

بسم الله الرحمن الرحيم

Sudan University of Sciences & Technology

College of Engineering

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Design of Induction cooker

تصميم طابخه حثيه

**A Project Submitted In Partial Fulfillment for the
Requirements of the Degree of B.E. (Honor) In
Electrical Engineering**

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الآية

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قال تعالى: (قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ)

صدق الله العظيم

سورة البقرة (٣٢)

DEDICATION

We wholeheartedly dedicate this piece of work to:

**Our fathers who taught us that the best kind of knowledge to
have is that which is learned for its own sake?**

**Our mothers who taught us that even the largest task can be
accomplished if it is done one step at a time. Friends who have
encouraged us.**

Schoolmates who have supported us throughout the project.

ACKNOWLEDGEMENT

Firstly, thanks for Allah the god of all which helps us to perform this project.

Secondly, we send our thanks and appreciation to **Dr. Nagm Eldeen**

Abdo Mustafa who was a candle to light our way. This man was a sea of science who provided us more of his knowledge and solved more of the problems which faced us to perform this project.

Lastly, thanks for all who helped us.

ABSTRACT

Most of the traditional methods used in cooking such as: coal stoves, dung and natural gas stoves (Albotgas), oil residue stoves and resistive heater, etc... Each of these methods suffer from problems such as environmental pollution, energy waste as well as the high cost and takes a long time to heat up as it's unsafe. Therefore, it is necessary to have an alternative method deal with all those problems

Induction cooker is a method of cooking depends on the induction electromagnetic in heating utensils cookers made of Magnetic materials . This method preferable from other heating methods because it's easy to control , security and relatively quick heating up, in addition to that it's non-polluting . The cooker considered rather expensive except it's better than other heating methods.

The main reflected benefit in the induction cooker is that the heating is limited to the cooking pot only making it more secure and efficient

مستخلص

معظم الطرق التقليدية المستخدمة في الطبخ مثل: مواقد الفحم والروث ومواقد الغاز الطبيعي (البوتغاز) ومواقد مخلفات البترول والسخان العادي (الهيتر) وغيرها ... كل هذه الطرق تعاني من مشاكل مثل التلوث البيئي وهدر الطاقة إضافة الى التكلفة العالية وتستغرق زمن طويل للتسخين كما انها غير امنة .. لذلك من الضروري وجود طريقه بديله تعالج كل تلك المشاكل.

الطابخة الحثيه هي طريقة للطبخ تعتمد على الحث الكهرومغناطيسي في تسخين اوعية الطبخ المصنعة من مواد مغناطيسيه . وتمتاز هذه الطريقه بسرعه التسخين الدقيق وسهوله التحكم والامن إضافة الى انها غير ملوثة للبيئة، وتعتبر الطابخة الحثية مكلفة نوعا ما. الا انها افضل من الطرق الاخرى للتسخين.

تتجلى الفائدة الرئيسية للطابخة الحثية في ان التسخين يكون مقتصرًا على وعاء الطبخ فقط مما يجعلها اكثر امانا وكفاءة.

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LIST OF ABBREVIATIONS

AC	Alternating Current
IH	Induction Heating
DC	Direct Current
IGBT	Isolated gate bipolar transistor
ZVS	Zero Voltage Switching
EMF	Electro Magnetic Field
R	Resistance
R _t	Transfer resistance of rectifier and filter
V	Voltage
P	Power
I	Current
d	Depth
f	Frequency
c	Capacitor
L	Inductor
VSM	Maximum voltage across the Switch

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CHAPTER ONE

INTRODUCTION

1.1 General Concept

Induction heating is a non-contact heating process. It uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the material being heated. It is also very efficient since the heat is actually generated inside the workpiece. This can be contrasted with other heating methods where heat is generated in a flame or heating element, which is then applied to the workpiece. For these reasons Induction Heating lends itself to some unique applications in industry[1].

Induction heating takes advantage of the heat produced by the eddy currents generated in the material. It has many advantages compared to other heating systems (e.g. gas- and oil-fired furnaces), such as quicker heating, faster start-up, higher production rates and the input power can be easily controlled. The previous researches done in specific power supplies for this application, the numerical and computational methods developed, as well as the decrease of the cost of these systems, has led to a widespread of Induction Heating in many processes and applications, such as cooking, automotive sealing, motor heating, paper making, tube and bar heating or aluminum melting . When a ferromagnetic material is placed in a time varying magnetic field, an E.M.F is induced in the ferromagnetic material. This induced E.M.F causes eddy currents to flow along the surface of the material. The major factors that control the magnitude of these eddy currents are (i) the magnitude of the time varying magnetic field , (ii) frequency of the time varying magnetic field, and (iii) the resistivity of the material. These eddy currents are beneficial in the case of induction heating because they flow inside the

material and produce losses (I^2R) which causes the material to heat up. So by controlling the amount of eddy current we can control the temperature of the material. This requires a coil suitably dimensioned to heat up a workpiece to a given temperature [2].

Heat loss, occurring in the process of electromagnetic induction, could be turned into productive heat energy in an electric heating system by applying Lenz's Law. This law explains the fact that induced current flows inverse to the direction of changes in induction magnetic movement [2].

Absence of any physical contact to heating devices precludes unpleasant electrical accidents. High energy density is achieved by generating sufficient heat energy within a relatively short period of time.

The demand for better quality, safe and less energy consuming products is rising. Products using induction heating include electronic rice cookers and pans. Safe, efficient and quick heating appliances attract more customers. Induction heating converts up to 90% of the energy expended energy into useful heat; batch furnaces are generally only 45% energy-efficient. And since induction requires no warm-up or cool-down cycle, stand-by heat losses are reduced to a bare minimum. The repeatability and consistency of the induction process make it highly compatible with energy-efficient automated systems [3].

Induction heating eliminates the problems associated with open flame, torch heating and other methods. Once the machine is properly calibrated and set up, there is no guess work or variation, the heating pattern is repeatable and consistent. With modern solid state systems, precise temperature control provides uniform results; power can be instantly turned on or shut off. With closed loop temperature control, advanced induction heating machines have the capability to measure the temperature of each individual part. Specific ramp up, hold and ramp down rates can be established and

data can be recorded for each part that is run. Non-conductive materials are not affected and can be located in close proximity to the heating zone without damage. For all these advantages we choose induction heating over convection, radiant, open flame or another heating methods [3].

1.2 Problem Statement

Heating conductive objects for cooking can be performed by many methods, it can be performed by open flame heating (gas or coal) or by use of sun cookers, but these methods have a low efficiency, affect badly on environment, cause pollution to the living beings and may take a long time as in sun cookers, so that it must look for an alternative method which can perform the purpose and has less dangers to the living beings and environment. Induction cookers is studied as successful alternative, because it is safe and have high efficiency beside that it has a small size.

1.3 Objectives

To use of eddy current and losses in heating of the workpiece for cooking besides designing of an induction cooker.

Also to save and reduce the use of coal and bio gas in cooking and reduce the population that they make.

1.4 Methodology

There are two methods to get high heating, this can be done by using high current or high frequency supply, but an increasing in current will destroy the coil beside that it needs a coil with large diameter that affects on the size, so that it is preferred avoiding it by resorting to the other method. To get high frequency, it was used a technique of converting AC current to DC as first stage, and then the DC current was converted to AC current with high frequency by using the inverters to induce current in the object which need to be heated

1.5 Project Layout

This project consist of five chapters, chapter one includes the general concepts, problem statement, the objectives of the project and methodology

Chapter two includes a background and illustration of electrical heating process, benefits and limitations .

Chapter three includes operating theory of induction cooker, description of how does induction cooking work and the components of the cooker.

Chapter four contains the practical circuit in details. The conclusion and recommendations are presented in chapter five.

CHAPTER TWO

BACKGROUND AND ILLUSTRATION

2.1 Introduction

Induction heating is a non-contact heating process. It uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the material being heated. It is also very efficient since the heat is actually generated inside the workpiece. This can be contrasted with other heating methods where heat is generated in a flame or heating element, which is then applied to the workpiece. For these reasons Induction Heating lends itself to some unique applications in industry [2].

2.2 Background

Alternating current flowing through a coil generates a magnetic field. The strength of the field varies in relation to the strength of the current passing through the coil. The field is concentrated in the area enclosed by the coil; while its magnitude depends on the strength of the current and the number of turns in the coil. Eddy currents are induced in any electrically conductive object a metal bar, for example placed inside the coil. The phenomenon of resistance generates heat in the area where the eddy currents are flowing. Increasing the strength of the magnetic field increases the heating effect. However, the total heating effect is also influenced by the magnetic properties of the object and the distance between it and the coil. The eddy currents create their own magnetic field that opposes the original field produced by the coil. This opposition prevents the original field from immediately penetrating to the center of the object enclosed by the coil. The eddy currents are most

active close to the surface of the object being heated, but weaken considerably in strength towards the center. high-frequency induction heating heat treatment is usually used in current frequency of 10 to 300 kHz, Figure 2.1 shows Eddy currents are induced (hence the term 'induction') on the surface of the workpiece within the coil. Note that induction is a no-contact heating method, at no time does the coil actually touch the workpiece [2].



Figure 2.1 flows of eddy currents in the work piece

2.3 Benefits of Induction Heating

- No flame. The point at higher temperature is the material in heating thanks to the physics of the induction heating that allows the heating of the material by induced currents.
- Easy maintenance.
- Presence only of electric power with adequate control systems and high security.
- Having overall heating work piece deformation is small, small power consumption.
- Heating equipment can be installed in the mechanical processing production line, easy to realize mechanization and automation, easy to

manage, and can reduce the transportation, saving manpower, improve production efficiency.

- Capacity for adjusting the heating temperature of the pieces in quickly and directly.
- Short heating time, each piece remains in heating for a short time (that is sufficient for the heart of the material to get the desired temperature) avoiding oxidation and decarburization.
- a high conversion efficiency.
- Installation of compact size with limited space requirements.
- Plant outer limited to the system of water cooling and the source of electrical energy.
- Induction heating is more environmentally friendly.
- Finally, the induction heating is a better choice of metalworking for replacing coal heating, oil heating, gas heating, electric cooker, electric oven heating and other heating methods [4].

2.4 limitations of Induction Heating

- Complexity of the machine with electronic technology inside.
- Need for adequate electrical distribution system.
- The cost of operation is high [4].

2.5 Applications of Induction Heating

Induction heating can be used for any application where we want to heat an electrically conductive material in a clean, efficient and controlled manner. The application can be divided in to :

2.5.1 Manufacturing Applications

The applications in manufacturing require high power such as:

- **Induction Welding**

With induction welding the heat is electromagnetically induced in the work piece. The speed and accuracy of induction welding make it ideal for edge welding of tubes and pipes. In this process, pipes pass an induction coil at high speed. As they do so, their edges are heated then squeezed together to form a longitudinal weld seam. Induction welding is particularly suitable for high volume production. Induction welders can also be fitted with contact heads, turning them into dual purpose welding systems.

- **Induction Hardening**

Induction hardening uses induced heat and rapid cooling (quenching) to increase the hardness and durability of steel. Induction is a no-contact process that quickly produces intense, localized and controllable heat. With induction, only the part to be hardened is heated. Optimizing process parameters such as heating cycles, frequencies and coil and quench design results in the best possible outcomes.

- **Induction Melting**

Induction melting is a process where metal is melted into liquid form in an induction furnace's crucible. The molten metal is then poured from the crucible, usually into a cast. Induction melting systems are used in foundries, universities, laboratories and research centers. The systems melt everything

from ferrous and non-ferrous metals to nuclear material and medical/dental alloys.

- **Induction Straightening**

Induction straightening uses a coil to generate localized heat in pre-defined heating zones. As these zones cool they contract, ‘pulling’ the metal into a flatter condition. Induction heating is widely used to straighten ship decks and bulkheads. In the construction industry it straightens beams. Induction straightening is increasingly used in the manufacture and repair of locomotives, rolling stock and Heavy Goods Vehicles.

- **Induction Annealing**

This process heats metals that have already undergone significant processing. Induction annealing reduces hardness, improves ductility and relieves internal stresses. Full-body annealing is a process where the complete workpiece is annealed. With seam annealing (more accurately known as seam normalizing), only the heat-affected zone produced by the welding process is treated. Induction annealing and normalizing is widely used in the tube and pipe industry. It also anneals wire, steel strips, knife blades and copper tubing. In fact, induction is ideal for virtually any annealing task.

2.5.2 Medical Applications

From medical specifications and requirements we can summarize some of advantages in manufacturing medical instruments like clean heating, fast, accurate, better joint quality, heat for very small areas within precise production tolerances, hands-free heating that involves no operator skill for manufacturing like annealing tube and surgical instruments, hardening surgical instruments, soldering surgical tools, metal to plastic insertion and brazing steel dental tools [5].

2.5.3 Domestic Applications

In induction cooking, an induction coil in the cook-top heats the iron base of cookware by cyclic magnetic induction. Copper-bottomed pans, aluminum pans and other non-ferrous pans are generally unsuitable. The heat induced in the base is transferred to the food via (metal surface) conduction. Benefits of induction cookers include efficiency, safety (the induction cook-top is not heated itself) and speed.

Figure 2.2 shows a schematic induction cooker. The induction cooker is a modern electric cooker that uses the electromagnetic induction principle to heat vessels. The induction cooker has a heatproof glass panel or ceramic, which is used as the cooker plane. Through the electrified coil under the plane, the AC current creates a magnetic field that induces a vortex in iron and stainless steel pan bottoms. This heats the pan bottom quickly, and then conducts the heat to food.

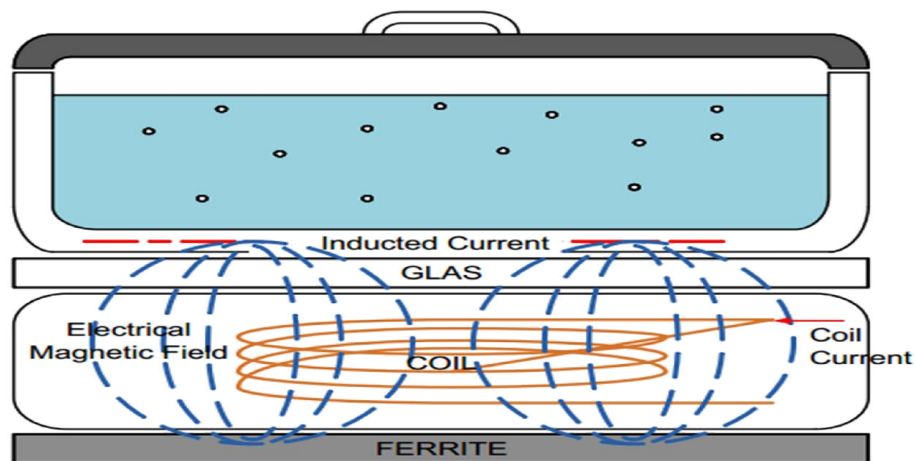


Figure 2.2 Scheme of an Induction Cooking

Higher switching frequencies can reduce the inductance of the coil and size of the resonant capacitor, allowing for cost savings of the unit. Induction heating is based on electromagnetic laws. The overall system can be approximately similar to an electric transformer, where the primary is the copper coil into the

induction cooker and the secondary the bottom layer of the pot as shown in figure 2.3

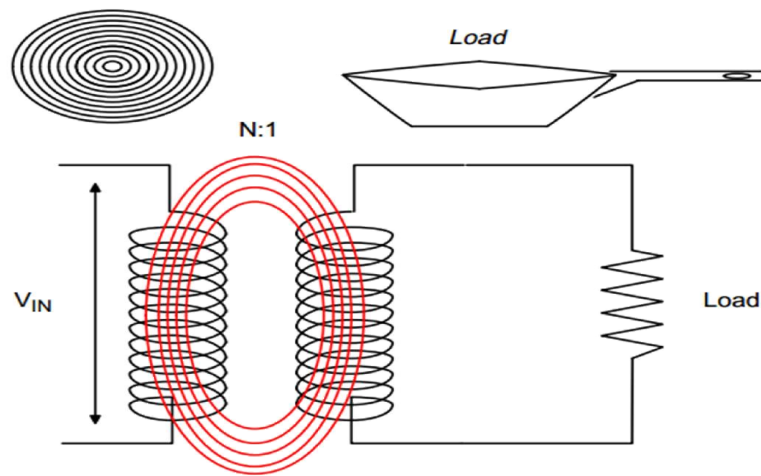


Figure 2.3 Equivalent of an Induction Cooking System

The flow of current in the induction coil generates the magnetic field as shown in figure 2.4

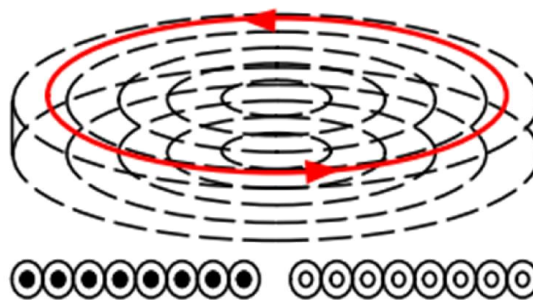


Figure 2.4 Current on Induction heating coil

Finally Induction heating technology for cooking applications is a very attractive technology which is becoming very popular due to the high conversion efficiency [4].

2.6 Heating Systems Methods

Prior to describing induction heating, some types of electric process heating are mentioned below:

- Resistance heating.
- Conduction heating.
- Infrared radiation heating.
- Induction heating.
- Dielectric hysteresis heating.
- Electric arc heating.
- Plasma heating.
- Electron beam heating.
- Laser heating.

2.7 Efficiency of Heating Methods

Efficient heating is the most important factor in the cost of the heating process, which is the amount of energy produced by the source of heat itself relative to the actual energy that reaches the thing to be heated to raise the temperature, and vary the efficiency of the heat exchange depending on the ways to implement style exchange and distribution of the heat source on the surface to be heated, but in the best of cases, for example, the efficiency of the heat exchange of the torch exposed (flame gas or coal or electrical resistance) to the cooking pot or skewer iron or pipe heating severe in machines injection does not increase more than 45%, which means that losses energy represents 55% of the thermal energy source, in addition to the low efficiency of heating a negative impact on a very important factor is the speed of heating any time of the arrival of the thing to be heated to the desired temperature.

Induction Heating efficiency much greater than resistance or flame heating methods, because there is no losses or leaked gas.

Using the same amount of electrical energy, two liters of water can be boiled two times faster than an electric or gas heaters, the efficiency of different heating types shown in table 2.1 below:

Heating method	Efficiency
Induction	90%
Electric	58%
Gas	40%

Table 2.1 Efficiency of different heating systems

CHAPTER THREE

INDUCTION COOKER

3.1 INTRODUCTION

Application of induction heating in industry and home appliances is acutely started after 1990. In fact the induction heating is an efficient, high speed and low pollution method for producing heat, especially when concentrated heat in a specific area is needed.

Electric heating for cooking vessel can be divided into two types depend on the heat generation within the cooking vessel: First, the resistance heating is one of the most commonly of the heat generation and is found in a wide range of domestic application. Resistance heating is a process where thermal energy is produced by passing an electrical current through a resistor converts electrical energy into heat energy. The advantages of resistance heating are the low cost and easy maintenance because of the simple circuit design configuration. However, the main problem of the resistance heating is low efficiency due to the Contact heating method. Second, the induction heating is the process of heating an electrically conducting object by electromagnetic induction, where eddy currents are generated within the vessel and resistance leads to heating of the vessel. The cooker is one of applications of IH [7].

An induction cooking system consists of following parts:

- Input power
- Rectifier and its output filter
- Inverter circuit
- Load or Resonant circuit
- Control unit

The output resonant circuit consists of a planar coil and a capacitor bank.

High frequency currents flow through the coil produce magnetic flux crossing the load, this time varying flux in the metallic load body induces eddy currents. The eddy currents in the load produce power losses which are function of the conductivity of load material (metallic pan in cooker). The power losses, here are the output power which leads to rise the load temperature [7].

3.2 Induction cooker work

Figure 3.1 shows the principle of induction cooker working. The AC input current from the source is converted into DC by a rectifier, Next the DC current is converted into ultrasonic high frequency AC current by a high frequency electric power conversion device, by connecting the high frequency AC current to the flat, hollow, helical heating coil. The passing of current through the coil generates a very intense and rapidly changing magnetic field in the space within the work coil. The work piece to be heated is placed within this intense alternating magnetic field.

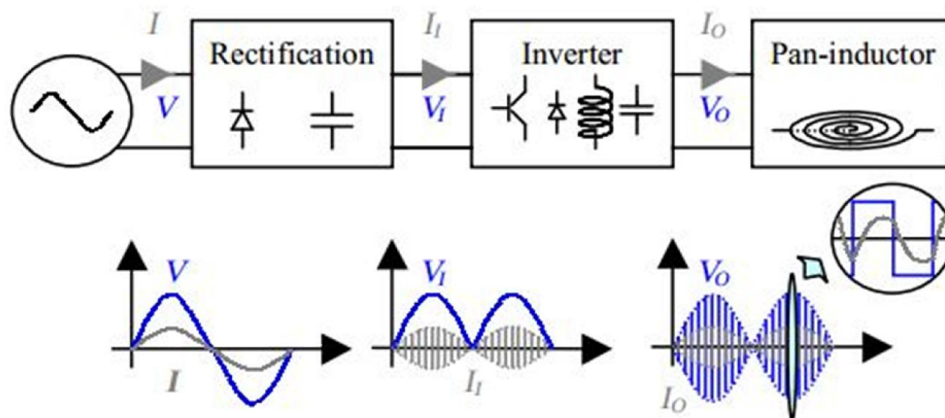


Figure 3.1 block diagram of induction cooker

Depending on the nature of the work piece material the alternating magnetic field induces a current flow in the conductive work piece. The Arrangement of the work coil and the work piece can be thought of as an electrical Transformer. The work coil is like the primary where electrical energy is fed

in, and the Work piece is like a single turn secondary that is short-circuited. These cause tremendous Currents to flow through the work piece. These are known as eddy currents. In addition to this, the high frequency used in induction heating applications gives rise to a phenomenon called skin effect. This skin effect forces the alternating current to flow in a thin layer towards the surface of the work piece. The skin effect increases the effective resistance of the metal to the passage of the large current. Therefore it greatly increases the heating effect caused by the current induced in the work piece [8].

Induction cooker can be divided into two sections:

- Power circuit
- Control circuit

3.3 Power circuit

The power circuit consist mainly:

- Rectifier
- Filters
- Inverter
- Working coil
- Resonant capacitor

3.3.1 Rectifier

Rectifiers are the circuits used to convert an alternating current (AC) to direct current (DC), a process known as Rectification. This involves a device that only allows one-way flow of current. As we know that a semiconductor diode does this.

A single phase full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output as shown in figure 3.2. Full-wave rectification converts both polarities of the input waveform to pulsating DC (direct current), and yields a higher average output voltage [6].

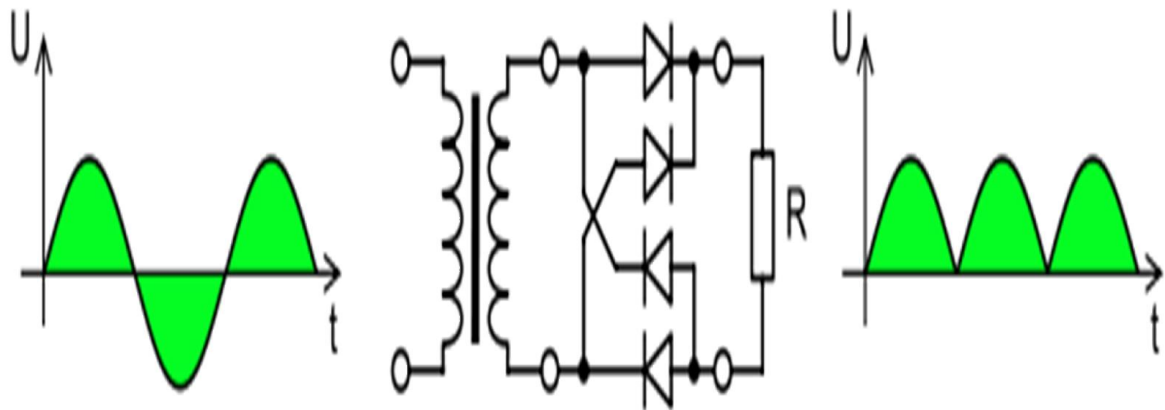


Figure 3.2 single phase Full wave rectifier waves

3.3.2 Inverter

Inverters are circuits that convert dc to ac. We can easily say that inverters transfer power from a dc source to an ac load. The objective is to create an ac voltage when only a dc voltage source is available. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc voltage is fixed & not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter. The inverter gain can be defined as the ratio of the ac output voltage to dc input voltage.

3.3.3 Resonance capacitor

The capacitor bank used in the tank circuit of an induction cooker must carry the full current that flows in the work coil for extended periods of time. This current is typically many tens of amps at many tens of kilohertz. They are also exposed to repeated 100% voltage reversal at this same frequency and see the full voltage developed across the work coil. The high operating frequency causes significant losses due to dielectric heating and due to skin effect in the conductors. Finally stray inductance must be kept to an absolute minimum so that the capacitor appears as a lumped circuit element compared to the reasonably low inductance of the work coil it is connected to [8].

3.4 Heat Transfer

The aforementioned phenomena leads to the generation of unwanted currents into the conductor placed nearby (they so called eddy current as shown in Figure 3.3). These currents induced into the conductor generate heat. The amount of heat generated into the conductor follows the Joule heating law, also known as ohmic heating, which is the process by which the passage of an electric current through a conductor is dissipated as power and releases heat. This effect is also known as Joule's First law:

$$Q = P = R \cdot i^2 = v \cdot I \quad [3.1]$$

Where:

Q = P = power converted from electrical energy to thermal energy.

R= equivalent resistance of the conductor.

I= current.

V= voltage drop across the element

Where Q and P [W] represent the power converted from electrical energy to thermal energy, I [A] is the current that goes through the conductor (in this

case the eddy current), v [V] is the voltage drop across the element and R [Ω] is the equivalent resistance of the conductor (in the case of induction cooker is the resistance of the bottom layer of the pot. The amount of heat released is proportional to the square of the current. The heating technology (one of the principles of the induction heating technology) has a coefficient of Performance of 1.0, meaning that every watt of electrical power is converted to 1 watt of heat. By comparison, a heat pump can have a coefficient of more than 1.0 since it also absorbs additional heating energy from the environment, moving this thermal energy to where it is needed.[6]

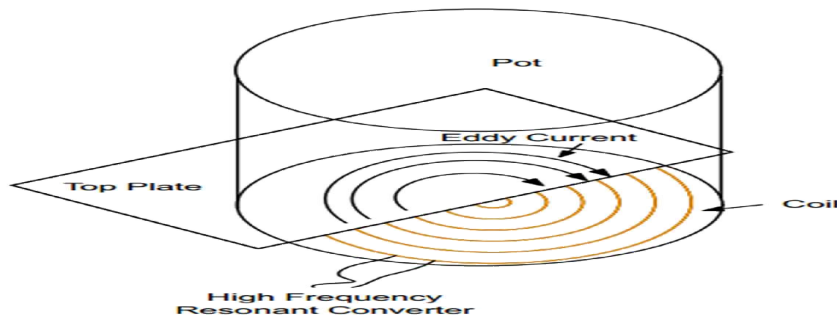


Figure 3.3 Generated Eddy Current into the POT's Bottom

3.5 Skin Effect

When an AC current flows in a conductor, the distribution is not uniform within the conductor, but it has the tendency to flow mainly on the surface of the conductor with the depth based on its frequency. The equations dominating this effect are as follows:

$$\mathbf{J} = \mathbf{J}_s e^{-\frac{d}{\delta}} \quad [3.2]$$

$$\delta = \sqrt{\frac{2\rho}{\omega\mu}} \quad [3.3]$$

Where:

$\mathbf{J}$ = the current density [A/m^2]

$\mathbf{J}_s$ = current density at the surface

δ = skin depth.

d = depth.

ρ = resistivity of the conductor.

ω = angular frequency of current.

μ = absolute magnetic permeability of the conductor.

In a conductor, J the AC current density decreases exponentially from its value at the surface J_s according to the depth d from the surface (as shown in Figure 3.4).

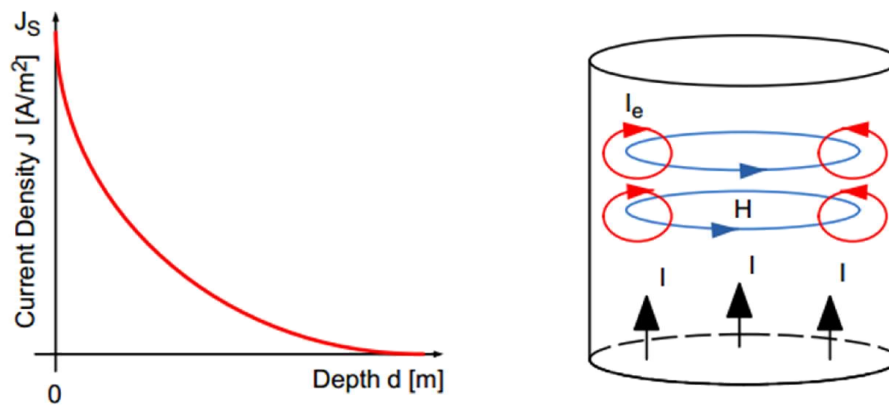


Figure 3.4. Current Density as a Function of Depth and Skin Effect and Eddy Current [6].

3.6 Hysteresis

Hysteresis losses occur only in magnetic materials such as steel, nickel, and a few other metals. As magnetic parts are being heated, such as those made from carbon steels, by induction from room temperature, the alternating magnetic flux field causes the magnetic dipoles of the material to oscillate as the magnetic poles change their polar orientation every cycle. This oscillation is called hysteresis shown in figure (3.5), and a minor amount of heat is produced due to the friction produced when the dipoles oscillate. When steels are heated above Curie temperature they become nonmagnetic, and hysteresis ceases. Because the steel is nonmagnetic, no reversal of dipoles

can occur. If an object has conductive properties like iron, additional heat energy is generated due to magnetic hysteresis. The amount of heat energy created by hysteresis is in proportion to the size of the hysteresis. This additional energy is ignored because it is far smaller (less than 10%) than the energy generated by induction current.

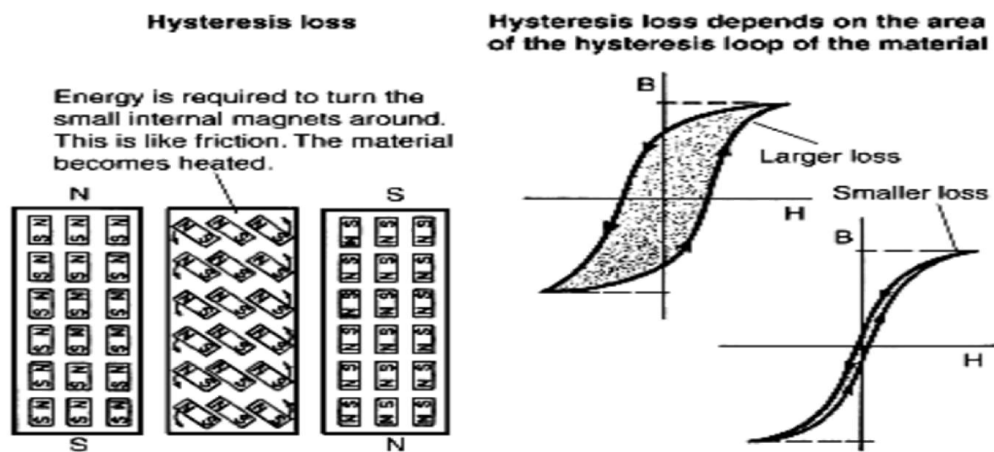


Figure 3.5: Hysteresis losses due to magnetic domains of ferromagnetic materials [6].

3.7 Control circuit

Control circuit in induction cooker contains mainly Microcontroller and isolated gate bipolar transistor (IGBT).

3.7.1 Microcontroller

The low price, wide range of applications, high quality and availability made the Microcontroller an ideal choice for control of induction cooker's processes. The micro send signals to IGBT, control the pulse width modulation and the duty cycle that determines the output power of the cooker. That signals goes through the IGBT, the component of IGBT and capacitor form an inverter that creates AC current with resonance frequency. At last the output received by the inductor as a high frequency alternating current.

3.7.2 Isolated Gate Bipolar Transistor

The insulated-gate bipolar transistor (IGBT) is a three-terminal power semiconductor device primarily used as an electronic switch which, as it was developed, came to combine high efficiency and fast switching. It switches electric power in many modern appliances, variable (VFDs), electric cars, trains, variable speed refrigerators, lamp ballasts, air-conditioners and even stereo systems with switching amplifiers.

The IGBT combines the simple gate-drive characteristics of MOSFETs with the high-current and low-saturation-voltage capability of bipolar transistors. The IGBT combines an isolated gate FET for the control input, and a bipolar power transistor as a switch, in a single device. The IGBT is used in medium-to high-power applications like switched-mode power supplies, traction motor control and induction heating. In induction cooker The IGBT with other devices work as inverter to convert DC in to AC with high frequency depending on the pulses received from the micro controller [7,8].

CHAPTER FOUR

DESIGN AND OPERATION

4.1 INTRODUCTION

To drive an induction cooker system, a general method of half bridge topology has been used by zero-voltage switching class-E resonant inverter for induction heating application ,zero voltage switching consists of a switch in series with a diode ,The circuit is shown in figure 4-1. The resonant capacitor is connected in parallel, and the resonant inductor is connected in series with this configuration. A voltage source connected in parallel injects the energy into this system. When the switch is turned on, a linear current flows through the inductor. When the switch turns off, the energy that is stored in the inductor flows into the resonant capacitor. The resulting voltage across the capacitor and the switch is sinusoidal. The negative half-wave of the voltage is blocked by the diode. During this negative half wave, the current and voltage in the switch are zero, and so it can be turned on without losses.

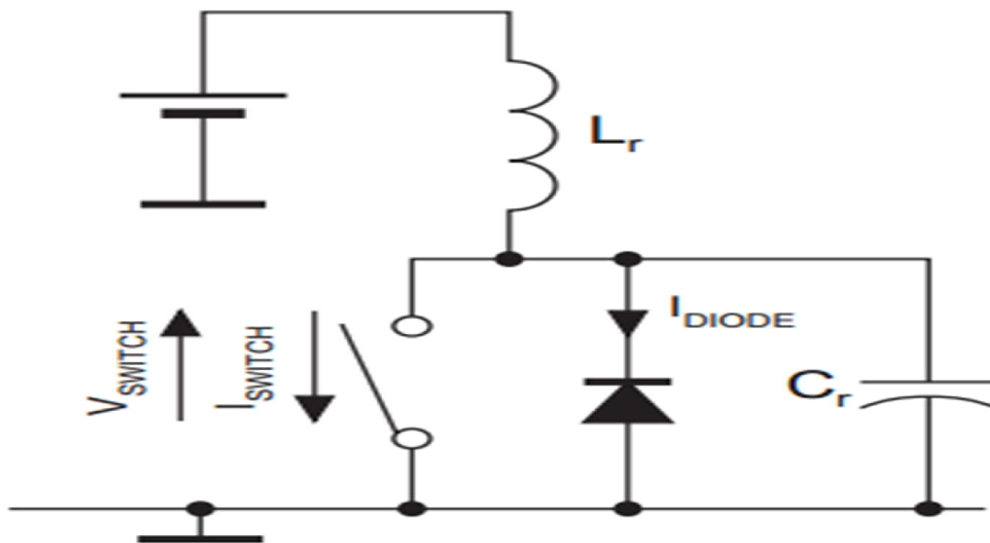


Figure 4-1 zero voltage switch topology

4.2 PRINCIPLE OF OPERATION

Operation circuit consists of a bridge rectifier, $D_1 - D_2 - D_3 - D_4$, an electromagnetic interference filter (EMI), $L_f - C_f$, and a class-E resonant inverter, $Q - L_r - C_r$ (Figure 4-2) . The pulse density modulation of the gate signal, v_{GE} , is controlled to regulate the temperature. In order to guarantee the zero-voltage switching (ZVS) condition.

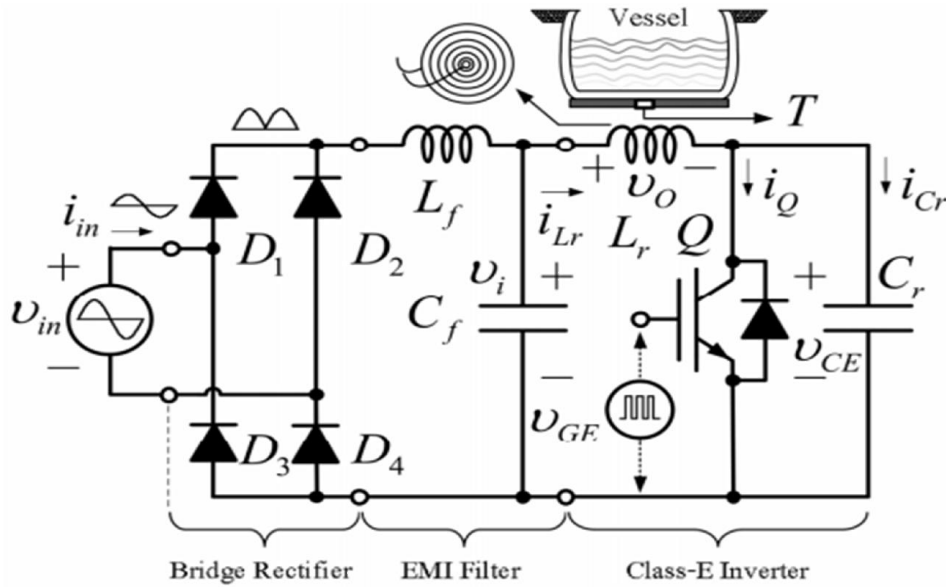


Figure 4-2 induction cooker base on class-E DC-AC resonant inverter

The principle of the operation of the high-frequency induction cooker on zero-voltage switching class-E DC-AC resonant inverter [9], is explained by an equivalent circuit shown in Fig. 2. The diodes, D_1 and D_4 , of the bridge rectifier operate during the positive half-cycle of the line voltage, which is represented as $v_{in} = V_{in} \sin \omega_L t$, where ω_L is the line angular frequency and the diodes D_2 and D_3 operate during the negative half-cycle. The model of the line-voltage rectifier output is a full-wave rectified sinusoidal voltage source $|v_{in}| = |V_{in}| \sin \omega_L t$. The equivalent circuit of ZVS class- E resonant inverter with cooking vessel can be replaced the simplest form of a transformer, when the coil of the secondary is turned only once with the resistance R which has

connected in parallel with the secondary size of the high frequency transformer, the planar multi turn winding or resonant inductor L_r [10,11] means the inductor on the primary side of the transformer is shown as Figure 4-3 (a). The induction coil and the vessel are insulated by glass-ceramic material. Whenever, the high frequency alternating electric current flow through the induction coil, which produces a high frequency magnetic field. This field induces an eddy current within the cooking vessel and converts electrical energy into heat across the bottom of the cooking vessel. And this can be simplified as in the Figure 4-3(b), where R_t indicates the equivalent parallel resistance is converted from the secondary side of the transformer.

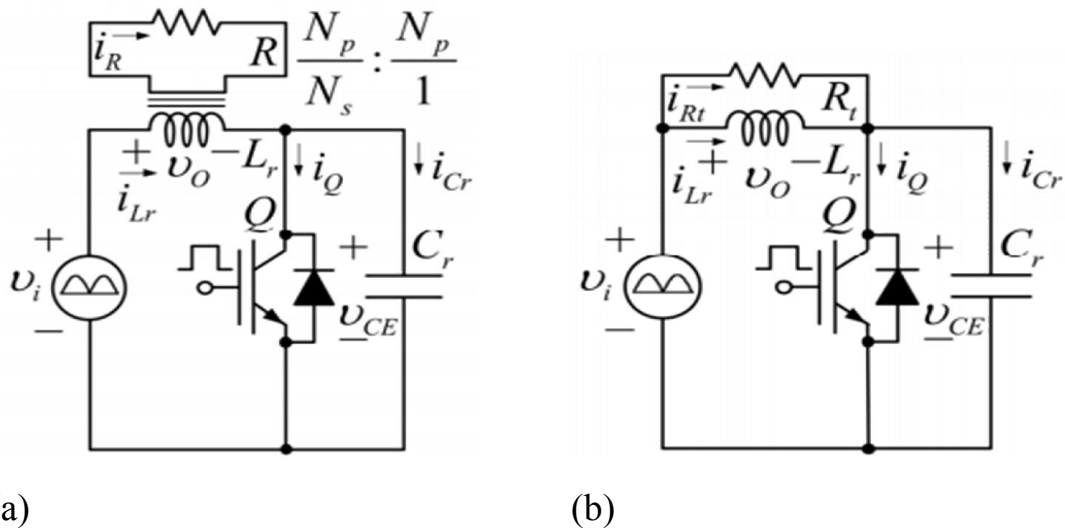


Figure 4-3 Equivalent circuit of induction cooker based on class-E inverter.

The equivalent circuit operation modes of the induction cooker based on class-E inverter as shown in Figure 4.4. Mode 1 when active switch Q is ON and Mode 2 when active switch Q is OFF. It can be seen that, the conduction loss of the anti parallel diode of the active switch can be neglected. Therefore, the high efficiency can be obtained. Figure 4.5 shows the operation waveforms of the proposed ZVS class-E DC-AC resonant inverter for high efficiency induction cook.

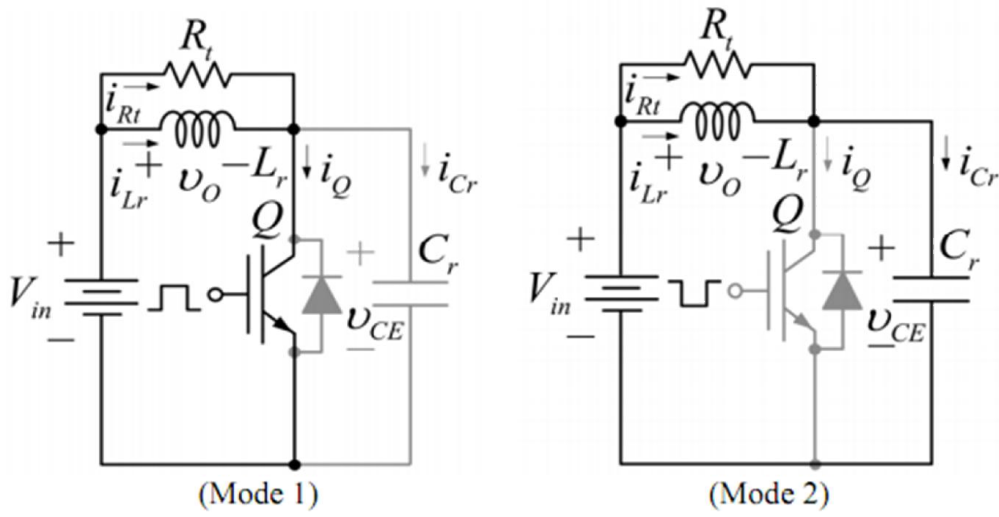


Fig.4-4 The operation mode of the proposed circuit.

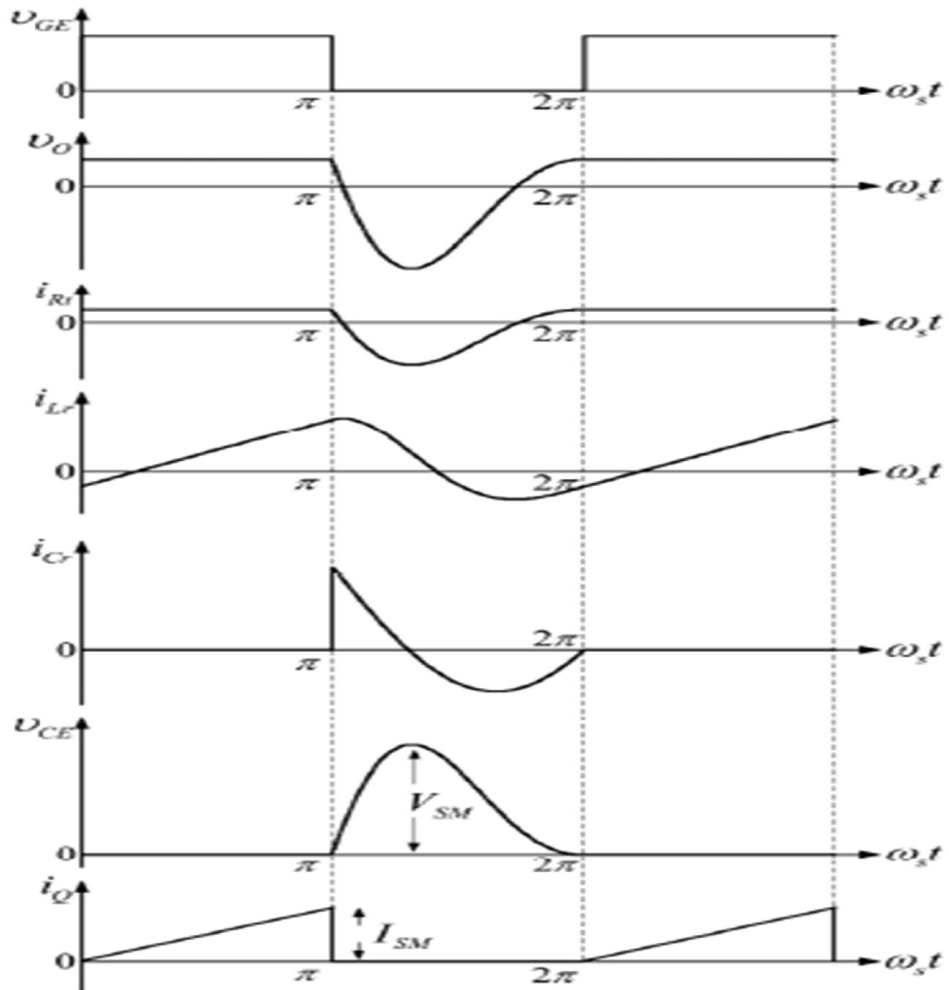


Figure 4-5 Key waveforms of the class-E resonant inverter.

4.3 Temperature Control method

The principle of the pulse-density modulation (PDM) [7,8] based temperature control is shown in Fig4.6. The PDM modulation is implemented keeping the switching frequency constant and adjusting output temperature through controlling the duty cycle, which is a term for a pattern that repeats “ON and OFF” in accordance with a control sequence to adjust its rms output voltage. Where v_{D-con} is a low frequency square wave signal, which can be adjusted the duty cycle, v_{HF} is a constant switching frequency signal and v_{GE} is gate signal from PDM of v_{D-con} and v_{HF} , respectively. Thus, this technique is suitable for induction cooker application base on class-E DC-AC resonant inverter, due to guarantee the ZVS operation.

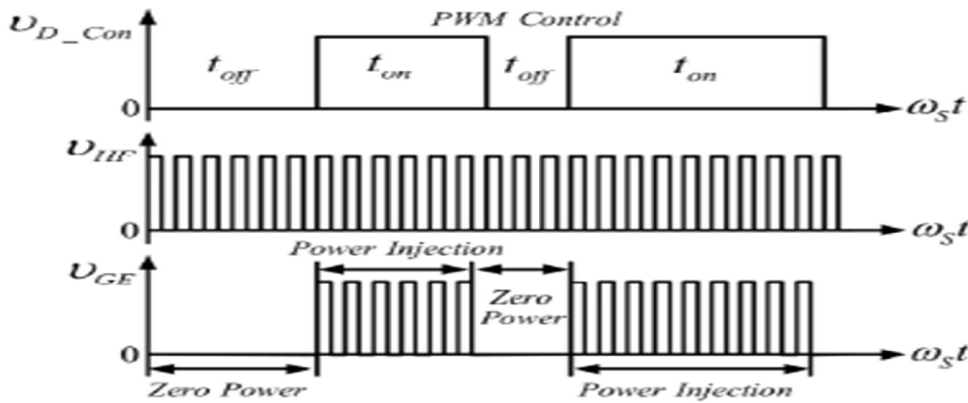


Figure 4-6 Principle of PDM control.

The simplified algorithm for the temperature control is shown in Figure (4.7), where T is the vessel temperature and $mean$ the commanded value. The transfer of output power to the load is depend on the active switch is duty cycle D_{v-con} . Then the temperature control for induction cooking will depend on the duty cycle D_{v-con} of the active switch as well. The simple temperature control by the principle as follows: start measuring the temperature to compare with the commanded value. If less than the command value will be increase the duty cycle D_{v-con} . If not, will be decrease the duty cycle D_{v-con} .

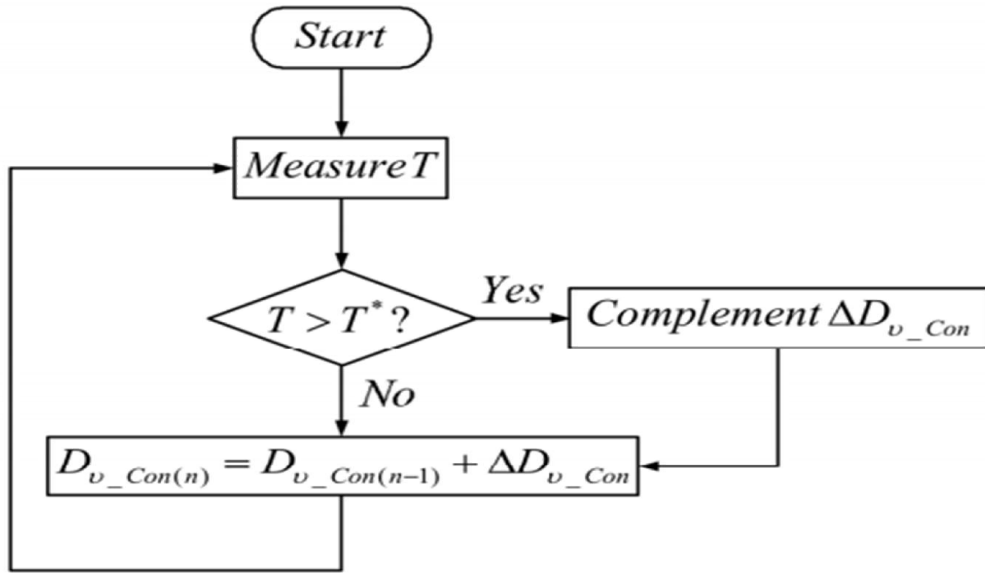


Figure 4-7 Simplified algorithm for the temperature control

4.4 DESIGN PROCEDURE

Referring to the equivalent circuit of the equivalent circuit of the induction cooker base on class-E inverter [9] is shown in Figure 4.3. For the steady-state operation, the operating at a 32 kHz switching frequency, the line rms voltage, v_{in} , of 220 V and a line frequency f_L of 50 Hz, a 2 kW output power, P_o , and the switching frequency, f_s , is approximately equal to resonant frequency, f_r , where ω_s is the switching angular frequency and then the equivalent resistance R_t is:

$$R_t = \frac{15.326 v_{in}^2}{\pi^2 P_o} \quad [4.1]$$

The resonant inductor is given by:

$$L_r = \frac{0.205 R_t}{2\pi f_r} \quad [4.2]$$

The resonant capacitor is obtained by:

$$C_r = \frac{0.512}{2\pi f_r R_t} \quad [4.3]$$

The maximum voltage across the switch is calculated as

$$V_{SM}=5.443V_{in} \quad [4.4]$$

4.5 Operation and Results

Firstly high-power circuit was fed from AC voltage source 220 V 50Hz then the rectifier which converts from AC to DC as shown in figure (4.8) was connected directly to the source, After that comes the part of filtering process by low pass filter. heating coil and resonance capacitor were connected in series to achieve resonance circuit, which it connected directly with low pass filter output , Next The IGBT which is used here as chopper device work to convert the DC current is into high frequency AC current by microcontroller which it used to controlling IGBT gate by sending signals.

The table(4.1) below shows the magnitudes of different circuit components calculated from the equations [4.1,4.4] above

Table 4.1 Circuit Parameter

Symbol	Value and part number
D1 – D4	GBP25-08
Q	H15R1202
C_f	4.7 μ f
C_r	82 nF
L_f	500 μ H
L_r	127 μ H

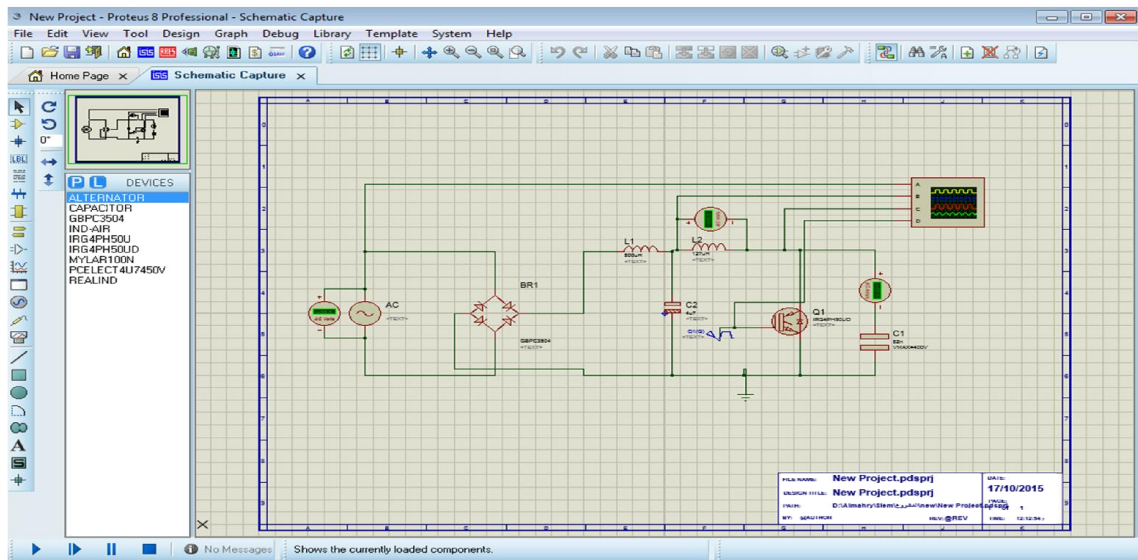


Figure 4-8 simulation model

Secondly the DC voltage source of 12V is connected to the voltage regulator have 5V on output terminal and were fed each of microcontroller ,LCD screen and potentiometer which is used to control the amount of PWM as shown in figure (4.9). Power range was controlled by varying the PWM as shown in figure (4.10). Then micro controller output 32k HZ (0 or 5 volts) amplified in to 12V through a photo transistor to feed IGBT gate. circuit information's were displayed by LCD screen. Microcontroller programing code shown in appendix .

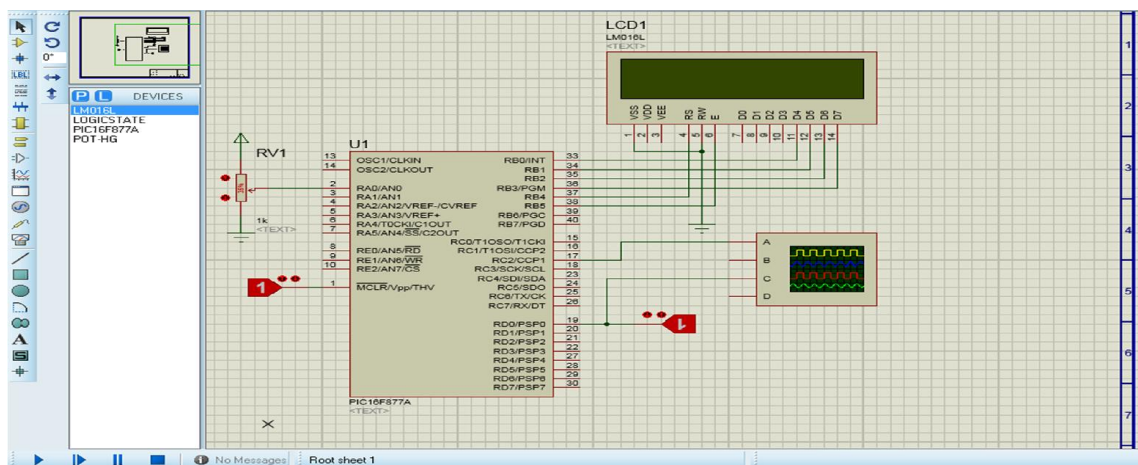


Figure 4-9 control circuit simulation

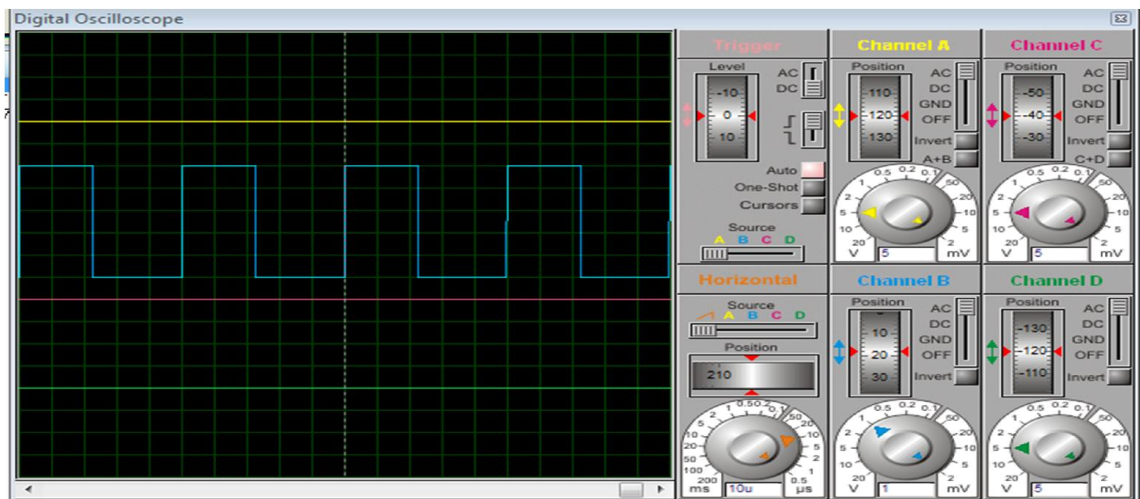


Figure 4-10 PWM output

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In this project we design an induction cooker with controllable frequency demonstrates the principles of high frequency magnetic induction. The induction cooker's parameters need to be designed properly and details of analysis and design of this induction cooker's components are described. A proposed high efficiency induction cooker is designed for an operating at 16A a 32-kHz frequency, a 220-V line rms voltage, a 50-Hz line frequency and a 2-kW output. The circuit is very simple to build and only uses a few common components.

The high efficiency, easy to control and operation, non-pollutant and small size make the cooker very attractive in term of commercial production.

5.2 RECOMMENDATIONS

- The design specifications must be very accurate and precise, high effective measurement devices used to calculate current and coil inductance and capacitor.
- The heating coil selection must have a suitable thickness and must be composed of a number of strands making it deal with high currents and it should have good specifications. Because any change in specifications or calculations creates bad effects and working problems.
- Also we recommend to Replace the IGBT by MODEL IGBT (IGBT with a very high values for each of the current and voltages).
- Controlling system by microcontroller recommended to change by using computer programs(C++ ,Matlap, etc.) or other controllers to processing signals for precise settings.

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APPENDIX

Appendix 1: Microcontroller program :

```
sbitSw at PORTD.B0;

// LCD module connections

sbit LCD_RS at RB4_bit;

sbit LCD_EN at RB5_bit;

sbit LCD_D4 at RB0_bit;

sbit LCD_D5 at RB1_bit;

sbit LCD_D6 at RB2_bit;

sbit LCD_D7 at RB3_bit;


sbitLCD_RS_Direction at TRISB4_bit;

sbitLCD_EN_Direction at TRISB5_bit;

sbit LCD_D4_Direction at TRISB0_bit;

sbit LCD_D5_Direction at TRISB1_bit;

sbit LCD_D6_Direction at TRISB2_bit;

sbit LCD_D7_Direction at TRISB3_bit;

// End LCD module connections


unsigned short current_duty;

unsignedintADC_Value;
```

```

int Power;

char txt[7];

void main() {

    Lcd_Init();           // Initialize LCD

    Lcd_Cmd(_LCD_CLEAR);  // Clear display

    Lcd_Cmd(_LCD_CURSOR_OFF); // Cursor off

    Lcd_Out(1,1,"Our Project 2 KW");

    Lcd_Out(2,1,"Induction Cooker");

    Delay_ms(2000);

    Lcd_Cmd(_LCD_CLEAR);  // Clear display

    Lcd_Cmd(_LCD_CURSOR_OFF); // Cursor off

    Lcd_Out(1,1,"Max Power 2.0 KW");

    Lcd_Out(2,1,"Power 0 - 100%");

    Delay_ms(2000);

    Lcd_Cmd(_LCD_CLEAR);  // Clear display

    Lcd_Cmd(_LCD_CURSOR_OFF); // Cursor off

    Lcd_Out(1,1,"Choose Power And");

    Lcd_Out(2,1,"Click Button SW");

```

```
Delay_ms(2000);
```

```
PORTA = 0X00; TRISA = 0XFF;           // configure PORTA pins as  
input
```

```
PORTD = 0X00; TRISD = 0XFF;           // configure PORTD pins as  
input
```

```
while (1) {
```

```
if(Sw == 0 ) break;
```

```
ADC_Value = ADC_Read(0);
```

```
Power = (ADC_Value*100)/1024;
```

```
current_duty = (Power*255)/100;
```

```
IntToStr(Power, txt);
```

```
Lcd_Cmd(_LCD_CLEAR);           // Clear display
```

```
Lcd_Cmd(_LCD_CURSOR_OFF);      // Cursor off
```

```
Lcd_Out(1,1,"Power SET NOW = ");
```

```
Lcd_Out(2,1,txt);
```

```
Delay_ms(100);
```

```
}
```

```
Lcd_Cmd(_LCD_CLEAR);           // Clear display
```

```
Lcd_Cmd(_LCD_CURSOR_OFF);      // Cursor off
```

```
Lcd_Out(1,1," High Temp Power");
```

```
Lcd_Out(2,1,txt);
```

```
Delay_ms(2000);
```

```
PWM1_Init(20000);
```

```
PWM1_Start();
```

```
// start PWM1
```

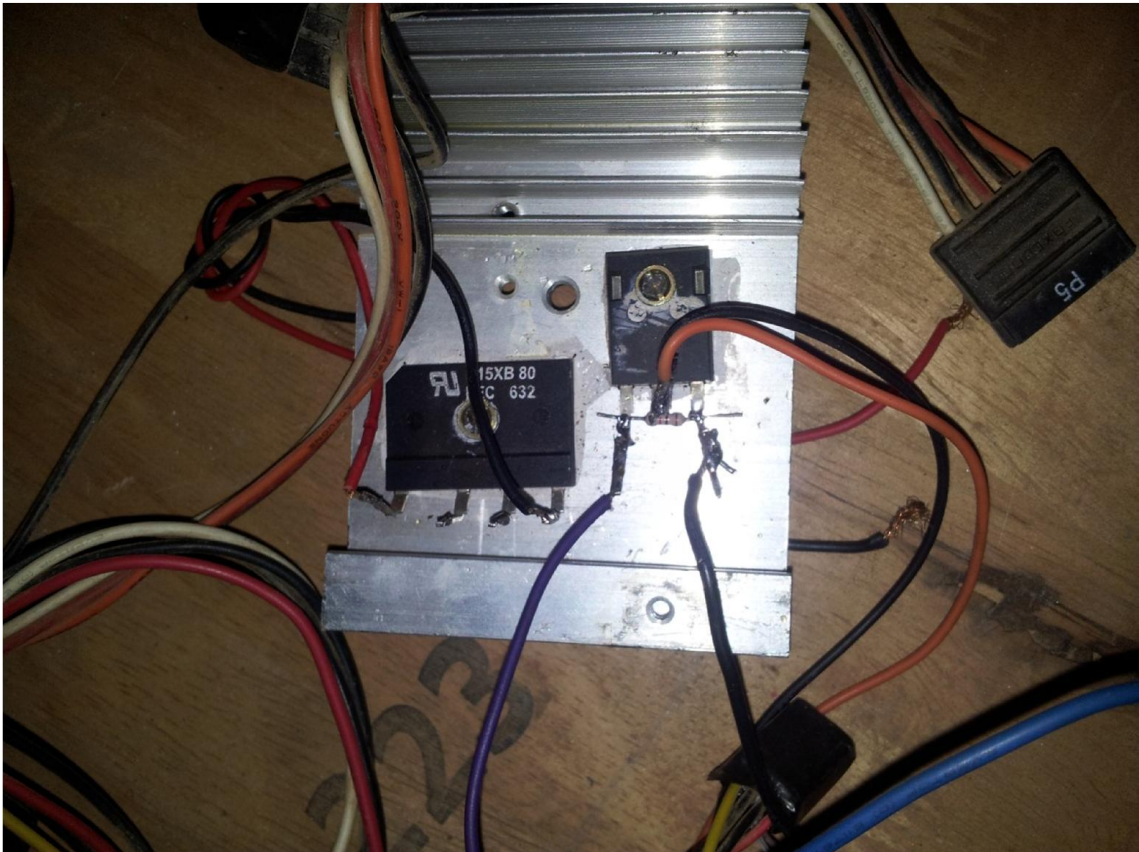
```
PWM1_Set_Duty(current_duty);
```

```
// Set current duty for
```

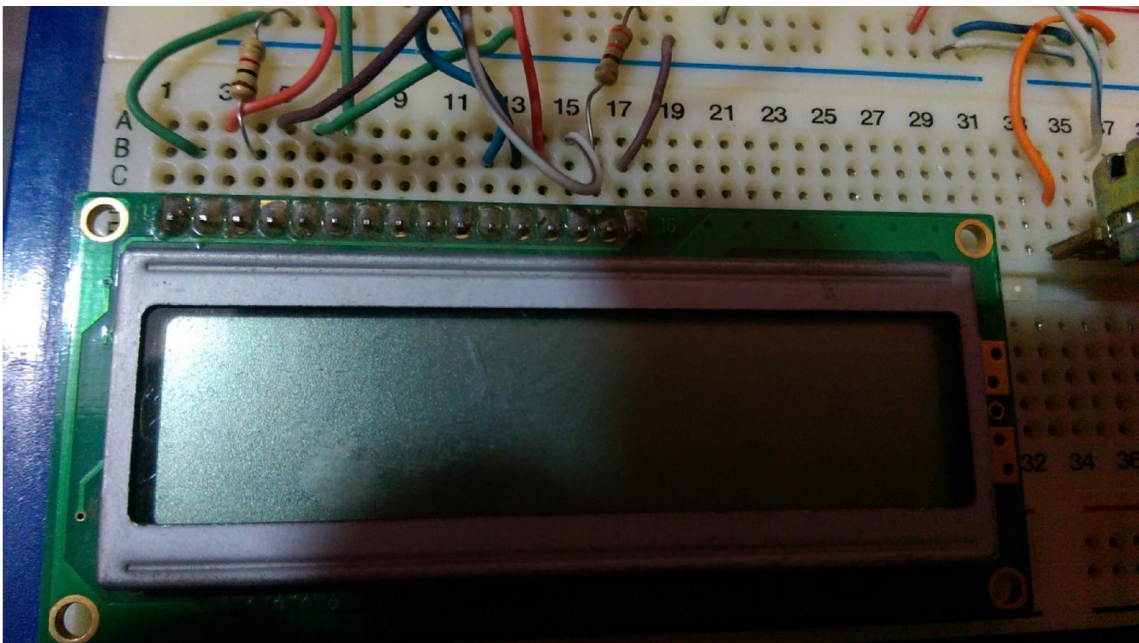
```
PWM1
```

```
}
```

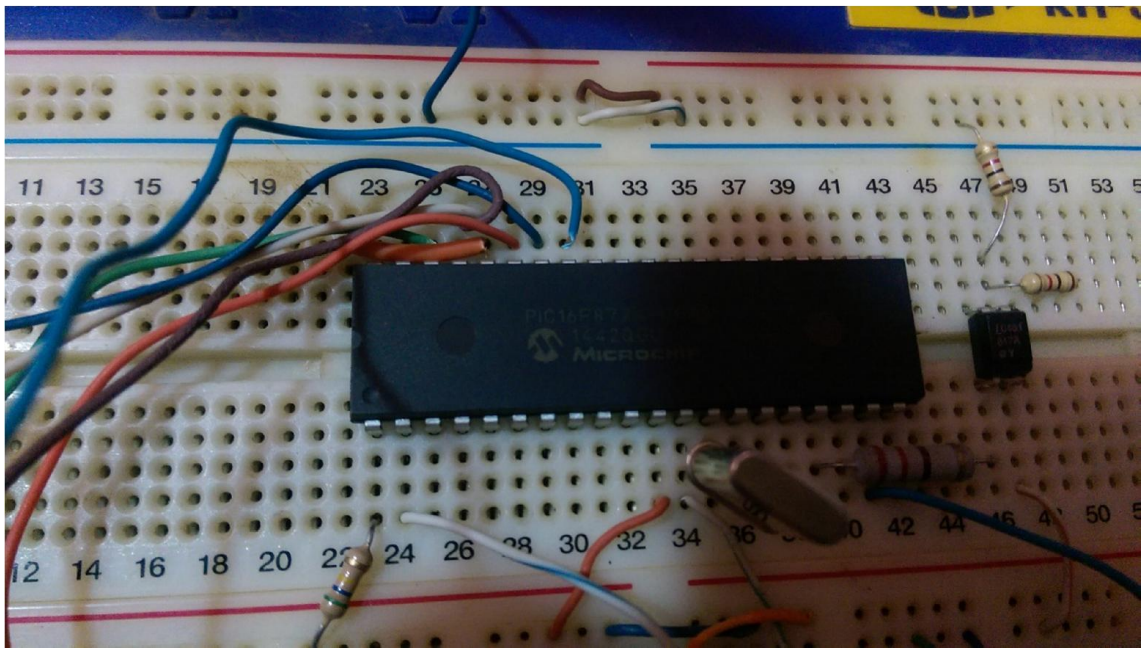
Appendix 2 : IGBT and rectifier



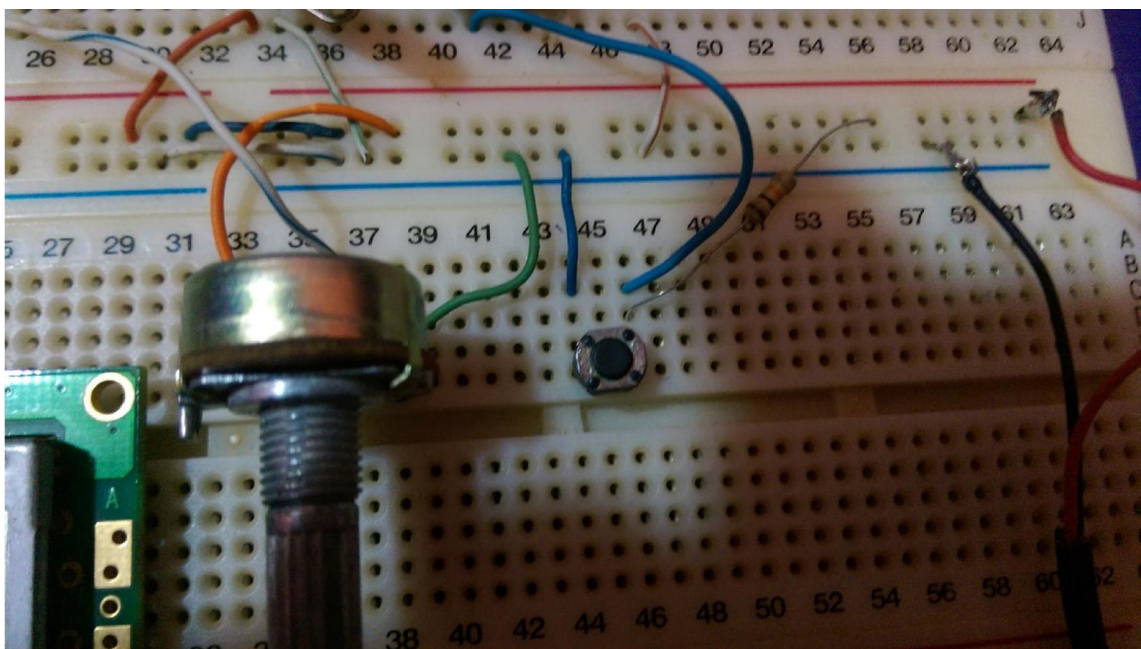
Appendix 3: The LCD screen



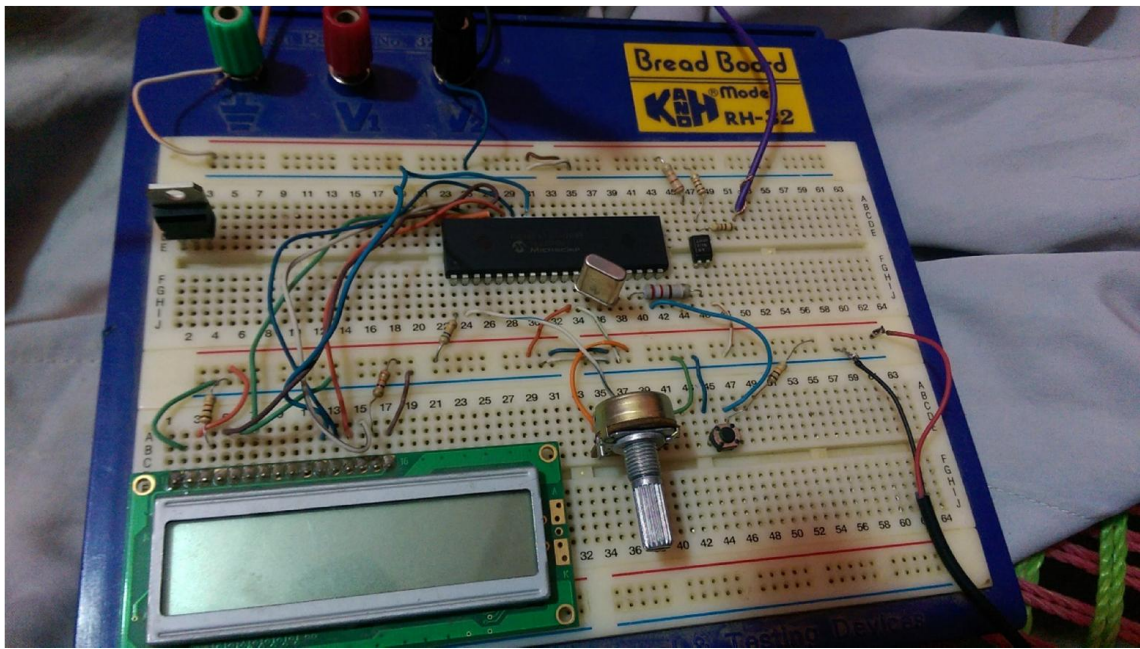
Appendix 4: The microcontroller



Appendix 5: potentiometer



Appendix 6: control circuit



Appendix 7: low pass filter

