CHAPTER 1

INTRODUCTION

1.1 **THE BACKGROUND**

Welding is a way of heating pieces of metal using electricity or a flame so that they melt and stick together. It can simply be defined as the process of joining two or more pieces of metal to make the act as a single piece. This is often done by melting the work pieces and adding a filler material to form a pool of molten material that cools to become a strong joint. Because of its strength, welding is used to join beams when constructing buildings, bridges and other structures. Welding can also be used to join pipes in pipelines, power plants at the construction sites and in home appliance. Furthermore, welding is used in shipbuilding, automobile manufacturing and repair, aerospace applications. There are many kinds of welding which include arc welding, resistance welding, gas welding among others. Emphasis will be laid on arc welding because it is the most common type of welding as well as the main aim of this project.

Arc welding is the process of welding that utilizes an electrical discharge (arc) to join similar materials together. Equipment that performs the welding operation under the observation and control of a welding operator is known as welding machine. To solve the problem of weight and size of conventional arc welding machine, it is necessary to design an inverter. The inverter provides much higher frequency than 50Hz or 60Hz supply for transformer used in welding. So transformer of much smaller mass is used to permit the handling of much greater output power. The welding noise produce by conventional arc welding machine is reduced by selecting the operating frequency over the hearing of human ability. The choice of 20Khz for the inverter type arc welding machine was determined to meet the above expectation. The output welding current is controlled by controlling the power supply for transformer at high frequency. This power supply is provided by a frequency inverter. Power switch IGBTs (Insulated Gate Bipolar Transistor) or MOSFETs is used for the inverter design due to its high switching. The control circuit use to control the output welding current is design to drive the power switch at high frequency. Insulated Gate Bipolar Transistor power switch is more efficient and less prone to failure than MOSFETs power switch.

1.2 AIMS AND OBJECTIVES OF THE PROJECT

The main aim and objective of this project is to design and build and arc welding machine that operates on 36vdc at variable frequency which of benefit to urban area. This reduces the weight and size of the transformer use for welding. To have an arc welding machine that is more efficient which produce neat welding.

1.3 **SIGNIFICANT OF THE STUDY**

The significant of this project is that it seeks to develop an arc welding machine that is cost effective, strong and portable. Not only that the arc welding machine is strong and portable, it is also mobile.

1.4 **LIMITATION OF THE PROJECT**

The project has certain limitations which are mentioned below.

- This project cannot weld bigger gauge of metals.
- The welding time and power depends on the battery input power.
- You are to have bands of battery for reliability when using battery.
- The machine must be used by a qualified welder. Welding can endanger the operator or people near the working area. Therefore, the performance of welding and cutting must only be done under the comprehensive observation of all relevant safety regulation.
- Switch function modes during welding could potentially damage the equipment. A safety switch is necessary to prevent the equipment from electric leakage. Use only high quality welding tools and equipment with this inverter type arc welding machine.

1.5 PROJECT REPORT ORGANIZATION

The organization of the project report is well detailed and vast in its coverage. It covers all the activities encountered during the research work. The first chapter is the introductory chapter which covers the background, project objectives, project justification, and scope of the project. Chapter two presents the literature reviews. Chapter three covers the system analysis and design methodology in details. Chapter four presents the system implementation which entails the circuits diagram of different stages and also the complete schematic diagram with necessary calculation involve in the design. Chapter five is emphasis on conclusion, problem encountered during project design, recommendations and suggestion for further improvement. Fig1.1 depicts an overview of project report organization.

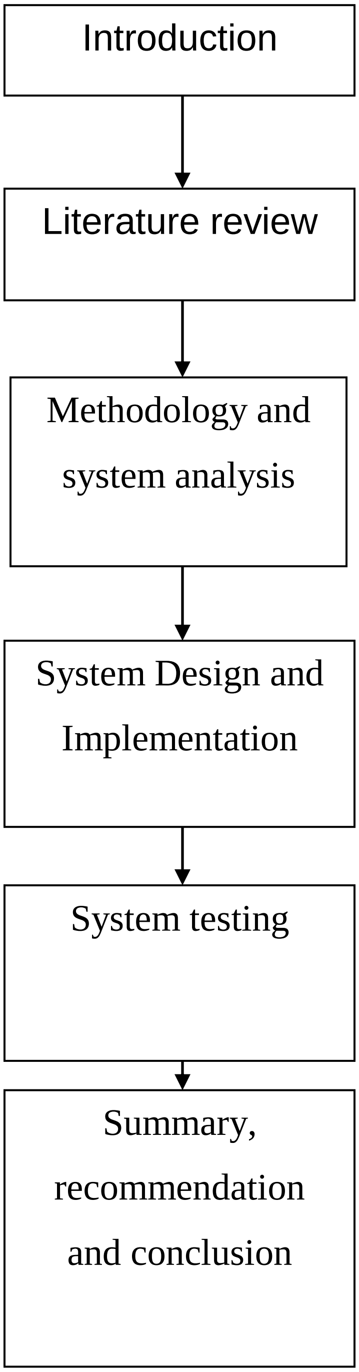

Fig1.1 An overview of project report organization

Chapter 2

LITERATURE REVIEW

2.1 HISTORY OF ARC WELDING MACHINE

The history of joining metals goes back several millennia that are Bronze Age or Iron Age in Europe and the Middle East. At that age, the process of joining similar or dissimilar materials is by forge welding. Arc welding did not come into practice until much later. In 1802, Vasily Petro discovered continues electric arc [5] and subsequently proposed its possible practical application including welding. The French electrical inventor Auguste De Metitens produced the first carbon arc torch, patended in 1881, which was successfully used for welding lead in the manufacture of lead-acid batteries. In 1881-1882, a Russian inventor Nikolai Bernados created the electric arc welding method for steel known as carbon arc welding. This type of arc welding uses carbon electrodes.

The advantages in arc welding continued with the invention of metal electrodes in the late 19th century by a Russian Nikolai Slavyanor (1888), and an American, L.C Coffin. Around 1900, A.P Strohmenger released in Britain a coated metal electrode which gave a more stable arc. In 1905 Russian scientist Vladimir Mitkerich proposed the usage of three phase electric arc for welding. In 1919, alternating current welding was invented by C.J Hoslag but did not become popular for another decade [6]. Competing welding processes such as resistance welding and oxyfuel welding were developed during this time as well, [6] but both, especially the later, faced stiff competition from arc welding especially after metal coverings (known as flux) for the electrode, to stabilize the arc and shield the base material from purities, continued to be developed [3].

During World War I, welding started to be used in ship building in Britain in place of riveted steel plates. The Americans also became more accepting of the new technology when the process allowed them to repair their ships quickly after a German attack in the New York Harbor at the beginning of the war. Arc welding was first applied to aircraft during the war as well, and some German airplane fuselages were constructed using this process [1]. In 1919, the British shipbuilder Cammell Laird started construction of merchant ship, the fullagar, with an entirely welded hull.

During the 1920s, Major advances were made in welding technology. Shielding gas became a subject receiving much attention as scientist attempted to protect welds from the effects of oxygen and nitrogen in the atmosphere. Porosity and brittleness were the primary problems and the solutions that developed included the use of hydrogen, argon, and helium as welding atmospheres. During the following decade, further advances allowed for the welding of reactive metals such as an aluminum and magnesium. This in conjunction with developments in automatic welding, alternating current, and fluxes fed a major expansion of arc welding during the 1930s and then during World War II [1].

Many new welding methods were invented in the middle of the century. Submerged arc welding was invented in 1930 and continues to be popular today. In 1932 a Russian, Konstantin Khrenor successfully complemented the first underwater electric arc welding. Gas tungsten arc welding was perfected in 1914 and gas metal arc welding followed in 1948, allowing for fast welding of non-ferrous materials but requiring expensive shielding gases. Using a consumable electrode and a carbon dioxide atmosphere as a shielding gas, it quickly became the most popular metal arc process. In 1957, the flux-cored arc welding process debated in which the self shielded wire electrode could be used with automatic equipment, resulting in greatly increased welding speeds. In that same year, plasma arc welding was invented. Electroslag welding was released in 1958 followed by Electrogas welding in 1961.

Arc welding is a type of welding power supply to create an electric arc between and electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding gas, vapor, and/or slag.

2.2 PROCESS OF ARC WELDING

- Gas metal arc welding
- Flux-cored arc welding (FCAW)
- Submerged arc welding (SAW)

2.3 CONSUMABLE ELECTRODE AND NON-CONSUMABLE ELECTRODE METHODS

2.3.1 CONSUMABLE ELECTRODE METHODS

One of the most common types of arc welding is shielded metal arc welding (SMAW), which is also known as manual metal arc welding (MMAW) or stick welding. An electric current is used to strike an arc between the base material and a consumable electrode rod or stick. The electrode rod is made of a material that is compatible with the base material being welded and is covered with a flux that gives off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination. The electrode core itself acts as filler material, making separate filler unnecessary. The process is very versatile, requiring little operator training and inexpensive equipment. However, weld times are rather slow, since the consumable electrodes must be frequently replaced and because slag, the residue from the flux, must be chipped away after welding.[3] Furthermore, the process is generally limited to welding ferrous materials, though specialty electrodes have made possible the welding of cast iron, nickel, aluminum, copper and other metals. The versatility of the method makes it popular in a number of applications including repair work and construction.

2.3.2 NON-CONSUMABLE ELECTRODE METHODS

Gas tungsten arc welding (GTAW), or tungsten/inert-gas (TIG) welding, is a manual welding process that uses a non-consumable electrode made of tungsten, an inert or semi-inert gas mixture, and a separate filler material. Especially useful for welding thin materials, this method is characterized by a stable arc and high quality welds, but it requires significant operator skill and can only be accomplished at relatively low speeds. It can be used on nearly all weld able metals, though it is most often applied to stainless steel and light metals. It is often used when quality welds are extremely important, such as in bicycle, aircraft and naval applications.[3] A related process, plasma arc welding, also uses a tungsten electrode but uses plasma gas to make the arc. The arc is more concentrated than the GTAW arc, making transverse control more critical and thus generally restricting the technique to a mechanized process. Because of its stable current, the method can be used on a wider range of material thicknesses than can the

GTAW process and is much faster. It can be applied to all of the same materials as GTAW except magnesium; automated welding of stainless steel is one important application of the process. A variation of the process is plasma cutting, an efficient steel cutting process. Other arc welding processes include atomic hydrogen welding, carbon arc welding, electroslag welding, electrogas welding, and stud arc welding.

2.4 ARC WELDING POWER SUPPLIES

To supply the electrical energy necessary for arc welding processes, a number of different power supplies can be used. The most common classification is constant voltage power supplies.

In arc welding, the voltage is directly related to the length of the arc, and the current is related to the amount of heat input. Constant current power supplies are most often used for manual welding processes such as gas tungsten arc welding and shielded metal arc welding, because they maintain a relatively constant current even as the voltage varies. Constant current is used in manual welding because it can be difficult to hold the electrode perfectly steady, and as a result, the arc length and thus voltage tend to fluctuate. Constant voltage power supplies hold the voltage constant and vary the current. Constant voltage power supplies are most often used for automated welding processes such as gas metal arc welding.

The direction of current used in arc welding also plays an important role in welding. Consumable electrode processes such as shielded metal arc welding and gas metal arc welding generally use direct current, but the electrode can be charged either positively or negatively. In welding, the positively charged anode will have a greater heat concentration and as a result, changing the polarity of the electrodes has an impact on weld properties. If the electrode is positively charged, it will melt quickly, increasing weld penetration and welding speed.

Alternatively, a negatively charged electrode results in more shallow welds [2]. Non-consumable electrode processes such as gas tungsten arc welding, can use either type of direct current as well as alternating current (AC). With direct current however, because the electrode only creates the arc and does not provide filler material, a positively charged electrode causes shallow welds, while a negatively charged electrodes makes deeper welds [1].

Alternating current rapidly moves between these two, resulting in medium-penetration welds. One disadvantage of AC is that arc must be re-ignited after every zero crossing. This disadvantage has been addressed with the invention of special power units that produce a square wave pattern instead of the normal sine wave, eliminating low-voltage time after the zero crossings and minimizing the effect of the problem [3]. Shielded metal arc welding and gas tungsten arc welding will use a constant current source. Constant voltage source is preferred in gas metal arc welding and flux-cored arc welding.

The welding power supplies most commonly seen can be categorized within the following types.

2.4.1 TRANSFORMER

A transformer style welding power supply converts the high voltage and low current electricity from the utility mains into a high current and low voltage (typically between 17 to 45 volts and 55 to 590 Amps). A rectifier is used to convert AC into DC to obtain dc output.

By moving a magnetic shunt in and out of the transformer core helps to vary the output current. A series reactor to the secondary controls the output voltage from a set of taps on the transformer’s secondary winding. This type of power supply is least expensive but bulky. It is a low frequency transformer which must have as high magnetizing conductance to avoid wasteful shunt currents. The transformer may also have significant leakage conductance for short circuit protection in the event of a welding rod becoming stuck to be workforce. The leakage inductance may be variable so the operator can set the output current [4].

2.4.2 GENERATOR AND ALTERNATOR

Welding power supplies may also use generators or alternators to convert mechanical energy into electrical energy. Modern designs as usually driven by an internal combustion engine but older mechanics may use an electric motor to drive an alternator or generator. In this configuration the utility power is converted first into mechanical energy to achieve the step-down effect similar to a transformer. Because the output of the generator can be direct current or even a higher frequency AC current, older mechanics can produce DC from AC without any need for rectifiers.

2.4.3 INVENTER

Since the advent of high-power semi conductors such as insulated gate field-effect transistor (IGFET) also known as MOSFET (metal oxide semiconductor field-effect transistor it is also now possible to build a switched-mode power supply capable of copying with the high loads of arc welding. These designs are known as inverter welding machine.

The utility AC power is first rectify to DC power; then the DC power switch (invert) into a step-down transformer at high frequency to produce the desire welding voltage or current. The switching frequency is typically about 20khz to 100khz [5]. The high switching frequency drastically reduces the bulk of the step-down transformer. The mass of magnetic components (transformer & conductors) goes down rapidly as the operating (switching) frequency increases. The converter circulatory can also provide features such as power control and overload protection. This type of welding machines (inverter based) are more efficient and provide better control of variable functional parameters than conventional welding machines. The IGBTs or IGFETs in an inverter based machine are controlled by a micro controller so the electrical characteristics of the welding power can be changed by software.

There are other types of arc welding machines which some were mentioned. We are to emphasis on Inverter type arc welding machine, since it is the topic of the project.

CHAPTER 3

METHODOLOGY AND SYSTEM ANALYSIS

3.1 METHODOLOGY

My approach to this project is realized through the design and implementation of its input subsystem, control unit and output subsystem. The welding of a metal occurs when the control unit and the output subsystem links together through the conductive objective to be welded. Welding is the process of joining two or more similar or dissimilar material with/without the application of heat and/or pressure with or without using the filler material.

3.2 DESIGN METHOLOGY

In the design I started with the overall system and begin to partion it into systems. The handy tool used at this stage is the block diagram shown below in fig3.1 the block diagram depicts the hierarchy of how the inverter sub-circuits will interact and interface with each other. A computer aided design software known as proteus (ISIS professional) was used for the design simulation of the paper design before the first hardware prototype was actualized or realized on an experimental breadboard. This was achieved through the implementation of the inverter input subsystem to the output subsystem. These were carefully done according to the project block diagram and the final schematic circuit diagram.

The system block diagram of the inverter arc welding machine project is shown in fig3.1

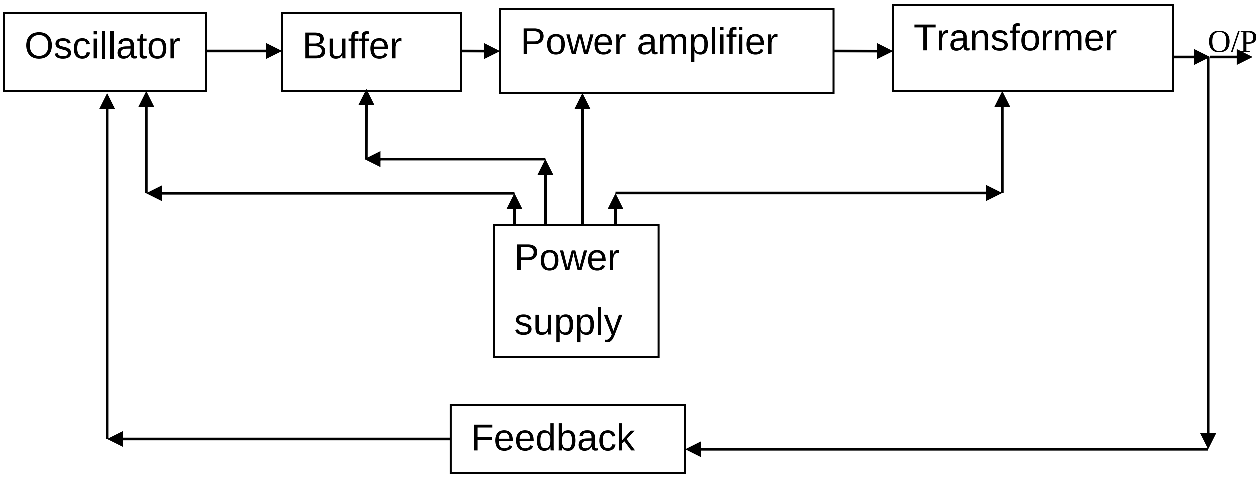

Fig3.1 Block diagram of an inverter type welding machine

The system is a flexible power supply designed as current source [6], corresponding to the block diagram shown above in fig1which consists of the following stage.

3.3 DESIGN ANALYSIS

3.3.1 **Power stage**: In this stage, battery supplies the oscillator, buffer, power amplifier, and transformer stage with the necessary voltage. A 36v battery is use in our design to power the circuit.

3.3.2 **Oscillator Stage**: An IC SG3524 is use to generate the necessary pulse needed to drive the MOSFET (IRF150) to alternate the DC supply. The output from the oscillator stage is amplified using transistor (9013). This amplified signal triggers the metal-oxide field-effect transistor with Vgs greater the threshold voltage. The frequency at which circuit operate is determined with the oscillator stage.

3.3.3 **Power amplifier stage**: this stage determines the primary power of the transformer. MOSFET (IRF150) is use in the design for power amplification as shown in fig4.3.

3.3.4 **Transformer:** This is the final stage which transforms the 36v (modified square wave) to about 25v depending on the frequency of the pulse generated at the oscillator stage.

3.4 DESIGN SPECIFICATION

Output Voltage – 25Vac

Output Current- 80A

Input Voltage – 36Vdc

Transformer Power rating - 2kva

Duty cycle = 20%

3.5 COMPONENTS/DEVICE IDENTIFICATION AND DESCRIPTION

The components/devices used for the construction of the inverter arc welding machine are explained below with their uses in the project.

3.5.1 IC SG3524

The SG3524 were designed for switching regulators of polarity, transformer-coupled dc-to-ac converters, transformerless voltage doublers, and polarity-converter applications employing fixed-frequency, pulse-width modulation (PWM) techniques. SG3524 is an integrated switching regulator circuit that has all essential circuitry required for making a switching regulator. The built in circuitries inside the SG3524 include pulse width modulator, oscillator, voltage reference, error amplifier, overload protection circuit, output drivers etc. SG3524 forms the heart of this PWM inverter circuit which can correct its output voltage against the variations in the output load. In a non PWM inverter the change in output load directly affects the output voltage (i.e. increase in output load result to decrease in output voltage and vice versa), but in a PWM inverter the output voltage remains constant over a range of output load.

3.5.2 **Metal-Oxide Semiconductor Field-Effect Transistor (MOSFET)**

MOSFET can also be called Insulated Gate Field-Effect Transistor (IGFET) because the metal gate is insulated from the channel [7] MOSFETs are much faster switch power device than relays and mechanical switches. They are best suited for digital circuit. We have two types of MOSFETs which is known as Mode of operation. They are Enhancement MOSFET and Depletion MOSFET. N-channel enhancement Metal-Oxide Semiconductor Field-Effect Transistor is use as a switch. The above mode of operation is subdivided into N-channel and P-channel. N-channels are more popular than P-channel because of their higher speed switching.

MOSFETs are unipolar devices which can be used as high power switch. They are voltage controlled devices. Fig 3.4 depicts MOSFET used as a switch.

If v_i = 0, the transistor is cut-off because the voltage between the gate and source is below the threshold voltage. Therefore v_o = v_{DD}.If $v_i > 0$, the $v_o \approx$ 0v which tells the ON state. Equations for MOSFET calculations are as follows.

$I_D = K(V_{GS} - V_{GS(th)})^2$------------------------ (5)

$V_{DG} = V_{DS} - V_{GS}$ ---------------------------- (6)

$V_{DS(sat)} = V_{GS} - V_T$ --------------------------- (7)

Where,

I_D = drain current

K = constant which depends on the particular MOSFET

V_{DG} = Drain-Gate voltage

$V_{GS(th)}$ = V_T = threshold voltage

V_{DS} = Drain- Source voltage

V_{GS} = Gate-Source voltage

From equation 5, K = $\frac{I_{D(on)}}{(V_{GS(on)} - V_T)^2}$ (A/V^2) ------------- (8)

Obtain from MOSFET data sheet $I_{D(on)}$, $V_{GS,}$ and $V_{GS(th)}$to calculate for K

Note: $I_{D(on)} = I_D, V_{GS} = V_{GS(on)}$.

3.5.3 **TRANSFORMER**

Transformer is defined as a static (or stationary) piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit. The physical basis of a transformer is mutual induction between two circuits linked by a common magnetic flux. We have two types of transformer according to construction classification as core-type and shell-type. In the design of the inverter arc welding machine we used shell type transformer. Fig3.5 shows the schematic diagram of the mentioned two types. For an inverter type arc welding machine, the transformer is design to be small in size and less weight compare to conventional type. In an arc welding machine electric discharge is use for welding. This electric discharge is known as an arc. The voltage requires in maintaining an arc is calculated using the equation 9.

$V = C + DL$ ----------------- (9)

Where,

C = 15 to 20 volts

D = 2 to 3 volts

L = length of arc in mm and its value is about 2 to 4 mm

An arc is maintained at a voltage of about 24 to 30 volts.

3.5.4 DIODE

fig3.7 physical view of a high power diode

Diode is defined as a two terminal p-n junction semiconductor. Silicon and germanium are semiconductor materials for making diodes. Diode made of silicon has a voltage drop of 0.7v whereas germanium has 0.3v. Diodes can be used as rectifiers, signal limiters, voltage regulator and switch. Diode conducts in one direction only. The fig 3.7 below shows the symbol of diode. A diode is said to be forward bias when the cathode is negatively charged relative to the anode and reverse bias when the cathode is positively charged with respect to the anode. Diode is use as rectifier as well as regulator in the project design.

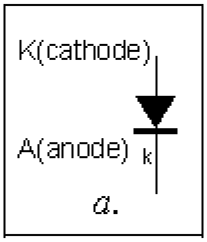

Fig3.7Diode symbols: a- standard diode

3.5.5 RESISTOR

In electronics, resistor is one of the basic components. Resistor is an electronic component which opposes the flow of current. Resistance which is the property of a resistor is measured in Ohms and it is represented by ‘R’. The value of a resistor is determined by the colour coding. The colour coding is found on the surface of a resistor. Fixed and variable resistors are the two types of resistor which there symbol is shown in fig3.9. Fixed resistor is the type of resistor which the resistance does not vary while in variable the reverse is the case. Equation 10 is use to determine the voltage across a resistor of a resistance with a current I

V = IR --------------------------------- (10)

Where,

V = voltage across the resistor (volts)

I = current through the resistor (Amp)

R = resistance of the resistor (ohms)

3.5.6 CAPACITOR

A capacitor is a passive two terminal electrical component used to store energy. It is originally refer to as condenser. Capacitors are widely used in electronic circuit for blocking direct current while allowing alternating current to pass. It can be use to smooth (i.e. removing the ripple) the output of power supplies. In electric power transmission systems capacitor stabilize voltage and power. In our design capacitor is use as voltage reservoir. Mathematically, the capacitance of a capacitor is C = $\frac{Q}{V}$

Where C = capacitance

Q = charge

V = potential difference

The symbol of a capacitor is shown in fig 3.9

3.5.7 CIRCUIT BREAKER

Circuit breaker is use as power ON and OFF of the project. The circuit breaker protects the inverter arc welding machine from over-current and it acts as an isolator. An isolator is a device that can break an electrical circuit, interrupting the current or diverting it from one conductor to another.

CHAPTER 4

SYSTEM DESIGN AND IMPLIMENTATION

4.1 **INTRODUCTION**

In this chapter we are to elaborate on each stage seen in chapter 3. Each stage is associated to a group of components/ device, which is aimed at achieving a specific purpose. In design a circuit, we first have to determine the power to the load and some other necessary parameters as the case may be. Stage 1 is the power supply, stage 2 is the oscillator, stage 3 is the power amplifier, and finally the transformer stage.

4.2 **DESIGN OF TRANSFORMER**

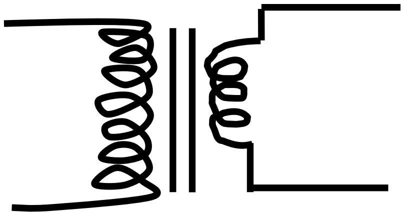

Fig 4.3 step down transformer

Welding transformers are designed upon the nature of welding operations. For an inverter-type welding machine, the transformer is designed to be small in size and less weight compared to conventional welding machine. In an arc welding machine electric discharge is used for welding. This discharge is known as an arc.

Voltage required in maintaining the arc is given by;

$$V = C + DL$$

Where; C = 15 to 20 volts

D = 2 to 3 volts

L = length of arc in mm and its value is about 2 to 4mm

An arc is maintained at a voltage of about 24 to 30 volts. The standard wire gauge (SWG) of the conductor used in secondary winding was obtained from the SWG table based on the maximum current that will flow through the conductor. The number of turns of primary and secondary winding is related to their voltages and currents with the following equations

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

Where,

N_1 = Number of turns of the primary
N_2 = Number of turns of the secondary
V_1 = Primary voltage
V_2 = Secondary voltage
I_1 = Primary current
I_2 = Secondary current

CORE DIMENSIONS

Voltage per turn $E_t = K\sqrt{KVA}$

Assume K = 0.55, $\therefore E_t = 0.55 * \sqrt{2}$

$$E_t = 0.78v$$

For square wave,

$E_t = 4\text{f}B_m A_i$, where $B_m = maximum\ flux\ density$; $A_i = area\ of\ the\ core$;

$f = frequency$. $B_m = 1.1T$, f = 50Hz

$\therefore\ A_i = {}^{0.78}/_{(4 * 50 * 1.1)}$ = 3.545 * $10^{-3}\ m^2$ = 35.45$cm^{\ 2}$

taking stacking factor as 0.9

Gross iron Area $A_{gi} = \frac{A_i}{0.9} = {}^{35.45}/_{0.9} = 39.39cm^{\ 2}$

Width of the central limb = 2 * width of the side limb

= 2*a

Core depth, b = 2.5 * width of the central limb = 2.5 * 2a = 5a

A_{gi} = b * 2a = 5a * 2a = $10a^2$

$\therefore 10a^2 = 39.39$; $a^2 = {}^{39.39}/_{10}$; a= $\sqrt{3.939}$ = 1.98cm

Since a = 1.98 $\therefore$ b $= 5 * 1.98$ = 9.9cm

Core depth, b = height of the yoke for shell type, H_y

$\therefore\ H_y = 9.9cm$

Depth of the yoke D_y = width of the side limb = 1.98cm

WINDOW DIMENSIONS

Window area (A_w) =$^{KVA}/_{(2.22 f B_m A_i K_w \delta \ \times 10^{-3})}$;

$K_w = space\ factor = 0.33$

$\delta = current\ density = 2.5\ A/mm^2$ = 2.5 * $10^6\ A/m^2$

$A_w = \ ^{2}/_{(2.22 * 50 * 1.3 * \ 3.545 \ * \ 10^{-3} \ * 0.33 * 2.5 \ * \ 10^6 * \ 10^{-3})}$

$A_w = 4.739 * \ 10^{-3} m^2 = 47.39 cm^2$

$A_w =$ Window height (H_w) * Window width (W_w)

Note;

$\frac{H_w}{W_w} = 3, \therefore \ H_w = 3W_w$ substitute for H_w in equation above to get

$A_w = \ 3W_w * \ W_w$ = $3{W_w}^2$; $W_w = \ \sqrt{^{47.39}/_{3}}$

$W_w = 3.97\ cm$; Hence, $H_w = 3 * 3.97$ = 11.92 cm

Overall height H = $H_w + 2$a = 11.92 + (2 * 1.98) = 15.88 cm

Overall width W = (2$*$ W_w) + (4* a) = (2*3.97) + (4*1.98) = 15.86 cm

WINDING

Primary winding Turns T_1= ${E_1}/{E_t}$ = ${36}/{0.78}$ = 46

Total number of turns at the primary is 92(center tapped)

Primary winding current I_1 = ${power}/{E_1}$ = ${2000}/{36}$ = 55.55A

Proper conductor for primary winding can be selected from standard wire gauge table

Taking current density of 2.5 A/mm^2 for primary, the conductor area

a_1 = ${55.55}/{2.5}$ = 22.22mm^2

To calculate the diameter of conductor,a_1 $= \boldsymbol{\pi r^2}$= $\boldsymbol{\frac{\pi d^2}{4}}$

Where a_1 = area of primary conductor, d = conductor diameter

d^2= (4 × 22.22) / 3.142 = 28.2877mm^2

d =$\sqrt{28.2877}$ = 5.3186mm. The standard wire gauge used equals 5

Secondary winding Turns T_2= ${E_2}/{E_t}$ = ${30}/{0.78}$ = 32

While calculating secondary number of turns, allowance of 5% is selected so as to compensate for the voltage drop in the windings

Therefore $\boldsymbol{T_2} = 32 + (0.05 * 32)$ = **34**

Secondary winding current I_2 = ${}^{power}/_{E_2}$ = ${}^{2000}/_{25}$ = 80A

Taking current density of 3.0 A/mm^2 for secondary, the conductor area

a_2 = ${}^{80}/_{3}$ = 26.67mm^2. The current at the primary helps to determine the type of power transistor to use. We used IRF150 MOSFET in our design as shown in fig4.3b.

To calculate the diameter of conductor,a_2 $= \boldsymbol{\pi r^2} = \boldsymbol{\frac{\pi d^2}{4}}$

Where a_2 = area of primary conductor, d = conductor diameter

d^2= (4 × 26.67) / 3.142 = 33.9529mm^2

d =$\sqrt{33.9529}$ = 5.8269mm. The standard wire gauge used equals 4

4.3 **DESIGN OF AN OSCILLATOR USING IC SG3524**

R_T ($R_8 + R_9$) and C_1 connected at pin 6 and pin 7 respectively determine the frequency of oscillation. Using equation below we determine the value of the unknown parameter. f = $^{1.18}/_{C_1 R_T}$

Assume $C_1 = 0.1 * 10^{-6} F$ and the required frequency f = 50Hz

Therefore, R_T = $^{1.18}/_{(0.1 * 10^{-6} * 50)}$ = 236000Ω = 236K

The IC SG3524 is used in the oscillation section of this inverter. This IC is used to generate the 50Hz frequency required to generate AC supply by the inverter. To start this process, battery supply is given to the pin 15 of the SG3524 through NPN transistor (TIP41). D_3 at the base of Q_3 as shown in fig4.3a is use to regulate the IC SG3524 supply voltage. The pin 8 is connected to the negative terminal of the battery. The pins 6 and 7 of the IC are the oscillation section pins. The frequency produced by the IC depends on the value of the capacitor and resistor connected at these pins. The capacitor (0.1 µF) is connected to pin 7. This capacitor decides the 50Hz frequency output by the IC. Pin 6 is the timing resistance pin. The resistance at this pin keeps the oscillator frequency constant. A preset variable resistor (20K) is connected to ground from pin 6 of the IC. This preset is used so that the value of the output frequency can be adjusted to a constant 50Hz. A fixed resistance of

220K is connected in series with the variable resistor as shown fig4.3a by the relation:

$$F = \frac{1.18}{R_T \times C_T}$$

Where F is the frequency in KHz, R_T is the total resistance at pin 6, and C_T is the total capacitance at pin 7. Therefore, to obtain a frequency of 50Hz,

Given

$C_T = 0.1\mu F$

Making R_T the subject of the formula

We have that $$R_T = \frac{1.30}{50 \times (0.1 \times 10^{-6})}$$

$$R_T = \frac{1.30}{0.000005} = 260K\Omega$$

Therefore, R_T must be varied at 100K to obtain a frequency of 50Hz. In our design, we used a fixed resistor of 200K and a variable resistor of 100K.

Signals generated at the oscillator section of the IC reach the flip-flop section of the IC. This section converts the incoming signals into signals with changing polarity. In this signal, changing polarity means when the first signal is positive, the second would be zero and when the first signal becomes zero, the second would be positive. Therefore, to achieve a frequency of 50Hz, this process most repeat every 50 times per second i.e. a pulsating signal with 50Hz frequency is generated inside the flip-flop section of the IC.

This 50Hz frequency alternating signal has an output at pins 11 and 14 of the IC. This pulsating signal may also be known as the **MOS drive signal.** This MOS drive signal at pins 11 and 14 is between 4.6 - 5.4V

Voltage at these pins should be same, because any variation in the voltage at these pins could damage the MOSFET at the output.

Since the reference voltage for the error amplifier (pin 2) is set to be 2.5v using voltage divider. Therefore voltage supplied to pin 1 said to be 2.5v.

Using voltage divider:

Assume R_4 = 4700Ω, $V_{pin1} = V_{ref} \times {}^{R_4}/_{(R_4 + R_3)}$; V_{pin1} = 2.5v

2.5 = $5 \times {}^{4700}/_{(4700 + R_3)}$; $4700 + R_3 = {}^{(4700\ \times 5)}/_{2.5}$; $R_3 = 9400 - 4700$ =4700

$$\therefore\ R_3 = 4.7K$$

$V_{pin2} = V_{out} \times {}^{R_s}/_{(R_s + R_5)}$; R_s =$R_6 + R_7$, note that V_{out} is positive value which is equals 14.5v in our design. Required voltage at pin 2 equals 2.5v

Assume$R_5 = 100K$; $R_s = \frac{V_{pin2} \times R_5}{V_{out} - V_{pin2}} = \frac{2.5 \times 100000}{14.5-2.5}$ =20833Ω. Taking preset R_6 as 20k then $R_7 = .83k$.

$$V_{pin15} = V_{D_3} - V_{BE(Q_3)}$$

$$V_{pin15} = 13 - 0.7 = 12.3\text{v}$$

4.4 **Complete circuit of the designed inverter type arc welding machine**

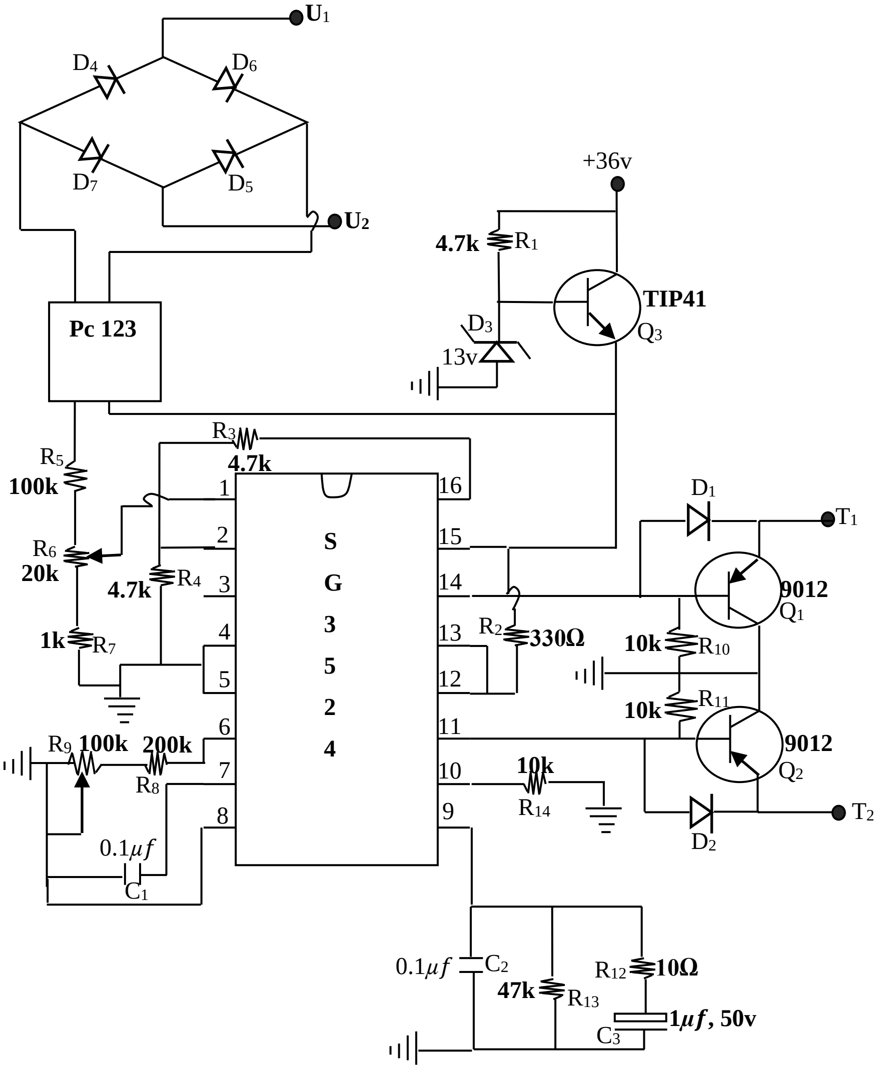

Fig 4.3(a) Oscillator/buffer stage

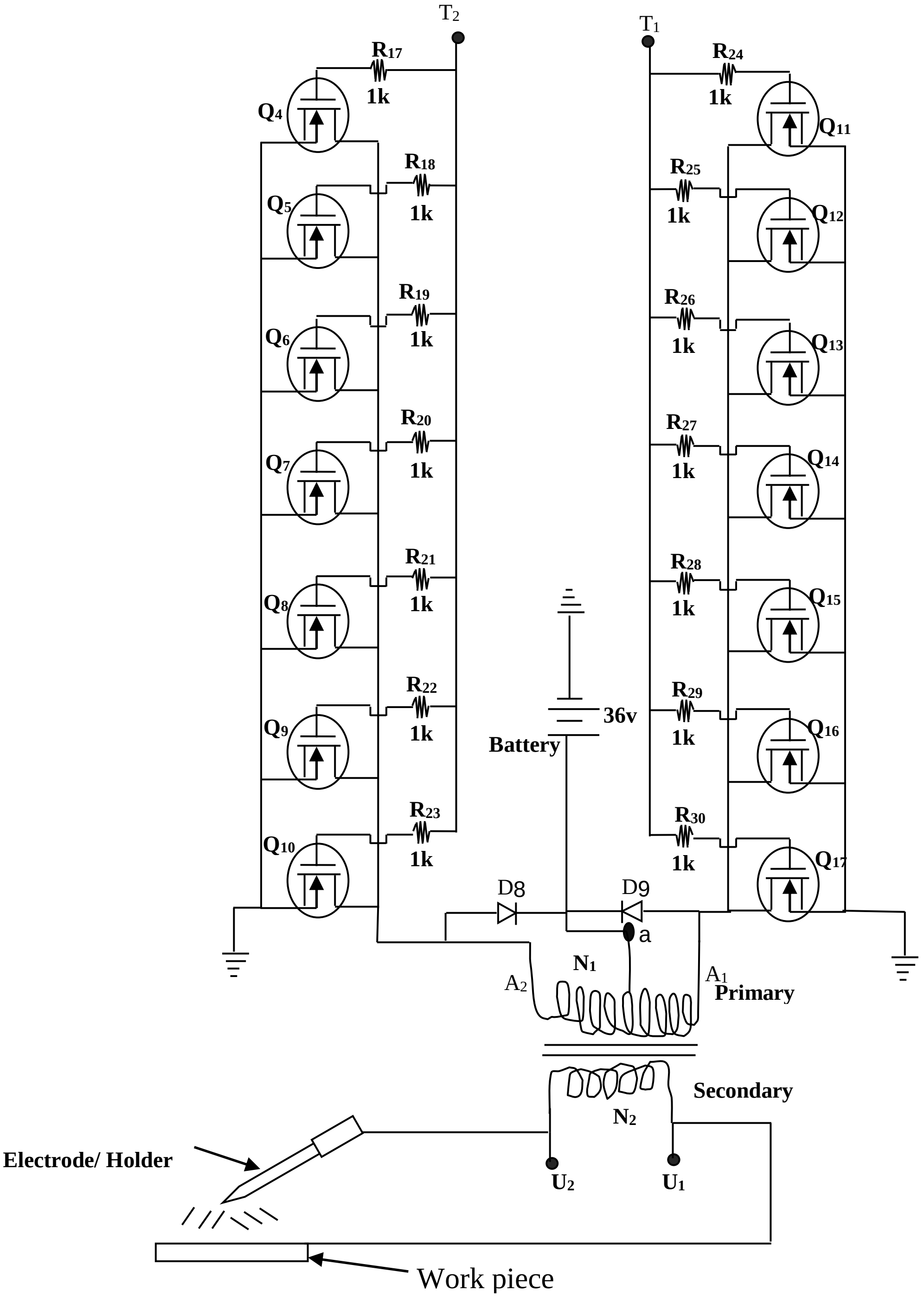

Fig 4.3(b) power amplifier/ transformer stage

4.5 **Operating principle of Fig4.3**

Resistor R_8 and capacitor C1 sets the frequency of the ICs internal oscillator. Preset R_9 can be used for varying of the oscillator frequency. Pin 14 and pin 11 are the emitter terminals of the internal driver transistor of the IC. The collector terminals of the driver transistors (pin 13 and 12) are connected together and linked to the Q_3 (+12.3v). When signal at pin 14 is high, transistor Q_1 is switched on which in turn makes transistor Q_{11} through Q_{17} ON for current to flow from the +36v source (battery) connected at point a (marked with label a) through the right half of the transformer (A_1) primary and grounded through the transistors $Q_{11,}$ $Q_{12,}$ $Q_{13,}$ $Q_{14,}$ $Q_{15,}$ $Q_{16,}$ and Q_{17}. As a result a voltage is induced in the transformer secondary (due to electromagnetic induction) and this voltage contributes to the upper half cycle of the 25v output waveform. During this period Pin 11 will be low and its succeeding stages will be inactive. When Pin 11 of the IC pin goes high Q_2 gets switched ON and as result Q_4 through Q_{10} will be also switched ON. Current flows from the +36v source (marked with label a) through the lower half of the transformer primary and grounded through transistors $Q_{4,}$ $Q_{5,}$ $Q_{6,}$ $Q_{7,}$ $Q_{8,}$ $Q_{9,}$ and Q_{10} and the resultant voltage induced at the A_2 secondary contributes to the lower half cycle of the 25v output wave form.

The output voltage regulation section of the inverter circuit works as follows. The inverter output (output of T2) is tapped from point's labeled b, c and supplied to opto-coupler. The diode $D_{4,}$ $D_{5,}$ $D6,$ and D_7 rectifies the inverter output voltage. The resulted voltage (will be proportional to the inverter's output voltage) is supplied to the pin1 (inverting input of the internal error amplifier of the IC) through R_5 and the voltage is compared with the internal reference voltage. This error voltage will be proportional to the variation of the output voltage from the desired value and the IC adjusts the duty cycle of the drive signals in order to bring back the output voltage to the desired value. Preset R_6 can be used for adjusting the inverters output voltage as it directly controls the amount of voltage fed back from the inverter output to the error amplifier section.

Diode D_3 and transistor Q_3 produce a 12v supply from the 36v source for powering the IC SG3524 and its related circuitries. Diodes D_8 and D_9 are diodes which protect the driver stage transistors from voltage spikes which are produced when the transformer primaries are switched. R_{17} through R_{30} limit the base current of Q_4 and Q_{17} respectively.

CHAPTER 5

SYSTEM TESTING AND INTEGRATION

5.1 TESTING

After the design and implementation phase, the system built has to be tested for Durability, Efficiency, and Effectiveness and also ascertain if there is need to modify this design. The system was first assembled using a breadboard. All components were properly inserted into the breadboard according to the designed circuit and tests were carried out at various stages. To ensure proper functioning of components' expected data, the components were tested using a digital multimeter (DMM).

5.2 TEST PLAN AND TEST DATA

This chapter entails an overall system testing of the integrated design of the voltage measurement device. The testing and integration is done to ensure that the design is functioning properly as expected thereby enabling one or even intended users for which the project was targeted for, appreciate its implementation and equally approaches used in the design and integration of the various modules of the project. However, this involves checks made to ensure that all the various units and subsystems function adequately. Also there has to be a good interface existing between the input/output unit subsystems. When the totality of the modules was integrated together, the system was created and all modules and sections responded to as specified in the design through the power supply delivering into the system designed.

5.2.1 COMPONENTS TEST

Similar components like resistors were packed together. Other components include capacitor, circuit breaker, transformer, diodes (rectifier), etc**.** Reference was made to resistor colour code data sheet to ascertain the expected values of resistors used. Each resistor was tested and the value read and recorded. Also for transistor test the DMM was switched to the diode range with the symbol. The collector, base and emitter junctions were tested in the following order. The collector, emitter and base pins were gotten from the data analysis on power transistor.

5.2.2 SYSTEM TEST

The system was powered and operated upon using several possibilities. During the test it was observed that the electrode holds on the work piece when trying to start an arc for welding. After the test the system is said to be up and running.

CHAPTER SIX

SUMMARY, RECOMMENDATION AND CONCLUSION

This section of this project report forms the concluding part of the write up and takes a look at some of the problems encountered during the progressive job on the system and also brings in suggestions for further improvement and/or enhancement for the system design.

6.1 SUMMARY OF ACHIEVEMENT

The design and development of this project has really been challenging, as I have been faced with choices far beyond what I expected. But in the long run the result paid off. After the complete design of the system, the deviation between the expected result and the actual result was very close. The performance and efficiency was beyond expectation and from every ramification, the design of the project was a success.

6.2 PROBLEMS ENCOUNTERED AND SOLUTION

During the course of the design of this system, there were series of problems which came in the way of achieving the design goals of this project, most of them where over come via share troubleshooting, in some cases some parts require redesigning and the software debugging also created a bit of a problem. One major setback of this project is the availability of components required to build the hardware of the system. In most cases I had to look through electrical catalogs to obtain replacements of some of the components which are not available in the market. After developing the transformer, it was very difficult to find a clamp. This posed serious problem as it brought about delay in the design time and it was also costly, this also affected the overall cost of the system. The final packaging of the design was also another trouble. This was actually one of the most challenging aspects of the circuit implementation phase.

6.3 RECOMMENDATION

This design of inverter arc welding machine can still be improved to get more efficient, portable inverter welding machine. To achieve this I recommend the following;

- Engineering students need early exposure to the use of electronic components for practical work, this will enable them know some high power semiconductor and low power semiconductor.
- Further research in the field of electronic switching, transformer design will go a long way in getting better inverter arc welding machine.
- Ensure that accurate components are used to avoid endangering the operator and for reliability

6.4 CONCLUSION

Welding is a fabrication process that joins materials, usually metals or thermoplastics. This is often done by melting the work-piece and adding a filler material to form a pool of molten material (the weld pool) that cools become a strong joint. The melting is achieved with pressure sometimes used in conjunction with heat, to produce the weld. Different power supply can be used for welding which include inverter arc welding power supply. Inverter arc welding machine transform low voltage low amperage primary power into the low voltage, high amperage power used for welding at high frequency. This high frequency transformation helps to reduce the weight and size of the transformer. The output power is precisely control by the inverter due high operating frequency.

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