# DESIGN AND CONSTRUCTION OF 3KVA POWER INVERTER

## (24V DC - 230V AC)


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# DEDICATION

This project is dedicated to Allah the Almighty, for his mercy over me since inception of my life till present and forever. Also I will like to dedicate the project to my entire family member.

# DECLARATION

I kabir usman, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also here by relinquish the copyright to the federal university of technology, minna.

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# ABSTRACT

This project is a design and construction of 3KVA inverter with the use of 24volt DC and produces 230volt AC. An **inverter** is an electrical device that converts direct current (DC) to alternating current (AC). The converted AC can be at any required voltage and frequency with the use of appropriate oscillator circuit, transformers, switching, and control circuits. Incorporated into these systems are devices such as transistors, MOSFETs, diodes, resistors and batteries which work hand in hand to obtain the overall desired operation of an inverter. Problems were encounter and solved in the course of this project design. This project was well research, criticized, analyzed, designed and constructed to give a specified output.

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# CHAPTER ONE

## 1.0 INTRODUCTION

Perhaps the most rapidly growing in modern power electronic is static frequency conversion, the conversion of ac power at one frequency to ac power at another frequency by means of solid state electronics. Traditionally there have been two approaches to static frequency conversion Cycloconverter and the rectifier inverter. The cycloconverter is a device for directly converting ac power at one frequency to ac power at another frequency, while the rectifier inverter first convert ac power to dc power and then to convert the dc to ac power gain at different frequency[1].

Inverter allows the use of 230V electrical appliances from a car battery or a solar battery. It must therefore supply a voltage that corresponds to an rms of 230 Volts sine-wave like household main supply or similar. Sine-wave voltages are not easy to generate. The advantage of sine-wave voltages is the soft temporal rise of voltage and the absence of harmonic oscillations, which cause unwanted counter forces on engines, interferences on radio equipment and surge currents on condensers. On the other hand, square wave voltages can be generated very simply by switches, example electronic valves like MOSFET transistors. In former times electromagnetic switches that operated like a door bell were used for this task. They were called "chopper cartridge" and mastered frequencies up to 200 cycles per second. The efficiency of a square wave inverter is higher than the appropriate sine wave inverter, due to its simplicity. With the help of a transformer the generated square wave voltage can be transformed to a value of 230 Volts (110 Volts) or even higher [2].

Pulse width modulation inverters require more complex control circuitry and faster switch components. Pulse width modulation is a process of modifying the width of the pulse in a pulse train in direct proportion to a small control signal; the greater the voltage, the wider the resulting pulses become. By using a sinusoidal of the desire frequency as the control voltage for a pulse width modulation circuit, it is possible to produce a high power waveform whose average voltage varies sinusoidal in manner suitable for driving ac motor [1].

A pulse width modulation inverter switches state many times during a single cycle of the resulting output voltage. The reference voltage with frequency as high as 12KHz are use in pulse width modulation inverter design so the component in a pulse width modulation inverter must change state up to 24,000 times per second. This rapid switching means that pulse width modulation inverter require faster component. Pulse width modulation inverter need high power high frequency components such as G.T.O, thyritor , IGBT, and/or power transistors for proper operation.( CMOSFET have the advantage for high speed, low power switching, so they are the preferred component for building pulse width modulation inverter) the control voltage fed to the comparator circuit is usually implemented digitally [1].

## 1.1 OBJECTIVES:

To design and construct a 3KVA capacity inverter with control unit and over load protection.

The project is use to find an alternative source of power supply, with great advantages such as free from noise, Free from smoke and Minimize cost in buying fuel unlike generator.

## 1.2 SCOPE OF THE STUDY

The scope of this inverter is suitable for a load up to 3KVA capacity. This means that it can serve load like electric drills, circular saws, electric chain saws, grinders Vacuum cleaners, coffee machines, irons, dryers, mixers, sewing machines, electric razors, etc. lamps, energy-savings lamps and Electronic devices, example music amplifiers, battery chargers, computers and accessories, UPS Televisions and radios, radio transmitters, high voltage generators, among other things.

## 1.3 METHOD OF STUDY

The method used in this study is by consulting several textbook, journals, data books, internet and consulting various technicians with vast experience.

# CHAPTER TWO

# LITERATURE REVIEW

# THE DEVICES AND SYSTEMS THAT MAKE UP THE INVERTER

## 2.1 HISTORY OF INVERTER

From the late 19$^{th}$ century, through the middle of the 20$^{th}$ century, direct current (DC) to alternating current (AC) power conversion was accomplished using rotary converters or motor generator sets (M-G sets). In the early 20$^{th}$ 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 [1]. The origins of the electromechanical inverters explained the source of the term inverter. Early AC to DC converters used an induction or synchronous AC motor directly connected to a generator (dynamo) so that the generator commutator reversed its connections at exactly the right moments to produce DC. A later development is the synchronous converter, in which the motor and generator windings are combined into one armature, with slip rings at one end and a commutator at the other only one field frame. The result is either ac-in dc-out. With an M-G set, the DC can be consider to be "mechanically rectified AC". Give the right auxiliary and control equipment, an M-G set or rotary converter can be "run backwards", converting DC to AC. Hence, an inverter is an inverted [3].

## 2.2 THE P-N JUNCTION DIODE

The P-N junction diode is a two terminal electronic device offering low resistance when forward biased and behaving almost as an insulator when reverse biased. It consists of a P-N Junction formed in either germanium or silicon crystal. Germanium is often used in low and medium power diodes since it has higher electrical conduction capabilities than silicon. Silicon is more suitable for use in high power application because it can be operated at higher temperatures than germanium. The low current diodes can carry a forward current of about 100mA and withstand a reverse voltage of 75V without breakdown. The medium current diodes can pass a forward current of about 500mA and withstand a reverse voltage of 250V. The high current or power diodes can pass a forward current of many amperes and survive several hundred volts of reverse voltage [4].

### 2.2.1 THE CURRENT/VOLTAGE CHARACTERISTICS OF THE P-N JUNCTION DIODE

These are static characteristics because they describe the dc behavior of the diode. The figure below shows the static current-voltage characteristics of a P-N junction diode.

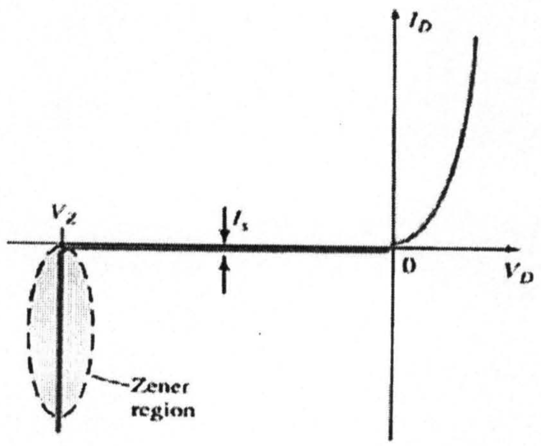



**Figure 2.1: current/voltage characteristics of p-n junction diode**

Forward biasing the p-n junction of the diode drives holes to the junction from the p-type_material and electrons to the junction from the n-type_material. At the junction the electrons and holes combine so that a continuous current can be maintained. When the diode is initially forward biased and the applied voltage is increased from zero, hardly any current flows through the device because the external voltage is being opposed by the internal barrier voltage $V_B$ whose value is 0.7V for silicon and 0.3V for germanium. As soon as $V_B$ is neutralized, the current through the diode increases rapidly with increasing applied battery voltage. A burnout is likely to occur if the forward voltage is increased beyond a certain safe limit [1]. The application of a reverse voltage to the p-n junction will cause a transient current to flow as both electrons and holes are pulled away from the junction. When the potential formed by the widened depletion layer equals the applied voltage, the current will cease except for a small thermal current. Increasing the reverse voltage from zero causes the reverse current to reach its saturation value (Is) very quickly. This maximum current is known as the leakage current. It is of the order of nanoamperes for silicon and microamperes for germanium. It is dependent on temperature and the physical size of the junction but independent on the applied reverse voltage. As seen from the current/voltage curve above, the leakage current suddenly and sharply increases when the reverse voltage exceeds a certain value called breakdown voltage, $V_{BR}$ or zener voltage, $V_Z$. At this point, the curve indicates zero resistance. A burnout is likely to occur with any further increase in voltage unless protected by a current limiting resistor [4].

## 2.3 THE POWER BIPOLAR JUNCTION TRANSISTOR (BJT)

Bipolar Junction Transistor (BJT) is a semiconductor device constructed with three doped semiconductor regions (Base, Collector and Emitter) separated by two P-N junctions. The P-N junction between the Base and the Emitter has a barrier voltage of about 0.6 V, which is an important parameter of a BJT. Current is produced by both types of charge carriers (Electrons and Holes) of the BJT, hence the name bipolar. There are three basic configurations for operating a transistor, common base, common emitter and common collector. The term 'common' is used to denote the electrode that is common to the input and output circuits [5].

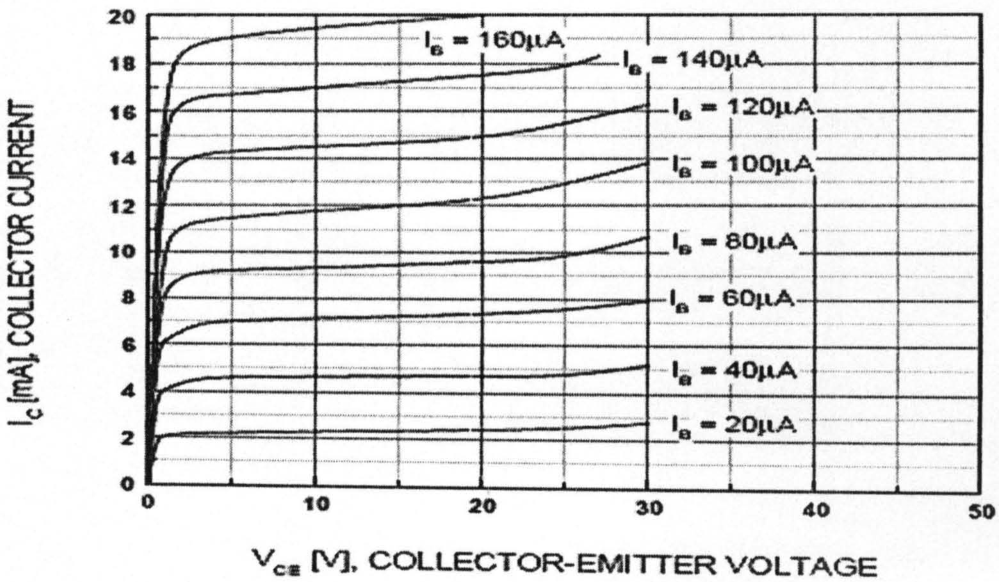



**Figure 2.2: collector characteristics of a silicon transistor in the common-emitter configuration**

### 2.3.1 THE CURRENT-VOLTAGE CHARACTERISTICS OF A TRANSISTOR

Since most applications have a common emitter configuration, its characteristics will be explained.

In figure 2.2, there are regions of operation the cut off saturation and active regions. If the base current is zero, the collector current, IC, is negligible and transistor is in the cut off region which is the off state of the transistor. In this region both the collector-base and base- emitter junctions are reverse biased and the transistor behaves as an open switch. However, if the base Current is sufficient to drive the transistor into saturation (the collector current is very high and $V_{CE}$ is approximately zero), then the transistor behaves as a closed switch. In the saturation region, both junctions are forward biased. In the active region of operation, the base- emitter junction is forward biased while the collector- base junction is reversing biased. The active region is used for amplification and is avoided in switching applications [1].

### 2.3.2 BIASING A TRANSISTOR

Biasing is the method of establishing predetermined voltages and/or currents at various points of a circuit to set an appropriate operating point. Small signal bipolar transistor_amplifiers must be properly biased to operate correctly. The discrete components commonly employed in biasing networks are resistors and capacitors. The two types of transistor biasing employed used in this project are the fixed biasing and voltage divider biasing [4].

### 2.4 DIGITAL INTEGRATED CIRCUIT

About 80 percent of the integration circuit (IC) market has been captured by digital integration circuits which are mostly utilize by the computer industry. Digital integration circuits lend themselves easily to monolithic integration because computers have large number of identical circuits. Moreover, such circuits employ relatively few capacitor and values of resistances, voltage and currents flow [6].

Digital electronic involves circuit and systems in which there only two possible states. These states are represented by two different voltage levels. A HIGH and A LOW. The two states can also be represented by current levels, open and closed switches [7].

#### 2.4.1 FLIP-FLOP

The most important memory element the flip-flop is made up of an assembly of logic gate. It may be noted that even though a logic gate by itself, has no storage capability but several such logic gate can be connected together in ways that permit information to be stored several different gate arrangement are used to produced these flip-flop[7].

##### 2.4.1.1 DUAL D-FLIP-FLOF

The D flip-flop tracks the input, making transitions with match those of the input D. The D stands for "data"; this flip-flop stores the value that is on the data line. It can be thought of as a basic memory cell. A D flip-flop can be made from a set/reset flip-flop by tying the set to the reset through an inverter. The result may be clocked. The D flip-flop tries to follow the input D but cannot make the required transitions unless it is enabled by the clock. Note that if the clock is low when a transition in D occurs, the tracking transition in Q occurs at the next upward transition of the clock show in figure 2.3 [4].

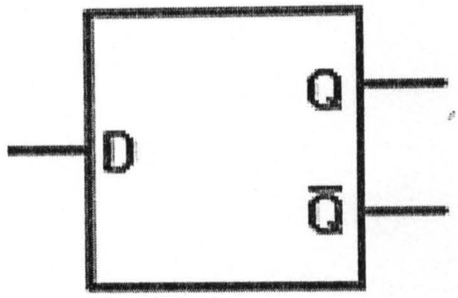



**Figure 2.3: D-flip flop**

This device contains two, identical flip-flop that are independent of each other except for sharing $V_{CC}$ and ground. It useful when a single data bit (0 or 1) is be stored. Note that the output is a square wave of half the frequency of input [6].

### 2.4.2 COMPLEMENTARY METAL OXIDE SEMI CONDUCTORS (CMOS)

The CMOS family of integration circuits (IC) competes directly with transistor-transistor logic (TTL) in the small and medium scale integration. As CMOS technology has produced better and better performance characteristics, it has gradually taken over the field that has been dominated by TTL for so long. As a matter of fact, TTL devices will be around for a long time, but more and more new equipment are using CMOS logic circuits. These days the CMOS integrated circuit (IC) provide all logic function that are available in TTL some special purpose functions provided in CMOS integration circuits are not provided even by TTL [6].

Using field-effect transistors instead of bipolar transistors has greatly simplified the design of the inverter gate. Note that the output of this gate never floats as is the case with the simplest TTL circuit: it has a natural "totem-pole" configuration, capable of both sourcing and sinking load current. Key to this gate circuit's elegant design is the complementary use of both P- and N-channel IGFETs. Since IGFETs are more commonly known as MOSFETs (Metal-Oxide Semiconductor Field Effect Transistor), and this circuit uses both P- and N-channel transistors together, the general classification given to gate circuits like this one is CMOS: Complementary Metal Oxide Semiconductor.

CMOS circuits aren't plagued by the inherent nonlinearities of the field-effect transistors, because as digital circuits their transistors always operate in either the saturated or cutoff modes and never in the active mode. Their inputs are, however, sensitive to high voltages generated by electrostatic (static electricity) sources, and may even be activated into "high" (1) or "low" (0) states by spurious voltage sources if left floating. For this reason, it is inadvisable to allow a CMOS logic gate input to float under any circumstances. Please note that this is very different from the behavior of a TTL gate where a floating input was safely interpreted as a "high" (1) logic level.

This may cause a problem if the input to a CMOS logic gate is driven by a single-throw switch, where one state has the input solidly connected to either Vdd or ground and the other state has the input floating (not connected to anything) [6]

**2.4.2.1 QUAD 2-INPUT NAND GATE**

The quad 2-input NAND gate (CD4093B) consists of four Schmitt-trigger circuits. Each circuit functions as a 2-input NAND gate with Schmitt-trigger action on both inputs. The gate switches at different points for positive and negative-going signals. The difference between the positive $V^{+}_{T}$ and the negative voltage $V_{T}^{-}$ is defined as hysteresis voltage $V_{H}$ [8].

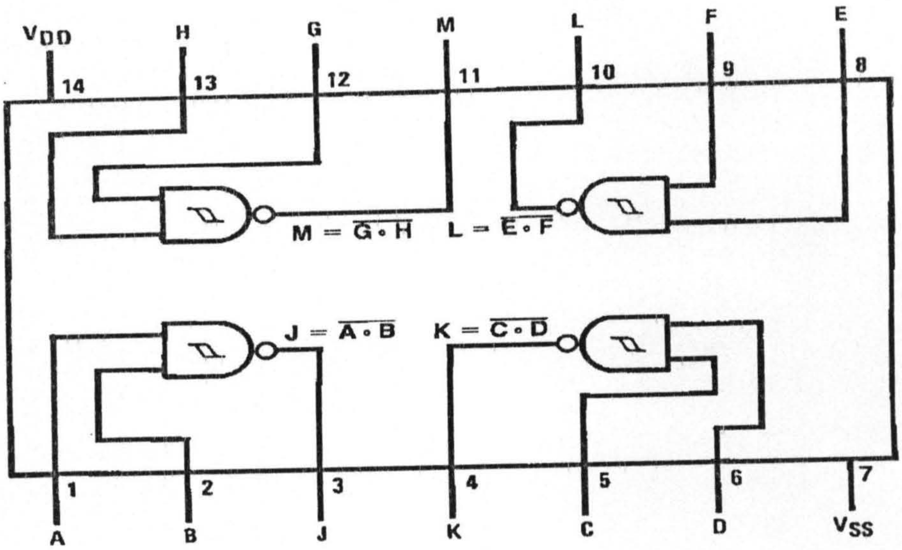



**Figure 2.4: Quad 2-input NAND gate**

All of quad 2-input series CMOS are pin compatible with the same types of devices in TTL. This means that a CMOS digital integration circuits such as 4093 (quad 2-input NAND), which contain four 2-input NAND gates in one integration circuit package, has the identical package pin numbers for each input and output [6].

### 2.4.2.2 THE POWER METAL-OXIDE SEMICONDUCTOR FIELD-EFFECT TRANSISTOR (MOSFET)

The Metal-Oxide Semiconductor Field Effect Transistor (MOSFET) or MOS transistor is a type of transistor that consists of a metal layer, an oxide layer, and a semiconductor layer. The semiconductor layer is usually in the form of single-crystal silicon substrate doped precisely to perform transistor action. The oxide is usually in the form of a silicon dioxide layer that insulates the semiconductor layer from the metal layer. The metal layer is used as contact for providing voltage inputs to the MOS transistor.

The MOS transistor consists of three terminals: a gate, a source, and a drain. These are equivalent to the base, emitter, and collector of a bipolar transistor. The metal layer of the MOS transistor serves as the gate, while the source and drain are fabricated on the substrate. Like a bipolar transistor, the current flowing through a MOS transistor is controlled by the input at its gate. However, unlike a bipolar transistor which is controlled by the amount of current into its base, a MOS transistor is controlled by the voltage level at its gate. The source and drain of a MOS transistor are created on the silicon substrate in such a way that they are 'sandwiching' the gate. The source and drain are doped to be of the same material type, which should be different from the doping received by the substrate. A MOS transistor is referred to as a P-channel MOSFET, or PMOS, if the source and drain are p-type, and the substrate is n-type. It is an N-channel MOSFET, or NMOS, if the source and drain are n-type and the substrate is p-type. Some of the advantages of MOSFET include its switching speed and thermal stability. An added advantage of The MOSFET is that it provides current and voltage gain yielding an output current into an external load which exceeds the input current and an output voltage across that external load which exceeds the input voltage. The voltage gain of the MOSFET is caused by the fact that the current saturates at higher drain-source voltages, so that a small drain current variation can cause a large drain voltage variation. The device has an infinite current gain in DC. The current gain is inversely proportional to the signal frequency, reaching unity current gain at the transit frequency [5].

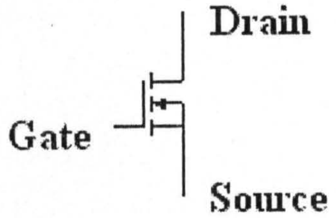



**Figure 2.5a: N-channel enhancement mosfet**

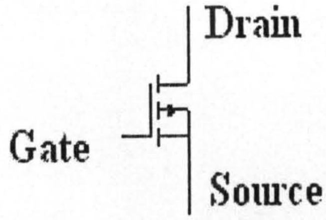



**Figure 2.5b: P-channel enhancement mosfet**

## 2.5 OPERATIONAL AMPLIFIERS

An operational amplifier is a very high gain differential amplifier with high input impedance and low output impedance. Typical uses of the operational amplifier are to provide voltage amplitude changes (amplitude and polarity), filter circuits, and oscillators

Although an operational amplifier is a complete amplifier, it is so designed that external components (resistors, capacitors e.t.c) can be connected to its terminal to change its external characteristics. Hence, it is relatively easy to tailor this amplifier to fit a particular application and it is, in fact, due to this versatility that operation amplifiers have become so popular in the industry [4].

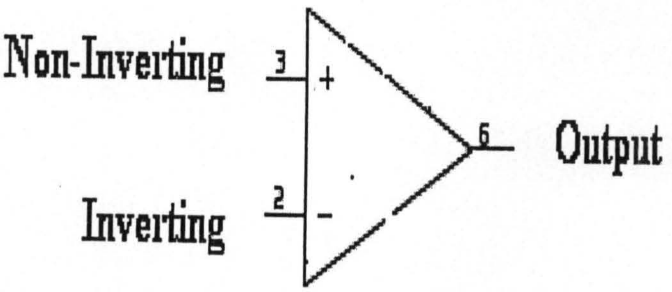



**Figure 2.6: Operational Amplifier**

### 2.5.1 OSCILLATOR

It is a circuit which generates an alternating current (AC) output signal without requiring any external applied input signal; it is an unsuitable amplifier show in figure 2.7 [7].

The use of positive feedback that result in a feedback amplifier having close-loop gain greater than 1 and satisfies the phase condition will result in operation as an oscillation circuit. An oscillation circuit then provides a varying output signal. If the output signal varies sinusoidal, the circuit is referred to as a sinusoidal oscillator. If the output voltage rises quickly to one voltage level and later drops quickly to another voltage level, the circuit generally referred to as a pulse or square wave oscillator [4].

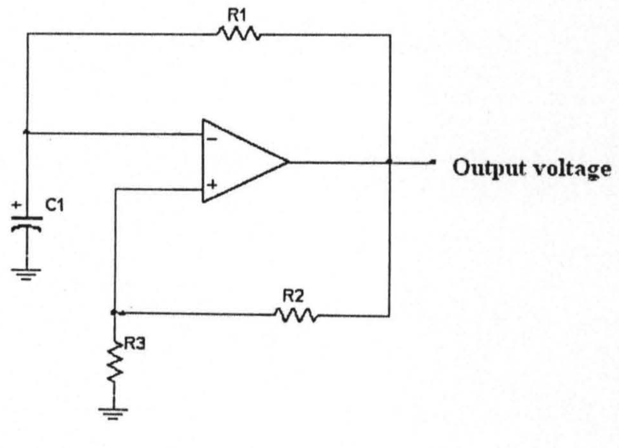



**Figure 2.7: Oscillator circuit**

## 2.6 VOLTAGE MULTIPLIER AND RECTIFICATION CIRCUIT

A rectifier is an electrical device comprising of one or more semi conductive devices such as diodes arranged for converting alternating current to direct current. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting AC to DC than is possible with just a single diode. Rectification could be either half-wave or full-wave In half wave rectification, either the positive or negative half of the AC wave is passed easily while the other half is blocked, depending on the polarity of the rectifier. It is very inefficient if used for power transfer because only one half of the input waveform reaches the output [4].

Voltage multiplier circuits are employed to maintain a relatively low transformer peak output voltage to two, three, four or more times the peak rectifier [2].

## 2.7 INTEGRATED CIRCUIT (IC) VOLTAGE REGULATOR

Voltages regulators comprise a class of widely use ICS. Regulator IC unit contain the circuitry for reference source, comparator amplifier, control device and overload protection, all in single IC. IC unit provide regulation of a fixed positive voltage, a fixed negative voltage or an adjustably set voltage [4].

### 2.7.1 FIXED POSITIVE VOLTAGE REGULATORS

The series 78 regulators provide fixed regulated voltage from 5v to 24v, having three terminals. A 7812 IC can connect to provide voltage regulator with output from this unit of +12v dc. An unregulated input voltage regulator is filtered by capacitor and connected to the integrated circuits (IC) input terminal. The IC output terminal provides a regulated +12, which is filtered by another capacitor (mostly for any high frequency noise). The third IC terminal is connected to ground the circuit symbol show in figure 2.8[4].

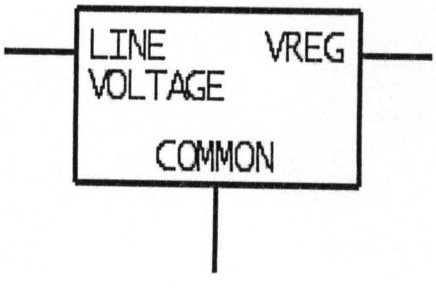



**Figure 2.8: Voltage regulator**

## 2.8 THE TRANSFORMER

When transmitting electrical power over long distances, it is far more efficient to do so with stepped-up voltages and stepped-down currents (smaller-diameter wire with less resistive power losses), then step the voltage back down and the current back up for use [5]. This can be done effectively with the use of a transformer. A transformer is an electrical device that transfers energy from one circuit to another purely by magnetic coupling. It consists of two electrical conductors called the primary winding and the secondary winding. Windings on both primary and secondary of a power transformer may have external connections (called taps) to intermediate points on the winding to allow adjustment of the voltage ratio. A center-tapped transformer is often used in the output stage of a power amplifier in a push-pull circuit [7].

## 2.9 THE BATTERY

A battery is a device that converts chemical energy directly to electrical energy. It has two terminals. One terminal is marked (+), or positive, while the other is marked (-), or negative. Electrons collect on the negative terminal of the battery. If a wire is connected between the negative and positive terminals, the electrons will flow from the negative to the positive terminal as fast as they can (and wear out the battery very quickly -- this also tends to be dangerous. Normally, some type of load is connected to the battery using the wire. Inside the battery itself, a chemical reaction produces the electrons. The speed of electron production by this chemical reaction (the battery's internal resistance) controls how many electrons can flow between the terminals.

# CHAPTER THREE

# DESIGN AND IMPLEMENTATION

## 3.1 ANALYSIS OF THE CIRCUIT DIAGRAM

The circuit design of an inverter with a load protection can be represented by the block diagram in Figure 3.0 below.

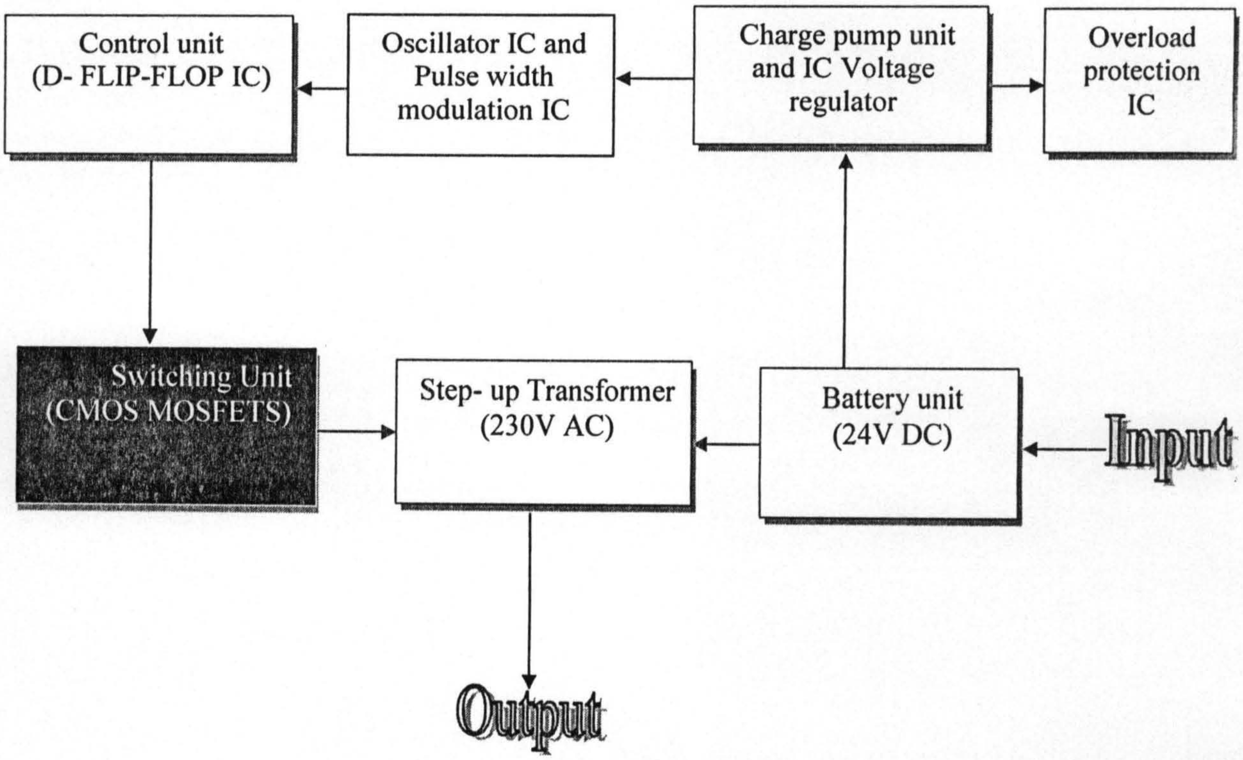


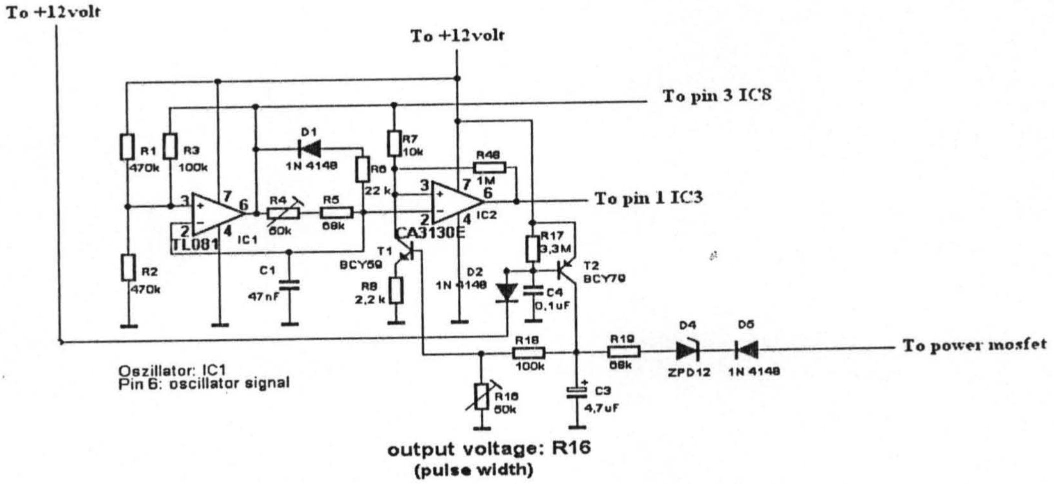

**Figure 3.1: Block diagram of the inverter**

The block diagram above displays a stage by stage breakdown of the major components required for the inverter design which are as follows:-

- Battery unit(24V DC)
- Charge pump( IC and voltage doubler)
- IC voltage regulator
- Oscillator IC

- Pulse width modulator IC
- Control unit ( D FLIP-FLOP)
- Switching circuit (CMOS MOSFEST)
- Over load protection IC
- Step up transformer(230V)

## 3.2 OSCILLATOR AND PULSE WIDTH MODULATION




. **Figure 3.2: Oscillator and pulse width modulation circuit**

The inverter chops the 24 Volt DC Battery voltage into a square wave voltage of 50 cycles per second and duty cycle of 25%, transformed by transformer to 230 Volt rms.

IC1 forms the oscillator with 100 cycles per second (120 cycles per second for 60 cycles output). Frequency was determined by C1 and the resistors R4 and R5. Resistor R6 determines the time of the fly back of the oscillator and affects likewise the frequency. In addition, R6 affects the RMS of the output voltage.IC2 determines the pulse width and thus RMS of the output voltage. The regulator consists of transistor T1, which receives its signal from the diodes D4 and D5, taken from the primary transformer coil. The regulator adjusts the output voltage by changing the pulse width. It prevents also rising of RMS on inductive or capacitive load. IC 8 will be switched directly by the oscillator signal, thus avoiding errors by unexpected oscillations of the PWM-IC 2. Here the alternate allocation of the impulses for both transistor lines, i.e. for the positive and the negative half wave of the output voltage take place. The final frequency of 50 cycles per second develops was

$f_0 = \frac{1}{2\pi RC}$ If $R_4 = R_5$ and $C_1$

But, since $R_4$ and $R_5$ is not the same value,

$$\therefore f_0 = \frac{1}{2\pi\sqrt{R_4 R_5 C_1}}$$

For $R_4 = 50k$

$R_5 = 68k$

$$f_0 = \frac{1}{2\pi\sqrt{50\times10^3\times68\times10^3\times47\times10^{-9}}}$$

$$f_0 = \frac{1}{4.490} = 0.2227H_z$$

### 3.3 CONTROL UNIT

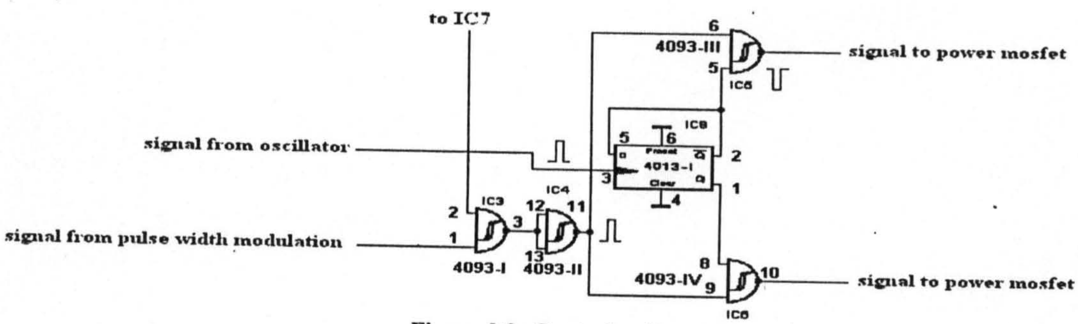



**Figure 3.3: Control unit**

Flip-flop IC7 stores a switching off instruction of the current limiter for the rest of the half wave. From the gates IC5 (4093-III) and IC6 (4093-IV), the control signal arrives at the complementary MOSFET-driver stage transistors T5/T6 and T7/T8. T6 and T7 are N-channel-enhancement MOSFETS and T5 and T8 are the complementary P-channel-enhancement MOSFETS. These transistors correspond to the well-known CMOS basic circuit, which represents the basic of the CMOS logic family (CMOS inverters). Resistors R44 to R47 in this circuit provide current limitation during shifting process and protect in cases of disturbances. The control unit is suitable for inverters up to 10 KW output power. The driver stage transistors T5 to T8 provide the signals for the power MOSFETS, which alternately magnetize the transformer. Inductive idle currents, how they are needed e.g. by electric motors, can be returned to the battery, thanks to the integrated ant parallel recirculating diodes of the transistors. Thus, they do not generate unnecessary losses, contrary to early inverters.

### 3.4 OVERLOAD PROTECTION

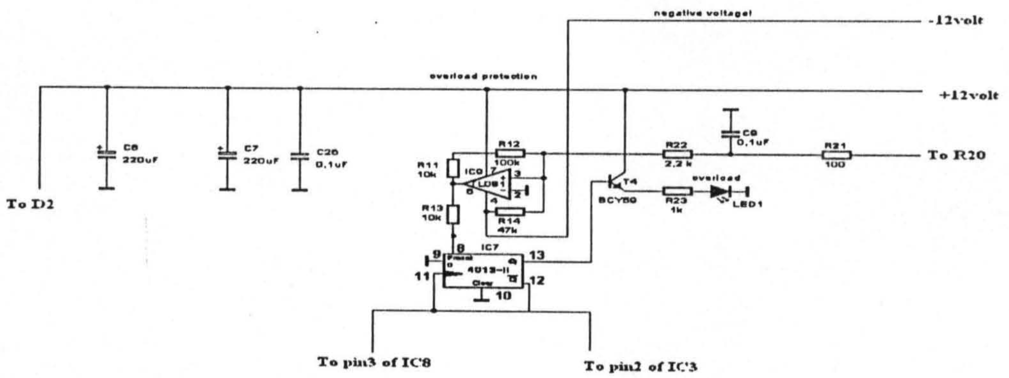



**Figure 3.4: Overload protection**

The electronic overload protection by IC9 is a special feature of our inverter. It needs an additional negative supply voltage, which is produced by a charge pump, consisting of IC10 and the transistors T9 and T10. IC9 works as threshold switch (Schmitt trigger). While starting the inverter, the negative supply voltage from the charge pump will be missing. This leads to immediate shutdown of the power MOSFETS, indicated by the red LED1. Thus indefinable control signals, that could result in unwanted switching, which would force small batteries to break down, are prevented. Our inverter therefore requests no maximum or minimum battery size - it works on any 12 Volt power supply. The electronic overload protection becomes active; when a positive output signal appears at pin 6 of IC9. Through resistor R13 the flip-flop IC7 is set, which keeps the blockage upright until the next half wave on pin 11 appears.

### 3.5 SWITCHING CIRCUITS

In this design, the output pulse from the oscillator is passed through a 0.001ohm resistor to the isolated gates of the power MOSFETS.

The source of the MOSFET was connected to the negative terminal of the 24V battery source while the drain of the MOSFET was connected to the negative terminal of the transformer via the heat sink which was screwed to the drains of the power MOSFET. This process enables the maximum voltage of the battery to flow to the primary windings of the power transformer.

The most important task in our inverter was done by the MOSFET transistors T13 to T28. They were connected in two groups, each of 8 transistors. They generate alternatingly, the positive and negative wave of the output voltage. Each transistor line works on its own transformer coil. When a transistor line was being switched off, the magnetic energy stored in the magnetic field of the transformer returns back to the battery by the integrated recirculating diodes of the second transistor line. The idle current of consumers with inductive load takes the same way. In case of strong heating up of the transistors, which should only happen on defects in the equipment, the bimetal thermal switch F2 shuts off the control electronics. In normal operation, temperature of the heat sink should be as low that could be touch.

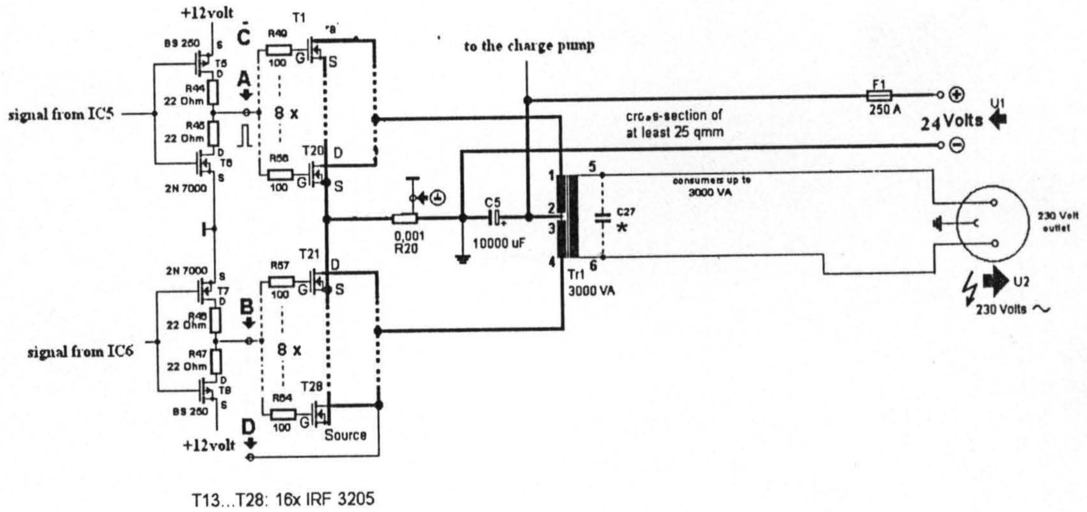



**Figure3.5: switching circuit**

The source-currents of the MOSFET transistors pass over resistor R20 with the very low value of 0.001 ohms. Load currents of 100 amperes thus produce a voltage drop of only 0.1 Volt, according to an energy dissipation of 10 Watts. The electronic current limiter becomes effective for currents above 350 Amperes, i.e. on voltage drops on R20 of more than 0.35 Volts. Main cause for such high currents are short-circuits or consumers with "large" inductances, e.g. welding transformers or large battery chargers, which exhibit remanence magnetism. Also large electrolytic capacitors from switching power supplies, cause immense peak currents (computer screen), just as asymmetrical load of devices with single period rectifiers or thyristor regulators, which cause a magnetically bias to the transformer of the inverter.

### 3.6 THE POWER TRANSFORMER

An alternating voltage was applied to the terminals of the primary windings of the transformer, with the secondary winding open circuited, a very small current flow in the primary circuit only, which serves to magnetize the core and to supply the iron losses of the transformer. Thus, an alternating magnetic flux was established in the core which induces an emf in both primary and secondary windings. As primary and secondary windings were wound on the same core and as the magnetic flux was common to both windings, the voltage induced in the primary and secondary windings were in direct proportion to the number of turns in these windings. The formulas connecting induced voltage, flux and number of turn's are-

$U_{ind} = n \times \Phi / t$ converted: 1') $n = U_{ind} \times t / \Phi$ (3.1)

$\Phi = B \times A$ (3.2)

| | |
|---|---|
| $U$=I nduced voltage | $n$ = number of turns |
| $\Phi$ = magnetic flux | $t$ = transistor switch-on time |
| $B$ = magnetic induction | $A$ = cross-section area of transformer core |

For power electronics, resistive load would not calculate on energy conversion. Thus the whole battery voltage will apply on the transformer coil for the whole switch-on time of the transistors. The switch-on time results in 5 milliseconds; depended on the period of the 50 cycles / second oscillation and a duty-cycle of 25% (period of a 50 cycle oscillation is 1 / 50 Hz = 20 milliseconds).

Calculation for the 3000 VA transformer:

Power rating p = 3000VA

Primary voltage $V_p = 24V$

Secondary voltage $V_s = 230V$

$P = I_p V_p$ , $I_p$= Primary current

$$I_p = \frac{P}{V_P} = \frac{3000}{24} = 125A$$

For secondary current $I_S$

$$P = I_S V_S$$

$$I_S = \frac{P}{V_s} = \frac{3000}{230} \approx 13A$$

Total current $I_t = I_S + I_p$

$$I_t = 125 + 13 = 138A$$

Cross-section area of the transformer calculates to A = 220 mm x 240 mm = 9,2 x $10^{-3}$ $m^2$

$U_{ind}$ = 23.7 Volt **B**= 1.1 Tesla = 1.1 Vs/ $m^2$

**t**= 20 ms **A**= 9.2 x $10^{-3}$ $m^2$

From equation 3.2

The magnetic flux $\Phi$ = **B** x **A** = 1.1 Vs/ $m^2$ x 9.2 x $10^{-3}$ $m^2$ = 10.12 x $10^{-3}$ Vs

Insert in equation 3.1

Results to

Number of turns $\mathbf{n}=\boldsymbol{U_{ind}}$ x t/Φ = $\frac{12.7V \times 20\times 10^{-3}}{10.12\times 10^{-3} V_s}$ = 8.82 (rounded up 9 turns).

Base on the calculation it shows that, the ratio of transformer windings is 1: 25. The schematic diagram shows that, it has two primary windings and one secondary. Both primary windings have the same number of turns and the secondary winding have by factor 25 more turns. The power transformer is not an energy conversion or energy source device and therefore cannot convert DC to AC. AC circuits are commonly connected to each other by means of transformers. A transformer couples two AC circuits magnetically rather than through any direct conductive connections, and permits a "transformation" of the voltage and current between one circuit and the other. i.e. by matching a high-voltage low-current AC output to a circuit requiring a low-voltage high-current source.

### 3.7 COMPARATOR AND VOLTAGE DOUBLER

Comparator circuits accept input linear voltage and provide a digital output that indicates when one input is less than or greater than the second. The output is a digital signal that stays at a high voltage level when the non-inverting (+) input is greater than the voltage at the inverting (-) input and switch to a lower voltage level when the non-inverting input voltage goes below the inverting input voltage.

Operational amplifiers can be used as comparator circuits separate IC comparator units are more suitable. Some of the improvements built into a comparator IC are a faster switching between the outputs levels, built in noise immunity to prevent the output from oscillating when the input passes by reference level and output capable of directly driving a variety of load.

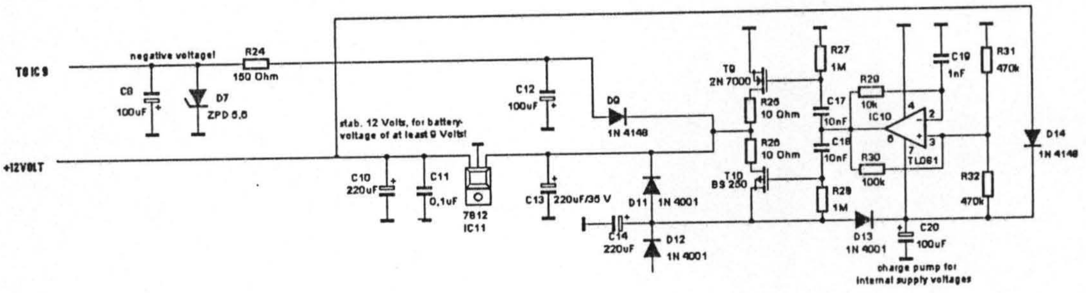



**Figure3.6: comparator and voltage doubler**

To get the reference voltage, divider theorem is use.

$$V_{ref} = \frac{R_{31}}{R_{32}+R_{32}} V_{cc}\ ,\quad V_{ref} = Reference\ voltage$$

$$V_{ref} = \frac{470k}{470k+470k} 24V$$

$$V_{ref} = \frac{470k}{940k} 24V$$

$$V_{ref} = 0.5 \times 24V$$

$$V_{ref} = 12V$$

### 3.7.1 VOLTAGE DOUBLER

In operation capacitor $C_{14}$ charges through diode $D_{11}$ to a peak voltage, $V_m$ during the position half cycle of the transformer secondary voltage capacitor $C_{12}$ charge twice the peak voltage $2V_m$ developed by sum of the voltages across capacitor $C_{12}$ and transformer, during the negative half cycle of the transformer secondary voltage.

If additional section of diode and capacitor are used, each capacitor will be charge to $2V_m$ measuring from transformer winding will provide odd multiples of $V_m$ at the output, where as measuring the output voltage from the bottom of transformer will provide even multiples of the peak voltage$V_m$.

The transformer rating is only $V_m$, maximum, and each diode in the circuit must be rated at $2V_m$ peak inverse voltage (PIV). If the load is small and the capacitors have little leakage, extremely high dc voltages may be developed by this type of circuit, using many sections to step up the voltage.

# 3000 VA Power-Inverter 24 V -> 230 V "modified sinus"

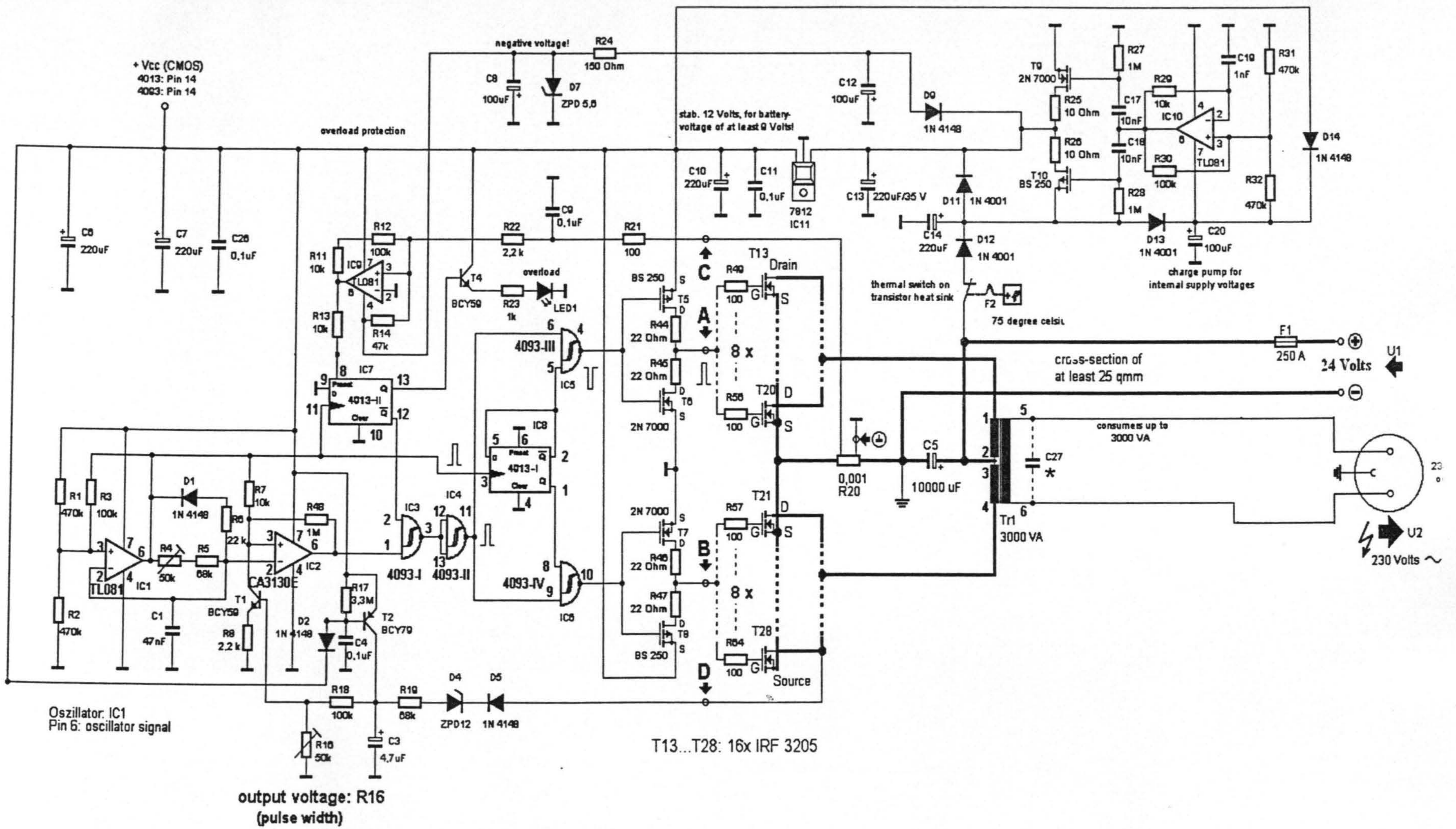



**Fig. 3.7: complete circuit diagram**

# CHAPTER 4

## CONSTRUCTION, TESTING AND RESULTS

### 4.1 CIRCUIT CONSTRUCTION

The construction of this project (3000VA Inverter) was done in three different stages which are as follows:-

- The testing of part of the construction on the breadboard.
- The soldering of the component on the Vero-board.
- The coupling of the entire project to the casing.

### 4.2 TESTING AND RESULTS

Series of problems were encountered during the implementation, testing and construction of this project which are as follows:-

1. After carrying out the paper design and analysis, the project was implemented and tested to ensure its working.

2. During the first connection of 2 fully charged 12 volt car batteries connected in series, arcing of the terminal contact was experienced. A spanner of required size was used to screw the bolt firmly.

3. The output frequency from the oscillator was gotten to be 0.2227Hz which is suitable for resistive, inductive and "pseudocapacitive" load (e.g. computers) the efficiency of a square wave inverter is higher than the appropriate sine wave inverter, due to its simplicity. With the help of a transformer the generated square wave voltage can be transformed to a value of 230 Volts (110 Volts) or even higher (radio transmitters)

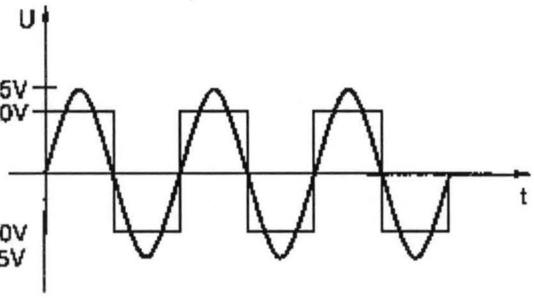



**Figure 4.1: 230 volts Sine-wave and conventional square wave voltage**

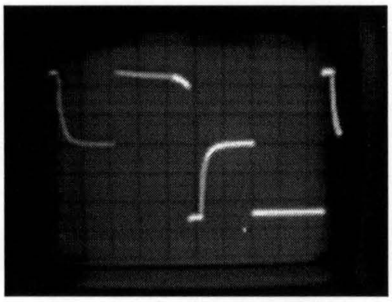


**Figure 4.2: output voltage with no load or inductive load**

## 4.3. TESTING OF THE MOSFETS

The transistors on the heat sink were tested while they were not yet connected to the transformer and the control unit. The source connections of the transistors were touched with one hand and gate connections with other hand. This discharges the gates. The source / drain connections behave like a diode, which ohm meter was use to test it. For the next test, we connect a car lamp between the drain connections of the transistors and the positive pole of a battery. The negative pole of a battery was connected to the source of the transistors. The gate was open. When touched with one hand the positive pole of the battery and with the other the gates, the lamp light up and when touched with the negative pole of the battery the lamp light off. With these tests carried out, it confirms that, the transistors are o.k. The output voltage gotten from the power MOSFET was equal to the battery voltage.

### 4.4 TESTING OF THE TRANSFORMER

The transformer built was first tested by connecting its 230 Volts windings to public electricity mains or any other 230 Volts source. Each low-voltage coil shows 18 Volts. The two primary coils were connected together and the 36Volts appears. But when 0volts appears, it shows that it has been connected wrongly. The output voltage of the transformer was measured to be 220Volt which can be used by domestic appliances. The expected voltage (230V) was not obtained due to losses incurred by the power transformer.

#### 4.4.1 OUTPUT WAVEFORM

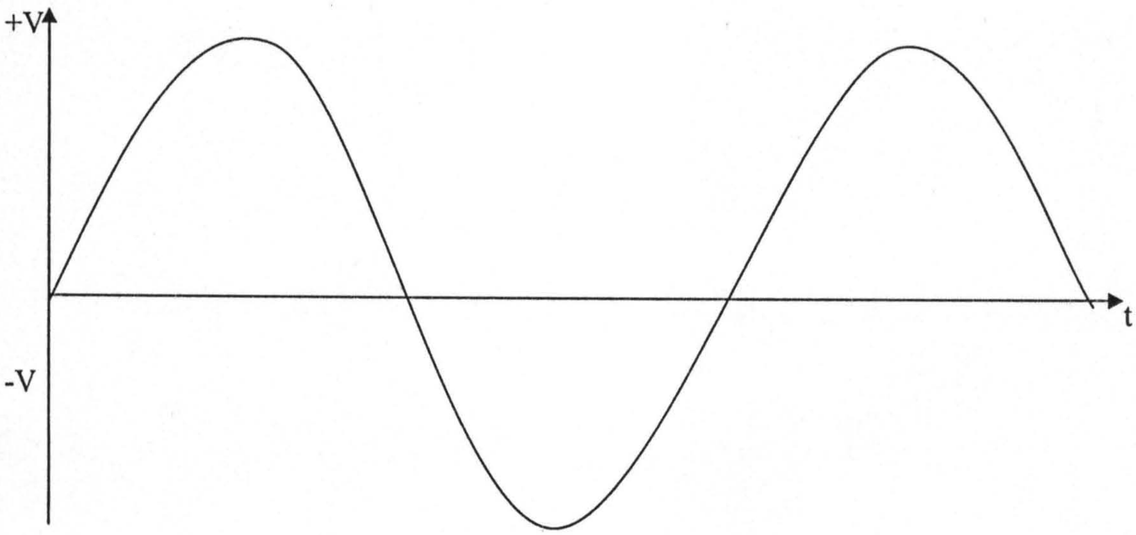



**Figure 4.5: Output waveform of the power transformer**

## BILL OF QUANTITY

| S/N | Component | Quantity | Unit Price | Total Amount |
|---|---|---|---|---|
| 1 | Resistors | 48 | 20 | 960 |
| 2 | Capacitors | 26 | 50 | 1,300 |
| 3 | Diodes | 20 | 20 | 400 |
| 4 | Zener Diodes | 8 | 50 | 400 |
| 5 | IC TL081 | 3 | 50 | 150 |
| 6 | IC CA3130E | 1 | 150 | 150 |
| 7 | IC LM741 | 2 | 70 | 140 |
| 8 | IC 4093 | 1 | 250 | 250 |
| 9 | IC 4013 | 1 | 250 | 250 |
| 10 | IC Regulator 7812 | 1 | 70 | 50 |
| 11 | Transistors BC547 and BC556 | 5 | 100 | 500 |
| 12 | Transistors BS 250 and 2N7000 | 7 | 120 | 840 |
| 13 | Mosfets IRF 3205 | 16 | 150 | 2,400 |
| 14 | LED | 2 | 20 | 40 |
| 15 | Relay | 1 | 200 | 200 |
| 16 | Transformer | 2 | 6000 | 12,000 |
| 17 | Casing | 1 | 1500 | 1500 |
| | | | | Total = 21,530 |

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 CONCLUSION

In this project work, the 3KVA INVERTER system was successfully designed, constructed and tested. For an estimated twenty minutes, it was able to provide back up when loaded close to its full load current rating. Below are some recommendations that would facilitate better results if the project was carried out a second time. The designed INVERTER gives sufficient and satisfactory results so as to be used practically in the home and offices. However, in the absence of cost constraints and with maximum efficiency as priority, the below recommendations should be considered.

## 5.2 RECOMMENDATIONS

During the testing of the inverting section of the inverter, it was observed that the IRF3205N MOSFETs that were used in the project usually got heated up easily. This provided an avenue for them to wear out and possibly burn out sooner than was expected and desired. Therefore, employing a more efficient cooling system such as heat sink and using MOSFETs with higher current handling abilities would be a good insurance against a regular burn out of the MOSFETs. It was also noted during testing that the actual power rating of the inverter transformer varied from that of its specified rating. Therefore, to create room for tolerance, it is advisable to purchase a transformer with a specified power rating above that required at the inverter output. This will ensure that the desired output is always attainable. A third recommendation will be to insert a filter circuit between the MOSFET drivers and the output transformer, so as to obtain the desired and expected inverter sinusoidal output in place of the square wave output obtained in the project work. This is necessary because the microprocessor pulse width modulator as a standard always gives out a square wave. Hence, the need arises for the additional filter circuitry to convert the square wave into a sinusoid at inverter output. A last recommendation wills be to use additional external batteries connected in parallel in order to improve on the backup time provided by the inverter. This is necessary because though ideally twenty minutes should be sufficient to switch power supply over from the UPS system to the generator system, the possibility of unforeseen delays could arise. These delays cannot be afforded since human lives are at stake in the hospital theatre

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