DESIGN AND IMPLEMENTATION OF A

1.5KVA SINGLE PHASE INVERTER

BY

AWELEWA, SUNDAY ARINBOLA

(MATRIC NO: EEE/11/0386)

A PROJECT REPORT SUBMITTED TO THE
DEPATMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING,
FEDERAL UNIVERSITY OYE-EKITI, IKOLE-EKITI CAMPUS

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF BACHELOR OF ENGINEERING (B.ENG) IN
ELECTRICAL AND ELECTRONICS ENGINEERING

SEPTEMBER 2016

DECLARATION

I, AWELEWA, SUNDAY ARINBOLA do hereby declare that all the work in this project was carried out by me, under the supervision of ENGR. HILARY UGO EZEA to the best of my knowledge, no such work has not been submitted to the department of Electrical and Electronics Engineering, Federal University Oye-Ekiti or any other institution for the award of a Degree.

CERTIFICATION

This project work titled "Design and Implementation of a Single Phase Inverter" by Awelewa, Sunday Arinbola, meets the minimum requirements governing the award of Bachelor degree in Electrical/Electronic Engineering Department, Federal University Oye-Ekiti, Ekiti.

.... 24/10/2016 ....

ENGR. Hilary Ugo EZEA
(Project Supervisor)

DATE

.... 24/10/2016 ....

ENGR. Dr. .. . O. AKINSANMI

(Head of Department)

DATE

....

EXTERNAL EXAMINER

DATE

ACKNOWLEDGEMENT

All glory, honour, power and praise be to my Heavenly Father, Redeemer, The most gracious and Father of our Lord Jesus Christ. I am really grateful and will praise You till eternity.

I am indeed grateful to my parents and the entire members of my immediate family-Awelewa's family- for their support spiritually, morally and financially. I say a big thank you to all of them.

I would like to recognize the patience, guidance and help shown by my Project supervisors: Engr. Dr. B.O. Anyaka (with whom I started this project work) and Engr. H.U. Ezea, under the leadership of the Head of Department (H.O.D), Engr. Dr. .. O. Akinsanmi. My profound gratitude goes to the Head of the department, all lecturers, technologists and administration staff of the Department of Electrical and Electronic Engineering, Faculty of Engineering, Federal University Oye-Ekiti, Ekiti for their support throughout my first degree.

Also, my sincere appreciation goes to Deeper Life Campus Fellowship, Ikole region under the leadership of my Daddy- Pastor A. Adetukasi for her magnanimous support.

I would like to show my profound gratitude to Pastor D. A. Adeyemo, Pastor and Mrs Obaloyo, Pastor Oguntuase, Mr and Mrs Adeyemo, Sis Wemimo Adedapo and others who assisted me in gaining admission and support during my stay in the school. Also, the support of Pastor and Mrs Oshinoyi (DLBC Shogunle, Lagos) for their support during the project.

I would like to show my sincere appreciation to Mummy Amos, Mrs Ajiboye, all acquaintances, and course-level mates who are too numerous to be mentioned.

Thank you all. The grace of the Lord Jesus Christ be with you all.

To God be the Glory.

DEDICATION

This thesis is dedicated to the Almighty God who spared my life throughout my first degree programme till this moment in sound health and made me what I am today by His grace.

Also, to my beloved parents Mr. F.A. Awelewa and Mrs. G.A. Awelewa for their love, support, care and encouragement in all areas. Not forgetting other members of my family, Leke, Seun, Paul, Pelumi who stood by me and challenged me to push through my First degree programme.

ABSTRACT

This project presents a single phase inverter system which serves as an alternative power supply. The conversion technique used is first converting the low voltage DC power to AC power using pulse width modulation (PWM), then boosted to high AC voltage using a step up transformer for constant output voltage instead of boosting the low voltage DC power to high voltage power source using a DC- DC booster which is then converted to AC power using pulse width modulation (PWM). It is a microcontroller-based single phase inverter system which produces a sine wave output approximate to the power supplied by the national grid which is stable and reliable. This constructed project finds application in communities for residential use; social groups for powering equipment such as lightings, cooling systems and sound systems; governmental and non-governmental organizations such as academic institutions for lightings, powering equipment for Wi-Fi facility and other equipment, virtual lectures; hospitals to supply constant power to equipment needed to keep vaccines at low temperature and in Industries.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS

Wi-Fi -	Wireless Fidelity
MCU -	Micontroller
VSI -	Voltage source inverters
CSI -	Current Source Inverter
ASD -	Adjustable Speed Drive
KVA -	Kilovolt-Ampere
AC -	Alternating Current
DC -	Direct Current
MOSFET-	Metallic Oxide Semiconductor Field Effect Transistor
PWM -	Pulse Width Modulation
DAC -	Digital-to-Analog converter
LCD -	Liquid Crystal Display
LED -	Light Emitting Diode

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

With the rapid depletion of non-renewable energy resources such as fossils-based on energy reserve- and rapid growth of energy demand as a result of population growth including a large population in rural areas, there is need to increase and maintain supply of electricity reliably[1].The national grid supply in developing countries is unreliable and almost unavailable in rural areas, hence the need to provide a greatly reliable, low cost, fuel free, pollution free, maintenance free, longer lifetime, and independent power source to this potentially deprived people to enable them gain access to more education, health care, communication, and entertainment [2]. For good availability of supply, electrical energy has to be stored in batteries (DC) from the national grid supply or any other means of supply for a later use. As a result of the nature of alternating current (the voltage level can be stepped up or down by use of transformers), most electrical devices in the world today are designed around AC/DC power conversion. It is therefore necessary to convert the DC energy from storage batteries to AC power to supply such devices with the needed energy. In practice, DC/AC conversion is done by a power inverter. In today's market, there are two different types of inverters: modified square wave and pure sine wave inverter. The modified square wave is similar to a square wave which is less efficient in power consumption, high number of harmonics which affects devices, hence, reducing its life time. Whereas, a pure sine wave inverter reduces the harmonics to minimum, thus increasing the efficiency of power consumption and life time of AC appliances. It also reduces the audible and electrical noise in audible equipment, TV's, Fluorescent lights and allows inductive load, like fan to run faster and quieter [3].

1.2 STATEMENT OF THE PROBLEM

In Nigeria, power outages have become more frequent owing to the lack of incentives to invest in aged national grid, transmission and distribution infrastructures, as well as the fact that energy from decentralized, "volatile" renewable sources is not well aligned to work on electricity grids. A practical example is seen in my area in Ikole Ekiti where there has been a black out since January, 2016 till now (August, 2016). Frequent power outages are inconvenient, expensive and difficult to mitigate without very expensive and efficient backup power systems. Some of the solutions to this problem is an auxiliary AC power generator and solar panels; but the cost of fossil fuels continues to increase rapidly, thus, it will not be cost effective in the future while solar power has some aesthetic, economic and technical drawbacks. A more effective and reliable alternative is battery power back-up system.

1.3 PURPOSE OF THE STUDY

As a result of the problem stated above,

The aim of the study is to design and implement a Single phase inverter.

The objectives of the study are:

(1) To design the oscillating stage
(2) To design the driver's stage
(3) To design the switching stage

Capable of producing a voltage of 220V (±5%) with a load capacity of 1.5KVA and delivering power at a frequency of 50Hz.

1.4 SIGNIFICANCE OF THE STUDY

This study is undertaken as a result of the problems of power instability and blackouts prevalent in our society today. The project would be of immense benefit to all especially people in the rural areas. The beneficiaries include:

(1) Individuals of the community for residential use
(2) Social groups for powering equipment such as lightings, cooling systems and sound systems
(3) Religious groups such as churches and mosques
(4) Governmental and non-governmental organizations such as academic institutions (lightings, powering equipment for Wi-Fi facility, virtual lectures such as power point lectures to enhance quality learning, and powering other equipment used in the academic environment); hospitals (to supply constant power such as to provide low temperature needed to keep vaccines effective and powering other equipment).
(5) Industries: To ensure that manufacturing process is not interrupted due to power failure.

1.5 SCOPE OF THE STUDY

This study is limited to designing of a 1.5KVA pure sine wave Inverter at a voltage of 220Vac, frequency of 50Hz. The circuitry involves a microcontroller PIC 16F72 to produce the pulse width sinusoidal waveform, drivers such as BC 547, BC 557 and TLP 250, H-bridge stage which contains IRF 3205 MOSFET switches, 1.5KVA Soft iron core transformer, feedback circuits, and low pass filter. The inverter requires a 12V DC battery as a source of DC energy and can also switch to the 220V AC mains for direct use by means of relay when there is power in the national grid supplied to the rural area.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Today, electricity is increased due to the world needs in making life convenient, safer to live in and reducing overall time for a process. The main reasons for this increase in demand are the population, the economic growth and the rapid depletion of non-renewable energy resources such as fossils based on energy reserve and rapid growth of energy demand [1]. More so, a huge population of Nigerians live in rural areas where the electricity supply from the national grid system is mostly unreliable or unavailable because of power outages and disturbances caused by overloading and bad weather conditions such as excessive rainfall and hurricane wind. There is therefore a great need for storing the electrical energy supplied for a given period from the national grid or from other sources such as solar and making it available when there is power outage. This is done by an inverter which provides a simple, greatly reliable, low cost, fuel free, pollution free, maintenance free, longer lifetime, and independent power source to this potentially deprived people to enable them gain access to more education, health care, communication, and entertainment [2].

2.2 OVERVIEW OF INVERTER SYSTEMS

The theory behind inverter systems is to provide reliable, disturbance free, clean power to its users irrespective of what happens at the primary power sources. There are primarily three types of inverters: square wave, modified square wave, and sine wave. All three have some characteristics in common but different levels of performance due to their output waveforms. The output of the off-the-shelf inverters (generally either square wave or modified-sine wave though delivering the same average voltage to a load) is not appropriate to delicate electronic devices which depends on precise timing and these inverters are less expensive to make. Pure sine wave inverters offer more accuracy and less unused harmonic energy delivered to a load, but they are more complex in design and more expensive. Pure sine wave inverters will power devices with more accuracy, less power loss, and less heat generation [4].

2.2.1 SQUARE WAVE INVERTER

Among the three types of inverters, square wave inverters are the most common and easy to build. It converts a DC signal to a phase shifting AC signal. But the output is not pure AC, i.e. in the form of a pure sine wave, but it is a square wave. At the same time they are cheaper as well. The simplest construction of a square wave inverter can be achieved by using an on-off switch, before a typical voltage amplifying circuitry like that of a transformer

2.2.2 MODIFIED SQUARE WAVE INVERTER

This is a modification of square wave form sometimes known as quasi sine wave inverter [5]. The construction of this type of inverter is a bit more complex than a simple square wave inverter, but still it is a lot simpler than a pure sine wave inverter. A modified square wave shows some pauses before the phase shifting of the wave, i.e. unlike a square wave, it does not shift its phase abruptly from positive to negative, or unlike a sine wave, does not make a smooth transition from positive to negative, but takes brief pauses i.e. stays for a period at the origin and then shifts its phase.

2.2.3 SINE WAVE INVERTER

The pure sine wave inverter is the most reliable inverter but with a complex structure. The electrical circuit of a pure sine wave inverter is far more complex than a square wave or modified sine wave inverter. A way to obtain a sine wave output is to obtain a square wave output from a square wave inverter and then modify this output to achieve a pure sine wave. The sine wave inverter has several advantages over square wave and modified square wave inverters: More efficiency, hence consumes less power; they can be modified according to consumers' power requirements, since several types are available with different power outputs; the output of a pure sine wave inverter is very reliable, but at the same time, there is a trade-off between the price and reliability. Due to this reason they are the best option for sensitive equipment [5].

The schematic diagram of the different outputs of the square wave, modified square wave and pure sine wave inverters are shown in Figure 2.1 [6]:

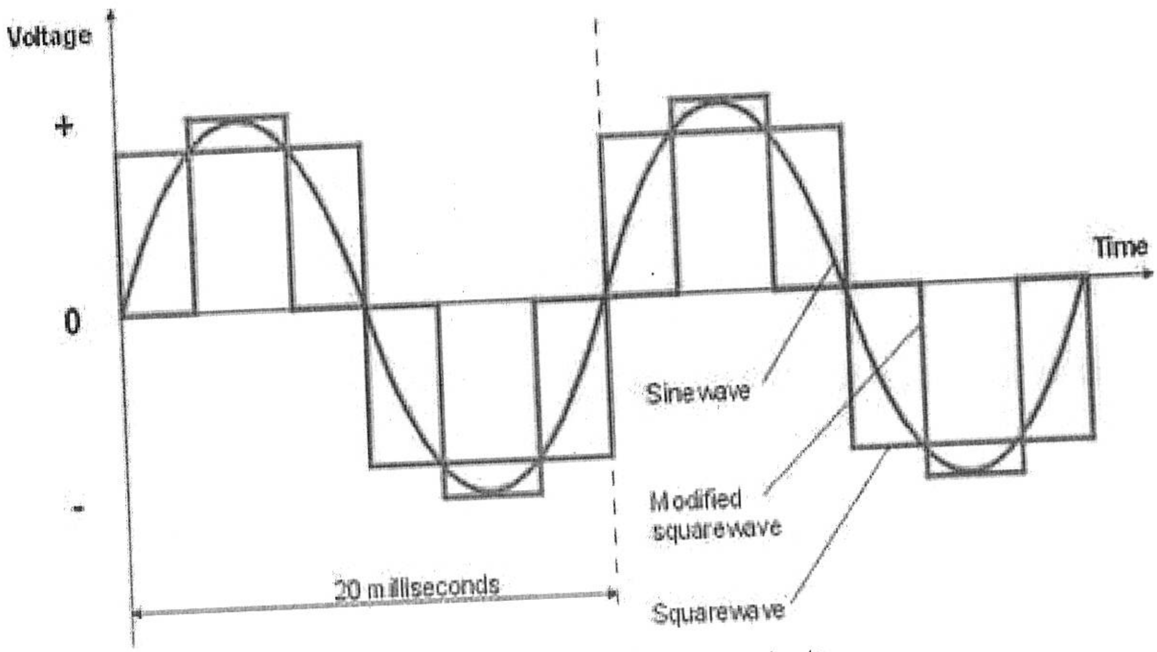


Figure 2.1: Types of inverter outputs

2.3 VOLTAGE SOURCE AND CURRENT SOURCE INVERTERS

Based on the type of ac output waveform, the inverter topologies can be considered as voltage source inverters (VSIs), where the independently controlled ac output is a voltage waveform. These structures are the most widely used because they naturally behave as voltage sources as required by many industrial applications, such as adjustable speed drives (ASDs), which are the most popular application of inverters. Similarly, the topologies where the independently controlled ac output is a current waveform is a current source inverters (CSIs). These structures are still widely used in medium-voltage industrial applications, where high-quality voltage waveforms are required [7].

2.3.1 CURRENT SOURCE INVERTER

The converter (known as active rectifier or active front end (AFE)) section uses silicon-controlled rectifiers (SCRs), gate commutated thyristors (GCTs), or symmetrical gate commutated thyristors (SGCTs). The DC link uses inductors to regulate current ripple and to store energy for the motor. The inverter section comprises gate turn-off thyristor (GTO) or symmetrical gate commutated thyristor (SGCT) semiconductor switches which are turned on and off to create a pulse width modulated (PWM) output which regulates the output frequency.

2.3.2 VOLTAGE SOURCE INVERTER

This inverter uses a diode rectifier that converts utility/line AC voltage (60 Hz) to DC. Unlike the current source inverter, the converter is not controlled through electronic firing. The DC link is parallel capacitors, which regulate the DC bus voltage ripple and store energy for the system. Insulated gate bipolar transistor (IGBT) semiconductor switches are used in the inverter section. Insulated gate commutated thyristors (IGCTs) and injection enhanced gate transistors (IEGTs) can be used as alternatives. These switches create a PWM voltage output that regulates the voltage and frequency to the motor [8].

2.4 CONVERSION TECHNIQUE

The low voltage DC power is inverted to AC power using either of the two methods below:

(1) The low voltage DC power is first boosted to high voltage power source using a DC- DC booster which is then converted to AC power using pulse width modulation (PWM).

(2) The low voltage DC power is first converted to AC power using pulse width modulation (PWM) then boosted to high AC voltage using a step up transformer.

The ability to produce a constant output voltage is a great advantage for the second method which makes it mostly used in modern inverters as compared to the first method which requires additional circuit to boost the voltage [9].

2.5 PULSE WIDTH MODULATION (PWM)

Power electronic converters must be appropriately controlled to supply currents, voltages, or frequency ranges required for the load and to ensure the achievement of the requested power quality. The process of power converter control is called gating which involves switching the power converter ON and OFF, adjusting its mode of operation, controlling the performance accordantly with the reference. The gating circuits usually perform the following operations:

(1) Clocking the discrete intervals for the system timing

(2) Generation of carrier signals

(3) Production of control pulses

(4) Conversion of the control pulses into the gate pulses

(5) Distribution of the gate pulses between the power switches

(6) Galvanic isolations of control and power circuits

Pulse Width Modulation technique combines both voltage and frequency control. The pulse width modulation circuit output is the chain of constant amplitude pulses, in which the pulse duration is modulated to obtain the necessary specific waveform on the constant pulsing periods. The controlled output voltage is easily obtained by switching the transistors on and off many times within a cycle (ranging from a few kilohertz in simple motor control systems up to several megahertz in resonant converters for power supply) to generate variable voltage output which is normally low in harmonic content. Modulation in which the pulse width continuously changes is known as sinusoidal pulse width modulation while modulation which operates at fixed pulse widths grouped in blocks is called picket PWM. The essence of sinusoidal PWM is to synthesize voltages that produce currents as close to sinusoidal as economically possible [10]. The two-level PWM signal contains a relatively high amount of higher level harmonics which can be removed using second order Low Pass Filter [11].

In order to create a PWM signal which more closely follows the desired sine wave output, The PWM technique can be expanded to 3-, 5-, 7- and 9+ level PWM. Each additional 2 levels added on top of the 3-level design adds an H-bridge (added in series), a comparator, and a summer. The major disadvantage of 5-plus level PWM designs is that it requires many more components to implement, with multiple DC voltage rails which must be placed in series. For our purposes, then, such a design is impractical and expensive. Though the potential advantages of these higher-level systems are certainly intriguing, but 3-level PWM is commonly used as a balance between cost and efficiency [12].

2.6 H- BRIDGE CONFIGURATION

An H- Bridge or full- bridge converter is a switching configuration composed of four switches in an arrangement that resembles a H. A positive, negative, or zero- potential voltage can be placed across a load by controlling different switches in the bridge [3]. The full H-bridge inverter circuit is used to convert a DC voltage from such source as a battery to a sinusoidal AC voltage at a desired output voltage and frequency [13]. When the load to be supplied with this desired output voltage and frequency is a motor, these states correspond to forward, reverse, and off [3]. The use of an H- Bridge configuration to drive a motor is shown in Figure 2.2 [13].

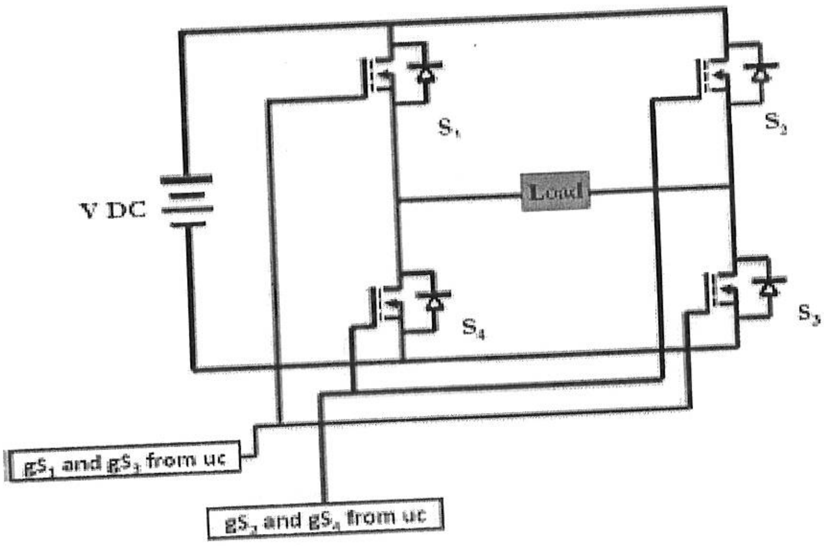


Figure 2.2: H- Bridge Configuration using N- Channel MOSFETs

As shown in Figure 2.10, the H- Bridge circuit consists of four switches corresponding to high side left, high side right, low side left, and low side right. There are four possible switch positions that can be used to obtain voltages across the load. These positions are outlined in Table 2.1. Note that all other possibilities are omitted, as they would short circuit power to ground, potentially causing damage to the device (switches) or rapidly depleting the power supply [3].

Table 2.1: Valid H-Bridge switch states

High Side Left	High Side Right	Low Side Left	Low Side Right	Voltage Across Load
On	Off	Off	On	Positive
Off	On	On	Off	Negative
On	On	Off	Off	Zero Potential
Off	Off	On	On	Zero Potential

The switches used to implement an H- Bridge can be mechanical or built from solid state transistors. Selection of the proper switches varies greatly. The use of P- Channel MOSFETs on the high side and N- Channel MOSFETs on the low side is easier, but using all N- Channel MOSFETs and a FET driver, lower "on" resistance can be obtained resulting in reduced power loss. The use of all N- Channel MOSFETs requires a driver, since in order to turn on a high- side N- Channel MOSFET, there must be a voltage higher than the switching voltage (in the case of a power inverter, 12V). This problem is often overcome by driver circuits capable of charging an external capacitor to create additional potential [3].

2.7 MOSFET DRIVERS

When switching a DC voltage across a load utilizing N-Channel MOSFETs, the drain terminals of the high side MOSFETs are often connected to the highest voltage in the system. This creates a difficulty, as the gate terminal must be approximately 10V higher than the drain terminal for the MOSFET to conduct. Integrated circuit devices known as MOSFET drivers are commonly utilized to achieve this difference through charge pumps or bootstrapping techniques. These MOSFET drivers are capable of quickly charging the input capacitance of the MOSFET quickly before the potential difference is reached, causing the gate to source voltage to be the highest system voltage plus the capacitor voltage, allowing it to conduct. A diagram of an N- channel MOSFET with gate, drain, and source terminals is shown in Figure 2.3 [14].

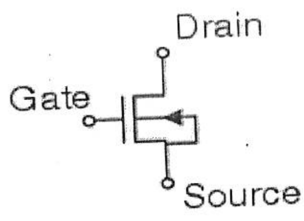


Figure 2.3: MOSFET symbol

There are many MOSFET drivers available to power N-Channel MOSFETs through level translation of low voltage control signals into voltages high enough to supply sufficient gate voltage. Advanced drivers contain circuitry for powering high and low side devices as well as N and P-Channel MOSFETs. N-Channel MOSFETS have high current handling capabilities. To overcome the difficulties of driving high side N-Channel MOSFETs, the driver devices use an external source to charge a bootstrapping capacitor connected between V_{cc} and source terminals which provides gate charge to the high side MOSFET. As the switch begins to conduct, the capacitor maintains a potential difference which makes the MOSFET to further conduct, until it is fully on. The name bootstrap component refers to this process and how the MOSFET acts as if it is "pulling itself up by its own boot strap" [3].

2.8 TRANSFORMER

A transformer is a static piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit; it can step down or step up the voltage in a circuit with a corresponding increase or decrease in current [15]. It is an electrical device that transfers energy between two circuits through electromagnetic induction. Other uses include current conversion, isolation with or without changing voltage and impedance conversion. A transformer consists of two windings of wire that are wound around a common core to provide tight electromagnetic coupling between the windings. Laminated iron core is commonly used as the core material. The coil that receives the electrical input energy is referred to as the primary winding; the output coil is the secondary winding [3].

Core form and shell form transformers include:

(1) Laminated steel cores. They have cores made of high permeability silicon steel.

(2) Solid cores. Their cores are made from non-conductive magnetic ceramic materials called ferrites, a combination of a high magnetic permeability and high bulk electrical resistivity material.

(3) Toroidal cores. They are built around a ring-shaped core, which, depending on operating frequency, is made from a long strip of silicon steel or permalloy wound into a coil, powdered iron or ferrite.

(4) Air Cores. They are produced by simply placing the windings near each other. The air, which comprises the magnetic circuit, is essentially lossless and so an air-core transformer eliminates loss due to hysteresis in the core material. The leakage inductance

is inevitably high, resulting in very poor regulation, and hence such designs are unsuitable for use in power distribution [14].

2.9 FILTERS

The idea behind realizing digital-to-analog (D/A) output from a PWM signal is to pass through an analog low- pass filter to remove most of the high frequency components, ideally leaving only the D.C. component. This is depicted in Figure 2.4. The bandwidth of the low-pass filter will essentially determine the bandwidth of the digital-to-analog converter. [14]

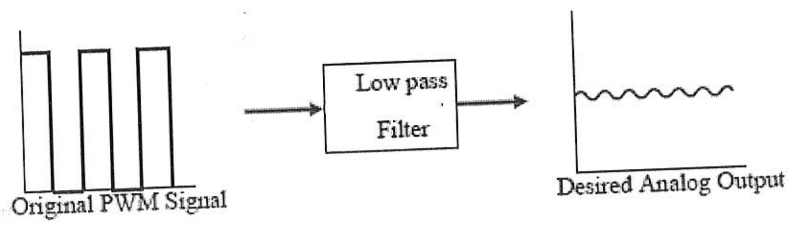


Figure 2.4: Analog filtering of PWM

Filters are classified based on performance. They include:

(1) Active filters (built using op-amps)

(2) Passive filters (composed solely of resistors, inductors, and capacitors).

Active filters avoid the impedance loading issues suffered by passive filters, where the upstream or downstream impedances surrounding the filter can change the filter properties. Passive filters can offer lower cost and reduced design complexity. With active filters, one must also consider the gain bandwidth of the op-amps used. The gain bandwidth represents the upper frequency that the op-amp can effectively handle when used in a closed-loop circuit configuration with small signal input. In terms of active low-pass filters, input signal components with frequency above the gain bandwidth will be attenuated since the op-amp will not have the ability to handle such frequencies.

Op-amps with sufficient gain bandwidth to handle these frequencies are relatively expensive, and at some point one may as well just use an actual DAC chip.

Passive filters do not suffer as much from a gain bandwidth problem. The biggest drawback of passive is always impedance related. Upstream and downstream impedances can affect the performance properties of the filter. In the PWM/DAC application, upstream of the filter will be the PWM output from the DSP. This is a low output-impedance source that will not significantly affect the filter. In the downstream direction, one can use a low-cost voltage follower op-amp to create a high-impedance input. Since the op-amp is in the signal chain after the low-pass filter, an op-amp with large gain bandwidth is not needed. [3].

2.10 MICROCONTROLLER

A microcontroller is a small computer on a single integrated circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, and watchdog, serial and analog I/O etc. Neither program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a, typically small, read/write memory.

Microcontrollers are designed for small applications. Thus, in contrast to the microprocessors used in personal computers and other high-performance applications, simplicity is emphasized. Some microcontrollers may operate at clock frequencies as low as 32 kHz, as this is adequate for many typical applications, enabling low power consumption (mill watts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just Nano watts, making many of them well suited for long lasting battery applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, remote controls, office machines, appliances, power tools, and toys. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes.

In order to use the H-bridge properly, there are four MOSFETs that need to be controlled. This can be done either with analog circuits or a microcontroller. Several reasons accounts for choosing the microcontroller over the analog system:

(1) It would be simpler to adapt. With an analog system, it would be difficult to make changes for the desired output. In many cases, this is a desired trait, as it would be designed for a single purpose and therefore a single output. However, as this is something that is designed to be available all over the world, it needs to be adjustable to different standards of frequency and voltage. With an analog circuit, this would require a different circuit that it would have to switch over to, while with a micro- controller, it merely requires a change in the program's code.

It can allow for easy feedback to control the power flowing through the load. One of the problems that can occur with systems like this is that the variances in load can cause variances in the supplied current and voltage. With a microcontroller, it is possible to have it "look" at the power output and change the duty cycle based on whether or not the load requires additional power or is being oversupplied [3].

For the pure sine wave inverter to be efficient and reliable, this project would have features such as voltage feedback, low battery detection, battery charger, overload shutdown, short circuit current protection. Another intriguing feature of this project is to design a display circuit for information concerning the project as a form of branding and security and to display if the battery is charging or discharging to enhance monitoring of battery by visualization.

CHAPTER THREE

SYSTEM DESIGN

3.1 INTRODUCTION

This chapter discusses the design procedure and the design analysis of a 1.5KVA inverter system. The scheme employed is the pulse width modulation scheme. In this scheme, pulse width modulations are generated by the oscillator. The inverter based on pulse width modulation has a lot of protection and control circuit as compared to traditional inverters. PWM or Pulse width Modulation is employed to keep the output voltage of the inverter at the rated voltage (220V AC) irrespective of the output load. In a typical inverter the output voltage varies according to the changes in the load. To cancel out the effect caused by the variant loads, the PWM inverter oscillator circuit adjusts the output voltage in accordance to the value of the load connected at the output. This is achieved by changing the width of the switching frequency generated by the oscillator circuit. The AC voltage at the output is dependent on the width of the switching pulse. The process is achieved by feeding back a part of the inverter output to the PWM controller section (PWM controller IC). Based on this feedback voltage, the PWM controller will make required adjustments in the pulse width of the switching pulse generated at oscillator section. This change in the pulse width of the switching pulse will nullify the changes in the output voltage and the inverter output will remain constant irrespective of the load changes.

3.2 DESIGN METHODS

This project is a microcontroller based pure sine wave inverter instead of the conventional discrete based square or modified square wave inverters for the oscillator stage. The conversion technique used is first converting the low voltage DC power to AC power using pulse width modulation (PWM), then boosted to high AC voltage using a step up transformer for constant output voltage instead of boosting the low voltage DC power to high voltage power source using a DC- DC booster which is then converted to AC power using pulse width modulation (PWM). H-bridge configuration was used instead of the conventional push-pull arrangement of switches for higher efficiency.

3.3 DESIGN ANALYSIS

Design analysis was carried out for the following sections of the project:

(1) The Inverter Section

(2) The Signal Conditioning Section

The inverter section consists of the:

(1) Oscillator Stage

(2) Driver Stage

(3) H-bridge Configuration

The signal conditioning section consists of the:

(1) Feedback Circuit

(2) Battery Current Control Circuit

(3) Low Battery Sensor Circuit

(4) AC Mains Sensor Circuit

(5) Overload and Short circuit Protection Circuits

The block diagram for the project is shown in figure 3.1

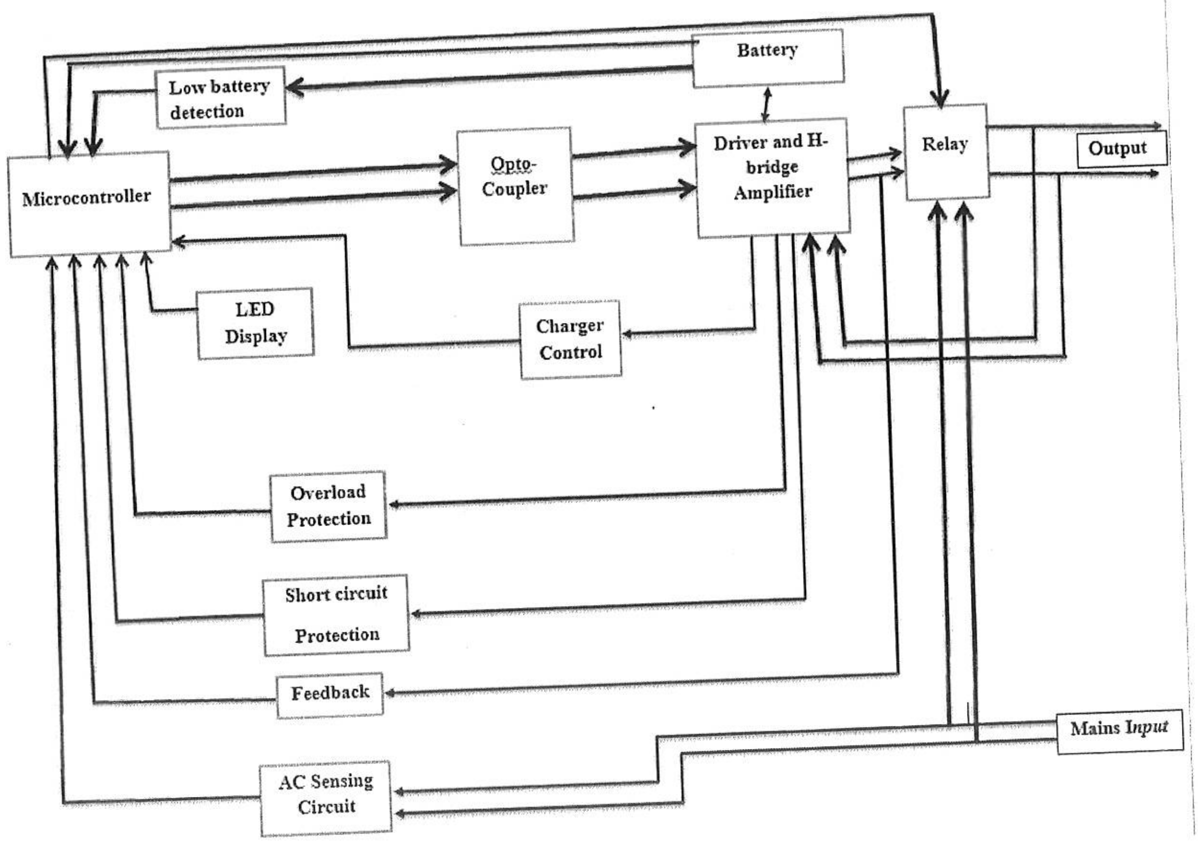


Figure 3.1: Block Diagram

3.3.1 THE OSCILLATOR STAGE

The oscillator stage is responsible for the generation of pulse width modulations. For this section, pulses are generated using the microcontroller by a method called Pulse Width Modulation (PWM) which are fed into the drivers to drive the switches. Due to availability, large memory size, high number of ports for signal conditioning, the PIC 16F72 is a 28-Pin, 8-Bit CMOS flash microcontroller with A/D Converter.

Special Microcontroller Features:

- 1,000 erase/write cycle FLASH program memory typical
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation

- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- In-Circuit Serial Programming (ICSP) via 2 pins
- Processor read access to program memory

Key Reference Manual Features PIC16F72

Operating Frequency DC - 20 MHz

RESETS and (Delays) POR, BOR, (PWRT, OST)

FLASH Program Memory - (14-bit words, 1000 E/W cycles) 2K

Data Memory - RAM (8-bit bytes) 128

Interrupts - 8

I/O Ports - PORTA, PORTB, PORTC

Timers - Timer0, Timer1, Timer2

Capture/Compare/PWM Modules - 1

Serial Communications - SSP

8-bit A/D Converter- 5 channels

Instruction Set (No. of Instructions) – 35

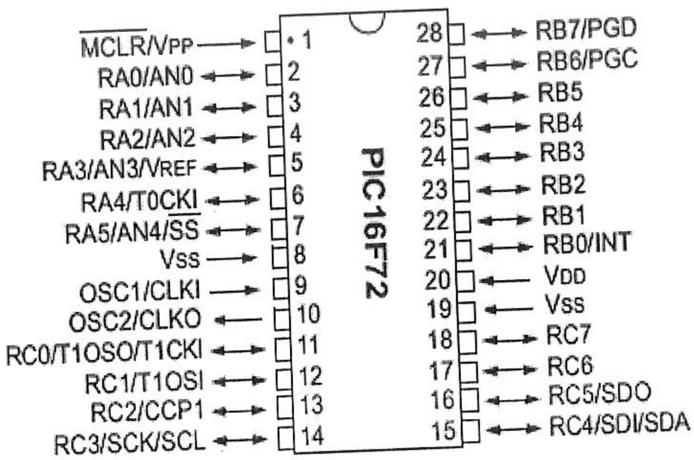


Figure 3.2: 16F72 Pin Diagram

3.3.2 THE DRIVER STAGE

A gate signal is required for every power semiconductor controlled device to bring it into the conduction state. Normally the driver circuit has to provide an electrically isolated gate=base signal. Driving a power MOSFET is similar to driving a very high-impedance capacitive network, thus a carefully designed very low power drive circuit is required. Normally, a unipolar drive signal (a positive voltage pulse) is sufficient for normal turn-on and turn-off of the device. However, for rapid turn-on and turn-off, bipolar signals (both positive and negative voltage pulses) are required. Moreover, for high switching performance, similar circuits with high (source and sink) capabilities are required and the transition current capability should be high (with low output power). Hence for the driver circuits, the signals from the microcontroller are first amplified then a complementary push pull class B configuration is used.

3.3.3 H-BRIDGE CONFIGURATION

Sine wave consists of both positive and negative sides. To achieve this, power switches are arranged in class B push-pull configuration. For higher efficiency, an H-bridge configuration is a suitable choice which allows switching at 90^0 for each side, thereby reducing current flow per unit time and hence, higher efficiency.

Output of inverter = 1500VA

$$P_{dc} = 1500 \times 0.7 = 1050W$$

Assuming that power is conserved at both sides of transformer,

$P_{dc} = \frac{2V_{cc}I_{max}}{\pi}$ (Push-pull class B amplifier)

V_{cc} is the voltage of the battery

But for H-Bridge, conduction angle for each side is $\frac{\pi}{2}$.

$$1050 = \frac{2\times12\times I_{max}}{\frac{\pi}{2}}$$

$$I_{max} = 68.72A$$

Practically, use approximately twice the maximum current

$\approx 68.72 \times 2 \approx 137.44A.$

Using IRF3205 MOSFET, $I_D = 105A,\ P_D = 139,\ V_{DS} = 55V,\ V_{GS} = 10V.$

Power dissipation, $P_d = \frac{2}{\left(\frac{\pi}{2}\right)^2} P_{ac(max)}$

But $P_{ac(max)} = \frac{V_{cc}I_{max}}{2} = \frac{12 \times 68.72}{2} = 412.32VA$

$\therefore P_d = \frac{2}{\left(\frac{\pi}{2}\right)^2} \times 412.32 = 334.21W$

Number of MOSFETS on each side of the H-Bridge configuration is

$$\frac{334.21}{139} \approx 3$$

$\therefore$ Three MOSFETS are used at each side of the H-Bridge configuration giving a total number of 12 MOSFETS.

Since 50Hz is expected to be the output frequency, the output is filtered using a $1.5\mu F, 50Hz\ AC$ Capacitor.

3.3.4 FEEDBACK CIRCUIT

The feedback stage which is a signal conditioning circuit consists of a rectifier unit that converts the inverter's output (AC) to DC. This DC signal is then filtered and fed into the ADC register inside the microcontroller.

The ADC register monitors the voltage rise and controls the output drive from oscillator stage to the H-bridge configuration via the driver circuits. The figure 3.3 below shows the feedback signal conditioning stage.

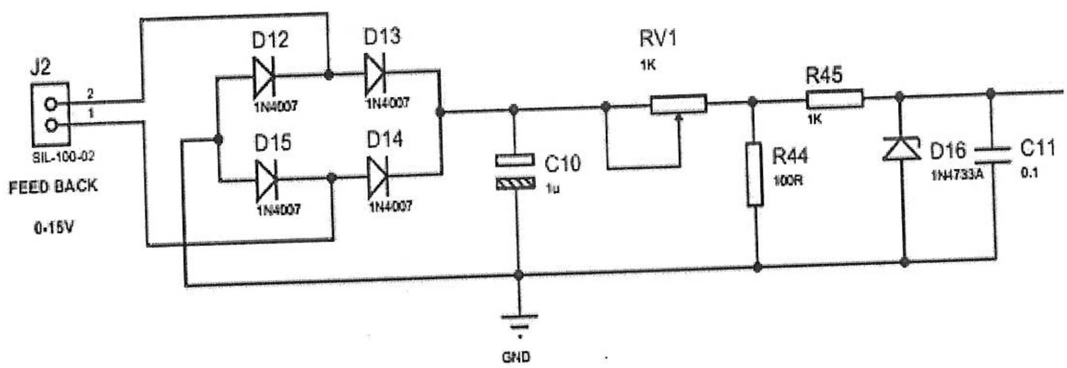


Figure 3.3: Feedback Signal Conditioning Circuit

D12 – D15 forms a bridge rectifier. The AC input from the feedback transformer is 12V. 1N4007 rectifier diodes were chosen. 1N4007 diodes are 1A diodes.

Since the microcontroller ADC input can sink or source a maximum current of 25mA.

Maximum voltage, $V_m = \frac{12}{\sqrt{2}} = 16.97V$

The average current through the rectifier,

$I_{dc} = \frac{2}{\pi}\frac{V_m}{R_l} \qquad (I_{dc} = 25\text{mA})$

$25 \times 10^{-3}\pi R_l = 2 \times 16.97$

$R_l = 430.35\Omega$

$\therefore R_l = 470\Omega$

$V_{dc} = I_{dc}R_l = 470 \times 25\text{mA} = 11.75V$

This voltage (pulsating dc) is filtered using a capacitor, C10 calculated as follows:

$C_{10} = \frac{1}{2fR_l(1-\frac{V_{dc}}{V_{pin}})} \qquad (f=100\text{Hz})$

$C_{10} = \frac{1}{2\times100\times470(1-\frac{11.75}{16.97})} = 0.35\mu F$

Since an electrolytic capacitor is used to filter the pulsating dc, an $1\mu F$ electrolytic capacitor is a suitable choice.

The maximum voltage into the ADC pin is 5.1V. Hence, a zener diode 1N4733A (D_{16}) is a suitable choice.

The capacitor C_{11} is to filter any spike or high frequency noise from the rectifier circuit.

3.3.5 BATTERY CURRENT CONTROL CIRCUIT

The current sensor for battery charger uses an integrator op-Amp as shown in figure 3.4

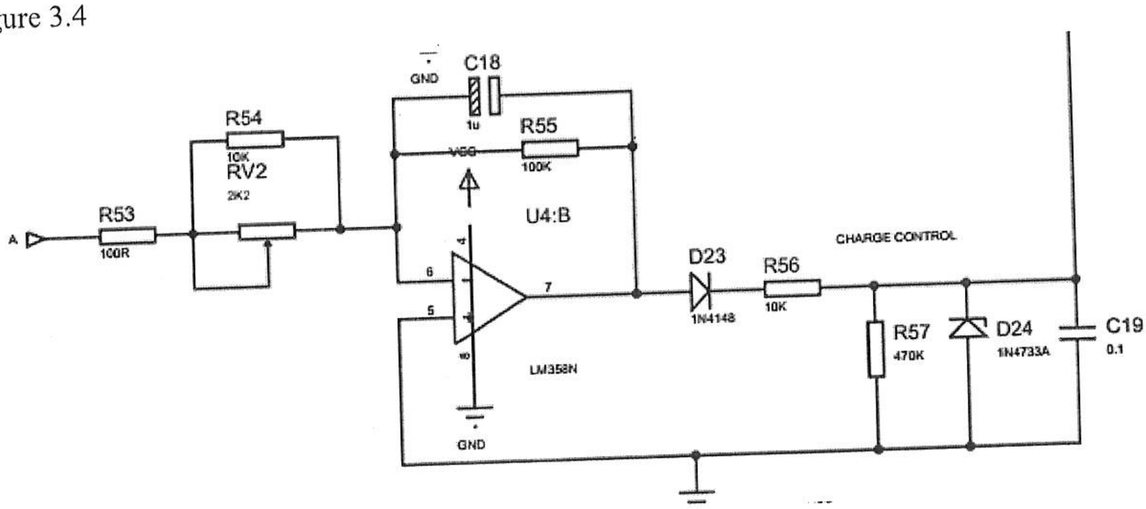


Figure 3.4: Battery Current Control Circuit

The battery current control stage gets a small error voltage from point A on the H-bridge circuit and amplifies the voltage for control of the charging current when operating in utility mode.

The use of integrator is because the signal generated by the battery when charging is not linear. Hence, integrator tends to linearize by approximating the amplified signal to enable easy control (of current) via the microcontroller. The integrator provides an output which is proportional to the integral of the input voltage.

3.3.6 LOW BATTERY SENSING CIRCUIT

The inverter battery has a low battery level that should not be exceeded. The signal level is been fed into the microcontroller and when it senses a particular voltage specified in its instruction which is the converted battery voltage, it trips off the inverter. The circuit diagram is shown in figure 3.5

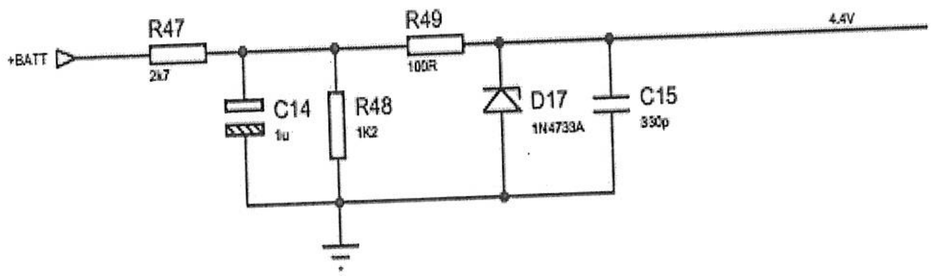


Figure 3.5: Low Battery Sensing Circuit

Considering a voltage of 4.4V when the battery is low,

$$V_{R48} = \frac{R_{48}}{R_{48} + R_{47}} \cdot V_{Bat} \quad (From\ kirchoff"s\ law)$$

Setting $R_{47} = 2.7K$

$$4.4 = \frac{R_{48}}{R_{48} + 2 \cdot 7} \times 10 \cdot 8$$

(Where 10.8V is the battery voltage at which the inverter indicate low battery)

R_{48}=1·8KΩ

Since the maximum voltage into the microcontroller is 5.1V, D_{17} is used to set this voltage. C_{14} and C_{15} are used to filter any ripple on the dc supply rail.

3.3.7 AC MAINS SENSING CIRCUIT

The circuit diagram for the AC mains sensing circuit is shown in Figure 3.6. The AC mains is fed into the Opto-coupler 4N35 to isolate it electrically from the signal conditioning circuit. The output of which is fed into the signal conditioning circuit which is a duplicate of the feedback signal conditioning circuit. The final output is now fed into the ADC of the microcontroller for processing to energize the relay.

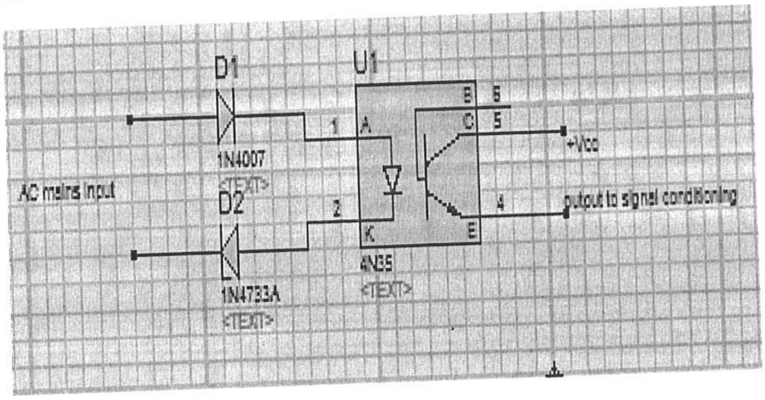


Figure 3.6: AC Mains Sensing circuit

3.3.8 OVERLOAD AND SHORTCIRCUIT PROTECTION CIRCUITS

When the inverter is overloaded, high current is being drawn by the load and hence, low voltage. This voltage is sensed by the overload circuit and fed into the microcontroller to shut down the inverter.

Also, when short circuit occurs, high current flows through the short circuit and hence low voltage. This is sensed by short circuit protection circuit and fed into the microcontroller to trip off the inverter. The circuit diagram is shown in Figure 3.7.

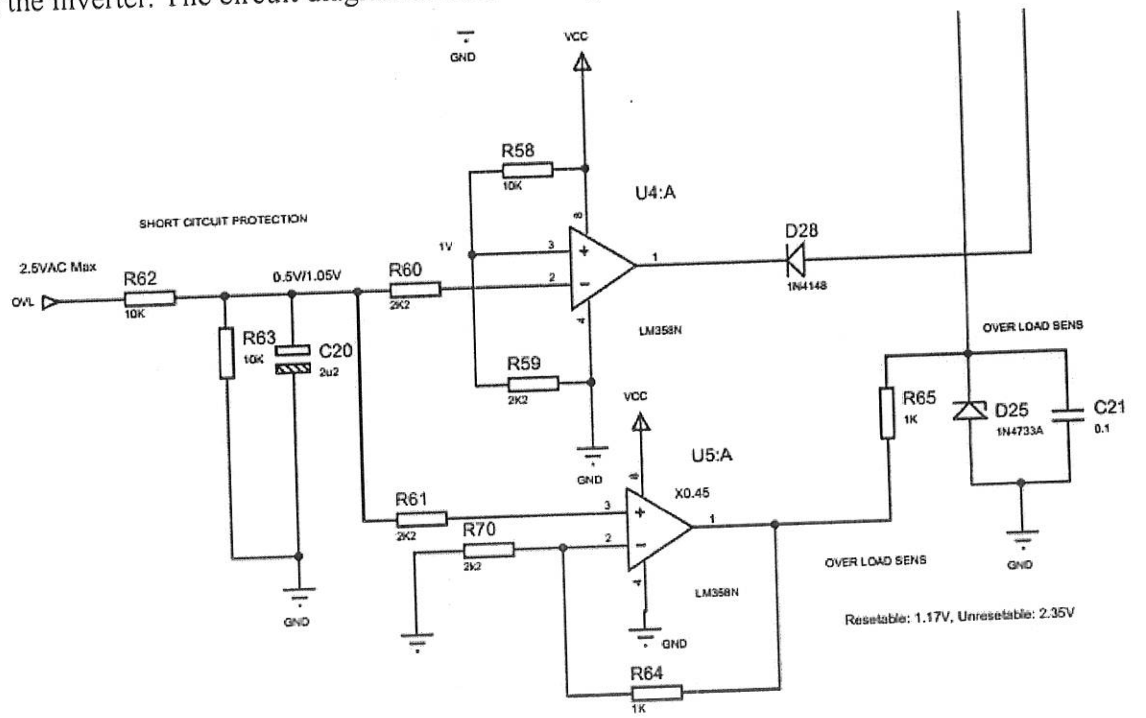


Figure 3.7: Overload and Short Circuit Protection Circuits

3.3.9 SWITCHING STAGE

The inverter supplies an output voltage when switched ON (discharging mode) but when there is mains supply, the inverter is on charging mode. Hence, there is need for switching between these two supplies to give an output when inverter is either on discharging or charging mode. A 15A, 250AC relay is chosen for this purpose being energized by the micro-controller PIC16F72.

3.3.10 DISPLAY

For monitoring the state of the inverter, LED indicators are used to indicate when the inverter section is ON, AC mains sensed, battery charging, low battery and overload. Also, for branding and security, the LCD displays information about the inverter and also if LED for ''battery charging'' is malfunctioning, the LCD can still give the status of the battery, as this is very important in the inverter because, without the battery, there is no inverter!

3.3.11 PACKAGING

The casing was designed using a software called SolidWorks. Figure 3.8 shows the various views of the casing.

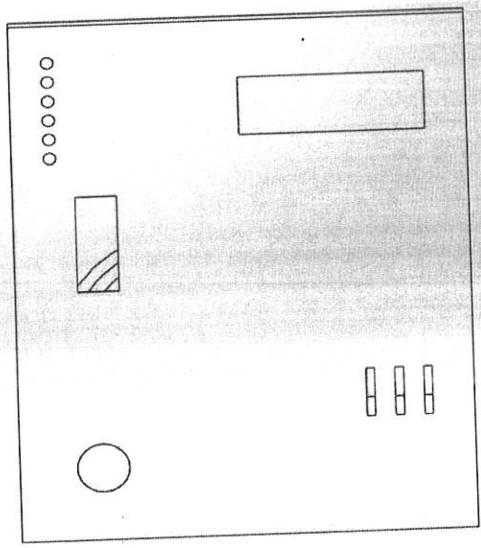


Figure 3.8a: Front View

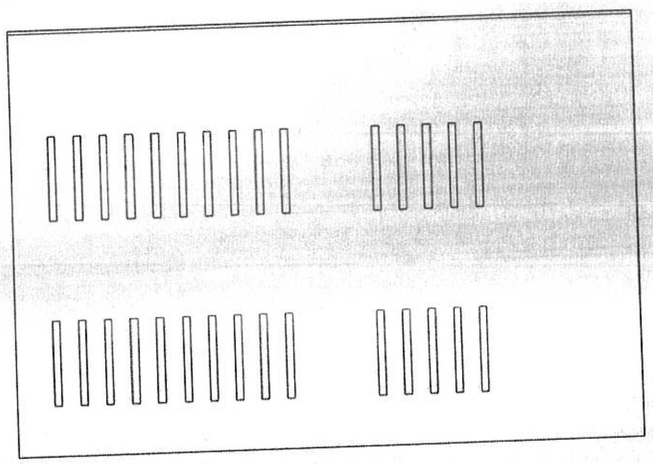


Figure 3.8b: Side View

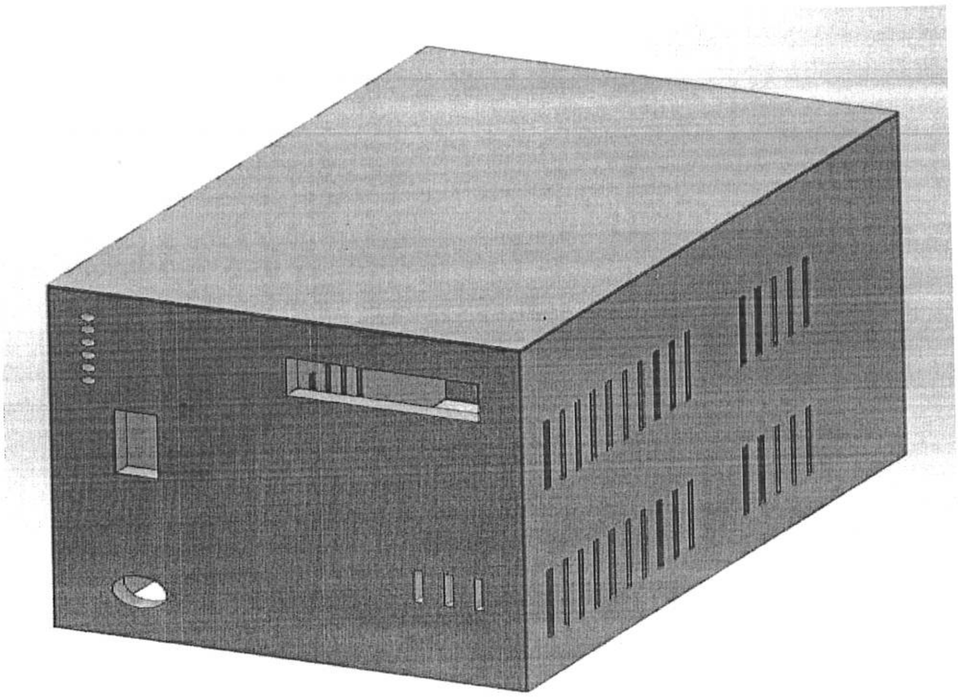


Figure 3.8c: 3D View

The 34cm by 22cm by 27cm casing encloses the footprint of the whole design.

3.4 IMPLEMENTATION

The final product took on a two-part design to keep the design within a 34cm by 22cm by 27cm design constraint. A rational choice was made to separate the low-voltage control components and the high-voltage power H-bridge configuration, connecting them with inter-board connectors. This reduces noise through capacitive and inductive coupling, and allows for modularity which helps in easier and faster troubleshooting. The MOSFETS on the high-voltage power H-bridge configuration were placed close to the driver IC's, in order to minimize the length of the gate traces and the soldering was done manually. The MOSFET board has a large copper ground plane which reduces signal noise by coupling capacitance between traces to ground. The MOSFET board is shown in figure 3.9.

All the IC's on the low-voltage control board have bypass capacitors placed close to their physical location to decouple them from the power supply in order to decrease input ripple. The main control board is shown in figure 3.10.

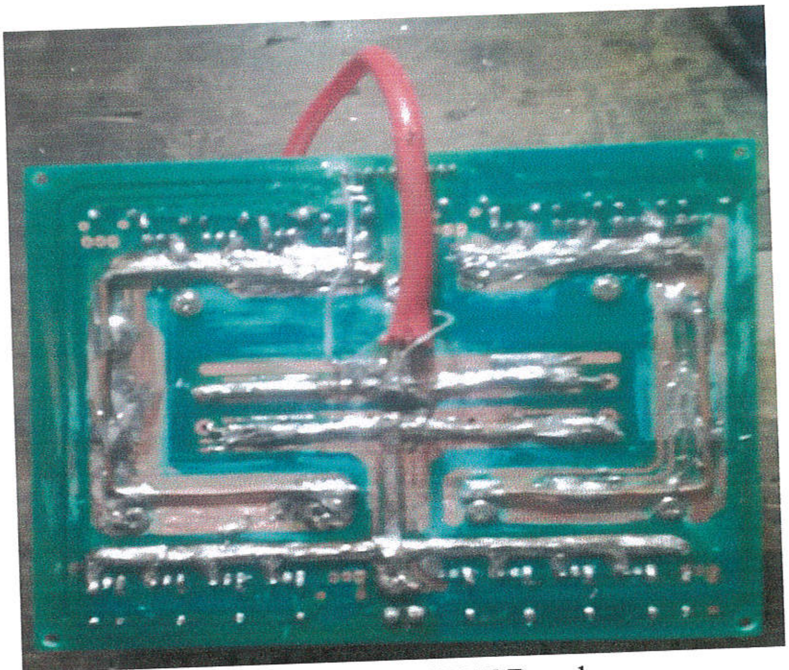


Figure 3.9: MOSFET Board

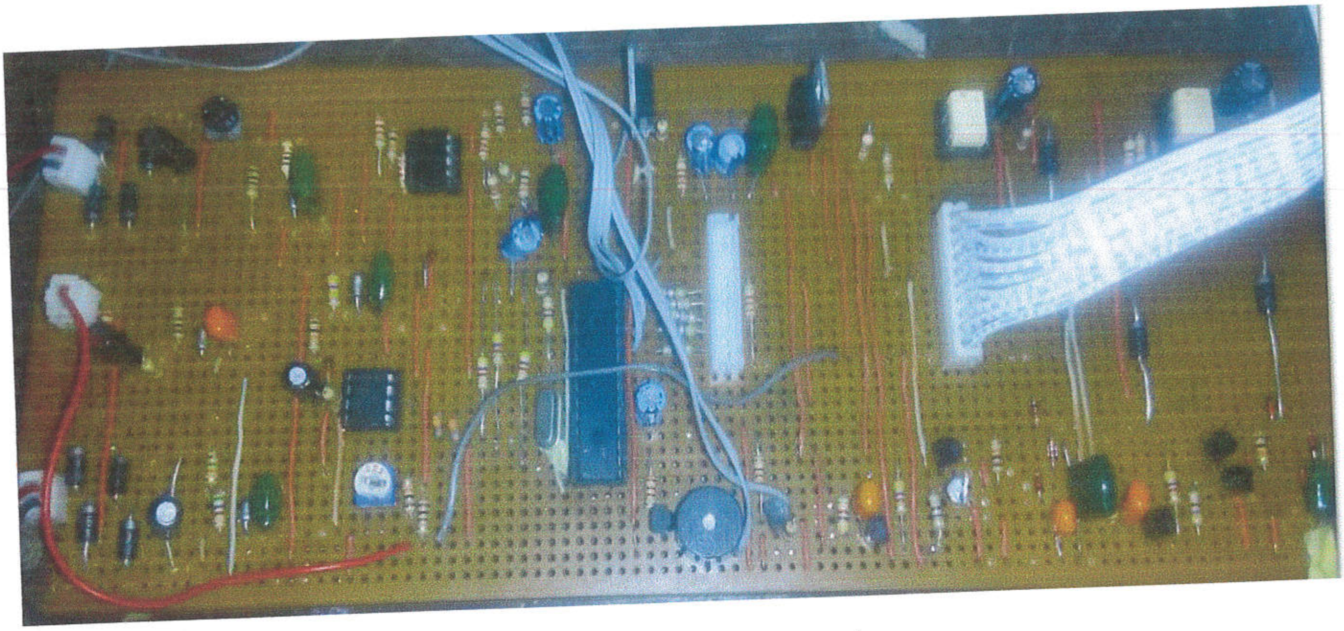


Figure 3.10: Main Control Board

The control board for the LCD display is shown in figure 3.11.

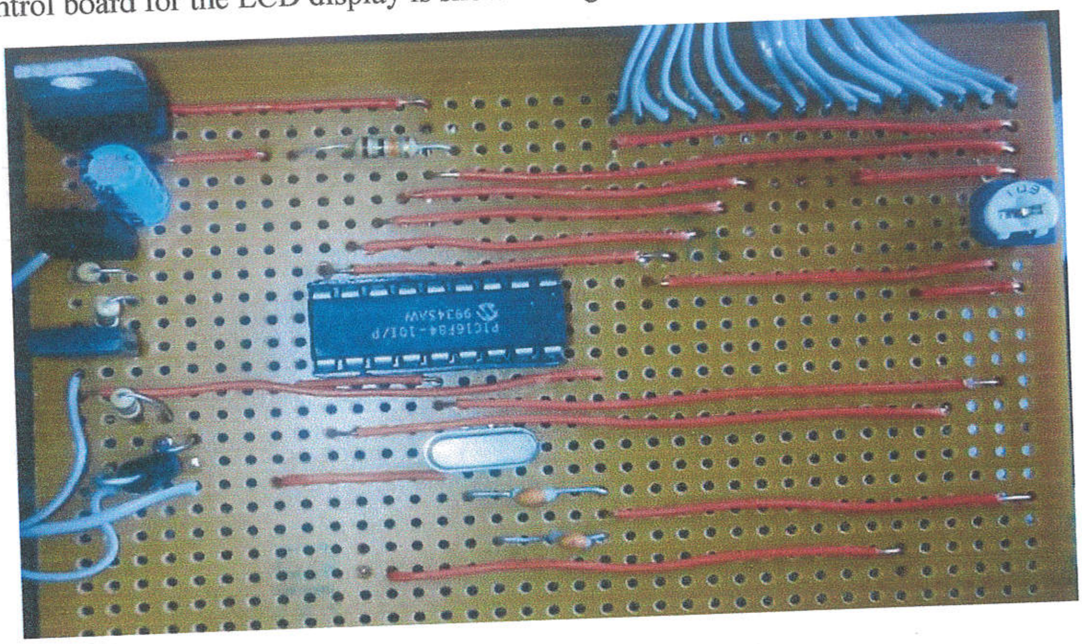


Figure 3.11: LCD Control Board

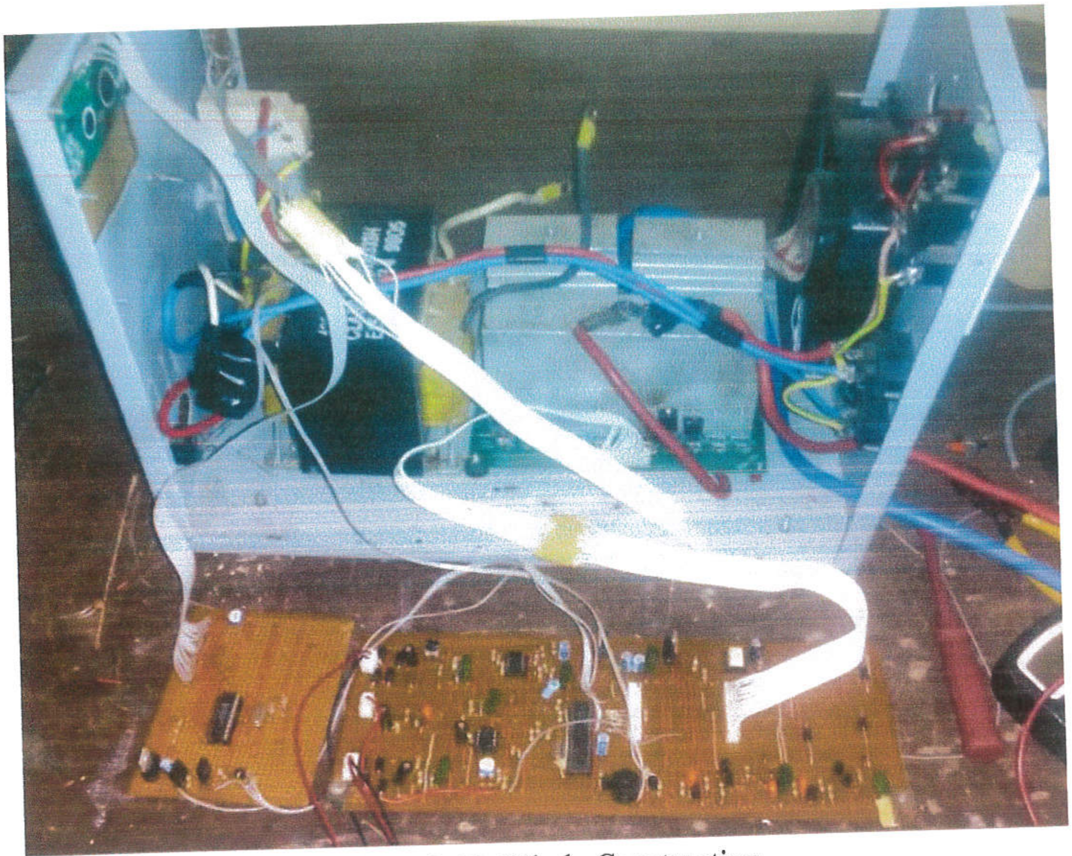


Figure 3.12: Whole Construction

3.5 TESTING

After carrying out all the paper design and analysis, this project was implemented and tested to ensure it's working ability, and was finally constructed to meet desired specifications. Stage by stage testing was done according to the block representation.

The process of testing and implementation involved the use of some test and measuring equipment stated below:

(1) Digital Multimeter: The digital multimeter as shown in figure 3.13 basically measures voltage, current, resistance, continuity, frequency, and temperature. The process of implementation of the design on the board required the measurement of parameters like continuity, voltage, and resistance values of the components and frequency measurements.

The digital multimeter was used to carry out these measurements.

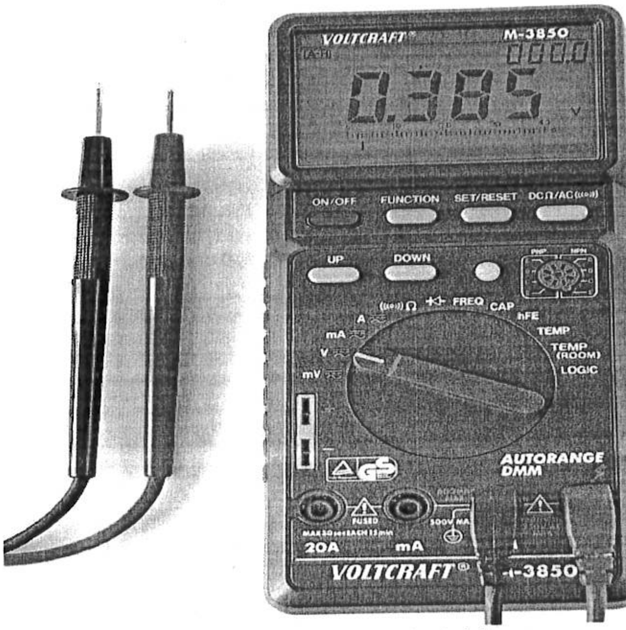


Figure 3.13: Digital Multimeter

(2) Digital Oscilloscope: The digital oscilloscope as shown in Figure 3.14 was used to visualize and analyze the output waveform.

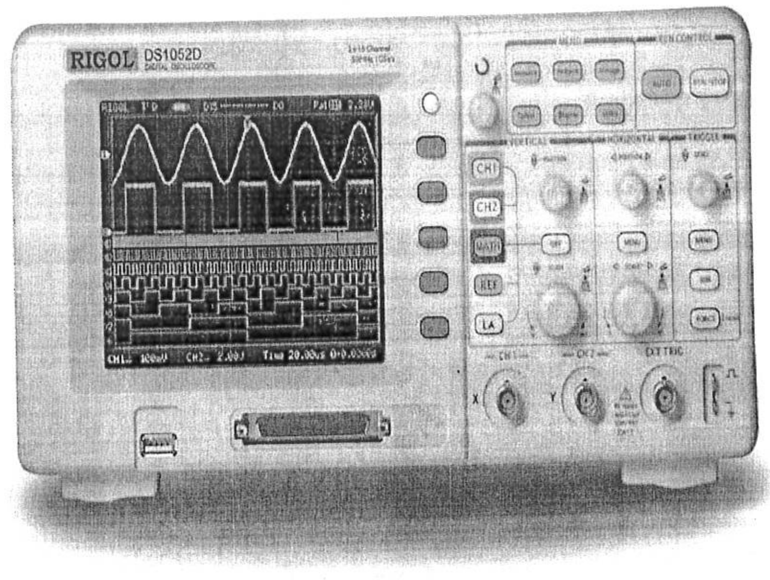


Figure 3.14: Digital Oscilloscope

(3) Clamp meter: The clamp meter as shown in Figure 3.15 was used to measure the charging current of the battery.

Figure 3.15: Clamp Meter

(4) Frequency meter: The frequency meter as shown in Fig. 3.16 was used to measure the output frequency.

Figure 3.16: Frequency meter

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 PERFORMANCE RESULTS

After construction, the following results shown in Table 4.1 were obtained:

Table 4.1: Results

Power output	1.5KVA
Output Voltage	220VAC (±5%)
Charging current	9.5A
Drawing current	18.5A

The output waveform from the digital oscilloscope is shown in Figure 4.1 below

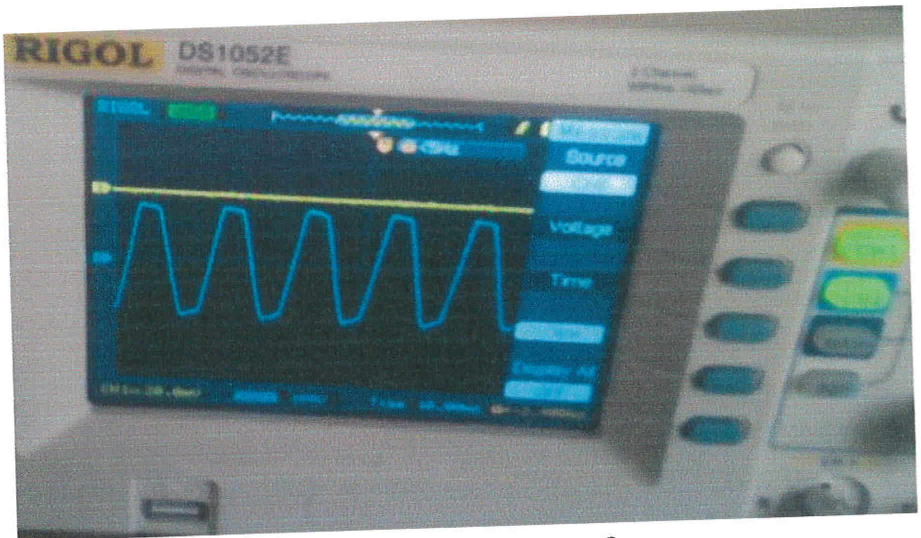


Figure 4.1: Output waveform

4.2 LOAD ANALYSIS

The inverter was loaded up to 800W by a mixture of three 200W and two 100W tungsten filament bulb and the inverter still worked perfectly.

Table 4.2: Load analysis

Load (Watt)	Current (Amperes)
100	0.45
200	0.91
300	1.36
400	1.80
500	2.26
600	2.70
700	3.18
800	3.60

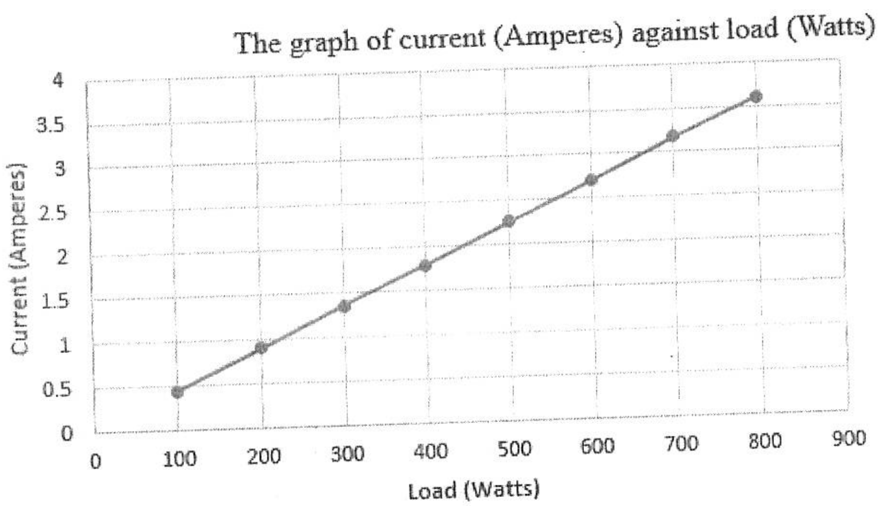


Figure 4.2: Load analysis

From Figure 4.2, it is discovered that the current drawn for the inverter system is directly proportional to the load drawing the current which follows that it obeys the equation 4.1:

$$P = IV \qquad (4.1)$$

When Voltage is constant, As P increases, I increases

Where P is the power, V is the Voltage and I is the Current

4.3 SHORT CIRCUIT TEST

When output terminals of the inverter were bridged to cause a short circuit, the inverter shutdown and when switched ON again, it worked perfectly.

4.4 RELIABILITY TEST

When tested with various loads such as resistive loads and inductive loads such as electric hand drilling machine, the inverter worked perfectly.

4.5 STABILITY ANALYSIS

This was done by examining the single phase inverter system for a period of 20 minutes under no load condition and load condition.

Table 4.3: Stability analysis at no load (battery very low 7.6V to 6.84V)

Time (minutes)	Voltage (Volts)
0	218
2	218
4	218
6	218
8	211
10	206
12	205
14	No output
16	No output
18	No output
20	No output

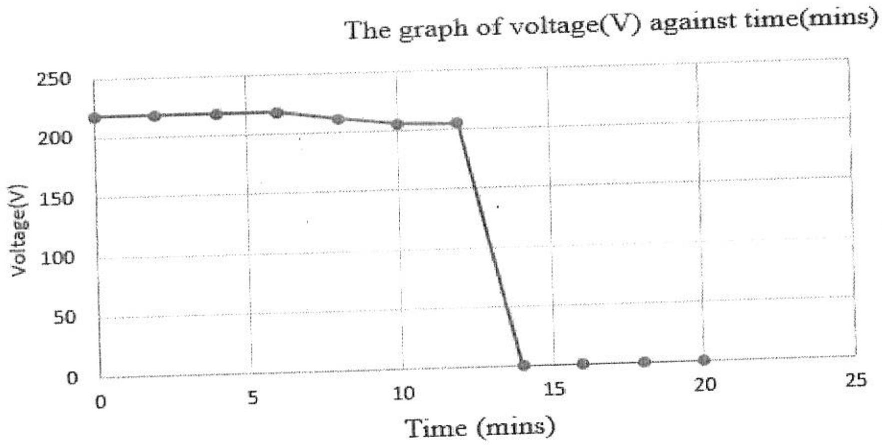


Figure 4.3: Stability analysis at no load (battery very low 7.6V to 6.84V)

From Figure 4.3, it is discovered that output voltage is within the range of the expected output voltage (±5%). The slight deviation is caused by inherent limitations in the battery and voltage drop across the battery with time.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The project which is the design and implementation of Single phase inverter was designed considering some factors such as design economy, availability of components and research materials, efficiency, compatibility and portability and also durability. The operation of the project and performance is dependent on the user who is prone to human error such as exposure of product to moisture and wrong handling. Proper care was taken while soldering the circuits so that dry joints do not form early to prevent the early project failure. Also integrated circuits were soldered far from components that radiate heat to prevent overheating which might affect the performance of the entire system. Other factors that might affect performance include transportation, packaging, ventilation, quality of components, and usage. The construction was done in such a way that it makes maintenance and repairs an easy task and affordable for the user should there be any system breakdown. This project has really exposed me to the design and construction of digital electronic and practical electronics generally, which is one of the major challenges in my field.

5.2 CONCLUSION

The purpose of supplying electricity is to meet the variable and instantaneous demand for electricity by wide and variety consumers at the most economic cost, and to satisfy consumers by a good standard reliability and quality typical in terms of voltage and frequency. It is obvious that the electrical energy supplied by the national grid to the consumers is inadequate and unreliable to overcome the challenges of the gigantic problems of power supply in the country. Hence, the need for new and alternative schemes in supplying power.

The design of a 220V voltage-fed MOSFET Single- phase, Pure Sine wave inverter that uses the pulse width modulation technique as the switching logic for the inverter circuit has been designed. The inverter circuit was tested using standard 12V dc source deep cycle battery.

Hence, to combat the challenges of inadequate power supply from the national grid, the Single-phase, Pure Sine wave inverter is a good choice for single phase loads.

5.3 PROBLEMS ENCOUNTERED

After soldering and construction, the following problems were encountered:

(1) The buzzer did not respond when the inverter was switched ON

(2) There was no output from the driver driving the right side of the H-bridge configuration

(3) There was no sound to show that the MOSFETs were working but when one of the TLP 250 was removed, sound is being heard.

(4) The LCD was not working when initially connected

(5) After the problem in (4) above had been rectified, the LCD did not display anything

(6) When the AC mains was supplied to the circuit, the PIC 16F72 was not sensing it and as a result, the relay was not energized

(7) When the inverter was on charging mode, the battery was not charging

(8) When the AC mains had been sensed, charging LED was blinking at intervals and when the inverter section was switched ON, The fan attached to it would only tend to rotate

(9) Whenever the AC mains was sensed, the LCD displays irregular and scattered lines

(10)After coupling the whole project, irregular hissing sound was being produced at the H-bridge configuration area and the inverter did not give any output

5.4 SOLUTIONS TO THE PROBLEMS ENCOUNTERED

The following solutions were given to the problems encountered in Art 5.2 respectively:

(1) It was discovered that there was no continuity between the PIC 16F72 and the transistor switching the buzzer. This was rectified by soldering the transistor to the appropriate PIC pin

(2) It was discovered that the two diodes in the circuit were missing and there was wrong connection of the PNP transistor at that stage. This was amended by soldering the diodes and repositioning the PNP transistor

(3) The connector pins between MOSFET board and main control board was not properly arranged and when it properly arranged, the hissing sound was heard

(4) The LCD was not grounded. When this was done, the backlight was ON.

(5) It was discovered that pin 13 and 14 of the LCD were bridged. When it was traced as to where they were bridged, it was discovered that it was an internal circuitry bridge that occurred. The LCD was replaced with another one and information were being displayed

(6) The 15K resistor was replaced with 4.7K resistor and $10\mu F$ capacitor was placed across the 5.6K resistor

(7) The variable resistor (2.2K) at the battery charging section on the main control board was varied and it caught fire. Then, it was replaced with another variable resistor of higher value (5K) and the battery started charging

(8) The battery that was being used at that time was changed. When this was done, the charging LED was blinking normally when AC mains has been sensed and relay is energized. Also, when the inverter was switched ON, the fan worked perfectly

(9) A reset button was soldered to the PIC 16F84 reset pin. Whenever such irregular and scattered lines appear and the reset pin is pressed, it will display normally

(10)It was discovered that screws used to fasten the main control circuit in the casing bridged the circuit with the casing. When insulators typically rubber rings were placed around the screws between casing and the holder for the main control board, the inverter produced the required output.

5.5 RECOMMENDATION

All the goals in the project were achieved. However, the voltage regulation can be improved upon by the PIC manufacturer's design. Further research can be made to display the battery level in percentage while charging and discharging so as to enhance monitoring and conserve battery for future use.

More so, an alternative source of DC (Solar) can be added to increase availability and reliability in case of blackout from the national grid for a long period and battery needs charging so as to save cost for new batteries.

REFERENCES

[1] Chauhan D. et al., "Policies for Development of Photovoltaic Technology: A Review". International Journal of software & hardware research in Engineering, Vol. 1, pp. 52-57, December 2013.

[2] Anyaka B. O., "Harmonic Reduction of single Phase Solar Electric Powered Inverter for Power Supply to Rural communities". Global Journal of Mechanical Engineering, Volume 3, Number 1, 2002.

[3] Mburu M. B., "A Pure Sine Wave Inverter for House Backup". Department of Electrical and Information Engineering, College of Architecture and Engineering, University of Nairobi, Project number 30, pp.16, 2014.

[4] Crowley I. F & H. F. Leung, "PWM Techniques: A Pure Sine Wave Inverter". Worcester Polytechnic Institute Major Qualifying Project, pp.6, 2010-2011.

[5] "Types of Inverters" available on-line at http://engineering.electrical-equipment.org/electrical-distribution/types-of-inverters.html, 2016.

[6] Dixit S. et al. "800VA Pure Sine Wave Inverter's Reference Design". Application Report, SLAA602, Texas Instrument, pp. 3, June 2013.

[7] Rashid M. H., "Power Electronics Handbook" ISBN: 0-12-581650-2, 2001.

[8] VanderMeulen A. & J. Maurin, "Current Source Inverter vs. Voltage Source Inverter Topology". White Paper WP020001EN. June 2014.

[9] Mburu M. B., "A Pure Sine Wave Inverter for House Backup". Department of Electrical and Information Engineering, College of Architecture and Engineering, University of Nairobi, Project number 30, pp.12, 2014.

[10] Vodovozou V., "Introduction to Power Electronics". ISBN: 978-87-7681-625-4. Pg. 76, 101-102, 2010.

[11] Shete P. S et al., "Performance of Sinusoidal Pulse Width Modulation based Three Phase Inverter". International Conference on Emerging Frontiers in Technology for Rural Area (EFETRA), 2012.

[12] Crowley I. F & H. F. Leung, "PWM Techniques: A Pure Sine Wave Inverter". Worcester Polytechnic Institute Major Qualifying Project, pp.22, 2010-2011.

[13] Prasad S.A., "Micro Controller Based Ac Power Controller ". Scientific Research, Vol. 2, pp. 76-81, 2009

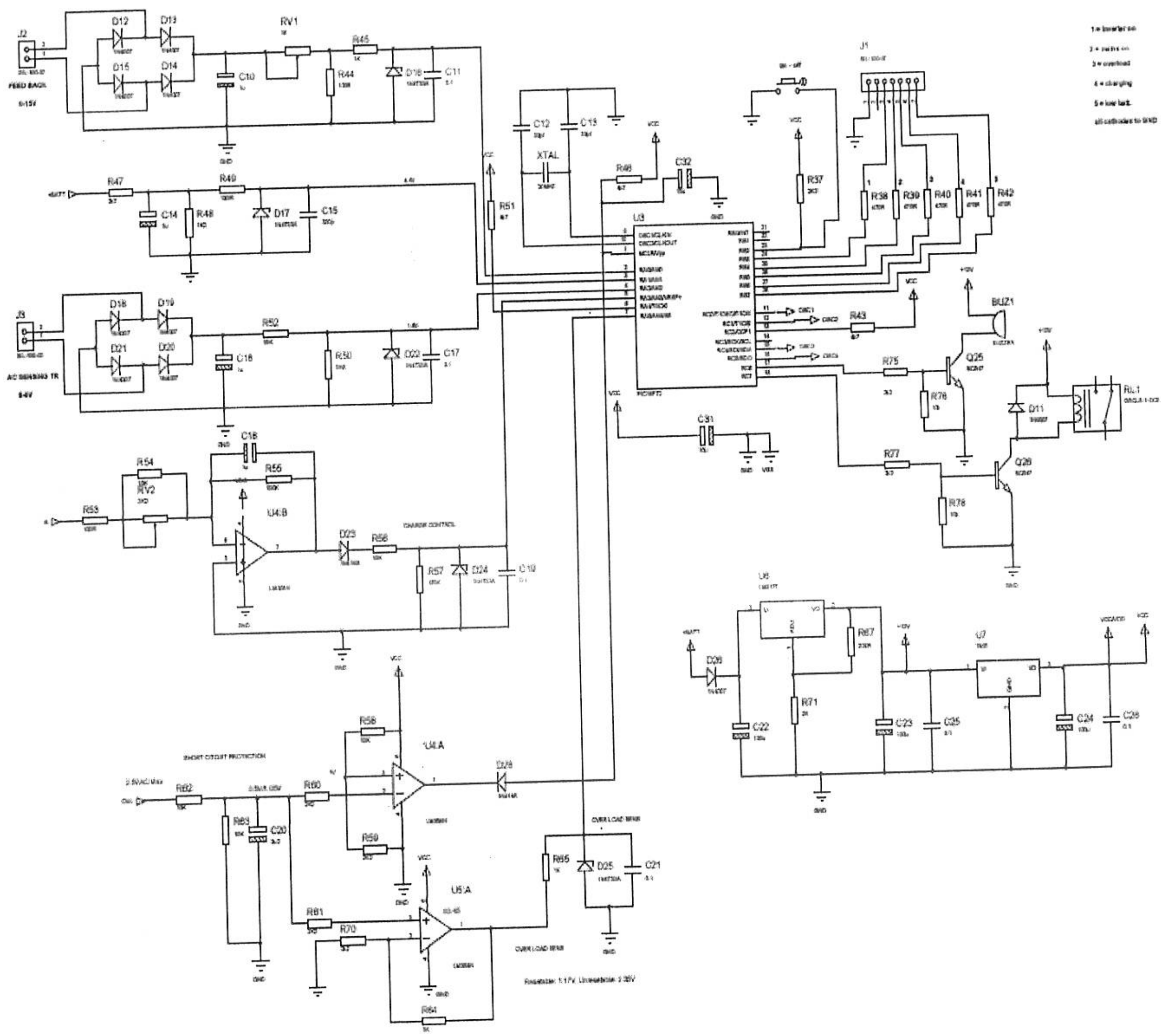
[14] Doucet J. et al., "DC/AC Pure Sine Wave Inverter". Worchester Polytechnic Institute, MQP Terms ABC 2006-2007.

[15] Theraja B.L. & A.k. Theraja,"A Textbook of Electrical Technology". ISBN: 81-219-2441-3. Pg 1116, 2012.

APPENDICES

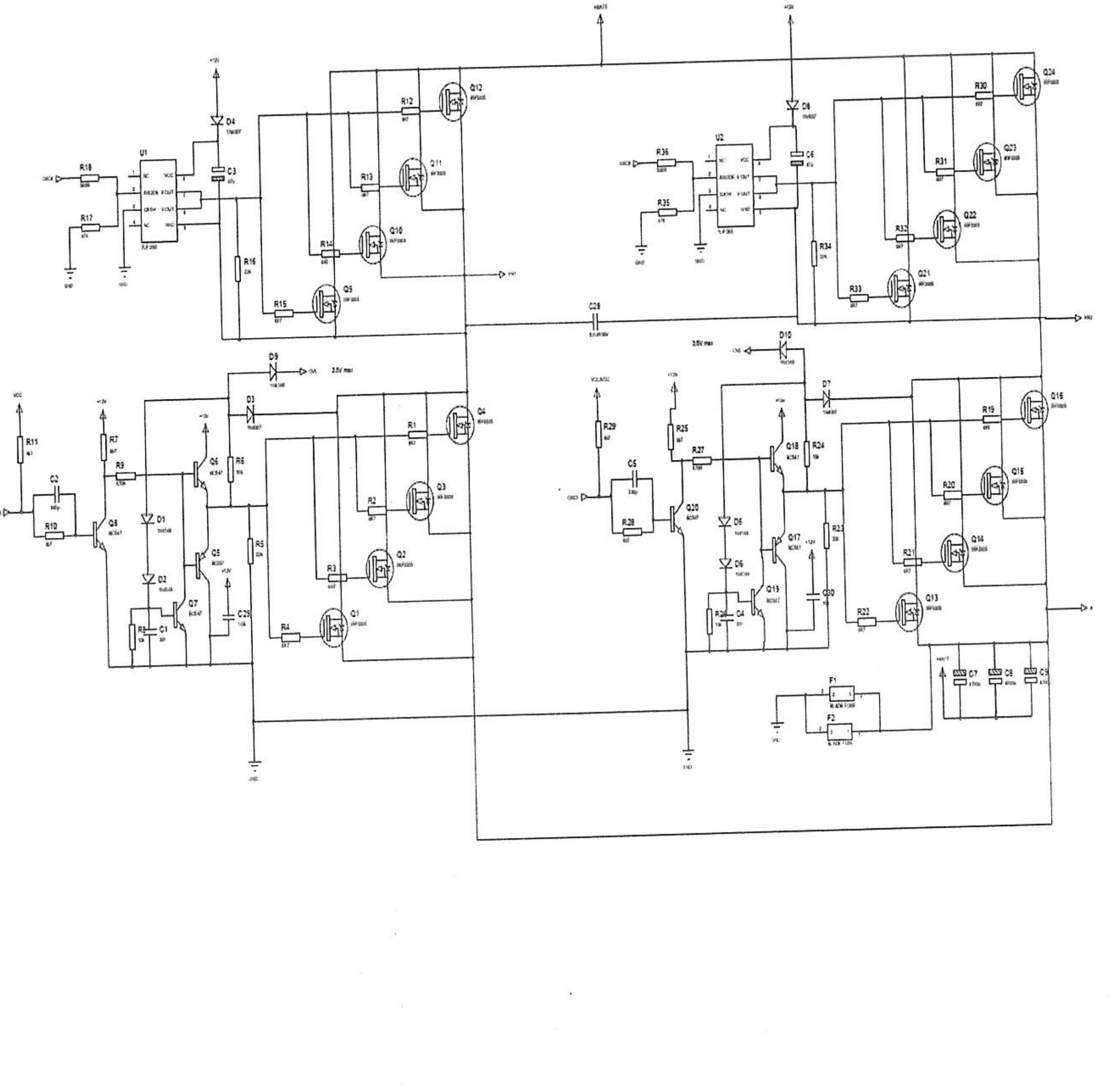
APPENDIX IA

SIGNAL CONDITIONING AND OSCILLATOR CIRCUIT DIAGRAM

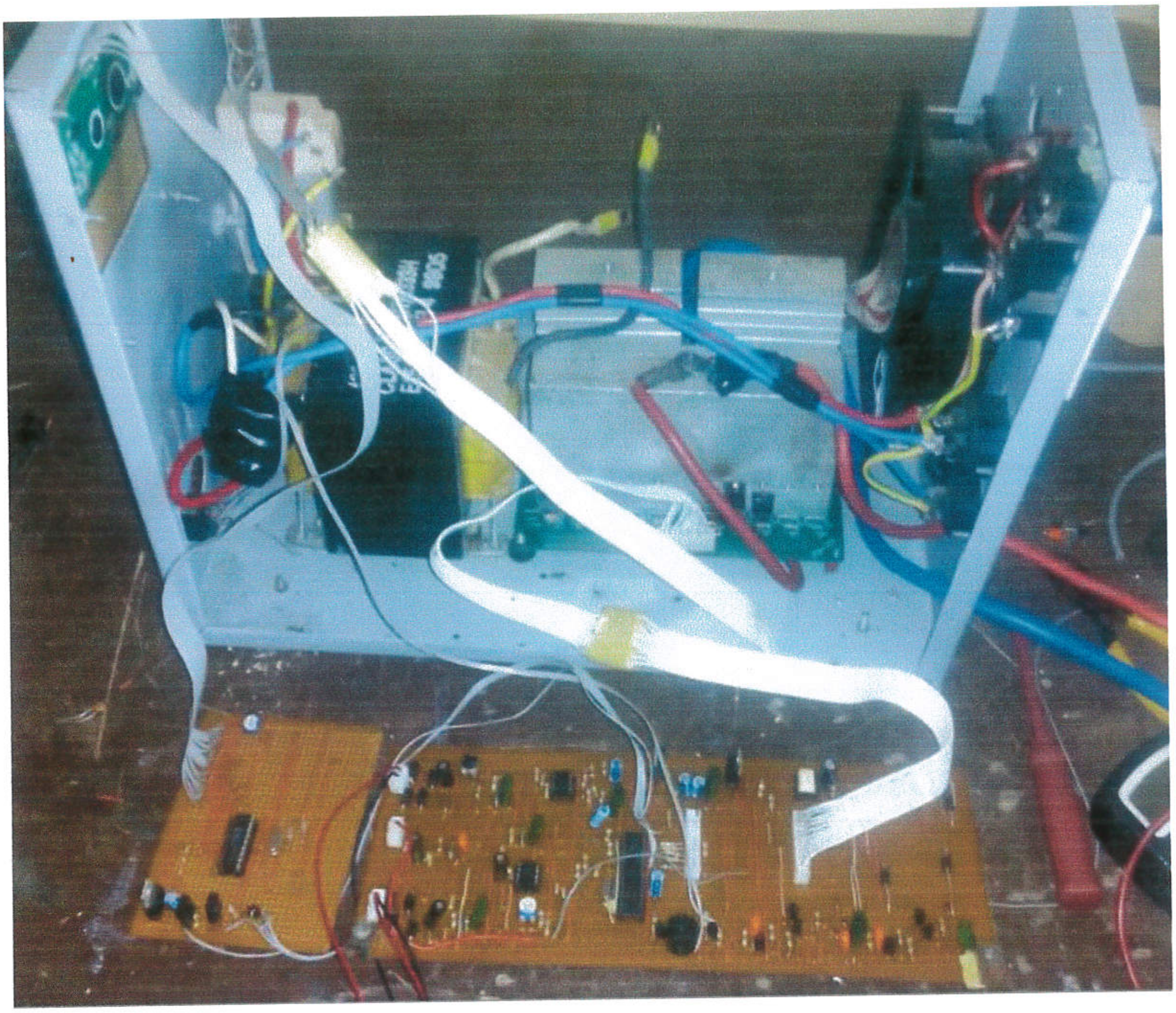


APPENDIX IB

H-BRIDGE CONFIGURATION CIRCUIT

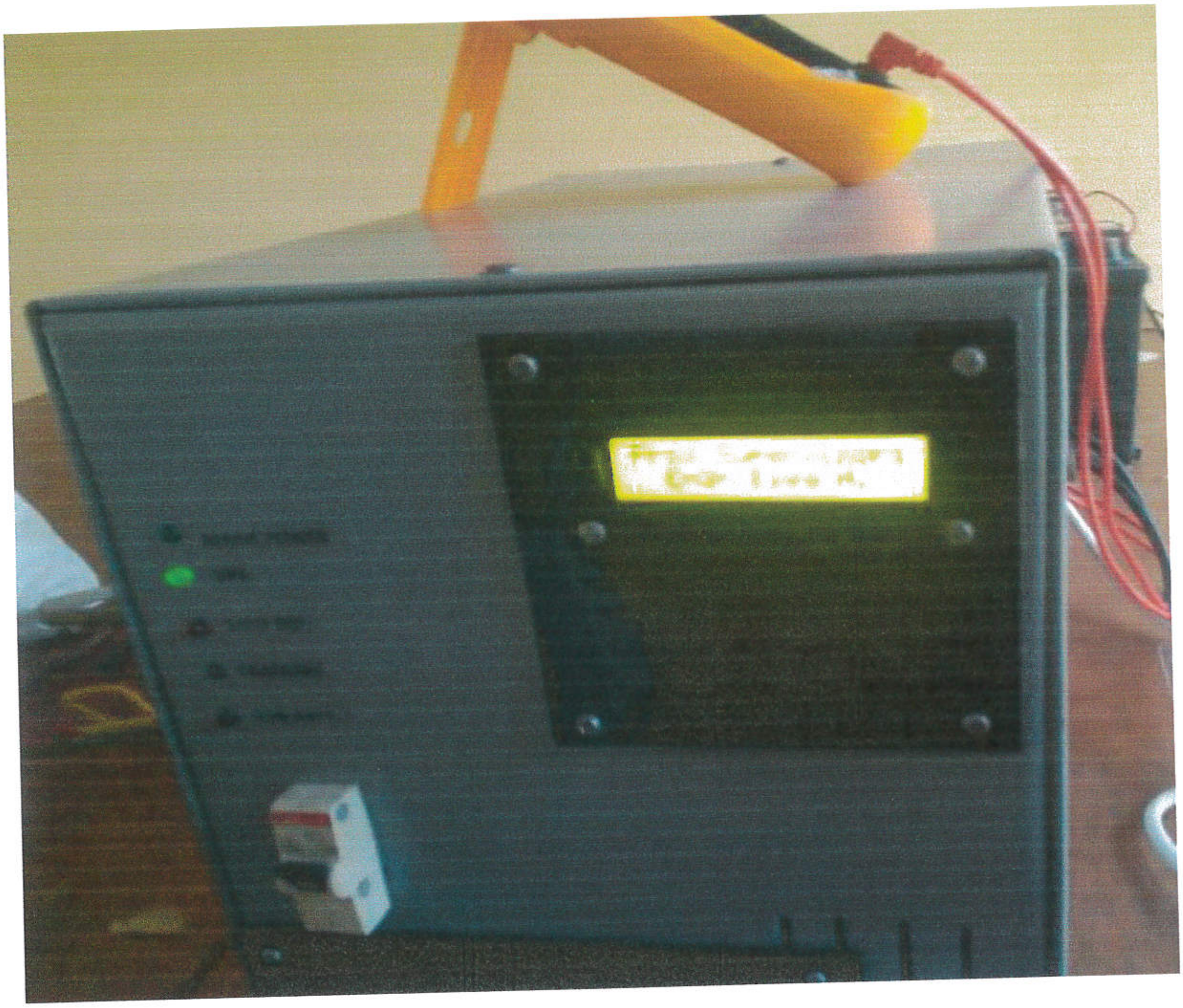


APPENDIX IIA
IMAGE OF THE WHOLE PROJECT BEFORE FINAL COUPLING



APPENDIX IIB

IMAGE OF THE WHOLE PROJECT AFTER FINAL COUPLING



APPENDIX III
COST EVALUATION OF THE WHOLE PROJECT

S/N	COMPONENT	COMPONENT DESCRIPTION	QUANTITY	UNIT AMOUNT(₦)	TOTAL AMOUNT(₦)
1	RESISTOR (OHM)	220	12	10	120
		100	3	10	30
		470	5	10	50
		560	2	10	20
		1K	5	10	50
		IK(VARIABLE)	1	50	50
		1.2K	1	10	10
		2.2K	7	10	70
		2.7K	1	10	10
		4.7K	10	10	100
		5K(VARIABLE)	1	50	50
		5.6K	1	10	10
		10K	16	10	160
		47K	2	10	20
		100K	2	10	20
		470K	1	10	10
2	DIODE	1N4007	13	10	130
		1N4148	7	10	70
		IN4773A	5	10	50

S/N	COMPONENT	COMPONENT DESCRIPTION	QUANTITY	UNIT AMOUNT(₦)	TOTAL AMOUNT(₦)
		1N539	1	10	10
		LED	5	10	50
3	CAPACITOR (FARAD)	33p	4	50	200
		230p	2	50	100
		231p	2	50	100
		330p	1	50	50
		104	8	30	240
		2.2u	1	30	30
		10u	3	30	90
		100u	3	30	90
4	TRANSISTOR	BC547	7	50	350
		BC557	3	50	150
5	VOLTAGE REGULATOR	7805	2	100	200
		LM317T	1	150	150
6	AMPLIFIER	LM358N	2	250	500
7	OPTO-COUPLER	TLP250	2	250	500
8	MOSFET	IRF3205	16	200	3200
9	MOSFET BOARD		1	1500	1500
10	MICRO-CONTROLLER	PIC16F72	1	1000	1000

S/N	COMPONENT	COMPONENT DESCRIPTION	QUANTITY	UNIT AMOUNT(₦)	TOTAL AMOUNT(₦)
		PIC16F84	1	1000	1000
11	CRYSTAL OSCILLATOR	4MHZ	1	150	150
		20MHZ	1	200	200
12	SOCKET	PIC SOCKET	2	200	400
		IC SOCKET	4	50	200
13	BUZZER		1	150	150
14	RELAY	AC RELAY	1	300	300
15	TRANSFORM ER	1.5KVA	1	6000	5000
16	CIRCUIT BREAKER		1	300	300
17	FILTER	AC FILTER CAPACITOR (50HZ)	1	300	300
18	OUTLET SOCKET		1	300	300
19	VERO BOARD		2	150	300
20	FAN	AC FAN	1	500	500
21	PLUGS	INPUT/OUTPUT	1	500	500
22	BOLTS AND NUTS		30	50	1500
23	CLIP	METAL CLIPS	2	30	60
		CABLE LUG	2	150	300
		RUBBER CLIPS	10	20	200
24	CABLE	2mm			300

S/N	COMPONENT	COMPONENT DESCRIPTION	QUANTITY	UNIT AMOUNT(₦)	TOTAL AMOUNT(₦)
		6mm (FLEX)			500
		10mm (STRAND)			800
		JUMPER WIRE			500
		RIBBON CABLE			300
25	CONNECTOR		3	100	300
26	SWITCH	DIGITAL SWICTH	1	50	50
		PUSH BUTTON	1	30	30
27	LCD	16 BY 2	1	1500	1500
28	CASING				7000
	GRAND TOTAL				32580

APPENDIX IV

COMPLETE SOURCE CODE FOR THE PIC16F72

```
LIST P=16F72A, F=INHX8M

include "P16F72A.inc"


__config _HS_OSC & _WDT_ON & _PWRTE_ON & _CP_OFF

W_TEMP equ 0x20

BATTV equ 0x4D

AD_RESULT equ 0x33

SEL_CHANEL equ 0x32

goto init    nop    nop    nop    goto isr    nop    nop    nop

table    ADDWF    PCL , F

RETLW .0   RETLW .6    RETLW .13    RETLW .19    RETLW .25
RETLW .31  RETLW .37   RETLW .43    RETLW .49    RETLW .55

RETLW .60  RETLW .66   RETLW .71    RETLW .76    RETLW .81
RETLW .86  RETLW .91   RETLW .95    RETLW .99    RETLW .103

RETLW .106    RETLW .110    RETLW .113    RETLW .116

RETLW .118    RETLW .121    RETLW .122    RETLW .124
RETLW .126    RETLW .127    RETLW .127    RETLW .128
RETLW .128    RETLW .128    RETLW .127    RETLW .127

RETLW .126    RETLW .124    RETLW .122    RETLW .121

RETLW .118    RETLW .116    RETLW .113    RETLW .110

RETLW .106    RETLW .103    RETLW .99     RETLW .95

RETLW .91     RETLW .86     RETLW .81     RETLW .76

RETLW .71     RETLW .66     RETLW .60     RETLW .55

RETLW .49     RETLW .43     RETLW .37     RETLW .31

RETLW .25     RETLW .19     RETLW .13     RETLW .6
```

RETLW .0

init clrf STATUS clrf PORTC clrf PORTB bcf STATUS,RP1

bsf STATUS,RP0 ; switch to bank 1

movlw b'11010101' movwf OPTION_REG movlw b'111111' movwf TRISA

movlw b'00000100' movwf TRISC movlw b'00000111' movwf TRISB

movlw .0 movwf ADCON1 bcf STATUS,RP0 ; switch to bank 0

movlw b'11000000' movwf INTCON movlw .0 movwf 0x10

bcf STATUS,RP0 ; switch to bank 0 movlw b'10000001' movwf ADCON0

clrf PORTA movlw b'00000111' movwf PORTC

call LEVEL_3 movlw .5 movwf 0x3C movwf 0x2A movlw .10 movwf 0x3E

call LEVEL_4 call LEVEL_4 goto LEVEL_5

LEVEL_3 movlw .80

movwf W_TEMP movlw .33 movwf FSR

LEVEL_6 clrf INDF

incf FSR,f decfsz W_TEMP,f goto LEVEL_6 return

ANASCAN movlw .5 movwf W_TEMP

LEVEL_7 decfsz W_TEMP,f goto LEVEL_7 movf SEL_CHANEL,w movwf W_TEMP bcf STATUS,C rlf W_TEMP,f rlf W_TEMP,f rlf W_TEMP,f

movlw .129 iorwf W_TEMP,w movwf ADCON0 movlw .20 movwf 0x37

LEVEL_10 decfsz 0x37,f goto LEVEL_8 goto LEVEL_9

LEVEL_8 btfss 0x2C,0 goto LEVEL_10 call LEVEL_11

LEVEL_9 bsf ADCON0,2

LEVEL_12 btfsc 0x2C,0 call LEVEL_11 btfsc ADCON0,2 goto LEVEL_12

movf ADRESH,w movwf AD_RESULT bcf 0xC,6 return

isr bcf INTCON,GIE movwf 0x31 movf STATUS,w movwf 0x30 bcf 0xC,0

bcf 0x10,0 btfsc 0x2B,0 goto LEVEL_13 btfsc 0x2C,3 goto LEVEL_14 goto exit

LEVEL_14 btfss 0x2D,5 goto LEVEL_16 bcf PORTC,4 bcf PORTC,5 movf 0x28,w movwf 0x26 movf 0x29,w movwf 0x27 movf 0x24,w movwf 0x22 movwf TMR1L

comf TMR1L,f movf 0x25,w movwf 0x23 movwf TMR1H comf TMR1H,f

bcf PORTC,0 bcf PORTC,1 bcf 0x2D,5 bsf 0x10;0 goto exit

LEVEL_13 btfss 0x2D,5 goto LEVEL_17 bcf 0x2D,5 bsf 0x2C,0 movf 0x28,w

movwf 0x26 movf 0x29,w movwf 0x27 movf 0x24,w movwf 0x22 movwf TMR1L

comf TMR1L,f movf 0x25,w movwf 0x23 movwf TMR1H comf TMR1H,f

movf 0x21,w btfss STATUS,Z goto LEVEL_18 movlw .8 xorwf 0x2B,f

;>>>

;DEAD BAND

;>>>

LEVEL_18 bsf 0x10,0 btfsc 0x2B,3 goto LEVEL_19 bcf PORTC,5 bsf PORTC,0

nop nop nop nop nop bsf PORTC,4 bcf PORTC,1 goto exit

LEVEL_19 bcf PORTC,4 bsf PORTC,1 nop nop nop nop nop bsf PORTC,5

bcf PORTC,0 goto exit

;>>>

;DEAD BAND

;>>>

LEVEL_17 bcf PORTC,4 bcf PORTC,5 movf 0x26,w movwf TMR1L comf TMR1L,f

movf 0x27,w movwf TMR1H comf TMR1H,f bcf PORTC,0 bcf PORTC,1

bsf 0x2D,5 bsf 0x10,0

exit movf 0x30,w movwf STATUS movf 0x31,w bsf INTCON,GIE retfie

LEVEL_42 movlw .2 ;MAINS SENSE

movwf SEL_CHANEL

call ANASCAN ;LEVEL 21,22,23

movf AD_RESULT,w sublw .67 btfsc STATUS,C goto LEVEL_21

movf AD_RESULT,w sublw .138 btfss STATUS,C goto LEVEL_21

movf AD_RESULT,w sublw .68 btfsc STATUS,C goto LEVEL_22

movf AD_RESULT,w sublw .135 btfsc STATUS,C goto LEVEL_23

LEVEL_22 clrf 0x55 clrf 0x34 clrf 0x35 return

LEVEL_23 btfsc 0x2B,1 return clrf 0x55 movlw .4 movwf 0x3D movlw .1

addwf 0x34,f btfss STATUS,C return incf 0x35,f movf 0x35,w sublw .50

btfsc STATUS,C return clrf 0x34 clrf 0x35 goto LEVEL_24

LEVEL_21 btfsc 0x2B,0 return incf 0x55,f clrf 0x34 clrf 0x35 movf 0x55,w

sublw .15 btfsc STATUS,C return goto LEVEL_25

LEVEL_40 btfss 0xC,2 goto LEVEL_26 bcf 0xC,2 clrf 0x36

goto LEVEL_27

LEVEL_26 btfss 0x2C,6 return incf 0x36,f movlw .4 subwf 0x36,w

btfss STATUS,C return clrf 0x36

LEVEL_25 btfss 0x2C,7 goto LEVEL_28 btfsc 0x2B,0 return

LEVEL_76 btfsc 0x2D,3 return call LEVEL_29 movlw .7 movwf 0x38

call LEVEL_30 bsf PORTC,7 call LEVEL_4 call LEVEL_4 clrf 0x34

clrf 0x35 clrf 0x55 call LEVEL_31 bcf 0x2B,1 bcf PORTB,4 bcf PORTB,5 bcf 0x2D,3 bcf PORTB,7 movlw .10 movwf 0x3D bsf 0x2B,0 movlw .0 movwf 0x21 call LEVEL_11 bsf 0x2D,5 movlw .200 movwf TMR1L movlw .255

movwf TMR1H bsf STATUS,RP0 ; switch to bank 1 bsf 0x8C,0 bcf STATUS,RP0 ; switch to bank 0 bsf 0x10,0 bsf INTCON,GIE clrf 0x40

clrf 0x41 clrf 0x42 clrf 0x4C return **LEVEL_28** btfss 0x2C,3 goto LEVEL_32 call LEVEL_29 call LEVEL_31 **LEVEL_32** clrf 0x55 bcf 0x2B,1 bcf PORTB,4 return **LEVEL_27** btfsc 0x2B,1 return movlw .1 addwf 0x34,f btfss STATUS,C return incf 0x35,f movlw .10 movwf 0x3D movf 0x35,w sublw .2 btfsc STATUS,C return clrf 0x34 clrf 0x35 **LEVEL_24** call LEVEL_33 bsf 0x2B,1 bsf PORTB,4 **LEVEL_31** bcf PORTB,6 bcf 0x2C,3 movlw .100 movwf 0x54 movlw .50 movwf 0x2F return **LEVEL_33** call LEVEL_29 call LEVEL_4 clrf 0x2Eclrf 0x3Aclrf 0x3B bcf 0x2B,0 bcf 0x2D,3 bcf PORTB,7 bcf PORTB,5 bcf PORTC,7 call LEVEL_4 return **LEVEL_4** clrwdt movlw .25 movwf 0x38 **LEVEL_30** clrwdt movlw .0 movwf W_TEMP **LEVEL_34** clrwdt decfsz W_TEMP,f goto LEVEL_34 decfsz 0x38,f goto LEVEL_30 return **LEVEL_54** movlw .1 ; BATTERY SENSE movwf SEL_CHANEL call ANASCAN movf AD_RESULT,w addwf 0x43,f btfss STATUS,C goto LEVEL_35 movf 0x44,w addlw .1 movwf 0x44 **LEVEL_35** movf 0x45,w addlw .1 movwf 0x45 andlw.128 btfsc STATUS,Z goto LEVEL_36 call LEVEL_37 movf BATTV,w sublw .215 ;CHG CUT OFF btfsc STATUS,C goto LEVEL_36 call LEVEL_29 call LEVEL_31 **LEVEL_36** goto LEVEL_38 **LEVEL_29** bcf INTCON,GIE bcf 0x10,0 bcf 0x12,2 bcf 0xC,0 bcf 0xC,2 bsf STATUS,RP0 ;switch to bank 1 bcf 0x8C,0 bcf STATUS,RP0 ; switch to bank 0 bcf PORTC,4 bcf PORTC,5 nop nop nop nop nop nop nop nop nop nop bsf PORTC,0 bsf PORTC,1 return **LEVEL_5** movlw .0 movwf TMR0 movlw .4 movwf 0x17 clrf 0x3A clrf 0x3B clrf 0x2E movlw .10 movwf 0x39 movlw .100 movwf 0x54 movlw .10 movwf 0x3E clrf 0x34 clrf 0x35 clrf 0x55 movlw .25 movwf 0x2A movlw .50 movwf 0x2F bcf 0x2C,7 bcf 0xC,2 movlw .10 movwf 0x3D bcf PORTC,7 call LEVEL_4 call LEVEL_4 call LEVEL_4 **LEVEL_38** clrwdt bcf 0x2C,6 btfsc INTCON,T0IF bsf 0x2C,6 bcf INTCON,T0IF btfsc 0x2C,0 call LEVEL_11 btfsc PORTA,4 goto LEVEL_39 call LEVEL_40 goto LEVEL_41 **LEVEL_39** call LEVEL_42 **LEVEL_41** call LEVEL_43 btfsc 0x2B,1 goto LEVEL_44 goto LEVEL_45 **LEVEL_45** btfss 0x2B,0 goto LEVEL_46 btfsc 0x2C,7 goto LEVEL_47 call LEVEL_33 goto LEVEL_46 **LEVEL_47** movf 0x2E,w btfss STATUS,Z goto LEVEL_46 movlw .4 ;OVERLOAD SENSE movwf SEL_CHANEL call ANASCAN movf AD_RESULT,w sublw .120 btfss STATUS,C goto LEVEL_48 movf AD_RESULT,w sublw .60 btfsc STATUS,C goto LEVEL_49 movlw .10 movwf 0x3D movlw .1 addwf 0x3A,f btfss STATUS,C goto LEVEL_49 incf

0x3B,f movf 0x3B,w sublw .5 btfsc STATUS,C goto LEVEL_49 **LEVEL_48** call LEVEL_29 clrf 0x3A clrf 0x3B movlw .50 movwf 0x2E movlw .50 movwf 0x3D bsf PORTB,5 goto LEVEL_46 **LEVEL_49** bcf PORTB,5 movf BATTV,w btfsc STATUS,Z goto LEVEL_50 bcf 0x2D,3 sublw .154 ;LOW BATTERY BEEP btfss STATUS,C goto LEVEL_50 bsf 0x2D,3 movf BATTV,w sublw .148 ;LOW BATTERY CUT btfss STATUS,C goto LEVEL_50 call LEVEL_29 bsf 0x2D,3 goto LEVEL_46 **LEVEL_50** movlw .0 ;FEED BACK movwf SEL_CHANEL call ANASCAN movf AD_RESULT,w addwf 0x40,f btfss STATUS,C goto LEVEL_51 movf 0x41,w addlw .1 movwf 0x41 **LEVEL_51** movf 0x42,w addlw .1 movwf 0x42 andlw b'00100000' btfsc STATUS,Z goto LEVEL_46 call LEVEL_52 call LEVEL_53 **LEVEL_46** goto LEVEL_54 **LEVEL_44** btfss 0x2B,1 goto LEVEL_55 btfsc 0x2C,3 goto LEVEL_56 movf BATTV,w sublw .101 ;CHG RESTART btfss STATUS,5 movf 0x2F,w btfss STATUS,Z goto LEVEL_55 bsf 0x2C,3 bsf PORTB,4 bsf PORTB,6 clrf 0x46 clrf 0x47 clrf 0x48 clrf 0x4E movlw .100 movwf 0x54 call LEVEL_57 ; LEVEL_57 = 0x346 movlw .200 movwf TMR1L movlw .255 movwf TMR1H bsf 0x2D,5 bsf STATUS,RP0 ;switch to bank 1 bsf 0x8C,0 bcf STATUS,RP0 ; switch to bank 0 bsf 0x10,0 bsf INTCON,GIE goto LEVEL_55 **LEVEL_56** movlw .3 ;CHARGING CURRENT movwf SEL_CHANEL call ANASCAN movf AD_RESULT,w sublw .180 btfsc STATUS,C goto LEVEL_58 call LEVEL_29 call LEVEL_31 goto LEVEL_55 **LEVEL_58** movf AD_RESULT,w addwf 0x46,f btfss STATUS,C goto LEVEL_59 movf 0x47,w addlw .1 movwf 0x47 **LEVEL_59** movf 0x48,w addlw .1 movwf 0x48 andlw .32 btfsc STATUS,Z goto LEVEL_55 call LEVEL_60 call LEVEL_61 **LEVEL_55** goto LEVEL_54 **LEVEL_52** movlw .5 movwf W_TEMP **LEVEL_62** bcf STATUS,C rrf 0x41,f rrf 0x40,f decfsz W_TEMP,f goto LEVEL_62 movwf 0x4C clrf 0x40 clrf 0x41 clrf 0x42 return **LEVEL_37** movlw .7 movwf W_TEMP **LEVEL_63** bcf STATUS,C rrf 0x44,f rrf 0x43,f decfsz W_TEMP,f goto LEVEL_63 movf 0x43,w movwf BATTV clrf 0x43 clrf 0x44 clrf 0x45 return **LEVEL_60** movlw .5 movwf W_TEMP**LEVEL_64** bcf STATUS,C rrf 0x47,f rrf 0x46,f decfsz W_TEMP,f goto LEVEL_64 movf 0x46,w movwf 0x4E clrf 0x46 clrf 0x47 clrf 0x48 return **LEVEL_43** btfss 0x2C,6 goto LEVEL_65 btfss 0x2C,3 goto LEVEL_66 btfsc 0x2C,5 goto LEVEL_66 movlw .128 subwf 0x54,w btfsc STATUS,C goto LEVEL_67 incf 0x54,f goto LEVEL_67 **LEVEL_66** btfss 0x2B,0 goto LEVEL_67 btfsc 0x2B,7 goto LEVEL_67 movlw .128 subwf 0x39,w btfsc STATUS,C goto LEVEL_67 incf 0x39,f **LEVEL_67** btfsc PORTB,2 goto LEVEL_68 movf 0x2A,w btfsc STATUS,Z goto LEVEL_69 decfsz 0x2A,f goto LEVEL_70 btfsc 0x2B,5 goto LEVEL_69 bsf 0x2B,5 btfsc 0x2C,7 goto LEVEL_71 bsf 0x2C,7 bsf PORTB,3 movlw .10 movwf 0x3D goto LEVEL_70 **LEVEL_71** bcf 0x2C,7 bcf PORTB,3 movlw .10 movwf 0x3D btfsc 0x2B,0 call LEVEL_33 movlw .10 movwf 0x39 movlw .10 movwf 0x3E goto LEVEL_70 **LEVEL_68** bcf 0x2B,5 **LEVEL_69** movlw .30 movwf 0x2A **LEVEL_70** decfsz 0x3C,f goto LEVEL_65 movlw .20 movwf 0x3C btfss 0x2D,3 goto LEVEL_72 movlw .10 movwf 0x3D movlw .128 xorwf PORTB,f **LEVEL_72** btfss 0x2B,1 goto LEVEL_73 btfss 0x2C,3 goto LEVEL_74 movlw .64 xorwf PORTB,f **LEVEL_74**movf 0x2F,w btfss STATUS,Z decf 0x2F,f **LEVEL_73** btfss 0x2B,0 goto LEVEL_75 movf 0x2E,w btfsc STATUS,Z goto LEVEL_75 decfsz 0x2E,f goto LEVEL_75 movlw .10 movwf 0x39 movlw .10 movwf 0x3E call LEVEL_76 **LEVEL_75** movf 0x3D,w btfsc STATUS,Z goto LEVEL_65 movlw b'1000000' xorwf PORTC,f decfsz 0x3D,f goto LEVEL_65 bcf PORTC,6 **LEVEL_65** return **LEVEL_61** movf 0x4E,w sublw .5 btfsc STATUS,C goto LEVEL_57 bcf 0x2C,5 movf 0x4E,w subwf 0x54,w movwf 0x52 btfss STATUS,C goto LEVEL_77 sublw .2 btfss STATUS,C goto LEVEL_78 return **LEVEL_78** bcf STATUS,C rrf 0x52,f clrf 0x53 movlw .1 movwf 0x52 movf 0x24,w addwf 0x52,f btfsc STATUS,C incf 0x53,f movf 0x25,w addwf 0x53,f movf 0x52,w sublw .0 movf 0x53,w movwf W_TEMP btfss STATUS,C incf W_TEMP,f movf W_TEMP,w sublw .2 btfsc STATUS,C goto LEVEL_79 movlw .0 movwf 0x24 movlw .2 movwf 0x25 goto LEVEL_80 **LEVEL_79** movf 0x52,w

movwf 0x24 movf 0x53,w movwf 0x25 goto LEVEL_80 **LEVEL_77** comf 0x52,f incf 0x52,f movf 0x52,w sublw .2 btfsc STATUS,C return bcf STATUS,C rrf 0x52,f clrf 0x53 movlw .5 movwf 0x52 movf 0x52,w subwf 0x24,f movwf 0x52 btfss STATUS,C incf 0x53,f movf 0x53,w subwf 0x25,f movwf 0x53 btfsc STATUS,C goto LEVEL_80 **LEVEL_57** bsf 0x2C,5 movlw .20 movwf 0x24 movlw .0 movwf 0x25 **LEVEL_80** bcf STATUS,C movf 0x25,w movwf W_TEMP movf 0x24,w sublw .200 movwf 0x28 btfss STATUS,C incf W_TEMP,f movf W_TEMP,w sublw .2 movwf 0x29 return **LEVEL_53** movf 0x4C,w sublw .5 btfsc STATUS,C goto LEVEL_81 bcf 0x2B,7 bcf 0x2B,2 movf 0x4C,w subwf 0x39,w movwf 0x52 btfsc STATUS,C goto LEVEL_82 bsf 0x2B,2 comf 0x52,f incf 0x52,f **LEVEL_82** movf 0x52,w sublw .2 btfss STATUS,C goto LEVEL_83 return **LEVEL_83** bcf STATUS,C rrf 0x52,f rrf 0x52,f movlw .1 movwf 0x52 btfss 0x2B,2 goto LEVEL_84 movf 0x52,w subwf 0x3E,f movf 0x3E,w sublw .89 btfss STATUS,C goto LEVEL_85 return **LEVEL_84** movf 0x52,w addwf 0x3E,f movf 0x3E,w sublw .89 btfsc STATUS,C return movlw .89 movwf 0x3E return **LEVEL_81** bsf 0x2B,7 movlw .10 movwf 0x39 **LEVEL_85** movlw .10 movwf 0x3E return **LEVEL_11** bcf 0x2C,0 incf 0x21,f btfss 0x21,6 goto LEVEL_86 clrf 0x21 **LEVEL_86** movf 0x21,w call table movwf 0x50 movf 0x3E,w movwf 0x51 call LEVEL_88 bcf STATUS,C rrf 0x53,f rrf 0x52,f bcf STATUS,C rrf 0x53,f rrf 0x52,f bcf STATUS,C rrf 0x53,f rrf 0x52,f bcf STATUS,C rrf 0x53,f rrf 0x52,f movf 0x52,w movwf 0x24 movf 0x53,w movwf 0x25 bcf STATUS,C movf 0x24,w sublw .200 movwf 0x28 movf 0x25,w movwf W_TEMP btfss STATUS,C incf W_TEMP,f movf W_TEMP,w sublw .2 movwf 0x29 return **LEVEL_88** clrf 0x53 clrf 0x52 movf 0x50,w bcf STATUS,C btfsc 0x51,0 addwf 0x53,f rrf 0x53,f rrf 0x52,f btfsc 0x51,1 addwf 0x53,f rrf 0x53,f rrf 0x52,f btfsc 0x51,2 addwf 0x53,f rrf 0x53,f rrf 0x52,f btfsc 0x51,3 addwf 0x53,f rrf 0x53,f rrf 0x52,f btfsc 0x51,4 addwf 0x53,f rrf 0x53,f rrf 0x52,f btfsc

0x51,5 addwf 0x53,f rrf 0x53,f rrf 0x52,f btfsc 0x51,6 addwf 0x53,f rrf 0x53,f rrf
0x52,f btfsc 0x51,7 addwf 0x53,f rrf 0x53,f rrf 0x52,f retlw .0 addlw .166 addlw
.255 addlw .255 addlw .255 addlw .255 movlw .10 addwf 0x52,f btfsc STATUS,C incf
0x53,f movlw .8 addwf 0x53,f movf 0x53,w movwf PCLATH movf 0x52,w movwf PCL
retlw .0 retlw .0 retlw .0retlw .0 retlw .227 retlw .54 retlw .0 retlw .227 retlw
.62 retlw .0 retlw .228 retlw .8 retlw .0 retlw .228 retlw .20 retlw .0 retlw .228 retlw
.34 retlw .0 retlw .228 retlw .54 retlw .0 retlw .229 retlw .32 retlw .0 retlw .230 retlw
.48 retlw .0 retlw .231 retlw .16 retlw .0 retlw .231 retlw .44 retlw .0 retlw
.232 retlw .4 retlw .0retlw .232 retlw .54 retlw .0 retlw .233 retlw .6 retlw .0 retlw
.233 retlw .60 retlw .0 retlw .234 retlw .27 retlw .0 retlw .234 retlw .36 retlw .0
retlw .227 retlw .57 retlw .0 retlw .228 retlw .17 retlw .0 retlw .228 retlw
.41 retlw .0 retlw .229 retlw .1 retlw .0 retlw .229 retlw .25 retlw .0 retlw .229 retlw
.49 retlw .0 retlw .230 retlw .9 retlw .0 retlw .230 retlw .33 retlw .0 retlw .230 retlw
.57 retlw .0 retlw .231 retlw .17 retlw .0 retlw .231 retlw .41 retlw .0 retlw .232 retlw
.1 retlw .0 retlw .232 retlw .25 retlw .0 retlw .232 retlw .49 retlw .0 retlw
.233 retlw .9 retlw .0retlw .233 retlw .33 retlw .0 retlw .227 retlw .60 retlw .0
retlw .228 retlw .21 retlw .0 retlw .228 retlw .44 retlw .0 retlw .229 retlw .4 retlw
.0 retlw .229 retlw .28 retlw .0 retlw .229 retlw .52 retlw .0 retlw .230 retlw
.12 retlw .0 retlw .230 retlw .36 retlw .0 retlw .230 retlw .60 retlw .0 retlw
.231 retlw .20 retlw .0 retlw .231 retlw .45 retlw .0 retlw .232 retlw .5 retlw .0
retlw .232 retlw .28 retlw .0 retlw .232 retlw .52 retlw .0 retlw .233 retlw .12
retlw .0 retlw .233 retlw .36 retlw .0 retlw .227 retlw 63 retlw .0 retlw .228 retlw
.23 retlw .0 retlw .228 retlw .47 retlw .0 retlw .229 retlw .7 retlw .0 retlw .229 retlw
.31 retlw .0 retlw .229 retlw .55 retlw .0 retlw .230 retlw .15 retlw .0 retlw 230 retlw
.39 retlw .0 retlw .230 retlw .63 retlw .0 retlw .231 retlw .23 retlw .0 retlw
.231 retlw .47 retlw .0 retlw .232 retlw .7 retlw .0retlw .232 retlw .31 retlw .0 retlw
.232 retlw .55 retlw .0 retlw .233 retlw .15 retlw .0 retlw .233 retlw .39 retlw
.0 retlw .228 retlw .2 retlw .0 retlw .228 retlw .26 retlw .0 retlw .228 retlw .50
retlw .0 retlw .229 retlw .10 retlw .0 retlw .229 retlw .34 retlw .0 retlw .229 retlw
.58 retlw .0 retlw .230 retlw .18 retlw .0 retlw .230 retlw .42 retlw .0 retlw
.231 retlw .2 retlw .0 retlw .231 retlw .26 retlw .0 retlw .231 retlw .50 retlw .0
retlw .232 retlw .10 retlw .0 retlw .232 retlw .34 retlw .0 retlw .232 retlw .58 retlw
.0 retlw .233 retlw .18 retlw .0 retlw .233 retlw .42 retlw .0 retlw .228 retlw .5
retlw .0 retlw .228 retlw .29 retlw0 retlw .228 retlw .53 retlw .0 retlw .229 retlw
.13 retlw .0 retlw .229 retlw .37 retlw .0 retlw .229 retlw .61 retlw .0 retlw .230 retlw
.21 retlw .0 retlw .230 retlw .45 retlw .0 retlw .231 retlw .5 retlw .0retlw .231 retlw
.29 retlw .0 retlw .231 retlw .53 retlw .0 retlw .232 retlw .13 retlw .0 retlw .232 retlw
.37 retlw .0 retlw .23 retlw .61 retlw .0 retlw .233retlw .21 retlw .0 retlw .233 retlw
.45 retlw .0 retlw .228 retlw .9 retlw .0 retlw .228 retlw .32 retlw .0 retlw .228 retlw
.56 retlw .0 retlw .229 retlw .16 retlw .0 retlw .229 retlw .40 retlw .0 retlw .230 retlw
.0 retlw .0 retlw .230 retlw .24 retlw .0 retlw .230 retlw .31 retlw .0 retlw .231 retlw
.8 retlw .0 retlw .231 retlw .32retlw .0 retlw .231 retlw 56 retlw .0 retlw
.232 retlw .16 retlw .0 retlw .232retlw .40 retlw .0 retlw .233 retlw .0 retlw .0 retlw .233 retlw
.24 retlw .0 retlw .233retlw .48 retlw .0 retlw .228 retlw .11 retlw .0 retlw .228 retlw .35
retlw .0 retlw .228 retlw .59 retlw .0 retlw .229 retlw .19 retlw .0 retlw .229 retlw
.43 retlw .0 retlw .230 retlw .3 retlw .0retlw .230 retlw .27 retlw .0 retlw .230 retlw
.51 retlw .0 retlw 231 retlw .11 retlw .0 retlw .231 retlw .35 retlw .0 retlw .231 retlw
.59 retlw .0 retlw .232 retlw .19 retlw .0 retlw .232 retlw .43 retlw .0 retlw