DESIGN AND CONSTRUCTION OF A 3KVA POWER INVERTER (24V DC – 230V AC)

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SUBMITTED TO

THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING IN PARTIAL FULFILLMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE.

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DEDICATION

This work is dedicated to **Almighty ALLAH**, the giver of knowledge and everything, my lovely father, my lovely mother **Hajiya Hassana Ndagi Isah** and my amiable, dedicated, committed and focused supervisor **ENGR. J. G. KOLO.**

DECLARATION

I MUHAMMAD ISAH ALFA, hereby declare that, dissertation is an original work wholly by me, under the supervision of ENGR. JORNATHAN GANA KOLO and has not been submitted before anywhere for the purpose of awarding degree or diploma to the best of my knowledge. I also hereby relinguish the copyright to the federal university of technology, Minna.

<u>*MUHAMMAD* ISAH ALFA</u>
STUDENT

<u>ENGR. J. G. KOLO</u>
SUPERVISOR

SIGNATURE AND DATE

SIGNATURE AND DATE

<u>*ENGR. A. G. RAJI*</u>
H.O.D

EXTERNAL SUPERVISOR

SIGNATURE AND DATE

SIGNATURE AND DATE

ACKNOWLEDGEMENT

I wish to express my profound gratitude to Almighty Allah for seeing me through this phase of my life. Without him life would have been misery. To my project supervisor, ENGR. J. G. KOLO, may almighty Allah bless and reward you and your family for your guidance and constructive criticism geared towards the success of this project work. Also to my technical supervisor MAL. YAHAYA may Allah bless you too and your family.

My sincere thanks and gratitude goes to my lovely parents Mal. Ndagi Isah Alfa and Hajiya, Hassana Ndagi Isah for bringing me into this world and nursing me through every stage, also my uncle Alhaji Danjuma Zubairu who has immensely contributed to my grassroots' education, my entire family members, you all will forever remain precious to my heart and may almighty Allah continue to guide and protect you all.

To my friends: Tasiru, BB, Baly, Bisallah, Zakari(Z-Man), Alaska (mology), ishak, Estugaie, yabagi (TK), Ibro, Hassan (Engr.), my study mates Babatunde (prof), salihu (alfa), Umar, Rabah, Usman, Raji, Musa, Hussaini (sauki), Hussaini (pikin), Abdullahi(chief servant) and Mohammed (momentum) and to all (not mentioned) who played an important role in my life, may your kind deeds be rewarded by Almighty Allah (Ameen).

Also the entire lecturers and technicians of the prestigious department of electrical and computer engineering, other lecturers of various departments who in one time or the other impacted knowledge in me, may almighty Allah continue to grant you all strength and sustenance.(Ameen)

ABSTRACT

The project involves the design and construction of a 3000VA power inverter (24V DC - 230V AC). In this project work an astable multivibrator is used to generate the operating frequency of 50Hz through capacitors and resistors. The maximum power requirement is met with the use of power CMOSFET (complementary metal oxide semi-conductor field effect transistor) as switches. The entire components and materials used were sourced locally, and readily availably. As usual, problems were encountered and solved in the course of this project design. This project was well researched, criticized, analyzed, designed and constructed to the given specifications as the output can be compared favourably with the existing power inverters in the market. The power inverter was tested for good performance.

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CHAPTER ONE

1.1 INTRODUCTION

The word electricity was first used by an English writer and physicist Sir Thomas Browne in 1646[1] Though, humans have known about the existence of static electricity for thousands of years, but scientists did not make great progress in understanding electricity until the 1700s[2]. But the widespread use of electricity as a source of power is largely due to the work of pioneering American Engineers and inventors such as Thomas Alva Edison, Nikola Telsa and Charles Proteus Steinmetz during the late 19^{th} and early 20^{th} centuries [1]. Since then, different means of generating electricity in large quantity becomes one of the major factor been considered by the Engineers. Discoveries have shown that, it can be generated through various means such as, hydro (water), wind, solar, nuclear, thermal e.t.c. but taking Nigeria as a case study, hydro and thermal are mainly use for the generation of electricity by the utility company (Power Holding Company of Nigeria [PHCN], for the bulky supply of electric energy to domestic, commercial and industrial customers for the purpose of consumption.

Statistics have shown that, all power interruptions result mainly from faults in the power stations, this always creates significant negative effect on the productivity of an industry or company who fully depend on power for effective production. For instance, a communication company can suffer a great loss of data that might take hours or days to rebuild or interruption in transmission and receiving of signals. In the area of transportation, where the means are made of electricity e.g electric trains, electric tramp, elevator, e.t.c. Power interruption can be hazardous and dangerous to human in that regard. More so, in the medical line , it could be life threatening, i.e when sensitive equipments like oxygen machine or blood transfusion gadget are been interrupted by power supply in the process of operation. This and several other factors call for the use of a standby power supply unit to safeguard the losses. Though, the fields of power electronics have gain rapid development and wide application in power systems, communication and computer engineering which fully bring out the real structure of this project design.

A power inverter is one of the solutions to the problem of power outages in Nigeria. It is basically an AC/DC/AC inverter. An inverter is an electrical device that converts direct current (DC) to alternating current (AC) in which the resulting AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits [3].

The inverter is just the opposite of a converter in which the inversion process can be achieved with the help of transistors, silicon controlled rectifiers (SCRs) and tunnel diodes. For low and medium outputs, transistorized inverters are suitable while for high power outputs, silicon controlled rectifiers (SCRs) inverters are essential. For very low voltage and high current requirements, tunnel diodes are used [4].

Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. The electrical inverter is a high-power electronic oscillator which 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 by converting DC electricity from sources such as battery to AC electricity. The electricity can be at any required voltage, in particular it can operate AC equipments designed for mains operation or rectified to produce DC at any desired voltage. It is a power supply system connected between the user equipment with or without outages. More so, the supply is free from frequency-variations, spikes and transients. It fall in to the category of equipment referred to as "Emergency/Standby System" it development can be traced back to the beginning of the first general purpose automatic electronic digital computer in 1947. [2]

1.2 AIMS AND OBJECTIVES

This project aims at designing and constructing a 3KVA capacity inverter with load protection, automatic changeover and dc charging unit using 24v dc. Source with the following-:

- To produce an alternating current (AC) from a direct current (DC) source such as car battery, modular panel (solar cell)
- To ensure the protection of the backup source, consumer equipments and supply.

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

1.3 SIGNIFICANCE OF THE STUDY

The project has a significant role to play in proffering a lasting solution to losses incurred by the industries in particular and the general society at large during possible power outages. Though, there had been in existence various type of inverter. This application is unique in the sense that, it requires no maximum or minimum battery size; it works on any 24 volts power supply and also combines the attributes of cold starting with the use of the CMOS POWER MOSFET equipment with an integrated anti-parallel recirculating diode as the switching device thereby prolonging the lifespan of the system. It has a very high overload capacity and latest design in the markets which reduce the price of the entire circuitry.

1.4 SCOPE OF THE STUDY

The scope of this project is limited to load up to 3 KVA capacities. This means that, it can serve loads like electric drills, fret saws, circular saws; electric chains saws, grinders, vacuum cleaners, coffee machines, irons, dryers, mixers, electric razor, lamps energy savings lamps electronic devices like, music amplifier, battery chargers, computers and accessories, ups, televisions, radios, high voltage generation e.t.c. This project was written in four chapters. Chapter one contains the introduction, aims and objectives, scope of the project, and significant of the study. In chapter two, the literature review (theoretical background) is discussed. Chapter three highlights the relevant information about the design and the calculations carried out, while chapter four contains information on the results obtained, and the discussions of those results. Finally, chapter five discusses the conclusions and recommendations.

1.5 METHOD OF STUDY

The methods adopted in this project is by consulting several textbooks, journals, data books, various designer manuals and consultations with learned individuals with vast practical experience and exposure.

Though, in the construction, complementary metallic oxide semiconductor (CMOS a specially and recently modified power mosfet) had been used as the switching device because of its vast advantages over other electronic switching devices such as thyristor, BJT (bipolar junction transistor). In addition to the above, the advantage of the CMOS body diode was also exploited i.e. integrated anti-parallel recircirculating diodes of the transistors. Also, components like power diodes, zener diodes, operational amplifier, voltage transformers, flip- flop IC, relays, resistors, capacitors, voltage transformer e.t.c. are also used.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical background of inverter

The introduction of vacuum tubes at the beginning of the 20^{th} century was the starting point of the modern electronics. Vacuum tubes and gas filled tubes were been used as switches in the inverter circuits. The most widely used type of tube was the thyraton which is low voltage non-self maintaining arc tube having three electrodes viz. anode, indirectly-heated cathode and a grid and is filled with an inert gas like neon, and argon e.t.c. or mercury vapours at low pressure. But 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)[3].

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 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 "mechanically rectified AC". Given 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 converter [4].

2.2 Controlled rectifier inverter

Transistors are made from semiconductors. These are materials, such as silicon or germanium, that are "doped" (have minute amounts of foreign elements added) so that either an abundance or a lack of free electrons exists. In the former case, the semiconductor is called n-type, and in the latter case, p-type. By combining n-type and p-type materials, a diode can be produced. When this diode is connected to a battery so that the p-type material is positive and the n-type negative, electrons are repelled from the negative battery terminal and pass unimpeded to the p-region, which lacks electrons. With battery reversed, the electrons arriving in the p-material can pass only with difficulty to the n-material, which is already filled with free electrons, and the current is almost zero.

The bipolar transistor was invented in 1948 as a replacement for the triode vacuum tube. It consists of three layers of doped material, forming two p-n (bipolar) junctions with configurations of p-n-p or n-p-n. One junction is connected to a battery so as to allow current flow (forward bias), and the other junction has a battery connected in the opposite direction (reverse bias). If the current in the forward-biased junction is varied by the addition of a signal, the current in the reverse-biased junction of the transistor will vary accordingly. The principle can be used to construct amplifiers in which a small signal applied to the forward-biased junction causes a large change in current in the reverse-biased junction [1].

Since early transistors were not available with sufficient voltage and current rating for most inverter application, it was the 1957 introduction of the thyristor or silicon controlled rectifier (SCR) that initiated the transition to solid state inverter circuits. The commutation requirements of SCRs are a key consideration in SCR circuit designs. SCRs do not turn OFF or commutate automatically when the gate control signal is shut off.

They only turn off when the forward current is reduced to below the minimum holding current, which varies with each kind of SCR, through some external process. For SCRs connected to an AC power source, commutation occurs naturally every time the polarity of the source voltage reverses. SCRs connected to a DC power source usually require a means of forced commutation that forces the current to zero when commutation is required. The least complicated SCRs circuits employ natural commutation rather than forced commutation.

In applications where inverters transfer power from a DC power source, it is possible to use AC-DC controlled rectifier circuits operating in the inversion mode. In the inversion mode, a controlled rectifier circuit operates as a line commutated inverter. This type of operation can be used in high voltage DC power transmission systems and in regenerative braking operation of motor control systems. Another type of SCR inverter circuit is the current source input (CSI) inverter. A CSI inverter is the dual of a six-step voltage source inverter. With a current source inverter, the DC power supply is configured as a current source rather than a voltage source. The inverter SCRs are switched in a six-step sequence to direct the current to a three phase AC load as a stepped current waveform.CSI inverter commutation methods include load commutation and parallel capacitor commutation. The load is a synchronous motor operated at a leading power factor. As they become available in higher voltage and current ratings, semiconductors such as transistors or insulated gate bipolar transistors (IGBTs) that can be turned off by means of control signals have become the preferred switching components for use in inverter circuits [4].

2.3 Digital integrated circuits ICs

Most integrated circuits are small pieces, or "chips," of silicon, perhaps 2 to 4 sq mm (0.08 to 0.15 sq in) long, in which transistors are fabricated. Photolithography enables the designer to create tens of thousands of transistors on a single chip by proper placement of the many n-type and p-type regions. These are interconnected with very small conducting paths during fabrication to produce complex special-purpose circuits. Such integrated circuits are called monolithic because they are fabricated on a single crystal of silicon. Chips require much less space and power and are cheaper to manufacture than an equivalent circuit built by employing individual transistors. The development of integrated circuits has revolutionized the fields of communications, information handling, and computing. Integrated circuits reduce the size of devices and lower manufacturing and system costs, while at the same time providing high speed and increased reliability. Digital watches, hand-held computers, and electronic games are systems based on microprocessors. Other developments include the digitalization of audio signals, where the frequency and amplitude of an audio signal are coded digitally by appropriate sampling techniques, that is, techniques for measuring the amplitude of the signal at very short intervals. Digital playback devices of this nature have already entered the home market. Digital storage could also form the basis of home video systems and may significantly alter library storage systems, because much more information can be stored on a disk for replay on a television screen than can be contained in a book [5].

2.4 Voltage-multiplier circuits

Voltage-multiplier circuits are employed to maintain a relatively low transformer peak voltage while stepping up the peak output voltage to two, three, four, or more times the peak rectifier voltage. Most electronic equipment requires DC voltages for its operation. These can be provided by batteries or by internal power supplies that convert alternating current into regulated DC voltages. The first element in an internal DC power supply is a transformer, which steps up or steps down the input voltage to a level suitable for the operation of the equipment. A secondary function of the transformer is to provide electrical ground insulation of the device from the power line to reduce potential shock hazards. The transformer is then followed by a rectifier, normally a diode. In the past, vacuum diodes and a wide variety of different materials such as germanium crystals or cadmium sulfide were employed in the low-power rectifiers used in electronic equipment. Today silicon rectifiers are used almost exclusively because of their low cost and their high reliability.

Fluctuations and ripples superimposed on the rectified DC voltage can be filtered out by a capacitor; the larger the capacitor, the smaller is the amount of ripple in the voltage. More precise control over voltage levels and ripples can be achieved by a voltage regulator, which also makes the internal voltages independent of fluctuations that may be encountered at an outlet. A simple, often-used voltage regulator is the zener diode. It consists of a solid-state p-n-junction diode, which acts as an insulator up to a predetermined voltage; above that voltage it becomes a conductor that bypasses excess voltages. More sophisticated voltage regulators are usually constructed as integrated circuits such as 7800 series regulators which provide regulatory fixed voltage from 5-24v as employed in this project.[4]

2.5 Amplifier circuits

Electronic amplifiers are used mainly to increase the voltage, current, or power of a signal. A linear amplifier provides signal amplification with little or no distortion, so that the output is proportional to the input. A nonlinear amplifier may produce a considerable change in the waveform of the signal. Linear amplifiers are used for audio and video signals, whereas nonlinear amplifiers find use in oscillators, power electronics, modulators, mixers, logic circuits, and other applications where an amplitude cutoff is desired. Although vacuum tubes played a major role in amplifiers in the past, today either discrete transistor circuits or integrated circuits are mostly used [2]. TL081 and CA3130E operational amplifier (OP-AMP) are used because of their high gain which can serve the purpose of comparator, integrator, differentiator, summer, dc amplifier multivibrator and band pass filter. They have very high gain, high – r_{in} directly coupled negative- feedback amplifier which can amplify signals having frequency ranging from 0Hz to a little beyond 1MHz.

2.6 Switching and timing circuits

Switching and timing circuits, or logic circuits, form the heart of any device where signals must be selected or combined in a controlled manner. Applications of these circuits include telephone switching, satellite transmissions, and digital computer operations. Digital logic is a rational process for making simple "true" or "false" decisions based on the rules of Boolean algebra. "True" can be represented by a 1 and "false" by a 0, and in logic circuits the numerals appear as signals of two different voltages. Logic circuits are used to make specific true-false decisions based on the presence of multiple true-false signals at the inputs. The signals may be generated by mechanical switches or by solid-state transducers. Once the input signal has been accepted and conditioned (to remove unwanted electrical signals, or "noise"), it is processed by the digital logic circuits. The various families of digital logic devices, usually integrated circuits, perform a variety of logic functions through logic gates, including "OR,""AND," and "NOT," and combinations of these (such as "NOR," which includes both OR and NOT). One widely used logic family is the transistor-transistor logic (TTL). Another family is the complementary metal oxide semiconductor logic

(CMOS), which use both PMOS and NMOS device in the same circuit. It gives the advantages of drastic decrease in power dissipation (12nW per gate) and increase in speed of operation. It has the lowest power dissipation amongst different logic families. It has very high package density i.e. larger number of circuits can be placed in a single chip. It is one of the major reason why it is been chosen as a switching device in this project. Several other, less popular families of logic circuits exist, including the currently obsolete resistor-transistor logic (RTL) and the emitter coupled logic (ELC), the latter used for very-high-speed systems.

The elemental blocks in a logic device are called digital logic gates. An AND gate has two or more inputs and a single output. The output of an AND gate is true only if all the inputs are true. An OR gate has two or more inputs and a single output. The output of an OR gate is true if any one of the inputs is true and is false if all of the inputs are false. An INVERTER has a single input and a single output terminal and can change a true signal to a false signal, thus performing the NOT function. More complicated logic circuits are built up from elementary gates. They include flip-flops (binary switches), counters, comparators, adders, and more complex combinations . IRF3205 is a specific type of metal oxide semi conductor field-effect transistor (MOSFET) designed to handle large amount of power compared to the other power semi-conductor devices like insulated gate bipolar transistor (IGBT) thyristors. Its main advantages are high commutation speed and good efficiency at low voltages. It shares with the IGBT an isolated gate that makes it easy to drive. It was made possible by the evolution of common metal oxide semiconductor (CMOS) technology developed for manufacturing integrated circuits in the late 1970s.The power MOSFET shares it's operating principles with its low-power counterpart, the lateral MOSFET. The power MOSFET is the most widely used low voltage switch found in most power supplies [4].

When the device is fully ON, the switch is almost closed at sufficiently large gate source voltage. It turns OFF when the gate source voltage is below the threshold value. They require continuous application of a gate source voltage of appropriate magnitude in order to be in the ON state. No gate current flows except during the transitions from ON to OFF or vice-versa when the gate capacitance is being charged or discharged.

Because of their unipolar nature, the power MOSFETs can switch at very high speeds in which the only intrinsic limitation in commutation speed is due to the internal capacitance of the MOSFET. This capacitance must be charged or discharged when the transistor switches. This can be a relatively slow process because the current that flows through the gate capacitance is limited by the external device. The circuit will actually dictate the commutation speed of the transistor [4]. The circuit symbol of the power MOSFET is represented in figures 2.1a and 2.2b

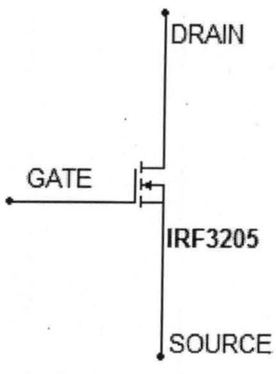


Figure2.1a: Circuit symbol of MOSFET

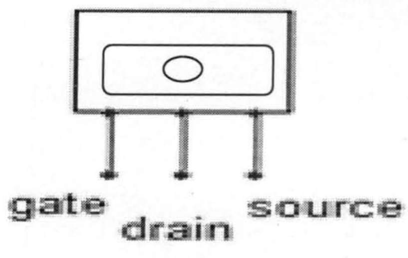


Figure2.2b: Component Symbol of MOSFET

2.7 The power transformer

A transformer is a device that transfers electrical energy from one circuit to another purely by magnetic coupling. The relative motion of the parts of the transformer is not required for the transfer of energy. The energy transfer allows AC power to be converted to any desired voltage but at the same frequency. Since a transformer works on the principle of electromagnetic induction, it must be used with an input source voltage that varies in amplitude (AC voltage source).

A transformer consists of two or more coils of wire placed near each other so that most of the magnetic field generated by one coil passes through the other coil. The transformer may have an air core or a metallic core of some nature. The coils may be tightly coupled together or loosely coupled. The schematic symbols of a transformer are given in figures 2.3a and 2.4b.

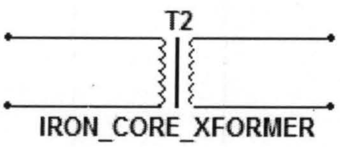


Figure 2.3a: Iron core transformer

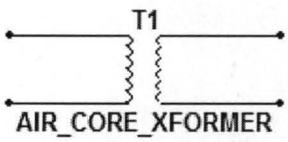


Figure 2.4b: Air core transformer

A transformer is basically electromagnetic static equipment based on the principle of Faraday's law of electromagnetic induction. A transformer essentially consists of a magnetic core, build-up of insulated silicon steel laminations, upon which are wound sets of coils suitably located with respect to each other and termed as primary and secondary windings. Such a combination may be used to derive a voltage higher or lower than what is immediately available. In the former case, the transformer is termed as a 'step-up' transformer, while in the latter case; it is known as a 'step-down' transformer.

The primary winding is that winding to which the supply voltage is applied, irrespective of whether it is a higher or lower voltage winding, the other winding to which the load is connected is termed as secondary winding.

. The transformer used in this design is a step-up transformer (center-tapped) which changes the voltage profile of the system from 24V to the desired 230V. The voltage output of the transformer is gotten across the secondary terminal. Figure 2.5 below shows the internal structure of the power transformer while Figure 2.6 shows the sinusoidal waveform that is the usual waveform of an AC power supply.

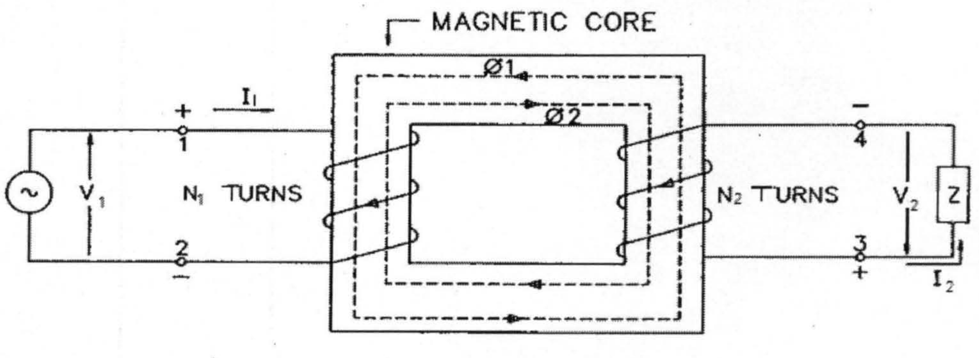


Figure 2.5: Internal structure of a transformer

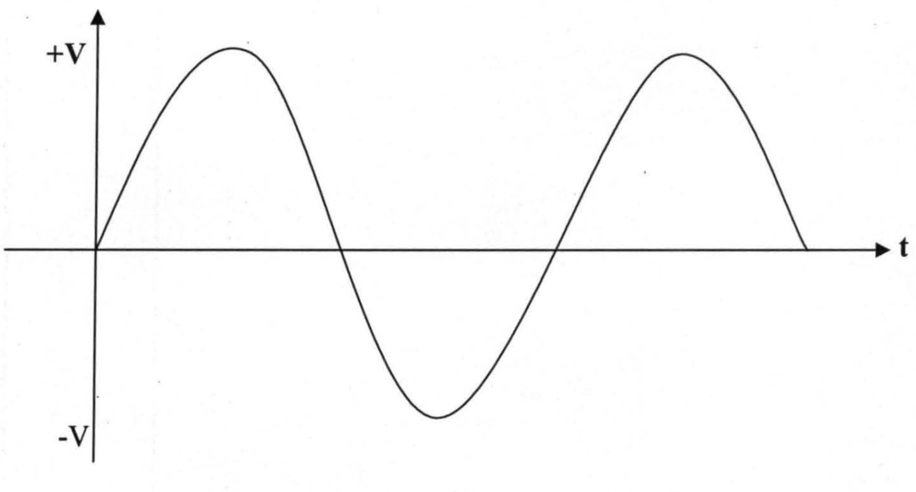


Figure 2.6: Output waveform of the power transformer

The alternation of the direction of current in the primary winding of the transformer produces alternating current (AC) in the secondary circuit [4].

The ideal power transformer is represented with the equations shown below:-

$$V_1 I_1 = V_2 I_2$$

(1)

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

(2)

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

(3)

Where,

V_1 = voltage in the primary

V_2 = voltage in the secondary

I_1 = current in the primary

I_2 = current in the secondary

N_1 = turns in the primary

N_2 = turns in the secondary

2.8 Application of inverter

- Generation of 50/60Hz, fixed voltage a.c from d.c source
- Speed control of three phase induction and synchronous motors.
- Uninterrupted power supply system (UPS)

- Induction heating.

- Standby power supply

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.

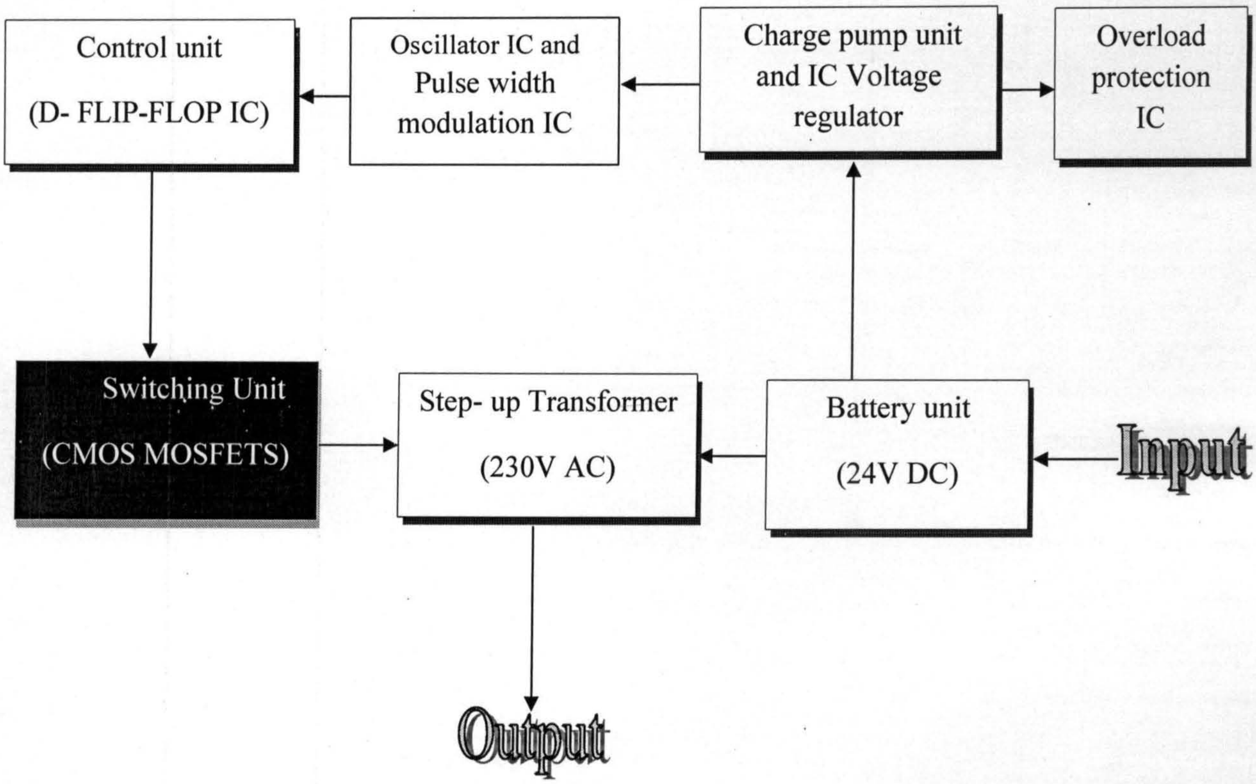


Figure 3.0 Block diagram of the inverter

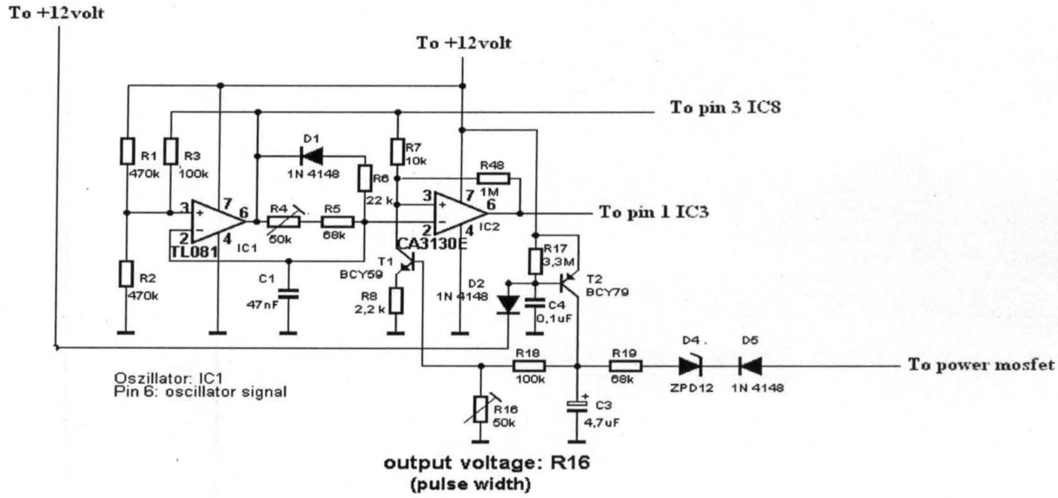
The block diagram above displays a stage by stage breakdown of the major components required for the inverter design which are as follows:-

- 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

In this design, an oscillator is a circuit which generates an ac output signal without requiring any externally applied input signal, it is an unstable amplifier. Though it differs from amplifier in one basic aspect, it does not require an external signal either to start or maintain energy conversion process. It keeps producing an output signal so long as the dc power is connected. The frequency of the output is determined by the passive components used in the oscillator.



. **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 $R_4 = 50k$

$R_5 = 68k$

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

$$f_o = \frac{1}{4.490} = 0.2227H_Z$$

3.3 Control unit

In this design, D flip-flop was used, which tracks the input, making transitions which 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. The 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 (VT+) and the negative voltage (VT−) is defined as hysteresis voltage (VH). All outputs have equal source and sink currents.

Hysteresis voltage (any input) TA = 25°C

DC Supply Voltage (VDD)

Typical VDD = 5.0V VH = 1.5V

VDD = 10V VH = 2.2V

VDD = 15V VH = 2.7V

Guaranteed VH = 0.1 VDD

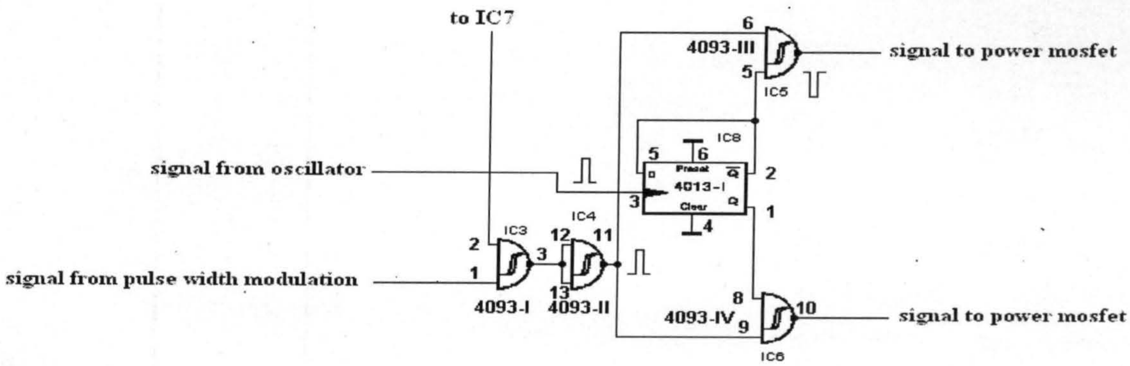


Figure 3.3: Control unit

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

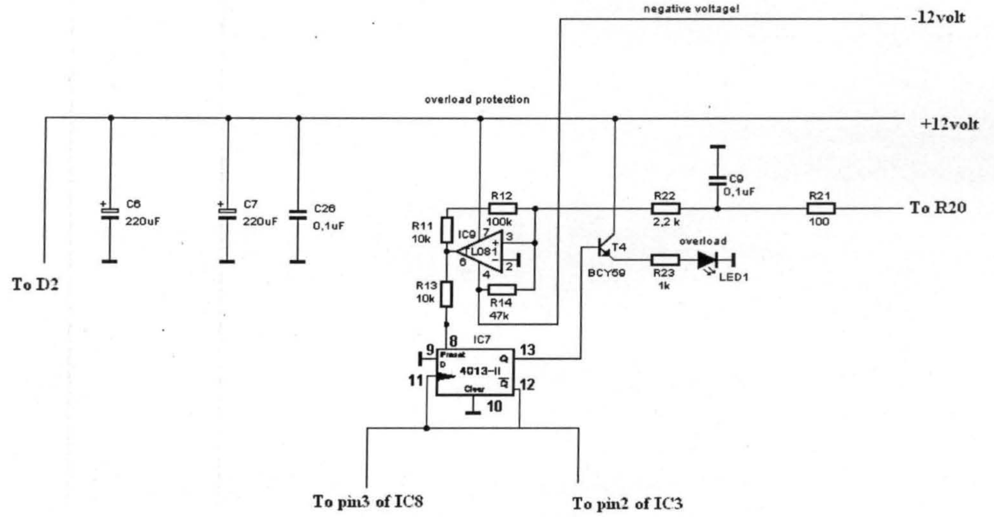


Fig 3.4: Overload protection

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 24 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..

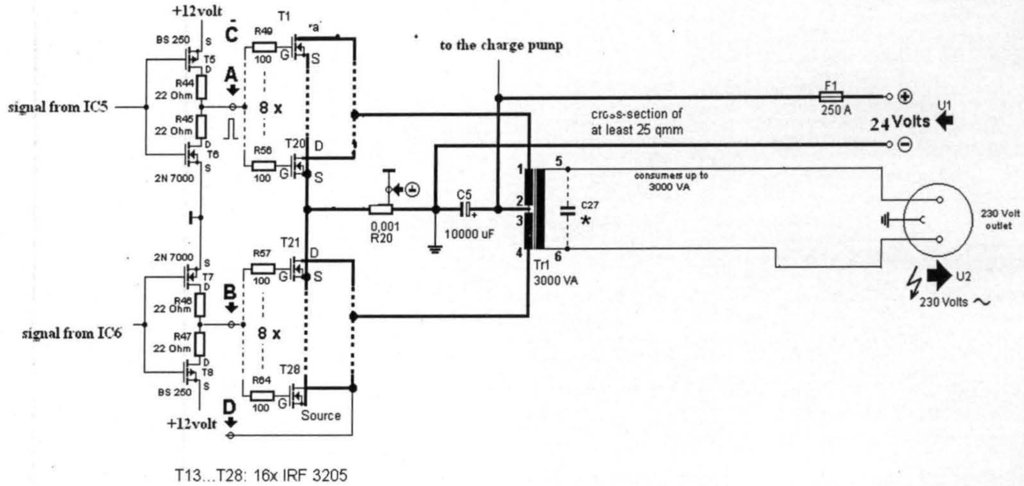


Figure3.5: switching circuit

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-

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

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

U=I nduced voltage	**n** = number of turns
Φ = 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

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

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

Using equation (3.2)

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

Substitute the value in equation (3.1)

It results to

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

Base on the calculation it shows that, the ratio of transformer windings is 1: 25. The schematic diagram in fig 2.4 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.

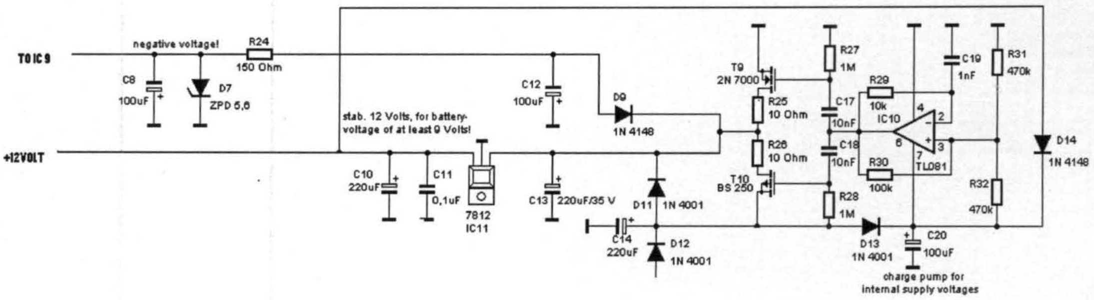


Figure3.6: comparator and voltage doubler

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 voltageV_m.

The transformer rating is onlyV_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"

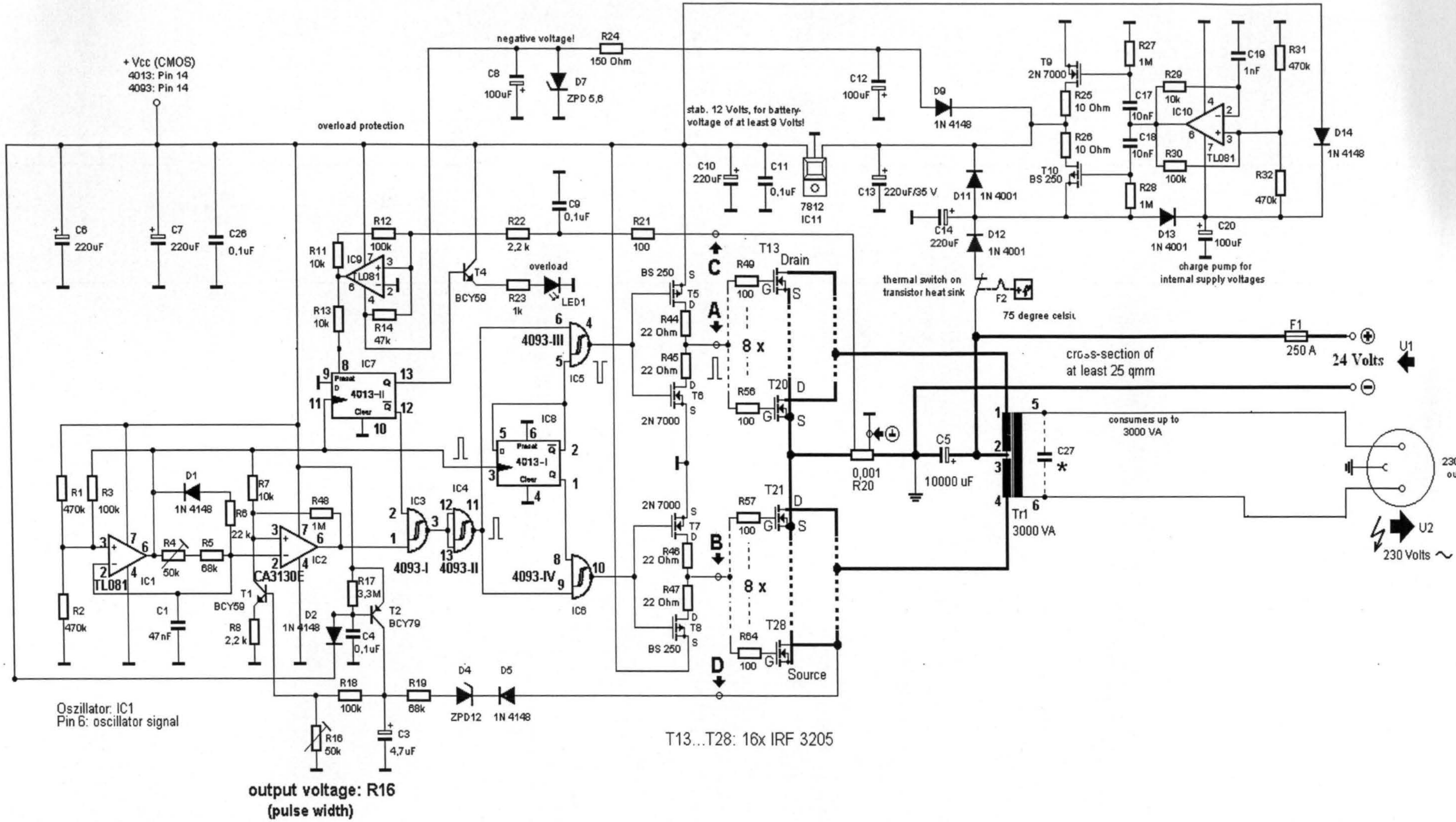


Fig. 3.7: complete circuit diagram

CHAPTER FOUR

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)