.82}{0.144} = 75.14A$$

$$I_m \text{(current maximum)} = \frac{75.14}{0.636} = 118.14A$$

3.5.3 FILTERING

The rectified voltage waveform still contain a large amount of Ac component which maks the output terminal still vary with time. Therefore, the action of the filter is to remove the ripples.

Calculation for the ripple voltage left after filtering;

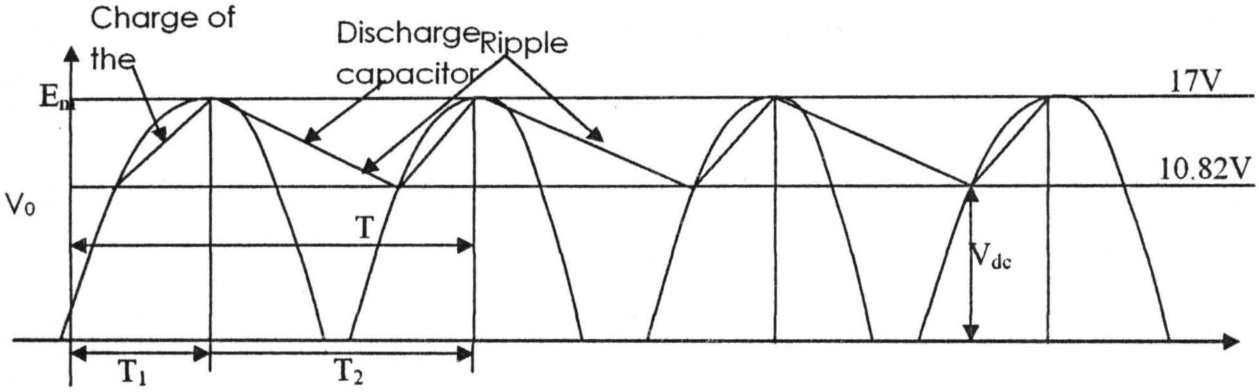


Fig 3.3 Diagram of Poor Filtering

To remove the ripple, I used a 50V, 3300μF capacitor after the rectifier.

Where T = The period of the rectified waveform

T_2 = Period of the discharge capacitor

T_1 = period of the chare capacitor

$\therefore$ $T = T_1 + T_2$

$$V_{ripple} = \frac{V_{dc}}{R_c} \times T_2$$

Therefore, the capacitor changes to the maximum voltage from the Dc voltage. Thus, $V_{dc} = E_m$ to obtain T_2; period of discharging of the capacitor it will discharge to 37% of the voltage supply (which is a standard)

$$37\% = \frac{37}{100} \times 17 = 6.29$$

$$V = V_D\left(\lambda^{-t/R_C}\right)$$

$$6.29 = 17\left(\lambda^{-t/4.7\times10^{-4}}\right)$$

$$\frac{6.29}{17} = \left(\lambda^{-t/4.7\times10^{-4}}\right)$$

$$0.37 = -\ \ln\frac{\frac{1}{t}}{4.7\times10^{-4}}$$

$$0.37 = -\ln\frac{4.7\times10^{-4}}{t}$$

$$0.37 = \frac{-(-7.662)}{-\ln t}$$

$$0.37 = \frac{7.662}{-\ln t}$$

$$-\ln t = \frac{7.662}{0.37}$$

$$-\ln t = 20.7$$

$$t = e^{-20.7}$$

$$T_2 = 1.0 \text{ x } 10^{-9}$$

$$V_{ripple} = \frac{V_{dc}}{4.7\times10^{-4}}\times1.0\times10^{-9}$$

$$V_{ripple} = \frac{17}{4.7\times10^{-4}}\times1.0\times10^{-9}$$

$V_{ripple} = 3.617 \text{ x } 10^{-5}$V

∴ The voltage ripple left in the system

$= 3.617 \text{ x } 10^{5}$V

3.5.4 INDICATOR

The voltage supply is 15V thus at the Zener diode resistance is 10mΩ. Therefore, the non – inverted voltage

$$\Rightarrow \quad V = \frac{15\times 1k}{1\times 10^{6} + 1\times 10^{3}} = \frac{15\times 1000}{1000000 + 1000} = 0.015\Omega$$

But at forward bias the current fall to

$$I_r = \frac{15-0.7}{1\times 1000} = 0.0105\text{A}$$

But 26 x 10^{-3} is constant from the internal voltage drop at the silicon diode

But dynamic resistance $r = \frac{26\times 10^{-3}}{I_r}$

$$r = \frac{26\times 10^{-3}}{0.0105} = 2.48\Omega$$

r =2.48Ω 26 x 10^{-3} = dynamic constant

At forward biase

$$\frac{15\times 1000}{2.48 + 1000} = 14.96$$

From this voltage, the Zener diode will substract – 68 = 14.96 – 6.8 = 8.16V

Therefore, +8.16Volts will be amplified to 2Volts less than rail voltage = 13V, which is delivered to the transistor and hence be conducted. Therefore, the NPN transistor is emitter follower which will indicate light at the emitter line (Red LED).

At the emitter follower = V_E = V_b. If 13V is fed to the base of the NPN transistor, the output voltage at the emitter will equal to the voltage base. Thus, the Red LED will be

ON at the emitter part of the transistor. Therefore, the voltage of the emitter is received by the diode that act as blockage to any reverse voltage by the battery

Hence, the battery will start charging until it becomes overloaded the excessive voltage will rise as positive voltage which is detected by the IN4001 diode.

Assuming overloaded voltage of 13V (above the nominal 12V) and varying the resistances of variable 10k and fixed 10k = 100k 17 x 10^3 and 3 x 10^3 = 17k + 3k;

$$\Rightarrow \frac{13\times17\times10^3}{17\times10^3+3\times10^3}=11.05\text{V}$$

Hence, the by the 11.05volt will be fed in the inverted of the operational amplifier which will be inverted to negative voltage comparator of the operational amplifier which was compared by the OP – amp.

= 13 – 11.05 = 1.95V

The above value will be amplified to 13V, thus positive voltage 1.95 which switches on the NPN transistor which indicated that the battery is fully charged.

3.6 CHANGEOVER

Here, there is an input sensor from the comparator which senses the drop of voltage to control a relay between one battery to the other, thus immediately the non – inverting input senses the drop of voltage excessively, it changes it's switches to change the battery and at the same changes over to a new battery. The comparator senses the voltage difference at the output to regulate the relay.

3.6.1 OPERATION

When 15 Volts is fed to the inverted input through the Zener diode. The diode becomes very low resistance to the incoming current, thus the resistance;

$$I_r = \frac{V-0.7}{10\times10^3} = \frac{12-0.7}{10\times1000} = \frac{11.3}{10\times1000} = 0.00113\text{A}$$

For ward current = forward resistance = $\frac{26\times10^{-3}}{1.13\times10^{-3}} = 23\Omega$

Therefore, the voltage acrsos the 10kΩ when varied t 7kΩ gives an output voltage at the input of inverted op-amp. Thus, the involved input V_o will be

Thus, the voltage at the inverted input

$= \frac{15\times7\times10^2}{7\times10^2+3.23} =$ 11.9V variable or the variable resistor varied to 6kΩ from 10kΩ.

therefore, the voltage received by the inverted input will be

$$\frac{15\times7\times10^2}{7\times10^2+3.23} = 11.9\text{V}$$

Therefore, the Zener diode subtrract the 3.3V from 11.9V to produce 8.6volts.

i. Put because the Zener resistance is very lower than the resistor adjacent the Zener diode.

ii. Also beON the cause the ohmic resistance of the Zener diode is close to the negative rail voltage, thus the negative voltage will be more pronounced at the inverted input. To this end, the inverted input receives a negative voltage of 8.6V, which is inverted by the op-amps to positive voltage of 8.6V.

The op-amp amplifies the 8.6V to 2V less than the rail voltage. Therefore, the voltage output is 10V, which switches BC 547 NPN transistor. The siwtching transistor base current.

$$I_b = \frac{V_H - 0.7}{R_b}$$

$$I_b = \frac{10-0.7}{10k\Omega} = \frac{10-0.7}{10\times10^3} = \frac{9.3}{10\times10^3} = 0.93\text{mA}$$

Hence, the collector current of the BC547 will yield? If the current gain I_c/I_b and gain for siheon transistor =200.

I_c = gain x I_b

$I_c = 200 \times 0.93 \times 10^{-3}$

$I_c = 0.186A$

Since the relay voltage and current capacity from the manufcaturer is 60A, 12V. Therefore, the resistance

$$R = \frac{V}{I} = \frac{12}{60} = 0.2\Omega$$

Voltage drop at the collector will be 0.2 x 0.186 (I_cR_c)

$V_{drop} = 0.0372V$

$\therefore$ The output voltage will be $V_{cc} - I_cR_c$

$= 12 - 0.0372 = 11.9628V$

Therefore 11.9628volts was used by the transistor to switch ON the relay. At the side when the battery voltage, the non – inverted input voltage wil rise up to 8.6V while the inverted voltage input will all due to the discharge of the battery in response to power consumption of the system attached. Therefore, the non – inverted input voltage received high voltage than the inverted input voltage. At such instance, the non – inverted input voltage gains dominates than the inverted input voltage of the op-amp. Hence, the non – inverting voltage will substract from the inverted voltage in which the non – inverted voltage will be more pronounced at the output of the op-amp. At this juncture the transistor is switched as a result of positive voltage received. Notice the Zener diode at its lower resistance during condition is coupled at the positive rail power supply. So that the input of the non – inverting op – amp to receive a positive signal. The transistor is switched ON, and it controls the relay to change the battery to the other one for constant power supply.

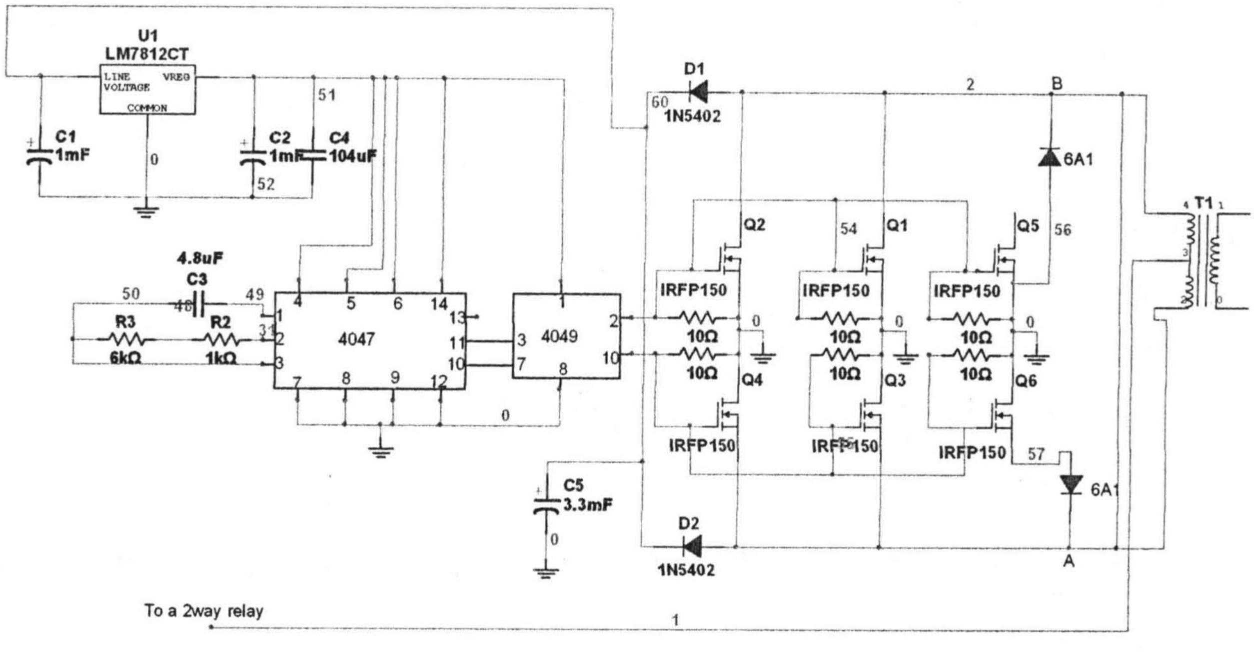


Fig 3.4 Inverting circuit

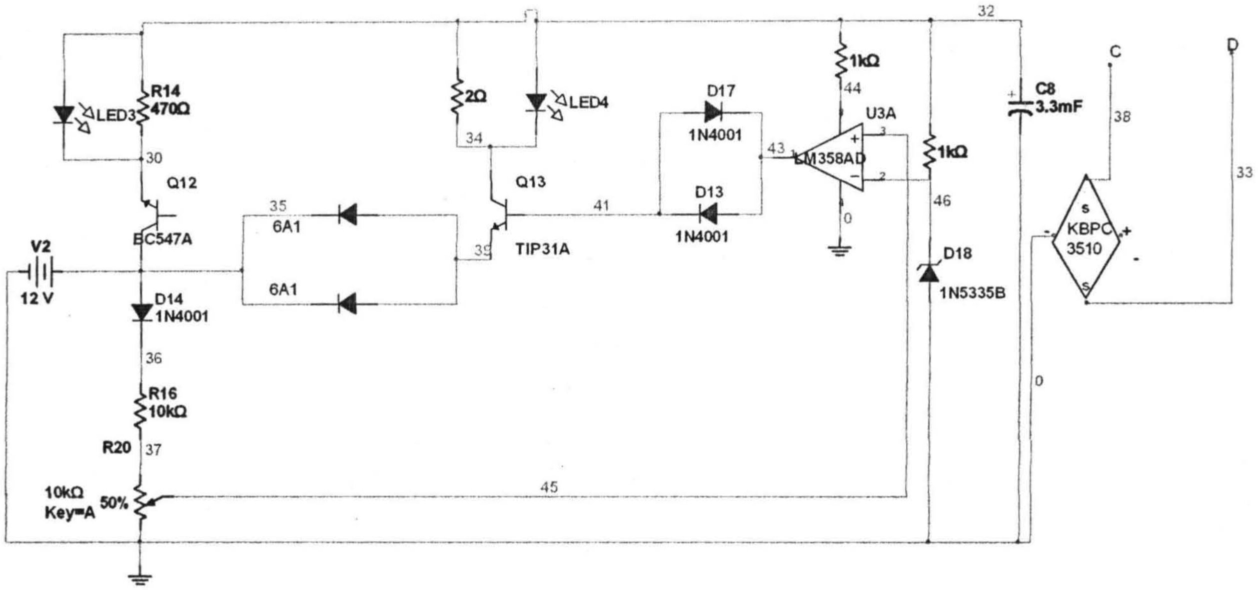


Fig 3.5 Circuit diagram of 1KVA voltage inverter

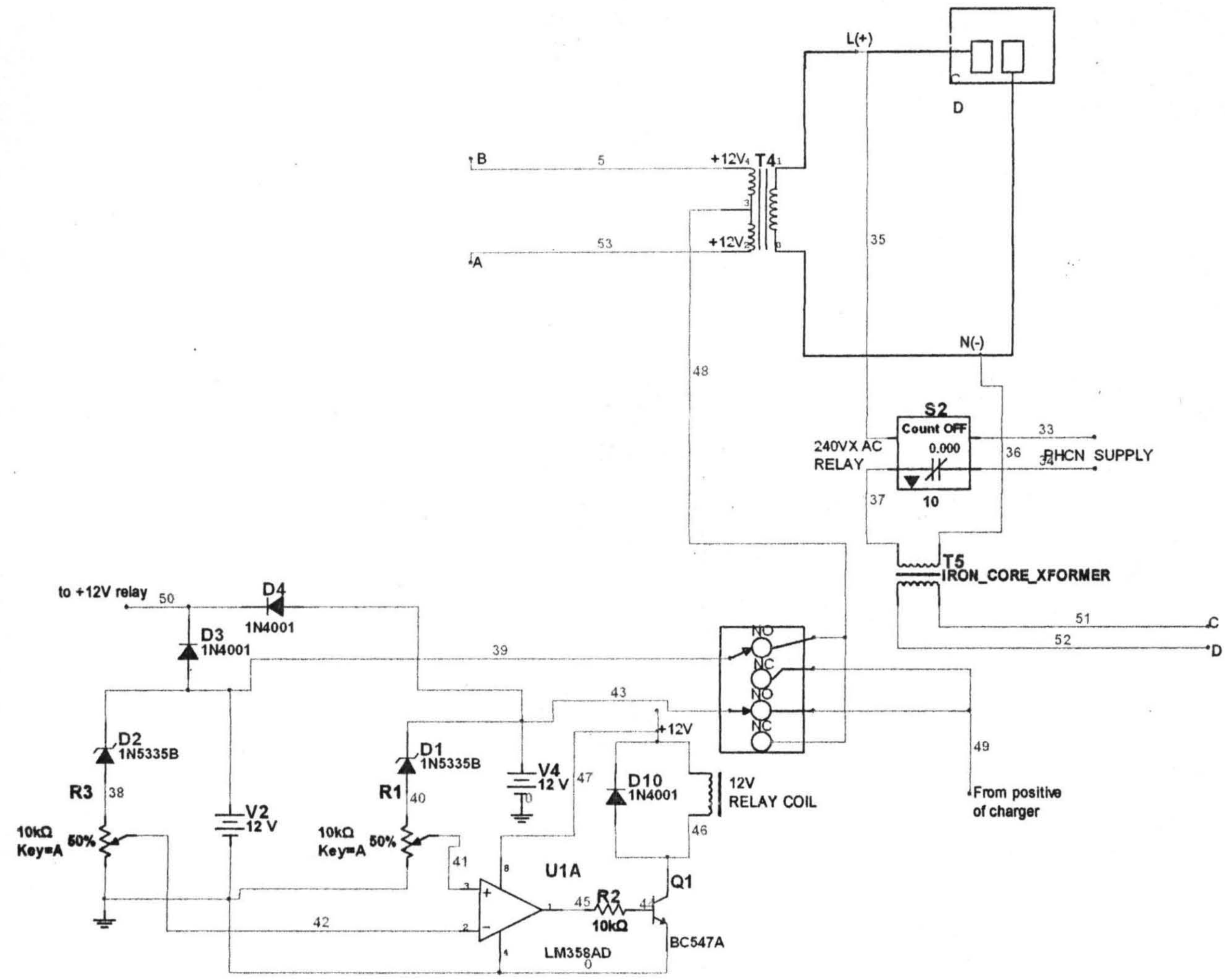


Fig 3.6 changeover system

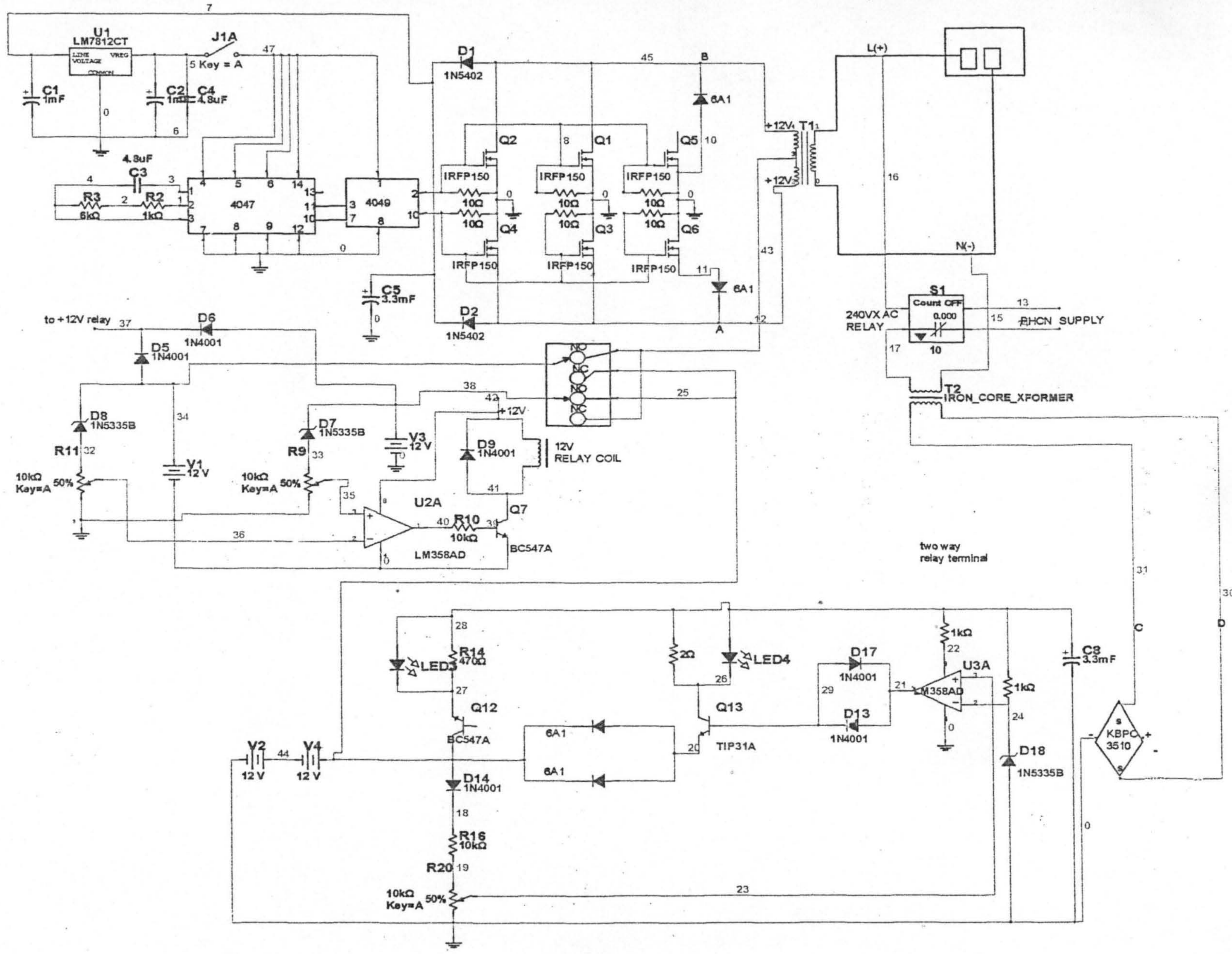


Fig 3. Complete circuit diagram

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1 CONSTRUCTION AND TESTING

The construction of this project was done in the stages; the soldering of components on the vero board and then the coupling of the entire project into a casing designed to contain the dfferent modules of the project. The inverter transformer was first constructed, then the inverting circuit, the changing and indicating circuit and then the changeover circuit. All of which are then assembled into a casing.

The vero boarding of the repsective components was doen on three different vero boards. This is because of the complexity of the cricuit and the modular approach in the design nd construction. The first vero board carried the inverting circuit (system) the second board is carrying the indicating and charging circuit and third is carrying the changeover cicruit.

The second stage is the casing of the project. The casing is made of metal. The metal material is wrought metal designed with special perforation to serve as vents and was also sprayed (painted) to ensure insulatioon and aesthetic value.

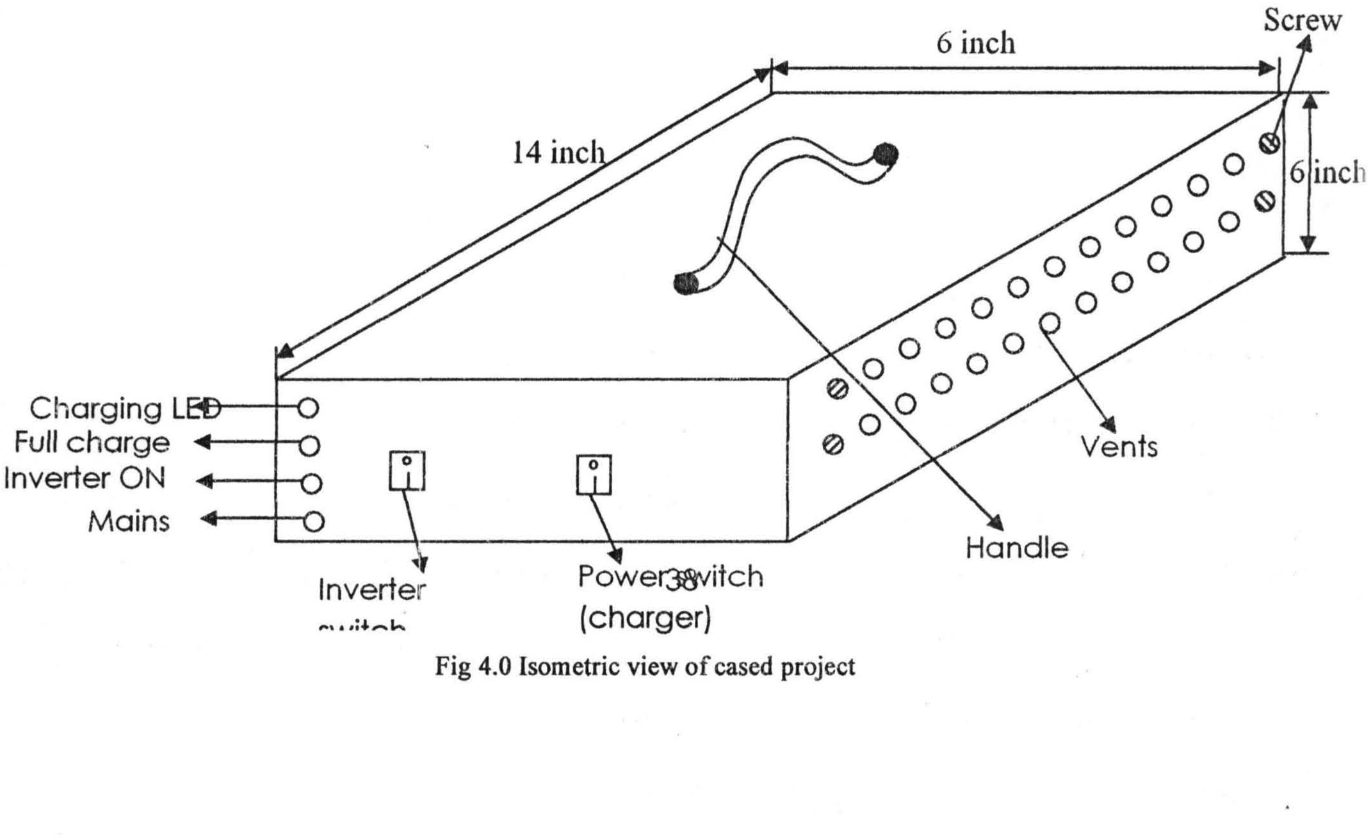


Fig 4.0 Isometric view of cased project

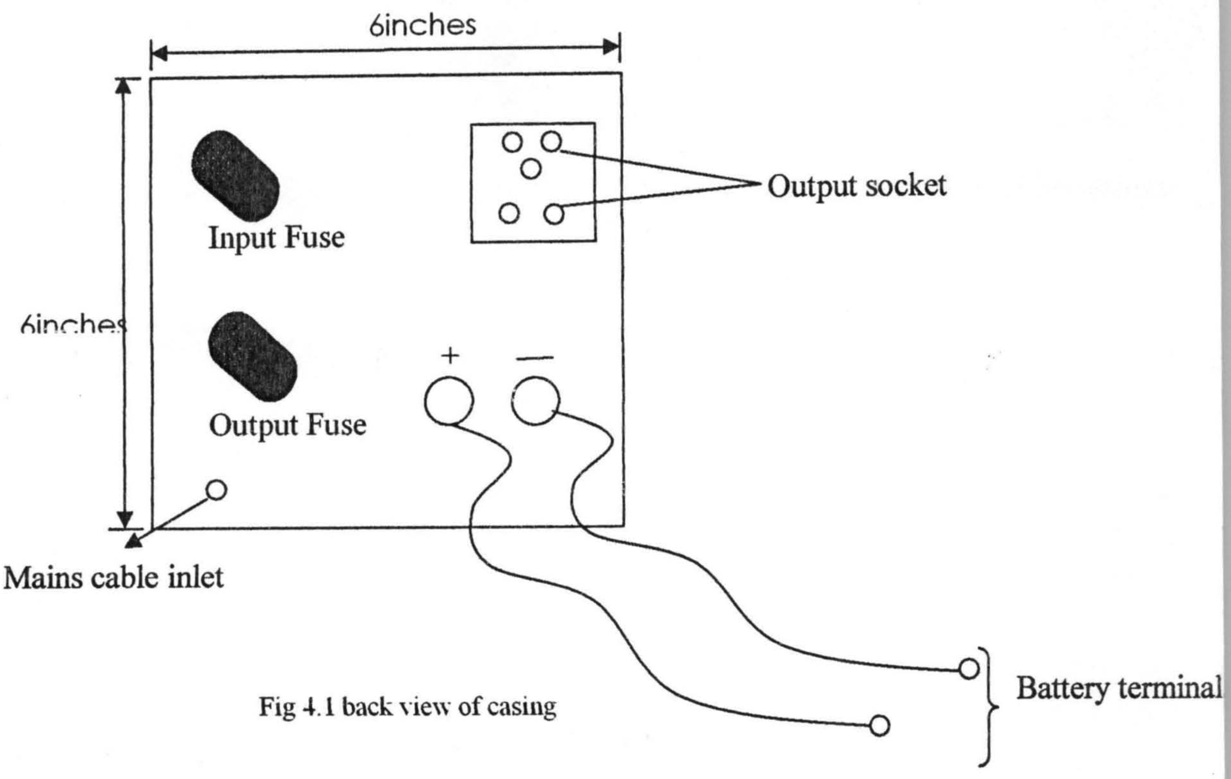


Fig 4.1 back view of casing

4.2 TESTING

The physical realization of the project is is very vital. This is where the fantasy of the whole idea meets reality. The work at this stage is not just on paper, but as a finished hardware system. After carrying out all paper design and analysis, the project was implemented and tested be sure of its working capability. Finally, it is constructed to meet the desired specification. The testing was carried out as follows;

- Oscilloscope: The oscilloscope was used to observe the ripple in the power supply wave form and also to check the oscillator wave form as well as the oscillator frequency.
- Multimeter: - The specified and expected input and out of the found correct. Continuity, resistance, voltage and current of components were also tested and found to comply with the calculations in chapter three.
- The entire system output test carried out on noload and on load.

4.3 DISCUSSION OF RESULT

The result obtained from the project is very satisfactory. The primary aim of obtaining a 1kVA output from the inverter was achieved and the interrupted constant supply was also achieved. 220VAC from 12VDc battery was also achieved.

4.3.1 DESIGN SPECIFICATIONS

- Output power 1kVA
- Output waveform = Pulse width modualation
- Output frequency = 50Hz
- Output voltage = 220 volts AC
- Charging type = constant voltage
- Charging mode indicator = Red LED
- Fully charged mode indicator = Green LED

The capacity of an inverter is a function of

- The type and number of power MOSFETS used
- The size and capacity of the power transformer.

4.4 PROBLEMS ENCOUNTERED

1. The MOSFET were overheating, hence, the idea of heat sink to reduce the heating.
2. There was noise in the inverting transformer, so a vanish was applied to hold the coils move compact together to clear the noise.

3. It was difficult getting some components over the shelf. Hence, equivalent were used after consulting the data sheet.
4. It was difficult at first to realise and constume the changeover system

CHAPTER FIVE

CONCLUSION AND RECOMMEDATION

5.1 CONLUSION

This project which is the design and construction of 1kVA voltage inverter with automatic changeover for remote application was carried out. The inputs were based on the following factors; economy, availability of components and research materials, efficiency compatibility, portability and druability. The performance of the project after testing met design specification. The general operation of the project and performance is dependent on the user whio is prone to human error, such as overloading the system making wrong battery connection or using wrong battery. (wrong battery voltage).

Also, the operation is dependent on how well the soldering is doen and the positioning of the components on the vero – board (if logic elements and ICs are soldered near components that indicate heat, overheating night affect the perofrmance of the entire system.

The construction was done in way that makes maintenance, troubleshooting for possible faults and repairs an easy task and affordable for the user in case of a breakdown/fault.

This project really exposed me more to eletronic components and ICs. An indepth knowledge of the internal circuitry, working and application practically of electronic components and ICs generally. The design of this project (1kVA inverter) involved research in electronics and multivibrators. The project was quite challenging, but was eventually a success. It has also prepared me to face present and future challenges in electronics handling.

5.2 RECOMMENDATIONS

1. I recommend tha the department should make provision for digital simulators and equipmennts to enable students carry out tests and measurements. This will reduce the time an trouble of obtaining results.
2. Further research should be done on the area of other energy sources like solar and wind.
3. Research should be done on building very high capacity inverters like 5kVA above.

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