DESIGN AND CONSTRUCTION OF 1KVA INVERTER WITH AUTOMATIC CHANGE-OVER WITH AN INFRARED REMOTE SWITCH

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DEDICATION

This project is dedicated to the Lord Almighty for his care, provision and protection, for the grace granted to me for seeing me through in my academics. I also dedicate this project to my Parents Gen. & Mrs Jibril Iyodo for their endless support.

Declaration

I Iyodo Edward Achor declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the federal university of technology Minna

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ACKNOWLEDGEMENT

I will like to give thanks to the Almighty God, for his guidance throughout the period of my stay in the university.

I want to use this medium to express my profound gratitude and thanks to my parents Gen. & Mrs J.A IYODO for their financial and moral support. I pray that you shall eat the fruit of your labour in my life time in Jesus Name. Amen

I will also like to appreciate the Head of my department Dr Y. A. Adediran, who is also my supervisor, and all lecturers in my department that contributed to the successful completion of my course and to all staff of the Federal University of Technology Minna. Finally, I want to say a big thanks to a lot of people whose names are not mentioned but have been a part of the success of this project. I pray that God will continue to bless you and enlarge your coast.

ABSTRACT

This thesis document outlines the research, design and implementation of a medium power DC to AC inverter with particular focus on remote locations. The final design consists of a remote control unit, a modulating module, consisting of an oscillator and a buffer and the step up stage. These two stages form the DC-AC inverting stage. The change over stage ensures continuous power supply is ensured. This is achieved by automatic switching over from the inverter to the main supply (PHCN).

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CHAPTER ONE

INTRODUCTION

An inverter can be defined as an electro-mechanical device that converts DC to AC. Inverters perform the opposite functions of rectifiers. The conversion is mainly achieved by the fast switching of controllable switches such as MOSFETS and BJT's. Application of inverters ranges from small switching power supplies in computers to large electric utility application that transports bulky power[2]. Inverters are of great importance to energy demanding households or location as we have in Nigeria, where power is not efficient and consistent.

Inverters can be designed in various ways depending on the purpose. The efficiency of inverters is highly dependent on the controllable switches of the inverter. The aim of this project is to produce efficient DC to single phase 220V AC inverter.

Inverters are capable of generating power for hours depending on the capacity and number of batteries used. The ability of inverters to do some functions more intelligently automatically gives it advantage over the engine drive generator.

Some of its various advantages over generators are.

- No noise
- No pollution
- Inverters are cost efficient
- No fuel
- No engine oil
- No spare parts cost

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

1.1 AIMS AND OBJECTIVES

This project is aimed at providing cheaper and stress-less power options which may be used in a small scale outfit e.g. barbing saloon, computer centers, etc, when utility power fails, or in remote area away from the national grid as it requires no fossil fuel to run on. It is environmental friendly, and at the same time saves the stress of changing over from the PHCN source to the inverter as a change over circuit was designed to take care of that. A remote control is designed also to switch off the inverter when the need arises; this will also save a lot of stress especially for the physically challenged.

Domestic power demand in Nigeria is increasing rapidly, especially in the urban areas. The rate of power consumption is growing faster than our ability to supply 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. Once utility power fails the DC power stored in the battery is inverted to AC through the circuitry and amplified to deliver power to the load.

1.2 METHODOLOGY

Consultations were made to relevant texts, journals, magazines, websites and individuals to have a good understanding of the theory behind the principles employed. In designing this inverter, a modular approach was employed; each module was independently designed, constructed and tested. Upon testing, the modules were found to be okay before combining them to form the whole circuit. The circuit design analysis was based on operation requirements. The casing was designed to accommodate the transformer, the inverting circuit, the charging circuit, the switching circuit and the changeover circuit. The system was tested again after the casing process.

1.3 SCOPE OF THE PROJECT

The scope of this project entails the designing of 1000VA inverter with a remote controlled switch 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 systems 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.

1.4 LIMITATIONS

1. It was difficult getting some components over the shelf, hence equivalent components were used.
2. The noise from the vibrating transformer could not be completely eliminated.

CHAPTER TWO

LITERATURE REVIEW

2.1 LITERATURE REVIEW

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) [2]. In the early twentieth century, vacuum tube and gas filled tubes began to be used as switcher in inverter circuits. The most widely used type of tube was the thyratron source of the term inverter. Early AC to DC converters 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 end and only one filed frame. The result with either is AC-in, DC-out. With an M-G set, the DC can be considered to be separately 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 an M-G set or rotary converter can be "run backwards", converting DC to AC. Hence, an inverter is an inverted converter [1].

Early inverters for the consumer market were used mainly for mobile applications like boats and recreation vehicles, and most were designed for 12-volt DC battery ignition systems. Due to an upper capacity limit of approximately 200 amps for the internal power components and heavy welding cables that were being used for connecting these mobile 12-volt systems, 2,400 watts was about the largest capacity inverter that could be made for these applications (12V x 200A = 2,400 W). To keep inverter costs low and the designs simple, these early inverters generated a "modified" sine wave output to simulate the 50-cycle 220-volt AC line voltage. The more "steps" in the modified waveform, the closer the output voltage will be to a normal AC sine wave. Until the explosive increase in personal computers and microprocessor-controlled appliances and audio/video equipment, most electrical loads that included older technology would work fairly well on a modified sine wave inverter. Incandescent lights and power tools also worked well, although some fluorescent fixtures and light dimmers had problems. An AM radio may produce an objectionable hum in the background, and a microwave oven will take much longer than normal to cook the same food, but most of these devices would still operate on a modified sine wave inverter.

In the early 1990s, quality modified sine wave inverters were being sold by Trace Engineering and Heart Interface. Although still limited to about 2500-watt output using a 12-volt DC input, these became the standard for residential off-grid and back-up power systems. Many of these early models are still in operation and have an excellent reputation for robust design and reliability.

By the mid-90s, lower costs for solar photovoltaic modules and the need to power more sophisticated appliances, computers, and digital audio/video systems created a demand for larger inverter capacities and a smoother 50-cycle voltage waveform. Manufacturers responded with inverter outputs up to 5,500-watts by using higher voltage 24 to 48-volt DC inputs and more Sophisticated internal electronics to increase the number of "steps" simulating the 50-cycle sine wave.

Some newer inverter models include a communications "link," which allows interconnecting multiple inverters to provide synchronized higher wattage and voltage outputs. Since these changes resulted in much higher inverter prices, most manufacturers still offer lower cost modified sine wave models when lower capacity and power quality are not a concern.

DC-to-AC inverters have been around for a long time. Energy loss in the DC-to-AC conversion process at first was very high: the average efficiency of early inverters hovered around 60%. In other words, you would have to draw 100 watts of battery power to run a 60-watt bulb.
A new way to build inverters was introduced in the early 1980s. These fully solid state inverters boosted efficiency to 90%. Trace Engineering helped to pioneer this technology. Their first model, the 1512, was introduced in 1984, and thousands of their "firstborn" are still going strong in every corner of the globe.

The key to the reliability of inverters are the elegance of their design. The use of a sophisticated Field Effect Transistor (FET) circuitry to convert the batteries' DC voltage (usually 12 or 24 Vdc) into AC. The resulting low voltage AC is then transformed into a higher voltage, usually 120 or 220 Vac. All of the power shaping - conversion to AC - and waveform shaping takes place on the low voltage side of the transformer [2].

There are various kinds of inverters depending on their applications, listed below are some varieties.

- Solar inverter
- Grid tie inverter
- Uninterrupted power supply (UPS)
- Full sine-wave inverter
- Modified sine wave inverter

This project is designed to improve on the previous inverters by the introduction of a changeover system and a remote controlled switch which to an extent reduces the stress of manually turning on and shutting down the inverter.

CHAPTER THREE

DESIGN AND CONSTRUCTION

3.1 THE FUNCTIONAL BLOCK DIAGRAM

In electronic designs, functional or logic block diagram are often to represent systems. The block diagram for this system is shown in fig. 3.1

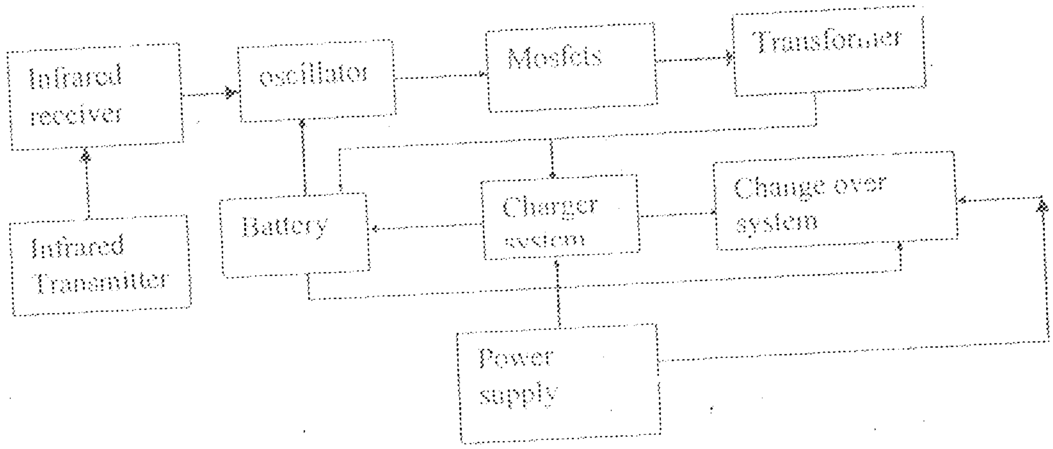


Fig 3.1 Block diagram of a 1KVA inverter

3.2 OSCILLATOR

Oscillator is the frequency generated per unit time. The oscillator frequency could be generated by a monostable or astable device. The astable multivibrator was used in this design, it has 50 duty cycles on the oscillator output. It also has good stable frequency stability.

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

- pulse repetition frequency
- pulse period
- duty cycle

Pulse reception frequency of a pulse wave front is the number of pulse which occurs 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) time.

The CD4047BC is an astable multivibrator possessing these characteristics which was capable of operating in either the monostable 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 freqency is determined by the timing component of the RC circuit.

Pulse repetition frequency generated by the CD4047BC is calculated using the formula

$$F = \frac{1.45}{(2R_1 + R_2)C} \qquad \text{.................. (3.1)}$$

$$F = \frac{1.45}{(2x1x10^3+6x10^3)4.8\,x10^{-6}}$$

$$F = \frac{1.45}{0.288} = 50.35$$

F=50Hz

T= 0.0199sec ≈ 0.02sec

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

Duty cycle D of the pulse wave form is calculated using the formula

$D = \frac{T_{ON}}{T_{ON} + T_{OFF}} x\ 100$ ……………………………………………………………… (3.2)

$T_{ON} = 0.693\ (R_1 + R_2)C$ ……………………………………………………………… (3.3)

$= 0.693\ (1x10^3 + 6x10^3)x4.8x10^{-6}$

$= 0.693\ (6000)x4.8x10^{-6}$

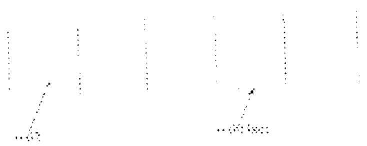
$= 0.02sec$

Therefore, it takes 0.02 sec. to ON with these parameters of component. To achieve the time OFF in the system the formula below is used.

$T_{OFF} = 0.693(R_2C) = 0.693(1e^3 \times 4.8e^{-6})$ ……………………………… (3.4)

$= 0.00333sec.$

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



Therefore the duty cycle

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

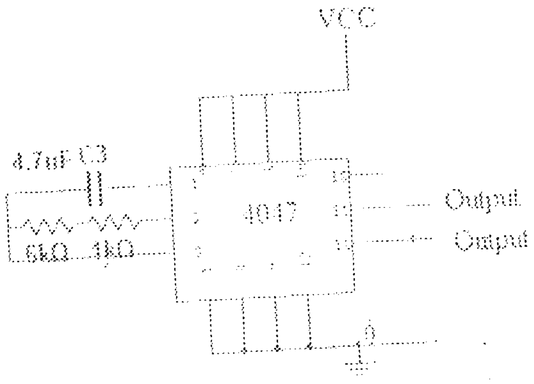


Fig 3.1 Diagram of the oscillator

3.3 BUFFER

The buffer is the driver that drives the current to the input of the power switching MOSFET. The component used for the buffer 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 trassistor. The device features logic level conversion using only one supply voltage. The input signal at high level can exceed the supply voltage when this device is used for logic level conversion. The device is intended for use as hex buffer.

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

3.4 POWER SWITCHING MOSFET

MOSFETS (metallic oxide semi conductor field effect transistors) are power semiconductors in which the gate is completely insulated from the channel by a thin (about I dm) layer of silicon oxide [2]. This permits 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 Picoamp (pA).

On the design, the MOSFET receives 12V alternative voltage. Therefore For complete OFF state of the MOSFET the gate was negatively biased to avoid damaging it, because without the negative bias, the MOSFET will not completely turn OFF before the arrival of the other pulses which might damage the MOSFET. Therefore, a 100Ω resistor was used to completely switch OFF the MOSFET.

Calculation

12V was fed to the switching MOSFET which makes

$V_{GS} = 0 \text{ at self bias}$

$I_G = \frac{V_{CC} - V_{GS}}{R_G}$ ....(3.5)

$I_G = \frac{12-0}{100} = \frac{12}{100} = 0.12\ Amp$ ....(3.6)

$I_d = \frac{V_{DD}}{R_D}$

Where I_d is the current drain.

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.

But power = 1kW

P = iV ....(3.7)

$1000 = 12 \times I$

$I = \frac{1000}{12} = 83.3Amp$

$X_L = \frac{V}{I}$ ....(3.8)

$$X_L = \frac{V}{I} = \frac{12}{83.3} = 0.14\Omega$$

$\Rightarrow$ at 50Hz the reactance of the coil was noted to be 0.147Ω, hence $R_D = 0.144\Omega$

$$I_d = \frac{V_{DD}}{R_D} = \frac{12}{0.144} = 83.3amps$$

3.4.1 POWER RATING AND TEMPERATURE OF THE MOSFET

Power semiconductors fail because of excess heat. The temperature rating of a material depends on the material used. Silicon devices can operate at temperature up to about 175°C to 200°C. Therefore, IRF3205 was used in this design, it has a power rating of 200 watts [4]. Therefore, using it for a load of 0.144Ω, and therefore the temperature will increase as power is dissipated.

$\Rightarrow$ Power dissipated from the MOSFET at 0.144Ω will be $= \frac{(V_{DD})^2}{\pi^2 \times R_D} = \frac{12^2}{(3.142)^2 \times 0.144} = 101.32watt$

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

3.5THE TRANSFOMER

The transformer is an electromechanical device that is used to transform voltages from one level to another. A transformer is made up of the primary coil and the secondary coil. Voltage can be induced with respect to coil turns ratio as voltage flows through the coil, Its

Voltage induction is proportional to the rise and fall of the magnetic field produced. To achieve the impedance of the coil, the parameters are noted.

Primary coil turns = 500 + 30 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 current that runs through the source to the drain of the MOSFET. This help in powering the transformer, because the transformer is the R_L (load resistor of the MOSFET)

$\therefore I_p$(Primary current) is given by

$\frac{I_P}{I_S} = \frac{V_S}{V_P}$ ....(3.9)

$$I_p = \frac{12 \times 83}{220} = 4.52A$$

$\therefore Primary\ current = 4.52A$

Power efficiency = power input = power output

Power efficiency = 12 x 83 = 220 x 4.52 = 994.4W

If secondary reactant $X_{cp} = \frac{V}{I} = \frac{12}{83} = 0.1466$

∴Inductance of the secondary coil

$X_L = 2\pi f L$

= 0.1446

=2 x 3.142 x 50L

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

L=0.00046211

L=0.4 x 10^{-3}H

Inductance of the primary coil

$$X_L = \frac{220}{4.52} = 48.7\Omega$$

$\therefore X_L = 2\pi f L$

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

$$L = \frac{48.7}{2 \times 3.142 \times 50}$$

L=0.15H

3.6 THE BATTERY CHARGER UNIT

This is composed of the transformer and the rectifier.

The transformer:

An auxiliary winding from the transformer with voltage rating 15V was used to supply AC voltage to the bridge rectifier.

The rectifier:

The bridge rectifier is there to produce a full wave rectified wave form. 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 voltage with respect to ground can be produced. Connecting the positive terminal to ground yields a negative supply while connecting the negative DC terminal to ground yields a positive supply.

The polarity of the AC voltage is such that it makes AC1 positive and AC2 negative. The polarity turns D1 and D3 ON (forward biased) and D2 and D4 OFF (reversed biased). As a result, the current I1 through D1 has the direction from +DC to −DC.

3.7 THE CHANGEOVER UNIT

This unit consists of a 220V dipole AC relay which is usually controlled by the main supply (PHCN). The relay is connected in such a way that it switches between the output of the inverter and the main supply.

3.8 THE INFRARED SENSOR UNIT:

This consists of the infra red module which is the transducer that receives the infrared signal from the transmitter and modulates into a wave train of modulated electrical signal. PIN diode and the preamplifier are assembled on lead frame, the epoxy package is designed as IR filter. The demodulated output signal can directly be decoded by a microprocessor. TSOP12 is the standard IR remote control receiver series, supporting all major transmission codes [9].

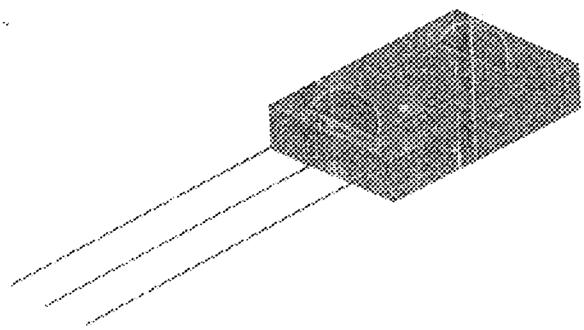


Fig 3.3 Diagram of the infrared sensor [9]

3.8.1 THE INFRA RED TRANSMITTER UNIT:

The transmitter is a gated 38 KHz oscillator designed to meet the operating requirements of the three terminal sensor used in the construction work. The frequency is sensed at the receiver to turn on the oscillator of the inverter.

The schematic diagram of the IR trasmitter is shown in fig 3.4

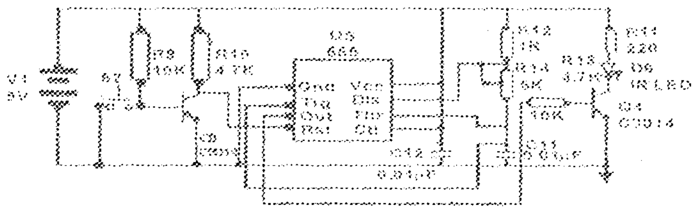


Fig 3.4 circuit Diagram of the infrared transmitter

3.8.2 THE TIMER GENERAL DESCRIPTION:

The 555 timer IC was first introduced around 1971 by the sigmatics corporation as the SE555/NE555 and was called the "Time machine" and was also the very first and only commercial timer IC available [5].

The LM555 is high stable device that can be used for time delays or oscillations. Additional pins are provided for triggering or resting if desired. In the time delay mode of operation, the time is precisely controlled by the free running frequency and duty cycle are accurately controlled with external resistor and one capacitor.

3.8.3 MONOSTABLE OPERATION

In this mode of operation, the timer functions as a one – shot. The external capacitor is initially held charged by a transistor inside the timer. Upon application of a negative trigger pulse of less than

(1/3)Vcc to pin 2, it is set which both releases the short circuit across the capacitor and drives the output high [6].

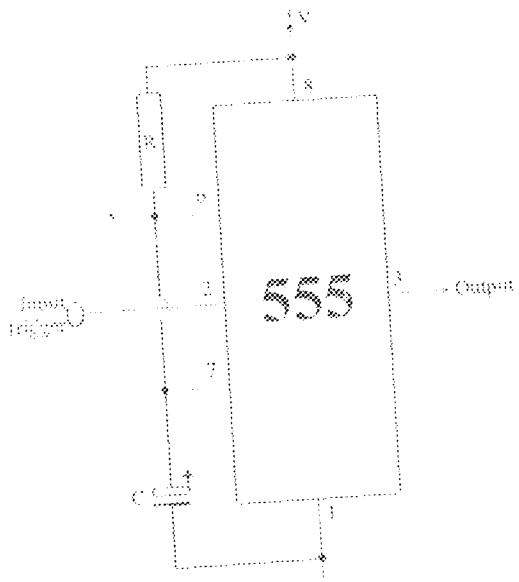


Fig 3.5 diagram of a 555 timer connected in a monostable state

During the timing cycle when the output is high, the application of another trigger pulse will not affect the circuit as long as the trigger input is returned high. However to reset the circuit a negative pulse is sent to the terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied. When the reset function is not in use, it is recommended that pin 4 be connected to Vcc to avoid any possibility of false triggering.

Whenever a trigger pulse is applied to the input, the 555 will generate its single – duration output pulse. Depending upon the values of external resistance and capacitance used, the output timing pulse may be adjusted from approximately one millisecond to as high as on hundred seconds for the intervals less than approximately 1 – millisecond, it is recommended that standard logic one – shorts designed for how narrow pulsed to be instead of a 555 timers are normally used where long output pulses are required. In this application, the duration of the output pulse in seconds is approximately equal to [5].

T= 1.1 × R × C (in seconds)

3.9 THE RELAY UNIT:

Relays are components which allow low power circuit to switch a relatively high current ON and OFF, or to control signals that must be electrically isolated from the controlling circuit to the controlling unit [8].

To make a relay operate, you have to pass a suitable 'pull in' and' Holding 'current (DC) thorough its energizing coil. Relay coils are designed to operate from a particular supply voltage often 12V. In each case the coil has a resistance which will draw the right pull – in and holding current when connected to that supply voltage [11].

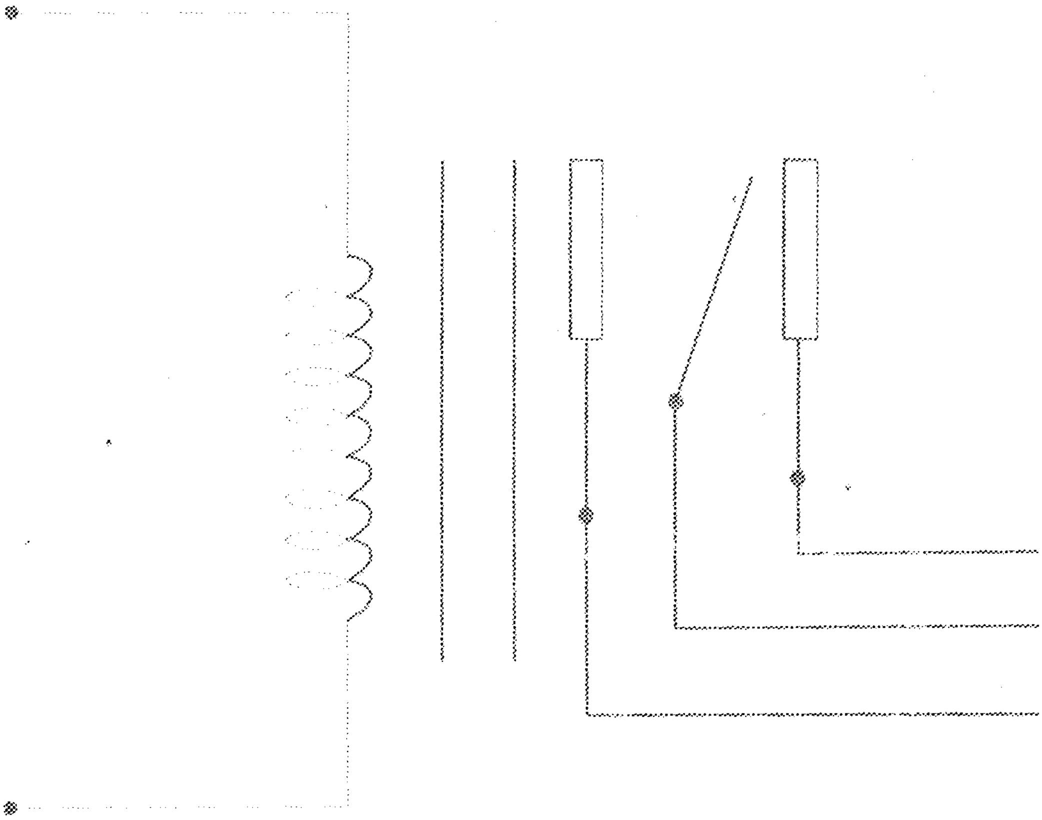


Fig 3.6 the relay diagram

3.9.1 RELAY DRIVE UNIT:

The relay unit circuit is made up of a current limiting resistor, resistor switch and a relay as shown in fig 3.7

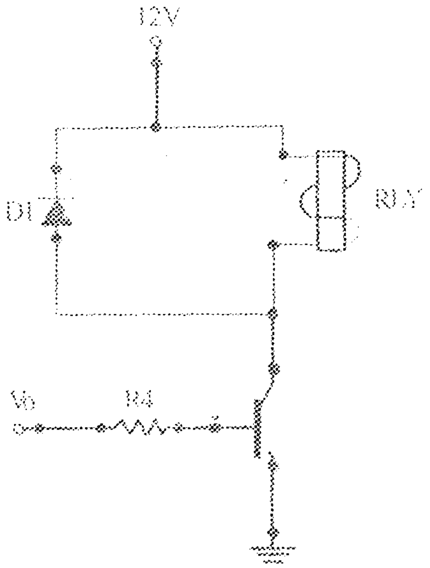


Fig 3.7 diagram of the relay drive unit

20mA will be required to switch on the transistor.

Relay data:-

Coil resistance=400Ω

V_{cc}=12V

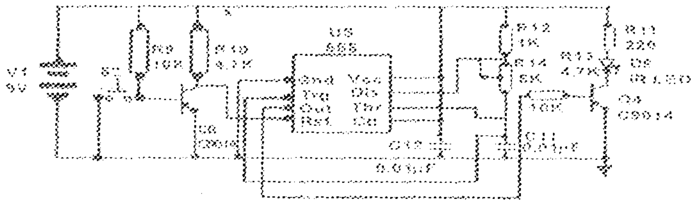
Coil current of the relay=12/400=30mA

I_c= 30mA

I_b= 20mA

$H_{FE} = I_c / I_b \quad (30 \; 10)/(20\times10) = 1.5$

Almost all the switching transistor can serve the equipment; therefore C945 was selected as TR.



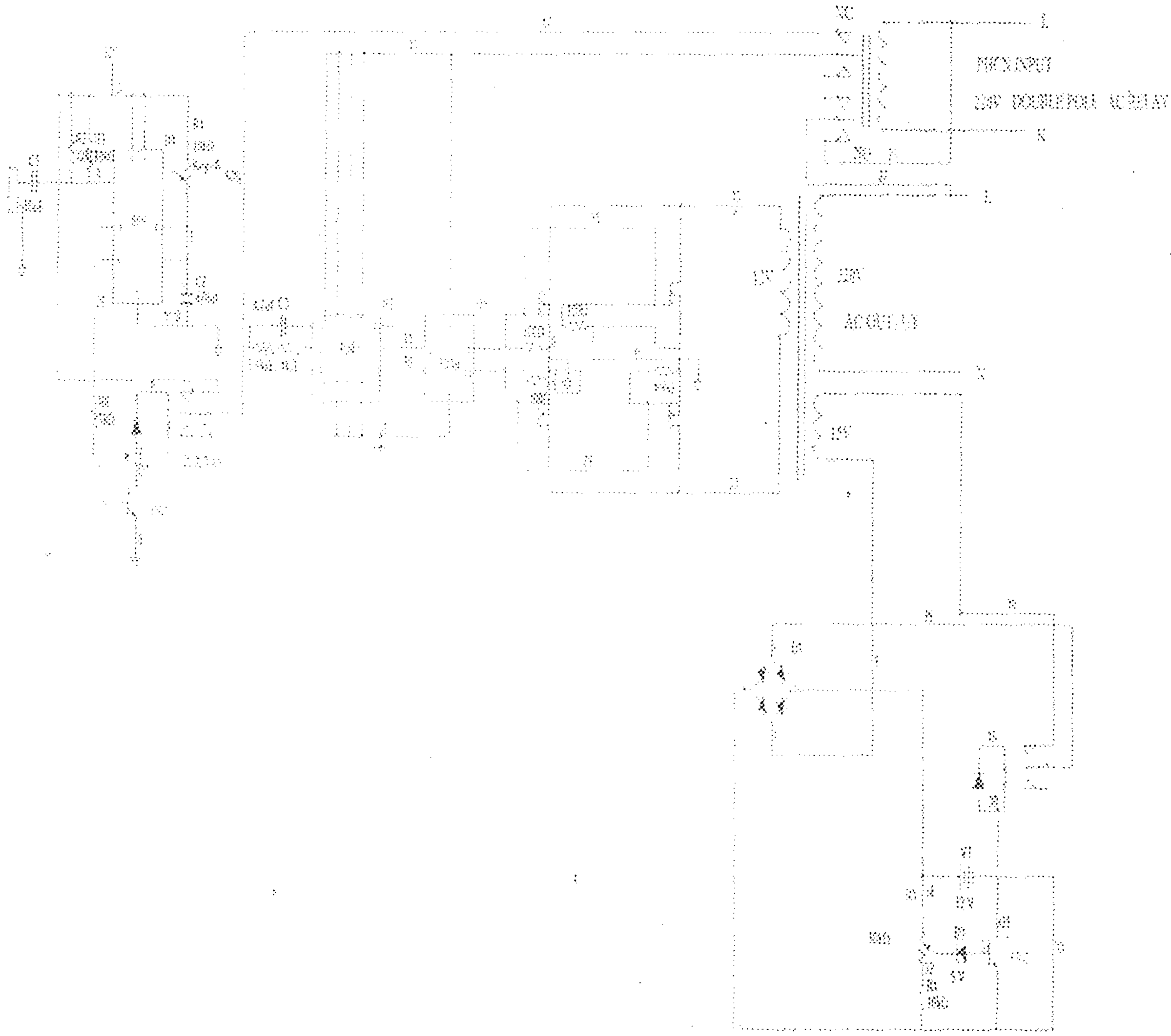


Fig 3.8 The complete circuit diagram

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1 CONSTRUCTION AND TESTING

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

This is because of the complexity of the modular approach in the design and construction.

The second stage is the casing of the project. The casing is made of metal

4.2 TESTING

After carrying out all paper design and analysis, the project was implemented and tested to be sure of its working. 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.
- Multi-meter: - 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 no-load and load.

Table 4.1 Results obtained from various blocks of the device

Item	Device	input	Output	Discussion
1	transformer	12/220 Volts	220 Volts	The standard output of the transformer is 220V but a value 219.8V was read due to voltage drop. The current in the secondary winding was calculated and gotten to be 83.3A. The current in the primary coil was tested using a multimeter and gotten to be 4.52A. Hence the output power of the transformer was calculated and tested to be 996W
2	The one shot 555 timer	9 Volts	12.0 volts	The output of the 555 timer after triggering was found to be 12.0 Volts held Of 2.0 seconds (i.e. period of 2 seconds) as a one shot and then fall back to zero.
3	The 220V AC Dipole Relay	220V	Latching	On receiving a voltage from the mains the relay coil is energized and the relay contacts switches between the normally open and normally close terminals
4	The relay	12 volts	Latching	The transistor serve as a switch which continues the ground connection of the relay which energizes the relay coil and the relay contacts are closed

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, the infrared remote controllable switch was achieved and the automatic change over was also achieved. 220VAC from 12VDc battery was also achieved

4.3.1 DESIGN SPECIFICATIONS

- Output power 1KVA
- Output frequency = 50Hz
- Output voltage = 220 volts AC
- Charging type = constant voltage

The power 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; a clip was applied to hold the coils more compact together to reduce the noise.
3. It was difficult getting some components over the shelf. Hence equivalent was used after consulting the data sheet.
4. The infra-red sensor can easily be triggered by external unwanted signals

CHAPTER FIVE

CONCLUSION

The aim of this design and construction of a 1 KVA inverter with automatic change over and remote controlled switch is finally achieved with a great deal of patience and good reasoning during the construction.

The objective of which is to invert 12V DC to 220V AC was achieved. The IR remote is also seen to have high sensitivity with a considerable distance of 3-4 meters away provided that the line of sight is maintained between the transmitter and the receiver.

The device is also reasonably portable.

This project really exposed me more to electronic components and ICs. I had an in-depth 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.

5.1 RECOMMENDATIONS

1. Further research should be done on other sources of energy.
2. Digital multi simulators should be made available to enable students carry out tests
3. Research should be done on longer lasting inverters

REFRENCES

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