DESIGN AND CONSTRUCTION OF TIME AND TEMPERATURE PROGRAMMABLE ELECTRIC OVEN WITH COOKER

BY

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2003/15336EE

DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING
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NIGER STATE, NIGERIA

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A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ELECTRICAL/COMPUTER ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY.MINNA, NIGERIA

NOVEMBR, 2008

DECLARATION

I, BABATUNDE KAZEEM TEMITAYO, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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DEDICATION

This project is dedicated to the Almighty Allah for his mercy and protection over me. Also, to Alhaji Mustapha Aremu Lawal for his encouragement, moral and financial support to see that I am educated.

ACKNOWLEDGEMENT

It is with pride and great pleasure to express my sincere and deep sense of gratitude to Almighty Allah for his guidance and grace over me.

I acknowledge the indebtedness to my project supervisor **Dr J. Tsado** for his support and advice and to all other lecturers and staff of the department.

My sincere appreciation goes to my parents, **Alh. Mustapha Ar[illegible] Lawal,** my mother **Hajia S. Ayoka,** and **Alh. Sheikh Abdulazeez Abdulrahman** for their relentless effort in making sure I get the best and their unending prayers for me. And to my brothers and sisters, their effort in the course of my academic pursuit cannot be under estimated, you all have been my source of inspiration.

I do wish to acknowledge my indebtedness to all who have contributed in any way to make my degree program a successful one especially **Mr. and Mrs. Ademola Ibidun** I hold you close to my heart. And also to my friends and colleagues in the struggle. **Adebiyi Ma'ruf Taiwo, Moh'd Abdulraheem Eleyele, Adebimpe Azeez, Tunde Lawal, Kareem O. Lawal, Ayanwale S. Kehinde** and lots more.

Thank you all for not letting me lose control. I say "JAZAKUMULLAHU KHAIRAN".

ABSTRACT

The Design and construction of a time and temperature programmable electric oven with cooker is presented in this project. The project is built around a PIC16F877, which is a microcontroller unit which can be used as a standalone controller system containing a RAM, ROM, PORTS, TIMERS and other peripherals like Analogue to Digital converter. The controller interfaces with a set of 4 by 4 keypad, a temperature sensor and 2 dual 7 segment displays, with two LEDs. The 4 by 4 keypad is used to communicate with system. The temperature sensor senses temperature in Analogue from which is converted to digital by the controller and processes it within the controller. These are used to display set temperature and time. The LEDs are used to interface to 2 triacs used to control the heating elements via an LDR.

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CHAPTER ONE

CHAPTER ONE

GENERAL INTRODUCTION

1.1 General Introduction

Time and temperature programmable electric oven with cooker is an electric appliance that converts electrical energy into heat energy for domestic and commercial cooking and backing.

The discovery of heating effect of current in 1841 by Joule now find a wide range of application for both domestic and commercial purposes, since the advent of electricity. Today heating appliances such as cookers, furnaces, boil utensils, e.t.c. are being powered by electricity. For instance, in many urban centres and developed countries:

1. Cooking with firewood has been replaced with electric cooker, stove, etc.
2. Baking with local oven has been replaced by electric oven, toaster, etc.
3. Boiling with naked fire has been replaced with electric kettle, boiler ring, etc.
4. Room warming with fire has been replaced with electric conventional water and tubular heater.
5. Charcoal iron has been replaced by electric iron. [1]

The heat or hot elements of these devices radiate heat as a form of energy, which is converted from electricity. Heat flows from higher temperature gradient to a lower temperature gradient. Temperature is the measure of the intensity of heat and is recorded in the lower ranges by thermometer. Pyrometer is used for the higher temperature. Heat is usually caused by difference in temperature between the body and its surrounding. When the temperature of the surrounding is higher than the temperature of the body, the body gains heat energy, otherwise, it loses energy to the surrounding. A common conductor for this heating element is the Nichrome wire which is an alloy of 60% of copper and 25% of Manganese and 15% of chromium. The length and thickness of the wire are chosen so that it becomes red hot at the required operating voltage. [2,3]

1.2 Motivations

Since the advent of cooker manufacturing in developing countries like Nigeria, solution has been found for heat control or regulation with the mostly only and there is yet to be an effective electrical device for timing domestic electric cooker. The failure to have operational timer for the indoor electric cookers has caused a lot of electric hazard and inferno. This has claimed the life and properties of many people. In fact, many people have been put away from the use of electrical appliances for indoor cooking and baking because of this problem, which is supposed, not be so.

The user of these appliances often forget to look after what they are cooking or baking and several times due to incessant power outages, they often forget to switch off their appliances when they are leaving their premises or even due to carelessness of the use. Due to this negligence, the cooker or oven will continue to generate heat when the power is restored. Heat continues to build up and when it gets beyond control, the house is set to ablaze, or when the appliance is too hot either because of the heat generated or the usage time the cooker get burn and affect other electrical appliance. Repeated occurrence of these electrical hazards have led to the loss of valuable things worth million of naira or set people to homeless.

However, with the help of operating timer, an effective solution is provided to these problems. An effective control timer for the cooker and thermostat control for the oven are therefore incorporated in the design and construction of time and temperature programmable electric oven with cooker to make it safe and easy as well.

1.3 Aims and Objectives

The aim of this project is to develop or construct a timer and temperature controlled electric cooker with an oven, controlled by microcontroller for domestic use.

i. The electric cooker and the oven are to use commercially available 1000W Nichrome element as their heating element.

ii. Cooker and oven operating voltage to be 220V

iii. To incorporate operational timer and temperature regulator.

iv. To provide both the cooker and oven an additional direct ON and OFF switch to the 220V supply voltage when the temperature regulator and the timer are not to be used thereby passing them.

v. Cooker to be easy to use and minimize risk of electric shock [4].

1.4 THESIS LAYOUT

This report consists of five chapters, each of which consists of sections and sub sections as outlined on the table of contents for easy referencing. the write-up is well structured to meet up the technical report standard figures, tables and symbols are numbered.

Chapter one contains or deals with the introductory aspect of the project research.

Chapter two reviews the literature and the existing types of the project and also describes in details the major components of the system.

Chapter three is based on the hardware design, analysis and the software techniques.

Chapter four, deal with the implementation, construction and testing.

Chapter five contains recommendation and conclusion.

Lastly, the sources of information and knowledge are referenced orderly. Some indispensable facts like, circuit diagrams, program source code, etc. are in the appendices.

CHAPTER TWO

LITERATURE REVIEW

A stove is a heat producing device. Typically the word is used to refer to a kitchen appliance used for generating heat for cooking. In British, however, the term cooker is normally used for cooking appliance, and store for a wood or coal-burning room heating appliance.

There are many types of stores:

A kitchen store is used to cook food, and refers to a device which has both burners on the top (also known as a cook top or range) or in British as a hob) and an oven.

Stove may generate heat by:

- Burning of

1. Natural gas
2. Heating oil
3. Wood, coal or synthetic heating pellet

- Electric resistance (by way of heating element).

In Europe, the history of the kitchen stove begins in earliest in the 18th century. Before, people cooked oven open fires fuelled by wood, which first were on the floor or on low masonry constructions. In the middle ages, waist high brick and mortar heaths and the first chimneys appeared, so that one didn't have to kneel or sit anymore to cook. The fire was lit on top of that construction, the space underneath was used to store and dry wood. Cooking was done mainly in cauldrons hung above the fire or placed on trivels. The heat was regulated by placing the cauldron higher or lower above it.

Open fire has three disadvantages that prompted already 16 century inventors to look for improvement; it is dangerous, produces a lot of smoke and the heat efficiency are poor. Attempts were made to enclose the fire to make better use of the heat it generated and thus reduces the enclosed on the sides by brick and mortar walls, covered by an iron plate. This technique also caused a change in the kitchen ware used for cooking, for it required flat-bottom pots instead of Cauldrons. Only in 1735 the first design that enclosed the fire completely appeared; the castrol stove of the French architect was a masonry construction with sword fireholes covered by iron plates with holes. It is also known as stew stove. Towards the end of the 18th century, the design was reformed by hanging the pots in holes through the top iron plate, thus improving heat efficiency even more. [2,3]

2.1 Iron Stoves

In the 18th century, the first non stoves appeared. An early example is the Franklin stove, a wood burning stove said to have been invented by Benjamin Franklin in 1742. It had a labyrinthine path for hot exhaust gases to escape. This allows heat to enter the room instead of going up the chimney. The Franklin stove however, was designed for heating not for cooking. Benjamin Thompson at the turn to the 19th century was among the first to present working non kitchen stove. It is Rumford stove used one fire to heat several pots that were also hung into holes so that they could be heated from the sides too. It was even possible to regulate the heat individually for each hole. His stove was designed for large canteen or castle kitchens, though, it would take 30 years until the technology had been refined and the size of the non stove been reduced enough for domestic use. Stewart stove was a much more compact iron stove, patented in the U. S.

in 1934. It became a huge commercial success with some 90,000 units sold in the next 30 years. In Europe, similar design also appeared in the 1830s. In the following years, these stoves evolved into veritable cooking machines with the water. The originally open holes into which the pots were hung were now covered with concentric iron rings on which the pots were placed. Depending on the amount of the heat needed, one cold remove the inner rings. [2,3]

2.2 Gas and Electric Stoves

The first gas stove is developed already in the 1820. It is rather unwieldy, but soon the oven was integrated into the base and the size reduced to fit in better with the rest of the kitchen furniture. In the 1910s producers started to enamel their gas stores for easier clearing. A high-end gas stove called the AGA cooker was invented in 1922 by Swedish Nobel prize winner Gustaf Dal A©n. It is considered to be the most efficient design and is a much sought after kitchen. The AGA, and similar products such as the Rayburn Range are example of always on-stove which continue to burn fuel even when cooking is not being performed. In 1880s, the electrical stove were made, which had a slow start, partly due to unstable technology and partly because first cities and town need to be electrified. By the 1930s, the technology had matured and the electrical stove started to slowly replace the gas stove especially in domestic kitchens. Stove started to slowly replace the gas stove especially in domestic kitchens.

The electrical stove technology has developed in several successive generations;

- The first technology used resistor heating coils which heated iron hot plates, on top of which the pots were placed. Though the technology is slowly fading into obsolescence, coil ranges skill provides the best durability out of all electric cook top implementations.

- In the 1970s, glass ceramic cook tops, started to appear, glass ceramic has a very low heat combustion coefficient, but lets infrared radiation pass very well. Electric heating coils or infrared halogen lamps are used in heating elements. Because of the physical characteristics, the cook top heat quicker, there is less after heat and only the plate heats up while the adjacent surface remain cool. Also these cook tops have a smooth surface and are thus easier to clean, but they only work with flt bottomed cook ware and are markedly more expensive.
- A third technology developed first for professional kitchens, but today also enter the domestic market are induction stoves. These heat the cookware directly through electromagnetic induction and thus require pots and pans with ferromagnetic bottoms. Induction stoves also often have a glass ceramic surface.[3]

2.3 Advantages of Oven/Cooker

Electrical oven technology: in the convection oven, a stream of hot air in a conventional electrical oven. Oven and stores throughout history have one thing in common. They will burn the person who comes in contact with this hot metal surfaces. For instance, the oven rack's front edge. Devices to protect the hands, such as oven gloves, have been developed, but need to be used consistently, to be effective; so people still be get burned. Recently, a device has been invented by Burnt Shulman of Wappingers Falls, New York, called the cool Touch, Oven Rack Guard, which is a fabric strip that attaches along the front edge of the oven rack and stays in the oven. If a person touches it, even at 500 degree F, they will met be burned. The fabric is made froma modern synthetic fiber called Nomex which can withstand 500^0F, temperature and has both low thermal conductivity and thermal mass. These material properties reduce the heat transfer to the skin during the touch, so no burn results. [3]

2.10 Heating Element

This consists simply of a thin wire, would in coil which is close to each other so that their heating effect is reinforced. The wire L an alloy which cannot be oxidized when it becomes red hot, and it is supported by a heat resistance, non conducting ceramic materials. There is usually a shinny metal reflector being the heating element to throw the heat forward.

The length and the thickness of the wire are chosen so that it becomes red hot with the required parting voltages. Some heating elements are shown in Table 2.10.

The weakest point of a round element is usually its end connections. Leads and termination for heating element must be made of materials that resist both oxidation and corrosion. Heat from the resistance element is conducted back to the leads and terminals which may become hot enough for oxidation to occur on the metal surfaces and in consequence, the bad contact will lead to arcing. The table gives some details of the resistive materials used for elements in heating appliances and apparatus. Most of the resistive conductors which we know as "elements" are made from Nickel – chromium alloys. Element are found in fires, space heaters, toaster, flat irons, kettles, immersion heaters, hair-driers; boiling places, grill boilers, oven elements and other appliances. The operating temperature of the elements is around 1000^0C depending on the actual composition of the alloy metal. [4]

2.11 Cable Selection

The resistance of a cable is affected by length, thickness, temperature and the material type. Since Ohms law tells us, that current is universally proportional to resistance; these factors must also influence the current carrying capacity of a cable. The table of current rating in 4 of the IEE Regulations contains correction factors so that current factory may be accurately determined under defined installation condition.

The size of a cable to be used for installation depends upon:

i) The current rating of the cable under defined installation condition.

ii) The maximum permitted drop in voltage as defined by Regulation 525.01.

The factors which influence the current ratings are:

i) The design current – the cable must carry the full load current.

ii) The type of cable – PVC, MICC, Copper conductors of Aluminum conductors.

iii) The installed conditions – clipped to a surface or installed with other cables in a trunk.

iv) The surrounding temperature – the cable resistance increase, as the temperature increases and insulation may mill of temperature is too high

v) The type of protection – for how long the cables have to carry fault current? Regulation 525.01 state what the drop in voltage from the supply terminals to the fixed current using equipment must not exceed 4 or 5 % of the main voltage [4,5]

The voltage drop for a particular cable may be found from

VD = Factor x design current x length of run ... 2.10

The factor is given in the table of appendix 4. The table rating may be determined:

Current rating = $\frac{\text{Current rating of protective device}}{\text{Any applicable connection factors}}$ 2.20

The current rating must be chosen to comply with regulation 4330-02-01 The correction factors which may use applying are given below:

Ca – the ambient or surrounding temperature correction factor which is given in tables $4C_1$ and $4C_2$.

C_g – the grouping correction factor which is given in table $4B_1$, $4B_2$ and $4B_3$.

C_f – The 0.725 correction factors to be applied when semi-enclosed in thermal infusion.

Regulation 523 – 04 gives us three possible correction values;

1. Where the cable is totally surrounded over a length greater than 0.5m, we mostly apply a factor of 0.5

2. Where one side of the cable is in contact with thermal insulation, we must read the current rating from the column in the table which relate to the reference method 4.

3. Where the cable is totally surrounded over a short length, the appropriate factor given in Table 52A should be applied.

Having calculated the cable rating, the smallest cable should be used or chosen from the appropriate table which will carry that current. This cable must meet voltage drop regulation 523-01 and this should be calculated as described earlier. When the calculated value is less than 4% of the main voltage, the cable may be considered suitable, if otherwise, the next larger cable size must be tested until a suitable cable is found which meet both the current rating and voltage drop criteria. [5]

2.12 Switch, Plug and Socket Outlet for Cooking Appliances Installation of Electrical and Electronic Equipments Regulation (IEE-Regulation)

IEE Regulation of British section nC.50 of 1976 Edition deal specifically with the use of switch plug and socket outlet for heater or boiler as stated below:

Section C.50; "the heater or boiler shall be permanently connected to the electricity supply through a double-pole linked switch which is separated from and within easy reach of the heater or boiler, and the wiring from the heater or boiler shall be directly connected to that switch without the use of a plug and socket-outlet where the heater or boiler. The switch shall comply in addition with regulation A.61 and D.19".

Section nA.26; "A final sub-circuit having a rating exceeding is appliers shall not supply more than one point, except as specifically admitted in Regulations A. 27.29 or A30-42, or A43-55, for the purpose of this regulation the following may each be regarded as one point:

i) A cooker control unit incorporating a socket outlet;

ii) A luminaries track system complying withB.S4533 provided that individual luminaries are protected against excess current.

Section A.27; "To determine the rating of a final-circuit supplying stationery cooking appliances in domestic premises, the current demand of the appliances shall be assessed as follows:

The first 10Amperes of the total rated aren't of the connected cooking appliances, plus amperes if a socket outlet is incorporated in the control unit."

Section A.28; "In domestic premises, a final sub-circuit having a reacting exceeding, samplers but not exceeding 30Amperes when determined in accordance with regulation A27, may supply too or more cooking appliances where these are installed in one room.

Section A29; "Every stationary cooking appliance in domestic premises shall be controlled by a switch separated from the appliance and installed within 2m of the appliance. Where low stationary cooking appliances are installed in one room of domestic premises, one switch may be used to control the two appliances provided that neither appliance is more than 2m from the switch. [4,5]

2.13 Keyboard/key pad

The keyboard is an input device for inputting data into an encoder, microprocessor or any other data accepting device. There are two types of keyboard existing, namely:

i) Fully encoded and

ii) Non-encoded.

Fully encoded keyboards: The keys on these boards are addressed. Hence each depressed key outputs a code (e.g. B. C. D). Fully encoded keyboards are easy to implement but expensive because of the needed associated electronic circuiting.

Non-Encoded keyboards; the keys on these boards are not addressed. Hence, once a key is depressed four tasks must be done, namely:

1. key identifying
2. Code generation
3. Debouncing

4. Protection against rollover. [6]

2.4 Operational Principles of the System

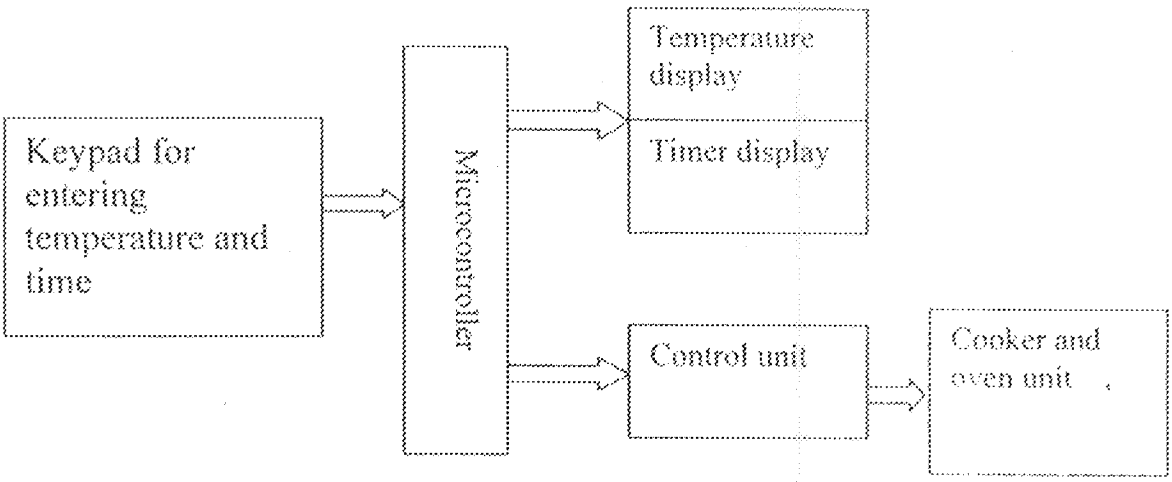

Figure 2.1 Block Diagram of the Project

This system is temperature and time programmable, stove and oven. The time and temperature can be set to any desired level. The block diagram shown above shows the working principle of the system.

When the power is ON, the microcontroller looks at the state conditions of the keypad and executes a section or section of program depending on the state of those keys either high or low. This phenomenon is referred to as scanning.

The output units consist of temperature display and time display units. Also there is stove or cooker and even control by microcontroller via a special control unit.

The cooker and oven can be set to on at the same time or one at a time. The time and temperature for each unit can be set based on what to be cooked or preserved.

When the time set is reached, the cooker or oven unit is/are turned off automatically by the control unit.

2.5 Microcontroller

Microcontroller is an exciting new device in the field of electronics computer engineering and control systems. Unlike microprocessors, microcontrollers include EEPROM program, flash memory, user RAM for storing program data, timer circuits, an instruction set, special formation registers (SFR), power on, reset, interrupts, low power consumption and a security bit software protection.

The general description of PIC 16 F877

The peripheral interface controller (PIC) is a version one of varieties of microcontroller manufactured by microchip technology. The pin out diagram of 16F877 is shown in figure

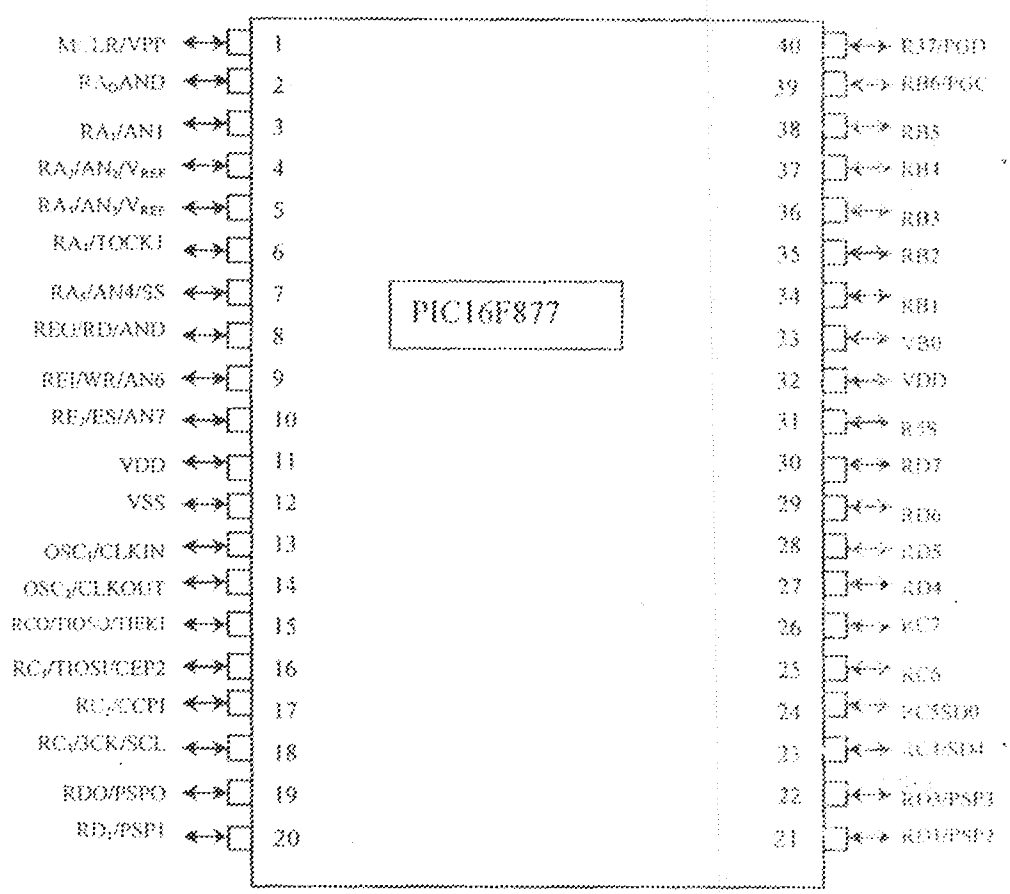

Fig.2.2 16F877 PIC PIN OUT.

The PIC 16F877 is a very versatile chip and can be programmed to a number of different configurations. The 16F877 PIC is a flash device that can be electrically erased and reprogrammed without using an ultraviolet eraser. The PIC 16F877 has the following features:

It can be used up to an oscillation frequency of about 16mHz and comes as a standard 40 pin package.

It has flash memory of 8 kilobytes and data memory of 368 bytes.

It includes an EEPROM data memory of 256bytes.

It has five input/output ports labeled as ports A, B, C, D and E.

It has temperature range between -40^0 to 85^0C. It has 13 – bit program counter capable of addressing an 8kilobyte and 14 – byte program memory device.

The PIC 16F877 is a 33 input/output device which means it has 33 inputs and outputs. The inputs and outputs can be configured in any combination, i.e. 13 inputs, 20 inputs, 18 inputs, 15 outputs etc. These inputs/outputs are connected to outside world through registers called ports. As stated earlier, it has five ports, PORT A, PORT B, PORT C, PORT D and PORT E.

PORT A is a six – bit wide and bi-directional port. As shown in figure 2.2, it consists of RA_0, RA_1, RA_2, RA_3, RA_4 and RA_5 on pin numbers 2, 3, 4, 5, 6 and 7 respectively. Same ports are multiplexed with friction. For example RA_4 is multiplexed with timer 0 module clock input to become RA_4/Tock 1 pin. Other PORT A pins are multiplexed with analog input and analog V_{REF} i.e. (Voltage reference) input for both the Analog to Digital converters and the comparators.

PORT B is an eight – bit wide and bi-direction port. It consists of RB_0, RB_1, RB_2, RB_3, RB_4 RB_5 RB_6 and RB_7 on pin numbers 33, 34, 35, 36, 37, 38, 39 and 40 respectively. Three pins of PORT B are multiplexed with in – circuit debugger and low voltage programming function: RB_3/PGM, RB_6/POC and RD7/PGD. These functions are part of special function registers (SFF).

PORD C is also an eight bit wide and bi-directional port. It consists of RC_0, RC_1, RC_2, RC_3, RC_4, RC_5, RC_6 and RC_7 on pin numbers, 15, 16, 17, 18, 23, 24 25 and 26 respectively.

In the same way, PORT C is also multiplexed with several peripheral functions such as Schmitt Trigger inputs buffers.

PORT D is also an eight bit wide port with Schmilt trigger inputs buffers and also bi-direction that is each pin is individually configurable on an input or output. It consist of RD_0, RD_1, RD_2, RD_3, RD_4, RD_5, RD_6 and RD_7 on numbers 19, 20, 21, 22, 27, 28, 29 and 30 respectively.

PORT E has only three pins REO RE_1 and RE_2 on pin numbers 8, 9, and 10 respectively. These pins have schmilt trigger input buffers. It is also a bi-directional. [6, 7]

2.6 Temperature Sensors (LM35)

The LM 35 are precision integrated – circuit temperature servers, whose output voltage is linearly proportional to the Celsius (centigrade) temperature. The LM35 has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. The LM35 does not require any external calibration or trimming provided typical accuracies of 1¼^{0}C at room temperature and 1¾^{0}C over a full -55 to +150^{0}C temperature range. The LM35's low output impedance, linear output and precise inherent calibration make interfacing to readout or control circuitry especially easy.

However, LM35 has the following advantages:

Low cost due to water-level trimming

It operates from 4 to 30 volts.

It is suitable for remote applications.

It has a low impedance output, 0.1 for 1mA load low self-heating, 0.8^{0}C in still air. [8]

2.7 BT139 General Description

Glass passivated triacs in a plastic envelope, intended for use in application requiring high bi-directional transient and blocking voltage capability and high thermal cycling performance. Typical applications include motor control, industrial and domestic lighting, heating and static switching.

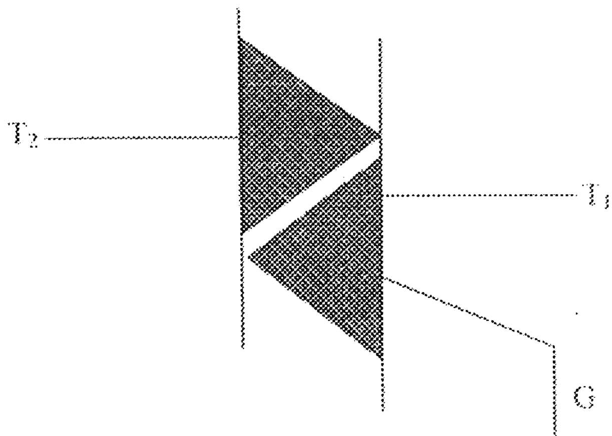

Figure 2.3 BT139 Pin Configurations

Where T_1 and T_2 are the terminals 1 and 2 respectively. G is the gate. [9]

2.8 LIGHT DEPENDENT RESISTORS (LDRs)

Two Cadmium Sulphide (Cds) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch and burglar alarm systems.

Circuit symbol

Figure 2.4 Light Dependent Resistor.

Light dependent resistors (LDRs) have a particular property so that they remember the lighting conditions in which they have been stored. This memory effect can be minimized by storing the LDRs in light prior to use. Light storage reduces equilibrium time to reach steady resistance values. [10]

2.9 Dual Seven-Segment Display

Seven-segment display consists of seven LEDs that are arrayed such that they form a digit 8. It is housed in a typical dual-line integrated circuit package as shown in figure . Dual seven segment is a two seven-segment in one package mainly used for two digits display.

By energizing the proper pins with a typical 2V DC level a number of LEDs can be energized and the desired numerical or alphabets displayed. The pins can be identified directly using data sheet or by the use of multimeter. Most seven-segment displays are either common anode or common cathode displays with the anode referring to defined positive ide of each diode and the cathode referring to the negative side. [11]

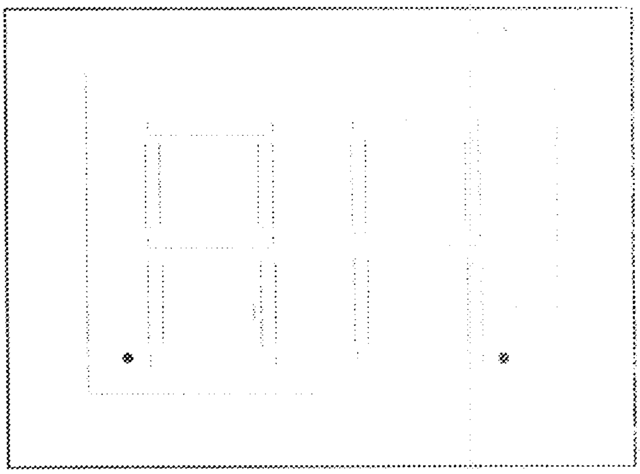

Figure 2.5 Dual Seven-Segment Display

CHAPTER THREE

DESIGN AND ANALYSIS

3.1 Introduction

The block diagram of the design is as shown below for analysis purpose.

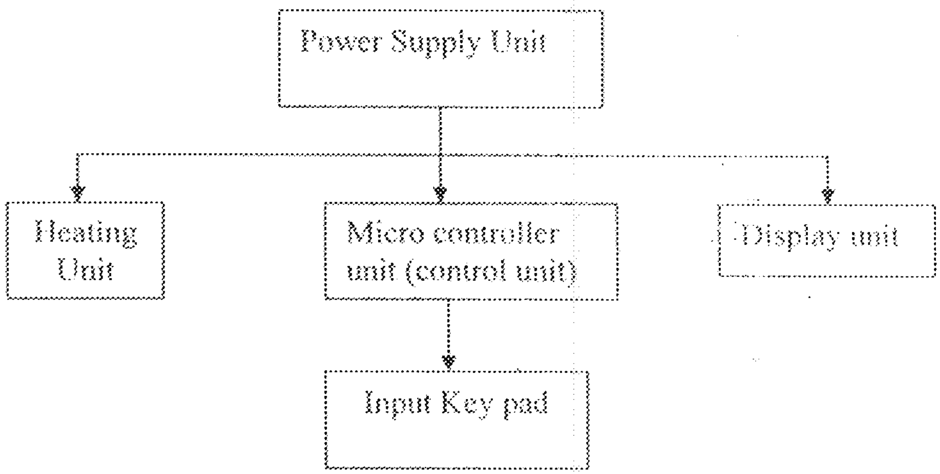

Fig. 3.1 Analysis Block diagram

3.2 Power Supply Unit

The power supply unit consists of 220/9V step-down transformer, bridge rectifier, filter and LM 7805 for the purpose of regulation. The power supply unit is as shown.

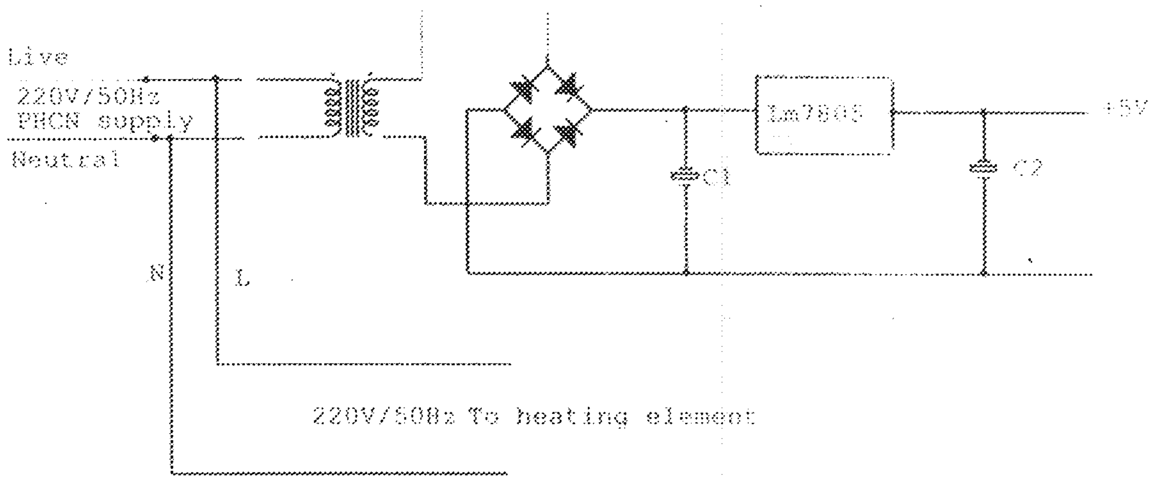

Figure 3.2 power supply unit

The figure 3.2 above shows the entire power supply unit, the 220V/50Hz is connected directly to the heating unit of the circuit and also there is output voltage of constant 5V from LM7805 for microcontroller and other components.

From the diagram above, after the stepping down of 220V to 9V, the bridge rectifier converts the ac voltage to dc voltage.

The capacitor C_1 connected is for the purpose of filtering transformer secondary voltage, root mean square value.

$V_2 = 9V$

Let the transformer peak voltage $=$ V_0

Root mean square value of current I = 1000mA (transformer rating)

$V_0 = \sqrt{2} \times V_2$ ... (3.1)

$V_0 = \sqrt{2} \times 9V = 12.73V$

V_d = diode voltage drop

Typically $V_d = 0.6 - 0.7V$, but let $V_d = 0.7V$

Now for fullwave bridge rectification.

V_{dt} = output voltage

$V_{dc} = 2 \times V_d = 2x0.7 = 1.4V$

Total output voltage

$$V_{dc} = \frac{2V_0}{\pi}$$

And Vo = 12.73V

$$V_{dc} = \frac{2 \times 12.73}{\pi} = 8.10V$$

Applying the KVL to the first loop of the low voltage side of the transformer

$V_0 = V_{dc} + V_{dr} + \Delta V$ ... 3.3

Where $\Delta V = V_0 - V_{dc} - V_{dr} = 12.73 - 8.10 - 1.40$

$\Delta V = 3.23V$

$i = C \frac{dv}{dt}$ ... 3.4

$dv = \frac{i}{c} dt$ ... 3.5

$dt = \frac{1}{2f}$ ... 3.6

$dv = \frac{i}{2fc}$ ... 3.7

$C = \frac{i}{2f\Delta v}$ ... 3.8

i = 1.0A, f = 50Hz (PHCN Supply) and ΔV = 3.23V

$c = \frac{1.0}{2 \times 50 \times 3.23} = 3.09 \times 10^{-3} F$

c = 3090µF

Therefore 3900µF capacitor was used in the value of C_1 due to market unavalability.

The LM7805 was used as regulator to stabilize the output voltage of 5V [12]. The voltage input to the LM7805 is V_{dc} = 8.10V and the current supply is 1A.

If the output voltage of LM7805 is 5V

Voltage across the regulator

$V_L = V_{dc} - V_{out} = 8.10 - 5 = 3.10V$

Power dissipated = IVL = 1.0 x 3.10V = 3.10watts.

The power dissipated is not much, so ventilation will be provided in the design.

The capacitor C_2 connected to prevent any high frequency component and acts basically on a line filter to improve transient response.

3.3 Microcontroller Units

The hardware that microcontroller needs to be function is as shown figure3.3:

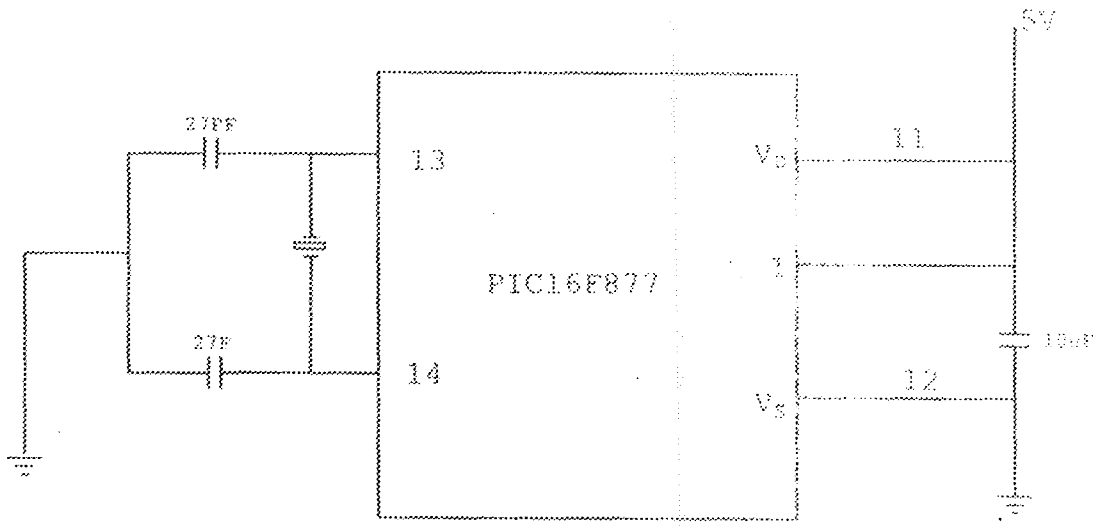

Fig. 3.3 Microcontroller Hardware

The crystal and capacitor connected as shown above produce clock pulse that regulates time. The 10µF capacitor places between 5V and 0V is to divert any electrical noise in the 5V supply to zero.

The power supply of the microcontroller needs to be between 2 – 5V from the data sheet for this project and effective operation, 5V supply is used.

The clock is needed for ease movement of data. The crystal used for this project is 4MHz, i.e. standard configuration, and capacitor beside 27pF [7,13].

The higher the capacitance value, the higher the stability of the micro controller.

The microcontroller full unit is shown in figure 3.4 below:

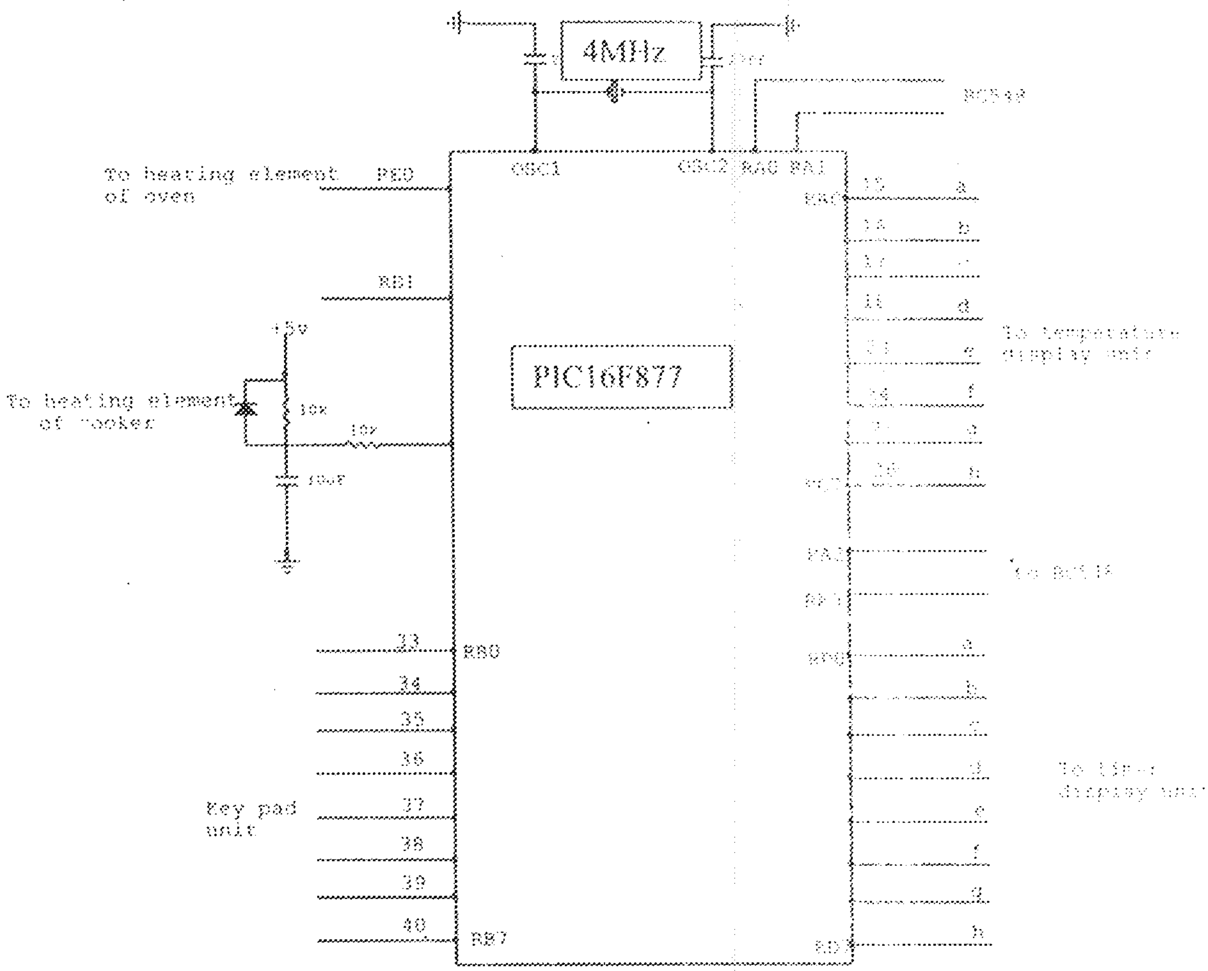

figure 3.4 full microcontroller unit

3.4: Keypad Units

The keypad unit is used to select either oven or cooker or both and also enter desired temperature and time.

The diagram is as shown in figure 3.5 below:

1	2	3	4
5	6	7	8
9	0	ON	OFF
OVEN	COOKR	TIME	TEMP

Figure 3.5: Keypad

The design is as shown in figure 3.6 below:

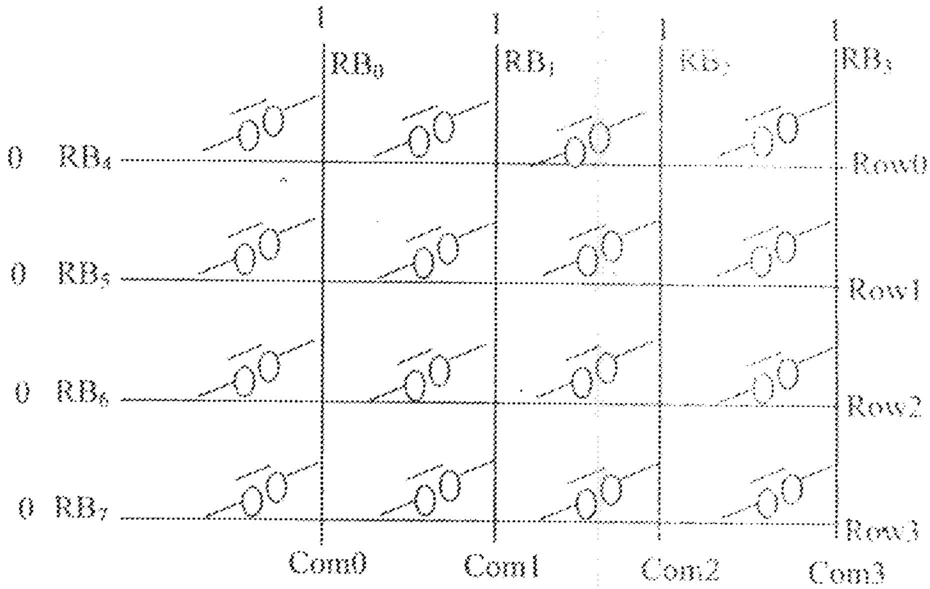

Fig. 3.6 Keypad design

As shown above, all the columns are connected to RB_0, RB_1, RB_2 and RB_3 of PORT B as shown and were made high (i.e. logic one) and Row0, Row1, Row 2, Row 3 were connected to RB_4 to RB_8 of PORT B respectively and were at low level. Whenever any key is pressed, their corresponding row will go high and send the signal to the microcontroller for appropriate action. For instance, if ON is pressed row 2 and column 2 will be connected and thus make row 2 to be high and send to the microcontroller i.e.

PORT B =	1	1	1	1	0	0	1	0
	RA_0	RA_1	RA_2	RA_3	RA_4	RA_5	RA_6	RA_7

This is how other keys are processed and appropriate action is taken based on the program or software developed in the microcontroller.

3.5 Display Unit

The display units, which consists of temperature display unit and time display unit [14, 15].

As shown in fig. 3.4 PORT C and PORT D were connected to display segments (a – h) of the dual segment display.

The two display units are the same as shown in figure 3.7 below:

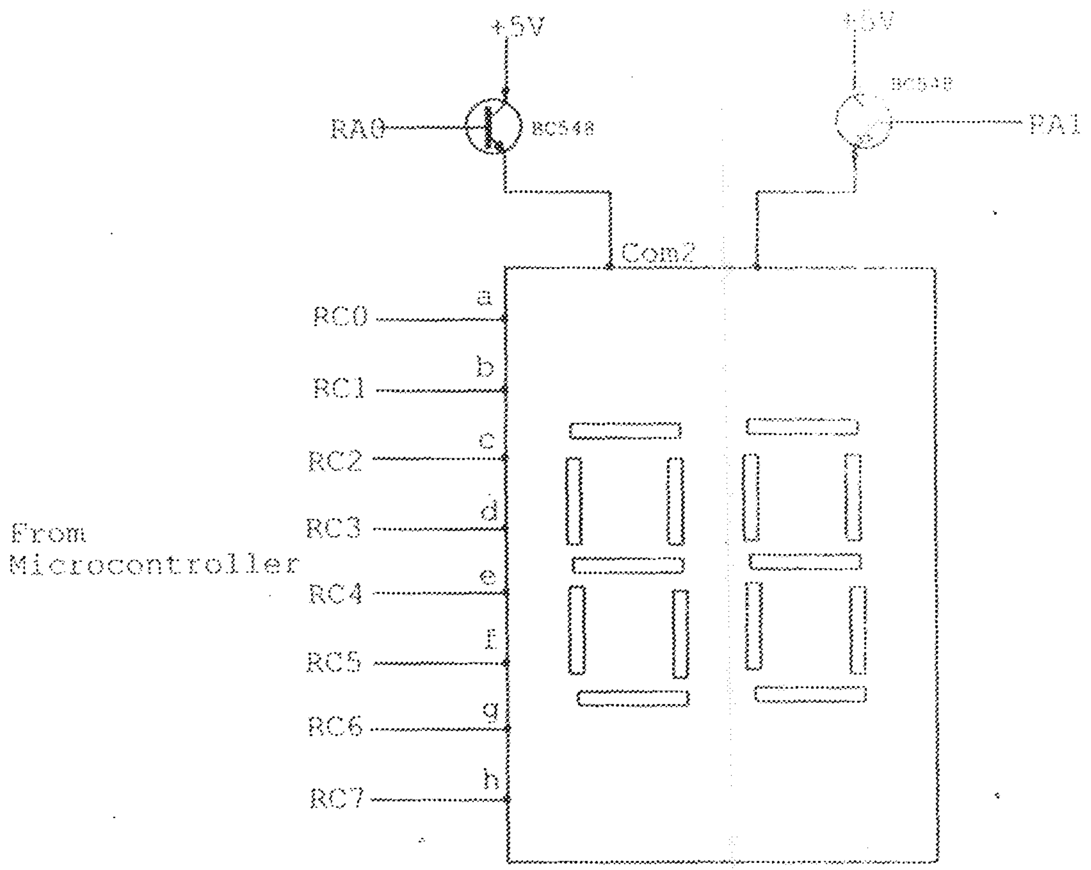

Fig 3.7 Temperature display unit

When temperature is selected from the keypad, RA_0 and RA_1 are activated from the microcontroller to make the two seven segment to ON and display default units.

The current source from the microcontroller is not more than 25mA which is insufficient to drive the segment display. A BC548 amplifying transistor is used as interfaced which was configured as emitter follower as shown.

The single seven segment display consists of seven LEDs with specification of 2v/10mA relay each, forming each segment [14].

The typical seven segments display and the truth table is as shown in figure 3.8 (a) and 3.8 (b) below:

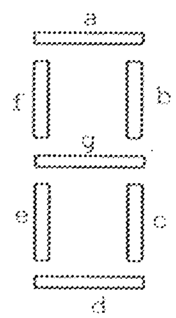

Figure 3.8(a) seven segment display

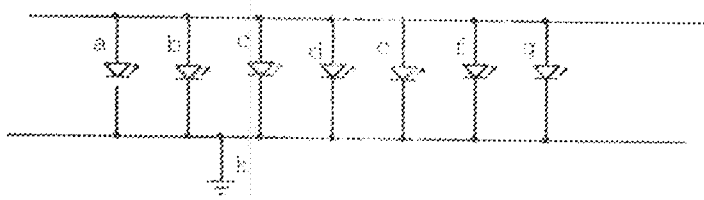

Figure 3.8 (b) common cathode

Table 3.1 Seven-Segment display truth table

Output display		Logic state							Hex
	a	b	c	d	e	f	g	h	
0	1	1	1	1	1	1	0	0	3F
1	0	1	1	0	0	0	0	0	06
2	0	1	0	1	1	0	1	0	5A
3	1	1	1	1	0	0	1	0	4F
4	0	1	1	0	0	1	1	0	66
5	1	0	1	1	0	1	1	0	6D
6	1	0	1	1	1	1	1	0	7D
7.	1	1	1	0	0	0	0	0	07
8	1	1	1	1	1	1	1	0	7F
9.	1	1	1	1	0	1	1	0	6F

Whenever any of the numbers is displayed, it implies that the corresponding hexadecimal value has been sent from microcontroller. When the key is pressed, for instance, one is pressed, it first appears on the second segment, if another number is pressed, it will display on the first unit.

3.6 Sensor Unit

The sensor unit consists of LM35 that is connected to RE_2 of the microcontroller. The sensor is placed inside the oven to sense the temperature and display it on temperature display unit when an oven is selected. This is called default temperature.

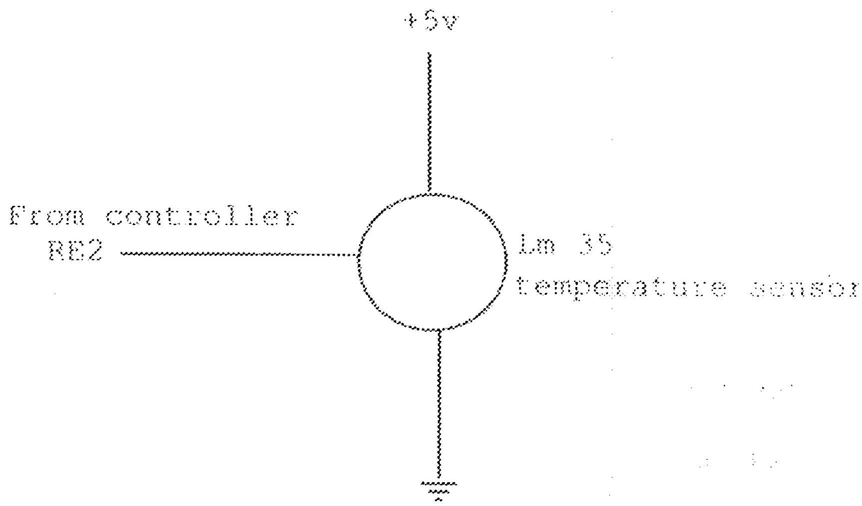

Figure 3.9 Sensor Unit

3.7 Heating Unit

The heating units consist of cooker and oven units controlled by triac (BT139) with light dependent resistor (LDR) as shown in figure 3.9 below:

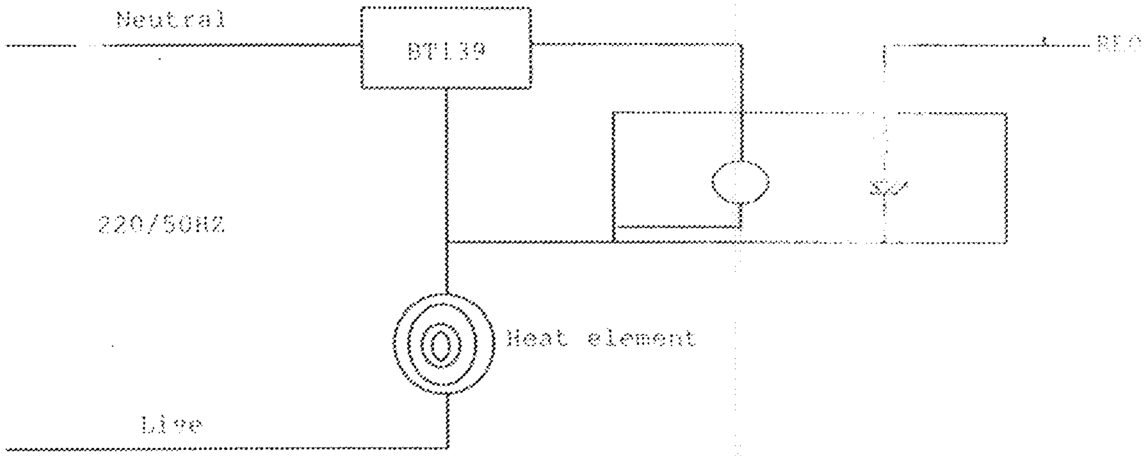

Fig 3.10 The Heating Unit

The heating unit consist of triac (BT139), heating element, light dependent resistor, (LDR), light emitting diode, (LED) cable size of $6mm^2$ was used for supply. 220/50Hz to the heat element boned one the IEEE standard [5].

The LDR and LED cover with black material. The triac connects to the heating element joining, the one of the LDR terminal by its gate terminal G. When a peak gate current, Igm of 2A and triac responded to both negative and positive at the anode. The terminal T_1 of the triac is connected to the neutral wire of the supply and T_2 is connected to light dependent resistors [10].

For the cooker unit, the light emitting diode (LED) is connected to the RE0 (PORT E, 0) of the microcontroller while for oven unit, it is connected to RE_1. The same design as shown above. As explained in chapter two, the PORT E. is a bi-directional PORT which is mainly used for Schmitt trigger [7].

Where the oven is selected, the RE_0 is set high and low and the speed of the high and low depend on the amount of temperature selected as shown in figure 3.10 below:

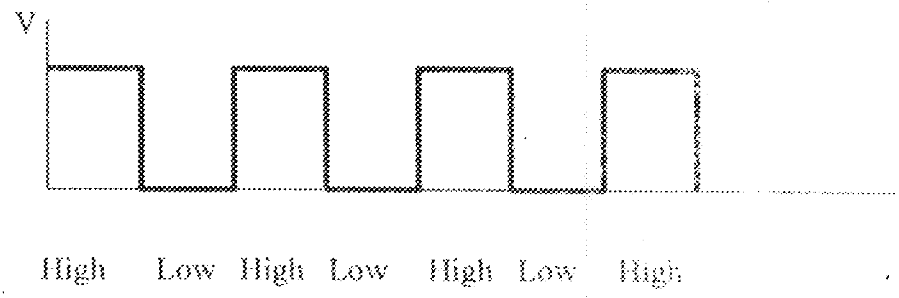

Figure: 3.11 Pulse generated by Microcontroller

When the RE_0 is high, LED give light which is directly to light dependent resistor and complete the circuit of heating element and BT 139. The triac control the cooker by switching ON and OFF during the positive and negative half-cycles of the input waveform as shown in figure 3.11 below:

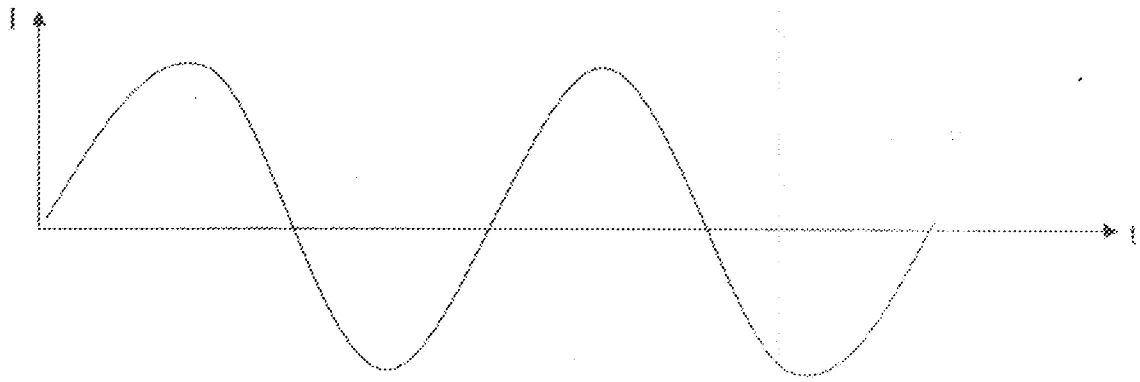

Fig 3.11 Voltage Output by Triac

The speed at which LED ON and OFF has been programmed based on the temperature required. The same design as explained above also applicable to cooker unit.

3.8 Programming the Microcontroller

The algorithm of the program is shown below:

Step 1: Switch on the

Step 2: Select the cooker

Step 3: Enter the temperature

Step 4: Enter the temperature unit

Step 5: Select the time

Step 6: Enter the time unit

Step 7: Repeat step 2 – 6 if oven is to be used by selecting oven at step 2, otherwise.

Step 8: End

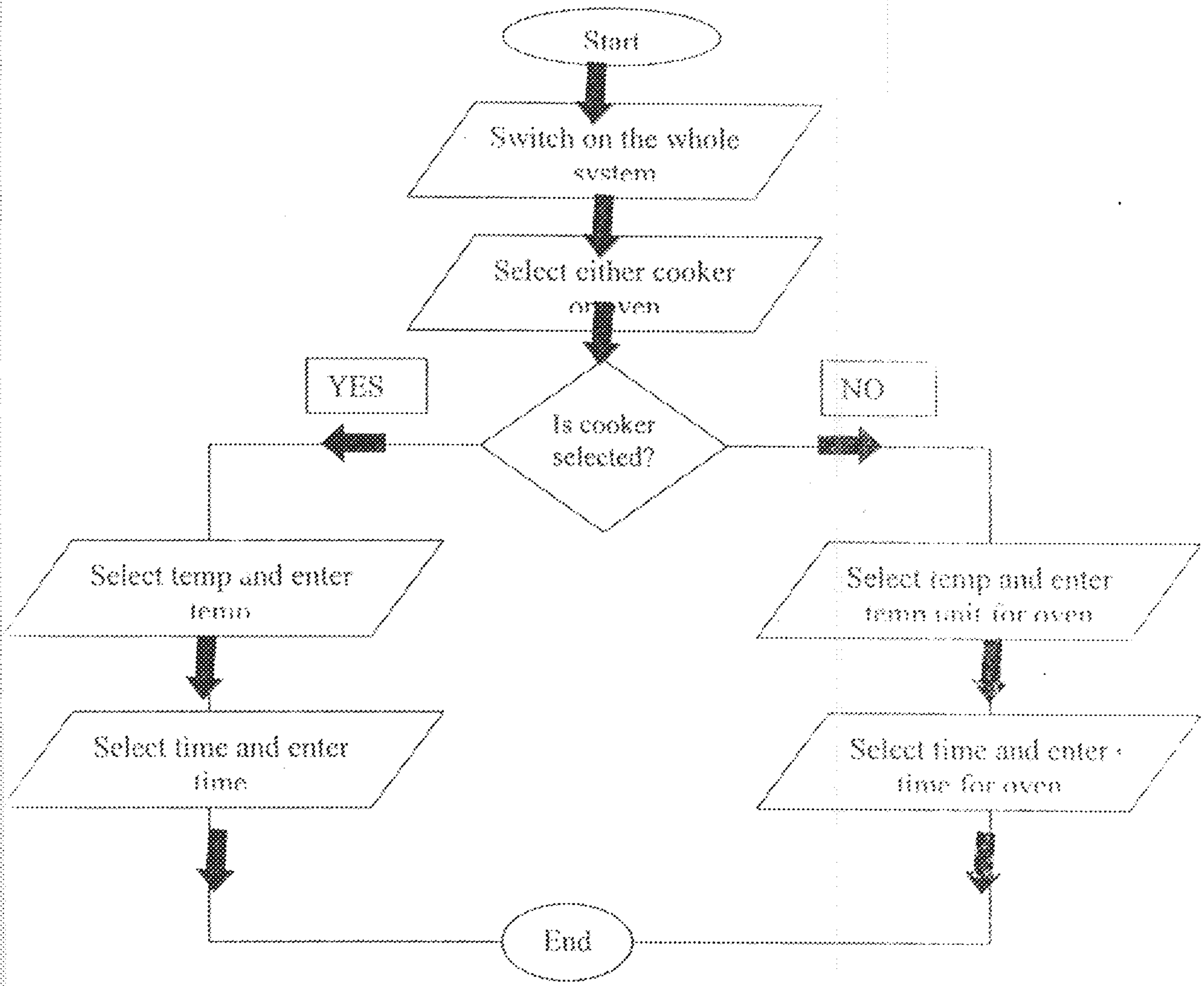

Fig 3.12 The flow chart

This program was written based on instruction set of PIC16F877 microcontroller and its detail is shown in appendix.

CHAPTER FOUR

4.0 CONSTRUCTION, TESTING AND PERFORMANCE ANALYSIS

4.1 Construction

The prototype construction of each unit (power supply units, control unit (microcontroller), display units and heating units) was carried out based on the development of the design.

For power supply unit and control unit which consists of microcontroller, light dependent resistor (LDR), light emitting diode (LED), crystal oscillator and keypad were carefully dipped in the holes of the Vero-board (10cm by 11cm). The two display units of temperature and time were forced to the tinted glass for the visuality.

The heating units consisting of oven and cookers were arranged in a box of dimensions 26cm x 26cm x 20cm. The heating element of the cooker was placed on the box which was supported by 26 cm thick clay and lagged to prevent radiation of heating to the oven unit which is housed inside the box.

In the oven unit, the heating element was placed below the metal and oven is placed on it.

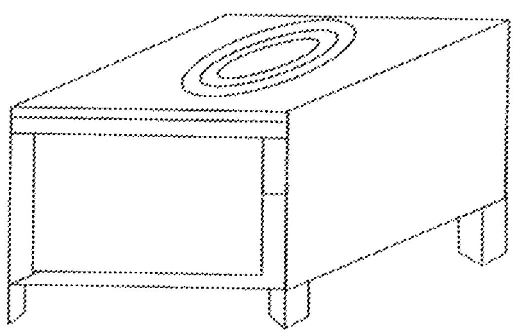

Fig. 4.1 Heating Unit

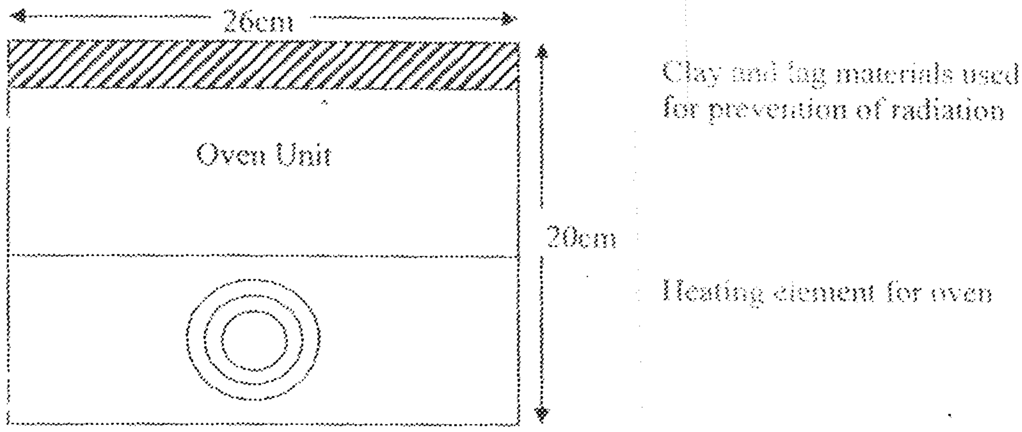

Fig. 4.2 Sectional view of oven unit

The multimeter was used to the continuity of each connection. Some observations were made and necessary modifications were carried out.

4.2 TESTING AND INTERFACING

After all the integrated circuits and other components have fixed on vero-board and the workability of each unit was ensured through testing, the followings were carried out after permanent circuiting.

4.2.1 Continuity Testing

With the aid of digital multimeter all the units and each component were tested individually. All terminals connected to the same port e.g. Vcc and ground were confirmed.

4.2.2 Performance Testing

The operational performance of each individual unit was tested. All the units especially the power supply unit was tested and then the expected output voltage was mounted using multimeter.

After testing the electric cooker, it was then connected to the supply and the time taken for the selected foods were taken and tabulated below.

Table 4.1 Time Taken for cooker

Food Sample	**Time Taken (minutes)**
1 milk tin of beans	20
1 milk tin of rice	10
Yam	15

Table 4.2 Time and Temperature by the Oven

Food Sample	Time Taken (min)	Temperature Setting
Bread(1kg)	25	35°C
Cake(1kg)	30	35°C
Fish (1kg)	25	35°C

4.2.3 Simulation

The users to check the operational performance of the microcontroller, the programme were simulated to show the real performance before programming into the microcontroller. Several simulations and debugging were carried out before actualizing the correct codes. Various manipulations and modifications were done until the exact output was achieved.

The modifications involved correcting syntax errors, changing resistor values, until optimum performance was reached.

4.4 Packaging and Casing

The plastic tinted glass was used to house the microcontroller, and other control elements such as light dependent resistor (LDR), the triac (BT139), power supply units for the microcontroller, keypad and display units for both timer and temperature.

The bottom of the keypad was arranged for easy access and identification. The holes were drilled at the end to provide cooling for the heat transfer. The casing was tight with bolts and nuts for durability.

The dimension of the casing is 13cm by 12cm by 4.5cm for portability.

The box used for housing the cooker and oven units is made from aluminum metal and painted iron metal to reduce the weight and at the same time conductivity.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

The project has been highly challenging its implementation was very interesting. All the hardware, the software, display unit, and others were completely achieved. It worth mentioning that sequel to the completion of this project great engineering knowledge had acquired both practically and theoretically.

The use of that versatile and electronic made simple chip, the microcontroller to accomplish easily some seemingly difficulty and tedious projects was understood.

5.1 RECOMMENDATION

1. The time and temperature programmable electric oven is recommended for every home to avoid the risk of electric hazards, which is always caused by the failure of conventional ones to switch off automatically when the user forget to put it off.

2. Also, since developed cooker is cost effective, is recommended for mass production. Large production could reduce further cost of production.

3. To the user: it is advised not to put the timer in menial overrides as this will defeat the purpose of the timer. If the food is envisaged to take a long time, the time can be set to maximum. If the food is yet to be completely cooked when the timer switch off, the user can start and reset the timer to a reduced time to finish the cooking.

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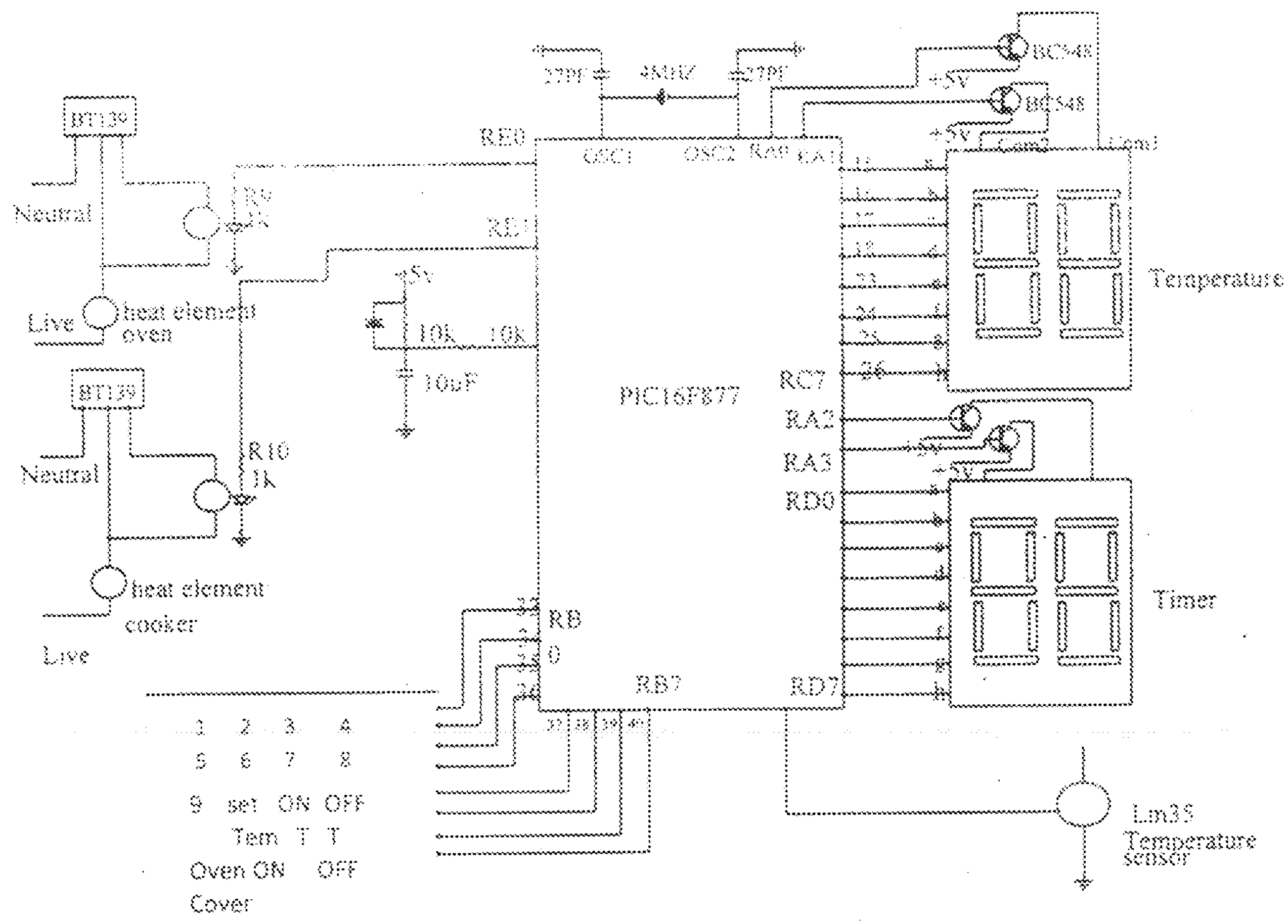
BILL OF ENGINEERING MEASUREMENT AND EVALUATION

S/No	Description of Materials	Quantity	Rate per Unit	Amount #
1	Step down transformer	1	300	300
2	Diode	10	30	300
3	Capacitors	6	20	120
4	Resistors	10	10	100
5	Opto Coupler	4	200	800
6	Transistors	8	40	320
7	Oven elements	1	1000	1000
8	Cooker elements	1	1000	1000
9	Switch	2	250	500
10	Soldering lead (small)	1	400	400
11	Micro controller	1	4000	4000
12	Seven segment display	4	200	800
13	Temperature Sensor	1	150	150
14	Keypad	2	150	300
15	$16mm^2$	2m	200	400

16	Metal plate	1 sheet	1200	1200
17	15 Amps	1	200	200
18	Welding		2000	2000
19	Panting	1	1000	1000
20	Regulator	2	150	300
21	Transportation		7000	7000
22	Wood		200	200
23	Circuit Casing	10 by 5m	450	450
24	Crystal	2	500	1000
25	Ceramic	1kg	350	350
26	Triac	2	100	200
27	Consultancy		5000	5000
TOTAL				29290



BT139
Neutral
R9
1k
Live
heat element
oven
BT139
Neutral
R10
1k
heat element
cooker
Live
RE0
RE1
+5v
10k
10k
10uF
27PF
4MHZ
27PF
OSC1
OSC2
RA0
RA1
BC548
BC548
+5V
PIC16F877
RC7
RA2
RA3
RD0
RD7
RB
0
RB7
Temperature
Timer
Lm35
Temperature
sensor
1 2 3 4
5 6 7 8
9 set ON OFF
Tem T T
Oven ON OFF
Cover

APPENDIX D

OVEN.ASM

```
TRISA EQU 85H
TRISB EQU 86H
TRISC EQU 87H
TRISD EQU 88H
TRISE EQU 89H
PORTA EQU 05H
PORTB EQU 06H
PORTC EQU 07H
PORTD EQU 08H
PORTE EQU 09H
ADCON1 EQU 9FH
ADCON0 EQU 1FH
GODONE EQU 2
ADRESL EQU 9EH
ADRESH EQU 1EH
INTCON EQU 0BH
STATUS EQU 03H
OPT EQU 81H
TMR0 EQU 01H
STOREW EQU 20H
STATE EQU 21H
OVENO EQU 22H
COOKO EQU 23H
TOSTATE EQU 24H
TCSTATE EQU 25H
COUNTO EQU 26H
COUNTC EQU 27H
KEYVAL EQU 28H
KEYPR EQU 29H
OVAL EQU 2AH
CVAL EQU 2BH
TOVAL EQU 2CH
TCVAL EQU 2DH
TMVAL EQU 2EH
GSTATE EQU 2FH
GSTATE1 EQU 30H
RESTOA EQU 31H
RESTOB EQU 32H
RESTMA EQU 33H
RESTMB EQU 34H
RESTCA EQU 35H
RESTCB EQU 36H
SEOVAL EQU 37H
DCOUNT EQU 38H
DVALA EQU 39H
DVALB EQU 3AH
DVALC EQU 3BH
DVALD EQU 3CH
GCOUNT EQU 3DH
RELTAA EQU 3EH
RELTAB EQU 3FH
TEMP EQU 40H
TEMP1 EQU 41H
TEMP2 EQU 42H
TEMP3 EQU 43H
ALARM EQU 44H
```

```
ALARMC       EQU   45H
ALARMA       EQU   46H
ALARMCA      EQU   47H
COUNTOA      EQU   48H
       LIST  P=16F877
       ORG   0
       GOTO  START
       NOP
       NOP
       NOP
INT
       MOVLW 0X83
       MOVWF TMR0
       MOVWF STORSW
       CALL  DISPLAY
       CALL  KEY1
       CALL  KEY2
       CALL  KEY3
       CALL  KEY4
       CALL  KEY5
       CALL  KEY6
       CALL  KEY7
       CALL  KEY8
       INCF  GCOUNT,F
       MOVF  GCOUNT,W
       SUBLW 0XFA
       BTFSC STATUS,2
       CALL  INT2
       MOVF  STORSW,W
       BCF   INTCON,2
       RETFIE
ADC
       CLRF  RESTAA
       CLRF  RESTAB
       BANKSEL     ADRESL
       RLF   ADRESL,F
       BANKSEL     ADRESH
       RLF   ADRESH,F
       MOVF  ADRESH,W
READC
       MOVWF TEMP3
       MOVLW 0X0A
       SUBWF TEMP3,W
       BTFSS STATUS,0
       GOTO  ADC1
       INCF  RESTAB,F
       GOTO  READC
ADC1
       MOVF  TEMP3,W
       MOVWF RESTAA
       BCF   ADCON0,GODONE
       RETURN
INT2
       CALL  EXE1
       CALL  EXE2
       CALL  EXE3
       CALL  EXE4
       CALL  EXE5
```

```
        CLRF  GCCUNT
        CALL  DEC1
        CALL  DEC2
        CALL  ALAM
        CALL  ALAM2
        BTFSS ADCON0,GODONE
        CALL  ADC
        RETURN
ALAM
        BTFSC ALARM.0
        GOTO  ALAMA
        CLRF  ALARMC
        RETURN
ALAMA
        INCF  ALARMC,F
        MOVF  ALARMC,W
        SUBLW 0X14
        BTFSS STATUS,2
        RETURN
        BCF   PORTE,0
        CLRF  ALARM
        RETURN
ALAM2
        BTFSC ALARMA,0
        GOTO  ALAMA2
        CLRF  ALARMCA
        RETURN
ALAMA2
        INCF  ALARMCA,F
        MOVF  ALARMCA,W
        SUBLW 0X14
        BTFSS STATUS,2
        RETURN
        BCF   PORTE,1
        CLRF  ALARMA
        RETURN
DEC1
        BTFSS TOVAL,0
        RETURN
        INCF  COUNTO,F
        MOVF  COUNTO,W
        SUBLW 0X3C
        BTFSS STATUS,2
        RETURN
        CLRF  COUNTO
        MOVF  RESTOA,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  DEC1A
        MOVF  RESTOB,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  DEC1B
DEC1AA
        CLRF  OVAL
        CLRF  TOVAL
        BSF   ALARM,0
        BSF   PORTE,0
```

```
        BTFSC GSTATE,0
        GOTO  DEC1C
        BTFSC GSTATE,2
        GOTO  DEC1C
        RETURN
DEC1A
        DECF  RESTOA,F
        MOVF  RESTOA,W
        SUBLW 0X00
        BTFSS STATUS,2
        RETURN
        MOVF  RESTOB,W
        SUBLW 0X00
        BTFSS STATUS,2
        RETURN
        GOTO  DEC1AA
DEC1B
        DECF  RESTOB,F
        MOVLW 0X09
        MOVWF RESTOA
        RETURN
DEC1C
        BSF   PORTA,5
        RETURN
DEC2
        BTFSS TCVAL,0
        RETURN
        INCF  COUNTC,F
        MOVF  COUNTC,W
        SUBLW 0X3C
        BTFSS STATUS,2
        RETURN
        CLRF  COUNTC
        MOVF  RESTCA,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  DEC2A
        MOVF  RESTCB,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  DEC2B
DEC2AA
        CLRF  CVAL
        CLRF  TCVAL
        BSF   ALARMA,0
        BSF   PORTE,1
        BTFSC GSTATE,1
        GOTO  DEC1C
        BTFSC GSTATE,4
        GOTO  DEC1C
        RETURN
DEC2A
        DECF  RESTCA,F
        MOVF  RESTCA,W
        SUBLW 0X00
        BTFSS STATUS,2
        RETURN
        MOVF  RESTCB,W
```

```
        SUBLW 0X00
        BTFSS STATUS,2
        RETURN
        GOTO  DEC2AA
DEC2B
        DECF  RESTCB,F
        MOVLW 0X09
        MOVWF RESTCA
        RETURN
KEY1
        BCF   PORTB,3
        BTFSS PORTB,4
        GOTO  KEY1A
        BTFSS PORTB,5
        GOTO  KEY1B
        BSF   PORTB,3
        RETURN
KEY1A
        BCF   STATE,0
        MOVLW 0XFC
        MOVWF PORTA
        BTFSC OVAL,0
        BCF   PORTA,5
        BSF   PORTB,3
        CLRF  TOSTATE
        MOVLW 0X01
        MOVWF GSTATE
        CLRF  GSTATE1
        RETURN
KEY1B
        BSF   STATE,0
        MOVLW 0XFA
        MOVWF PORTA
        BTFSC CVAL,0
        BCF   PORTA,5
        BSF   PORTB,3
        CLRF  TOSTATE
        MOVLW 0X02
        MOVWF GSTATE
        CLRF  GSTATE1
        RETURN
KEY2
        BTFSC STATE,0
        RETURN
        BCF   PORTB,3
        BTFSS PORTB,6
        GOTO  KEY2A
        BTFSS PORTB,7
        GOTO  KEY2B
        BSF   PORTB,3
        RETURN
KEY2A
        BSF   PORTA,4
        BCF   PORTA,3
        MOVLW 0X01
        MOVWF TOSTATE
        BCF   PORTA,5
        BTFSC TOVAL,0
```

```
        BCF    PORTA,5
        BSF    PORTB,3
        MOVLW 0X04
        MOVWF CSTATE
        CLRF  CSTATE1
        RETURN
KEY2A
        BCF    PORTA,3
        BCF    PORTA,4
        MOVLW [illegible]
        MOVWF TCSTATE
        BCF    PORTA,5
        BTFSC TEVAL,0
        BSF    PORTA,5
        BCF    PORTB,3
        MOVLW 0X08
        MOVWF CSTATE
        CLRF  CSTATE1
        RETURN
KEY3
        BTFSS CSTATE,0
        RETURN
        BSF    PORTB,3
        BTFSC PORTB,6
        GOTO  KEY3A
        BCF    PORTB,3

KEY3A
        BCF    PORTA,3
        MOVLW 0X01
        MOVWF TCSTATE
        BCF    PORTA,5
        BTFSC TEVAL,0
        BSF    PORTA,5
        BCF    PORTB,3
        MOVLW 0X10
        MOVWF CSTATE
        CLRF  CSTATE1
        RETURN
KEY4
        BTFSS CSTATE,0
        RETURN
        BSF    PORTB,2
        BTFSC PORTB,6
        GOTO  KEY4A
        BTFSS PORTB,7
        GOTO  KEY4B
        BCF    PORTB,2
        RETURN
KEY4A
        CLRF  ALARM
        CLRF  ALARMC
        BCF    [illegible]VAL,0
        BCF    PORTB,[illegible]
        [illegible]
        RETURN
KEY4B
        CLRF  ALARM
```

```
        CLRF  ALARMC
        BCF   OVAL,0
        BSF   PORTB,2
        BSF   PORTA,5
        RETURN
KEY5
        BTFSS GSTATE,1
        RETURN
        BCF   PORTB,2
        BTFSS PORTB,6
        GOTO  KEY5A
        BTFSS PORTB,7
        GOTO  KEY5B
        BCF   PORTB,2
        RETURN
KEY5A
        CLRF  ALARMA
        CLRF  ALARMCA
        BSF   CVAL,0
        BSF   PORTB,2
        BCF   PORTA,5
        RETURN
KEY5B
        CLRF  ALARMA
        CLRF  ALARMCA
        BCF   CVAL,0
        BSF   PORTB,2
        BCF   PORTA,5
        RETURN
KEY6
        BTFSS GSTATE,2
        RETURN
        BCF   PORTB,2
        BTFSS PORTB,6
        GOTO  KEY6A
        BTFSS PORTB,7
        GOTO  KEY6B
        BCF   PORTB,2
        RETURN
KEY6A
        BSF   PORTB,2
        MOVF  RESTOA,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  KEY6AA
        MOVF  RESTOB W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  KEY6AA
        RETURN
KEY6AA
        BCF   TOVAL,0
        BCF   PORTA,5
        RETURN
KEY6B
        BCF   TOVAL,0
        BSF   PORTB,2
        BSF   PORTA,5
```

```
        RETURN
KEY7
        BTFSS GSTATE,3
        RETURN
        BCF   PORTB,2
        BTFSS PORTB,6
        GOTO  KEY7A
        BTFSS PORTB,7
        GOTO  KEY7B
        BSF   PORTB,2
        RETURN
KEY7A
        BSF   TMVAL,0
        BSF   PORTB,2
        BCF   PORTA,5
        RETURN
KEY7B
        BCF   TMVAL,0
        BSF   PORTB,2
        BSF   PORTA,5
        RETURN
KEY8
        BTFSS GSTATE,4
        RETURN
        BCF   PORTB,2
        BTFSS PORTB,6
        GOTO  KEY8A
        BTFSS PORTB,7
        GOTO  KEY8B
        BSF   PORTB,2
        RETURN
KEY8A
        BSF   PORTB,2
        MOVF  RESTCA,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  KEY8AA
        MOVF  RESTCB,W
        SUBLW 0X00
        BTFSS STATUS,2
        GOTO  KEY8AA
        RETURN
KEY8AA
        BCF   PORTA,5
        BCF   TCVAL,0
        RETURN
KEY8B
        BCF   TCVAL,0
        BSF   PORTB,2
        BSF   PORTA,5
        RETURN
[illegible]
        [illegible]
        [illegible]
        CALL  KEYCA
        BCF   PORTB,0
        BCF   PORTB,1
        CALL  KEYCB
```

```
        BSF   PORTB,1
        BCF   PORTB,2
        CALL  KEYCC
        BSF   PORTB,2
        RETURN
KEYCA
        BTFSS PORTB,4
        GOTO  ONE
        BTFSS PORTB,5
        GOTO  TWO
        BTFSS PORTB,6
        GOTO  THREE
        BTFSS PORTB,7
        GOTO  FOUR
        RETURN
KEYCB
        BTFSS PORTB,4
        GOTO  FIVE
        BTFSS PORTB,5
        GOTO  SIX
        BTFSS PORTB,6
        GOTO  SEVEN
        BTFSS PORTB,7
        GOTO  EIGHT
        RETURN
KEYCC
        BTFSS PORTB,4
        GOTO  NINE
        BTFSS PORTB,5
        GOTO  ZERO
        RETURN
ONE
        BSF   KEYPR,0
        MOVLW 0X01
        MOVWF KEYVAL
        RETURN
TWO
        BSF   KEYPR,0
        MOVLW 0X02
        MOVWF KEYVAL
        RETURN
THREE
        BSF   KEYPR,0
        MOVLW 0X03
        MOVWF KEYVAL
        RETURN
FOUR
        BSF   KEYPR,0
        MOVLW 0X04
        MOVWF KEYVAL
        RETURN
FIVE
        BSF   KEYPR,0
        MOVLW 0X05
        MOVWF KEYVAL
        RETURN
SIX
        BSF   KEYPR,0
```

```
        MOVLW 0X06
        MOVWF KEYVAL
        RETURN
SEVEN
        BSF   KEYPR,0
        MOVLW 0X07
        MOVWF KEYVAL
        RETURN
EIGHT
        BSF   KEYPR,0
        MOVLW 0X08
        MOVWF KEYVAL
        RETURN
NINE
        BSF   KEYPR,0
        MOVLW 0X09
        MOVWF KEYVAL
        RETURN
ZERO
        BSF   KEYPR,0
        CLRF  KEYVAL
        RETURN
EXE1
        BTFSS GSTATE,2
        RETURN
        CALL  KEYC
        BTFSC KEYPR,0
        GOTO  EXE1A
        RETURN
EXE2
        BTFSS GSTATE,3
        RETURN
        CALL  KEYC
        BTFSC KEYPR,0
        GOTO  EXE2A
        RETURN
EXE3
        BTFSS GSTATE,4
        RETURN
        CALL  KEYC
        BTFSC KEYPR,0
        GOTO  EXE3A
        RETURN
EXE1A
        MOVF  KEYVAL,W
        BTFSS GSTATE1,0
        MOVWF RESTOB
        BTFSC GSTATE1,0
        MOVWF RESTOA
        MOVF  GSTATE1,W
        XORLW 0X01
        MOVWF GSTATE1
        RETURN
EXE2A
        MOVF  KEYVAL,W
        BTFSS GSTATE1,0
        MOVWF RESTMB
        BTFSC GSTATE1,0
```

```
      MOVWF RESTMA
      MOVF  GSTATE1,W
      XORLW 0X01
      MOVWF GSTATE1
      RETURN
EXE3A
      MOVF  KEYVAL,W
      BTFSS GSTATE1,0
      MOVWF RESTCB
      BTFSC GSTATE1,0
      MOVWF RESTCA
      MOVF  GSTATE1,W
      XORLW 0X01
      MOVWF GSTATE1
      RETURN
EXE4
      BTFSC OVAL,0
      GOTO  EXE4B
      CLRF  COUNTO
      CLRF  COUNTOA
      BCF   PORTC,5
      RETURN
EXE4B
      MOVF  RESTMB,W
      MOVWF TEMP
      BCF   STATUS,0
      RLF   TEMP,F
      BCF   STATUS,0
      RLF   TEMP,F
      BCF   STATUS,0
      RLF   TEMP,F
      BCF   STATUS,0
      RLF   TEMP,F
      MOVF  RESTMA,W
      ADDWF TEMP,F
      MOVF  RESTAB,W
      MOVWF TEMP1
      BCF   STATUS,0
      RLF   TEMP1,F
      BCF   STATUS,0
      RLF   TEMP1,F
      BCF   STATUS,0
      RLF   TEMP1,F
      BCF   STATUS,0
      RLF   TEMP1,F
      MOVF  RESTAA,W
      ADDWF TEMP1,W
      SUBWF TEMP,W
      BTFSS STATUS,0
      GOTO  EXE5A
      MOVF  COUNTOA,W
      MOVWF TEMP
      INCF  COUNTOA,F
      SUBLW 0X00
      BTFSC STATUS,2
      GOTO  EXE5B
      BCF   PORTC,5
      MOVF  TEMP,W
```