Dedication

To the memory of my late elder sister SCHOLASTICA .A OBAJE, may her soul rest in perfect peace.

DESIGN AND CONSTRUCTION OF AN AUTOMATED TEMPERATURE MONITORING AND CONTROL SYSTEM FOR INDUSTRIAL COOKING DEVICES

BY

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A thesis submitted to the department of electrical and computer engineering, Federal University of Technology Minna, in partial fulfillment of the requirements for the award of bachelor of engineering (B.Eng) degree in electrical and computer engineering.

NOVEMBER, 2007.

Declaration

I OBAJE JOSEPH SAINT, 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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Acknowledgment

I return all the glory and honor to God almighty, whose protection, provision and mercies has been sustaining me through the years and made this day a reality. My profound gratitude goes to my parents, Chief and Mrs. A.A. OBAJE for their moral, financial and spiritual supports, my unquantifiable gratitude goes to my sisters Martina, AGATHA, DOROTHY, DORCAS and my only brother SOLOMON and not forgetting my little nephew APOCHI and my little angel OGBENE for their contributions. My special thanks go to my supervisor Mr. E. ERONU for his encouragement and support My special gratitude goes to my mentor Dr. M.A OBAJE and his family. I will be ungrateful if I don't acknowledge the contributions of my friends, FLORENCE(Miss), SEUN(Programmer), BOLAJI, JOY, EZINNE, HENRY(One door) and many others.

Abstract

This device is used for cooking/baking. When the system is powered, desired values of temperature and time at which baking is expected to be carried out are input into the computer via the user interface, and the system program is run and baking begins. The computer, with the aid of a specialized system application program, compares the values of the desired temperature and the system temperature. If these values are equal, the computer system sends control signal via the control lines of the parallel port to disconnect the heating element by energizing a relay connected to the heating element. When this is done, the system temperature tends to remain constant for a while and then begins to fall. Once the temperature falls slightly below the desired temperature, the computer sends control signal to the relay to reconnect the heating element and heating continues. This temperature monitoring and control process continues until the desired time at which baking is expected to be completed elapses.When this happens, power is permanently cut off from reaching the element and baking or cooking is over. In addition, the system makes provision for changing the values of the desired temperature and time. If the need to change the values of these parameters arises, the user (baker) simply clicks on the "change value" command button on the user interface and the process is immediately halted. He then enters his new values and clicks on the "OK" command button, and the system resumes the baking process.

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CHAPTER ONE

1.0 INTRODUCTION

The relevance and role of food in the daily life of man can not be overemphasized. It constitutes one of the major necessities in the life of man in addition to clothing and housing. Well prepared food provides man with supplements with the correct nutrients required to build the body in other to carry out its daily activities, promotes his health status and perhaps prolongs his life span. But the means of preparing, processing and preserving this food for man's consumption play a very important role as well. This has however led to the invention and subsequent introduction of diverse cooking devices or ovens, both for industrial and domestic use over the years.

In either case, however, heat is required to cook the food, and the most important parameter that required strict attention in such a process is the temperature. Providing an efficient means of measuring, monitoring, and controlling the applied temperature is therefore necessary to properly cook the food, while retaining all its vitamins in the correct proportions as well as maintaining its natural nutritional values for the well being of the consumers.

The development and introduction of various food processing ovens especially in the baking and confectionery industry and more recently, of the microwave ovens were measures put in place to ensure that the temperature at which foods are being cooked is measured and regulated appropriately. But, with advances in technology and increased demand by consumers, these devices have proved unreliable and inefficient since they make no provision for monitoring and controlling the temperature automatically; leading to the current huge wastages incurred in the food processing industry and even in homes.

Besides this. foods processed using most of the traditional and modern ovens, such as the microwave oven, are not safe for consumption as they pose a great deal of health danger to consumers. For instance, various publications resulting from researches about the operations of the microwave oven reveal that foods cooked in a microwave oven are not safe for consumption [1].

Concerned about the increasing wastages incurred currently in the food processing industry, especially in the baking and confectionery industry, resulting from inadequate means of monitoring and controlling the temperature of cooking devices, and the inefficiency on the part of man to accurately monitor such processes; have consequently resulted in immense loss of large sums of money, as well as the health threats posed to man by providing him with improperly cooked and unsafe food led me to conceiving, designing and subsequent implementation of a better device referred to as " Automated Temperature Monitoring And Control System For Industrial Cooking Devices".

This device, as the name implies, is computer software controlled which provides a more accurate and efficient means of monitoring and controlling the temperature of industrial cookers. It also provides means of timing the baking process as well as regulating the operating temperature between defined or set limits. It further makes provisions for changing the temperature and even time to suit the particular food being cooked and the interest of the cook or baker. To cook or bake with this device, the baker simply sets the temperature and time at which he wants to cook the food, and the cooking, monitoring, and control processes are automatically carried out by the device. It possesses the capability to monitor and control the process by switching off the source of power when the set time elapses.

1.1 STATEMENT OF THE PROBLEM

The decision to embark on this project is influenced by some prevailing problems, which traditional and modern ovens have failed to address over the years. Such problems include: Inaccurate means of temperature measurement and control of cooking devices, which have led to the huge wastages of food and confectioneries prevalent in the food industry which consequently results in loss of large sums of money. Other problems are the improper cooking of foods and confectioneries due to uneven temperature distribution in most traditional and modern ovens, and the health hazards associated with consuming microwave food.

1.2 PURPOSE OF THE STUDY

The purpose for which this project is embarked upon can be itemized as follows:

I).To provide a more accurate means of measuring and controlling the temperature of cooking devices especially for industrial applications. This prevents wastage of foods.

ii).To provides safer finished foods and confectioneries for consumption.

iii).To provide a means of timing the cooking or baking process for enhanced food production.

1.3 SIGNIFICANCE OF THE STUDY

This project work shall find wide applications and significant deployment in the baking and confectionery industry with the view of achieving the objectives of the study as outlined in the proceeding section.

It shall also be significant to researchers who are interested in breaking new grounds about the study, as well as for domestic use. It shall further find wide applications in the oil and gas industry for monitoring and controlling the temperature of such equipment as heaters, boilers, furnaces, compressors and other industrial heating devices.

1.4 SCOPE OF THE STUDY

This work can find varied application in research institutions, oil and gas industry, baking and confectionary industry, domestic use among others, but for the purpose of this investigation, we shall focus its application on the baking and confectionary industry.

1.5 LIMITATIONS OF THE STUDY

The conditions under which the research work was carried out were affected adversely by such limitations as finance and because of the vast nature of the topic under investigation, sourcing related materials for the literature review that narrowed down to the scope of the study also posed a serious limitation to the research work.

1.6 REPORT STRUCTURE

The project work is implemented in five chapters. This first chapter is basically an introduction, while chapter two reviews some related literatures, which provided the required sound theoretical base necessary for the research work. Whereas chapter three considers the various materials and methods employed in realizing this project, chapter four presents and analyzes the data, findings and result obtained. The project concludes in chapter five by presenting a summary of the main points raised in the body of the research work, make recommendations for further research.

CHAPTER TWO

LITERATURE REVIEW

This chapter is intended to provide a sound theoretical framework for the study. To achieve this, the principles of various ovens, analogue-to digital converters and temperature transducers are reviewed.

2.1 BRIEF HISTORY OF STOVES AND OVENS

There have been historical records of the existence of cooking devices like stoves and ovens many centuries ago. These devices served their purposes and solved the problems of cooking in their times. The first historical record of a stove being built refers to a stove built in 1490, in Alsace, France [2]. This stove was made entirely of bricks and tiles including. Just after this invention, cast iron stove was invented and used mostly in America. Around 1728, cast iron stoves really began to be made in quantity. These first stoves of German design are called fire-plate. Not too long from then, Benjamin Franklin (1706-1790) invented the iron furnace stove or 'franklin stove' whereas Frans Wilhelm Lindqvist designed the first sootless kerosene store. Jordan Mott invented the first practical coal stove in 1833. Motts stove was called the baseburner [2]. The stove had ventilation to burn the coal efficiently. British inventor, James sharp patented a gas stove in 1826, the first successful gas stove to appear on the market.

As time went by, further inventions were made due to the shortcomings of already existing inventions and the increasing advances in technology. On June 30, 1896 [3], William Hadaway went on to design the first toaster made by Wetinghouse, a horizontal combination toaster cooker. Perhaps, one of the greatest discoveries of cooking devices was the invention of microwave oven. The history of microwave oven is of great interest

:o us because the project design and implantation under consideration will be a reliable substitute for these ovens especially for industrial applications.

Like many of today's great inventions, the microwave oven was a by- product of another technology. It was during a radar-related project around 1946 that Dr Percy Spencer [3], a self-taught engineer with the Raytheon corporation, while testing a new vacuum tube called a magnetron, discovered that the candy bar in his pocket had melted. This intrigued Dr. Spencer, so he tried another experiment. This time he placed some popcorn Kernels near the tube and, perhaps standing a little farther away, he watched with an inventive sparkle in his eyes as the popcorn cracked and popped all over his lab.

Dr Spencer fashioned a metal box with an opening into which he fed microwave power. The energy entering the box was unable to escape, thereby creating a higher density electromagnetic field. When food was placed in the box and microwave energy fed in, the temperature of the food rose very rapidly. Dr. Spencer had invented what was to revolutionize cooking, and forms the basis of a multimillion dollar industry, the microwave oven.

2.1.1 Types of Ovens

An oven is the most important equipment for baking foods in the baking and confectionery industry [4]. They include;

- Hearth ovens: This kind of oven includes 1-4 levels with about 2-3 trays thick [4]. Each level is an independent oven since it is equipped with industrial steam producer, temperature regulator, timer and lighting.
- Conventional ovens: Conventional ovens apply heat from the bottom and as the heat rises, it creates different temperature areas or zones within the oven [5]. Hence, they

are often refereed to as zoned ovens. When operational, the hottest area is at the top, the centre is moderate while the coolest part is at its bottom.

- Fan Assisted Ovens: This type of oven operates like a conventional oven but the addition of a fan at the rear [5]. As the heat rises from the bottom, it is circulated by the fan to create a more even temperature distribution.

2.1.2 DEFICIENCIES OF MODERN OVENS

The theoretical and practical framework on which this work was conceptualized is based on providing a means of cooking and heating foods that is much better than using microwave oven as one of the most widely known modern ovens. Although modern ovens include both electrical and microwave oven and other types of oven previously mentioned, we shall in this section refer to modern ovens strictly as microwave oven. As such, the deficiencies to be discussed here are with regards to microwave oven, which historians say is the greatest discovery since fire [7]. The identifiable deficiencies of the microwave oven are discussed below:

- Uneven Heating: In a microwave oven, food is heated for so short a time that it is often cooked unevenly. Microwave ovens are frequently used for reheating previously cooked food, and bacterial contamination may not be killed by the reheating resulting in food borne illness. The uneven heating is partly due to the uneven distribution of microwave energy inside the oven, and partly due to the different rates of energy absorption in different parts of the food [6].

The first problem is reduced by a stirrer, a type of fan that reflects microwave energy to different parts of the oven as it rotates, and by a turntable or carousel that turns the food. It is also important not to place food or a container in the centre of a microwave's turntable. That actually defeats its purpose. Rather, it should be placed a bit off-center so that the items travels all around the area of oven's cooking cavity, thus assuring even heating.

The second problem must be addressed by the cook, who should arrange the food so that it absorbs energy and periodically test and shield any part of the food that overheats [6]. However much these techniques are employed, the problem of uneven heating cannot be completely solved in microwave ovens.

- In some materials with low thermal conductivity where dielectric constant increases with temperature, microwave heating can cause localized thermal runaway.
- Many microwaves ovens' performance drops after about 15 minutes of continuous usage, which means food takes longer to cook. When heating several meals, the last meal to be cooked may not be heated properly as a result.
- Defrosting is another common weakness, as many microwave ovens may start to cook the edges of the frozen food, while the inside of the food remains frozen [6].

2.1.3 PROVEN DANGERS OF MICROWAVE OVENS

i). Liquids when heated in a microwave oven in a container with a smooth surface can superheat [6]. The boiling process can start explosively when the liquid is disturbed, such as when the operator grabs hold of the container to take it out of the oven, which can result in severe burns.

ii). Tin foil, aluminum foil, ceramics decorated with metals, and products containing other metals can cause sparks when they are used in a microwave. This is because any metal or conductive object placed into the microwave will act as an antenna, absorbing microwave radiation. If the object is pointed, for example metal pork, the pointed ends will act to concentrate the electric field formed at the tips. This has the effect of exceeding the dielectric breakdown gradient of air, about $3x10^{o}$ v/m causing sparks to form [6].

Perhaps the most controversial hazard of microwaving foods is the health implications. Research operations conducted by German and Russian researchers reveal three main categories of this hazard [1]

Category 1: Cancer –causing effects

Category 2: Nutritive destruction of foods

Category 3: Biological effects of exposure

2.2 TEMPERATURE TRANSDUCERS

The temperature of a body or substance is defined as its thermal state considered with reference to its power of communicating heat to other bodies or substance [9].

Thus, temperature is one of the primary variables that require careful attention in any system design. Its vital position, especially in industrial processes, has led to the development and subsequent deployment of more practical means of measuring, monitoring, and controlling variations in its magnitude.

A number of other variables, such as pressure and fluid flow exist whose magnitudes also need to be monitored and controlled, for the purpose of this project work however, we shall direct our focus on temperature. Whereas some applications require the use of transducers, which come in contact with the body of the substance whose temperature is to be measured, others require no such contacts. This explains why some industrial systems where very high temperatures are generated do not employ simple transducers such as bimetallic strips and glass thermometers [10]' which requires being in contact besides their low temperature range. Instead, such transducers as thermocouples, thermistors, pyrometers and many others are most often used.

2.3 ANALOGUE –TO- DIGITAL CONVERTERS (ADCS)

An analogue-to-digital converter (ADC) takes in analogue signal and produces a digital output code, which represents the analogue signal [15]. Because it is often used at the input of a digital system to produce a digital equivalent of an analogue voltage, it is sometimes referred to as "encoding device".

In an ADC arrangement, the input analogue voltage V_{in} is encoded into binary fraction of the reference voltage V_{ref} so that the output of the ADC consists of a digital word given by the expression;

$$\frac{V_{in}}{V_{ref}} = b_0 2^{-1} + b_1 2^{-2} + \ldots + b_{n-1} 2^{-n} \quad \ldots\ldots\ldots (2.1)$$

Where n is the number of bits in the digital word, and b_o, b_l etc, are binary bit coefficients which can have the logic value 0 or 1 [14]. The figure below is a block diagram showing a possible arrangement of a 3-bit ADC.

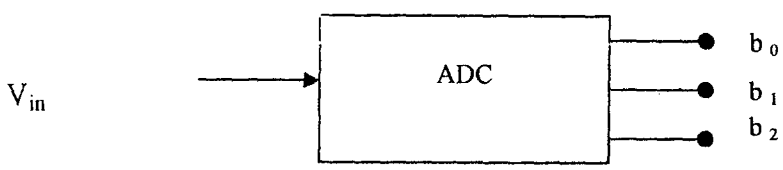


Fig 2.2 Block diagram of a three-bit ADC [14]

From the figure above, the analogue voltage is the input and the ADC quantizes this voltage at a particular sampling instant, to give a digital word corresponding to the particular analogue level. The analogue to digital translation process can be represented by the transfer characteristic shown in the figure below.

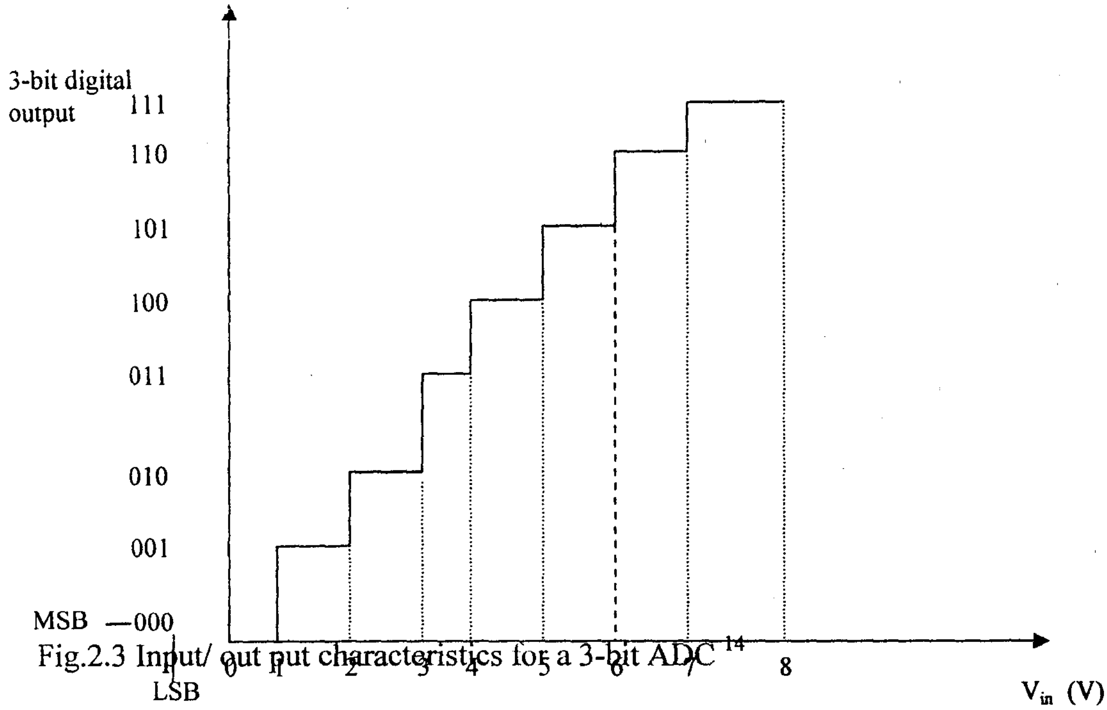


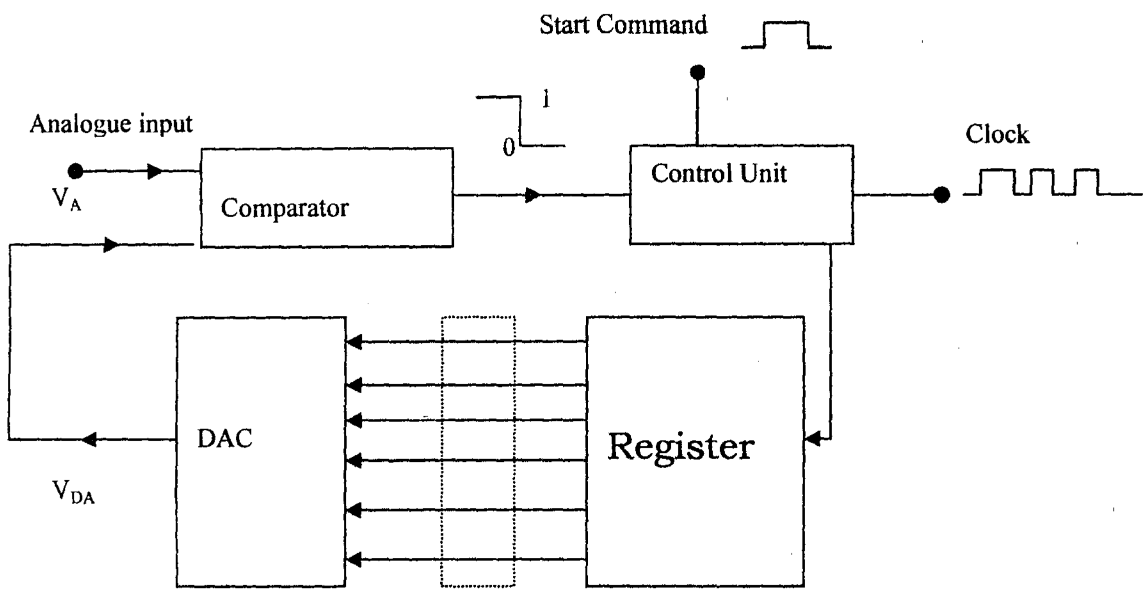
Fig.2.3 Input/ out put characteristics for a 3-bit ADC [14]

It is thus: clear that an analogue voltage of say, 3V can be represented by the digital word 011. However, any voltage between 2 ½ V and 3 ½ V would also be represented by the same digital sequence 011. This gives rise to quantization error in the ADC. This error can be reduced by using a digital word of greater length. But because the quantization process is inherent in the encoding process, the error can never be eliminated; only minimized.

Another problem with ADC circuits is time. Because the conversion rate of the circuit is finite, there must be a delay between the time of sampling V_{in} and producing the digital output. The delay is known as the conversion time.

2.3.1 Operation of ADCs

. The basic operation of an ADC depends on comparing two analogue signals, with the digital output depending on the outcome of such comparison. The figure below is a block diagram illustrating the operation of an ADC



2.4 Block diagram for an ADC [15]

The ADC consists of two main building blocks, a comparator and a control unit [12], as well as DAC (Digital-to-Analogue Converter) and a register. The control unit has three inputs, which are the input from the voltage comparator, a clock and a start command. The voltage comparator compares two analogue signals and its output to the control unit depends on which analogue signal is greater [15].

The operation follows a sequence of events when the ADC is switched on, as outlined below.

- The start command goes high and this causes the A/D conversion to commence operation.
- The clock determines the rate at which data is sent by the control to the register.

- The register holds a binary number, which is passed onto the DAC. Its output is an analogue signal, which is applied to the comparator.
- The input signal to the ADC is also fed into the comparator, which it compares with that provided by the DAC. Now, let the analogue signal be V_A and the output signal from the DAC be V_{DA}
- If $V_{DA} < V_A$, the comparator output is high.

If $V_{DA} = V_A$, the comparator output is low

If $V_{DA} > V_A$, the comparator output is low

If the comparator output is low, the comparator stops the process of modifying the binary number stored in the register. This is likely to occur when V_{DA} is approximately equal to V_A. At this stage, the digital number in the register is also the digital equivalent of the input signal V_A.

Finally, if the comparator output is high, the comparator continues the process of modifying the binary number stored in the register until the point is reached when the comparator output low [15].

CHAPTER THREE

3.0 DESIGN METHODOLOGY AND MATERIALS

This project was designed and realized in modules. These separate modules were then brought together to accomplish the complete project. This chapter seeks to consider the design approaches and the materials used.

3.1 DECRIPTION OF SYSTEM BLOCK DIAGRAM

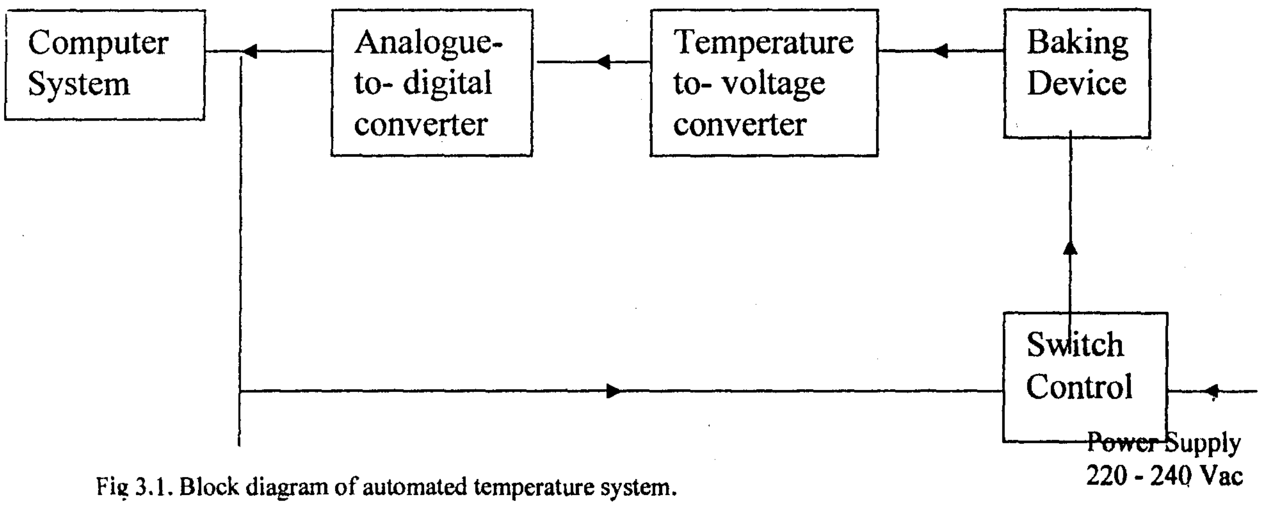


Fig 3.1. Block diagram of automated temperature system.

To fully explain the operation of the system as present in the figure above, it will be better to consider the functions of each of the constituent blocks.

- Power Supply: This provides a 220 – 240 Vac to the system as obtained from the public power utility. It supplies the system with the required power or electrical energy to operate.

- Switch Control: The function of this block is to switch the baking device on and off. Initially, when the system is powered, this unit switches on the baking device and it begins to heat up. The temperature at which the device is operating is then compared with a required value already inputed into the computer system. If the value of the operating temperature is less than the required value, the computer system sends command to the switch control to maintain the baking device in operation. But if the operating temperature value is equal to the desired value, the computer sends a command to the switch control unit to turn off the baking device. This it achieves by cutting off the source of power to the device. And when the temperature has fallen slightly below the desired valued, the control switch unit switches on the baking device by restoring power to it.
- Temperature-to-voltage Converter: This unit serves the purpose of converting the temperature of the baking device into measurable linear voltage. To achieve this, the unit incorporates a temperature transducer, which senses and converts the operating temperature of the baking device into electrical voltage equivalent that can be measured effectively and more accurately.
- Analogue-to- Digital Converter: The function of this block is to convert the varying or analogue electrical voltage into digital form that can be understood and interpreted by the computer system. This conversion is necessary since computer systems can only understand and interprete signals in 1s, 0s, i.e. binary signals. Hence, the electrical voltage from the output of the temperature sensor is converted to an equivalent binary form by the analogue-to-digital converter.
- Computer System: This unit serves to monitor and control the operations of the system through a specialized software package designed and incorporated in it for this

the baker; and depending on the result of the comparison, it issues command through the switch control unit to either maintain the baking device in operation or turn it off. That way, the temperature is properly and efficiently regulated and controlled. This unit forms the basis of the automation system. The software package is designed to also incorporate timing functions and switches off the entire system when the time required by the baker for the baking process elapses.

DESIGN OF TEMPERATURE-TO-VOLTAGE CONVERSION MODULE

This module is intended to play the vital role of converting the physical quantity of temperature into a measurable electrical voltage. It is also intended that the electrical voltage at its output terminal, which would be analogue in nature, be converted to digital form in order to be interpreted by a computer system. As a result, the desire to select a suitable temperature sensor capable of carrying out the required conversion function satisfactorily, and be compatible with an analogue to digital converter (ADC) became very important. To achieve this objective, the LM35 Chip package was used in the project work.

The LM35 is a 3-pin, precision integrated circuit temperature sensor, whose output voltage is linearly proportional to the Celsius [centigrade) temperature. The advantage of this device over other linear temperature sensors calibrated in degree Kelvin is that the user does not need to subtract a large constant voltage from its output to obtain convenient scaling [18].Other advantages offered by the device include the following:

i. The LM 35 does not require any external calibration or trimming to provide the desired accuracy.

ii. It provides typical accuracies of + ¼^{o}C at room temperature range.

i. The LM 35 does not require any external calibration or trimming to provide the desired accuracy.

ii. It provides typical accuracies of + ¼°C at room temperature range.

iii. It can be used with single power supplies, or with plus and minus supplies.

iv. It has very low self-heating capability of less than 0.1°C in still air, as it draws only about 60uA from its supply.

The low output impedance, linear output, and precise inherent calibration of the LM35 make interfacing to readout or control circuitry exceptionally easy.

3.1.1 DESIGN FEATURES AND SPECIFICATIONS

In addition to the advantages mentioned above, the choice of the LM35 as the suitable temperature sensor to achieve the purpose of this project work was necessitated by the following design features and specifications.

i. It is calibrated directly in degree Celsius.

ii. It has a linear scale factor of + 10.0mV/°C

iii. It has a guaranteeable accuracy of about 0.5°C (at +25°C)

iv. It is rated to operate over a –55°C to 150°C temperature range.

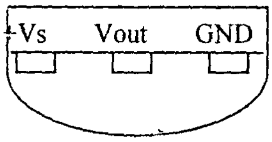
v. It is suitable for remote applications

vi. It can operate from 4 to 30 volts

vii. It draws only about 60uA of current from its supply.

viii. It has low impedance output of 0.1 for a 1mA load.

The figure below illustrates the connection diagram of the LM35 chip when viewed from its bottom.



Vs –Supply voltage

Vout – voltage output

Fig 3.2 Connection diagram of LM35 temperature sensor [18]

3.1.2 IMPLEMENTING THE DESIGN

The LM35 was applied easily in the same way as other integrated circuit temperature sensors. It was glued or cemented to the surface of interest. The reason is to obtain a temperature that would be within about 0.01^0C of the surface temperature, which would presume that the ambient air temperature is almost the same as the surface temperature.

In order to satisfactorily achieve the purposes of this project work, the design of this module was implemented by connecting the LM 35 package as shown in the figure below, to function as a temperature to digital converter.

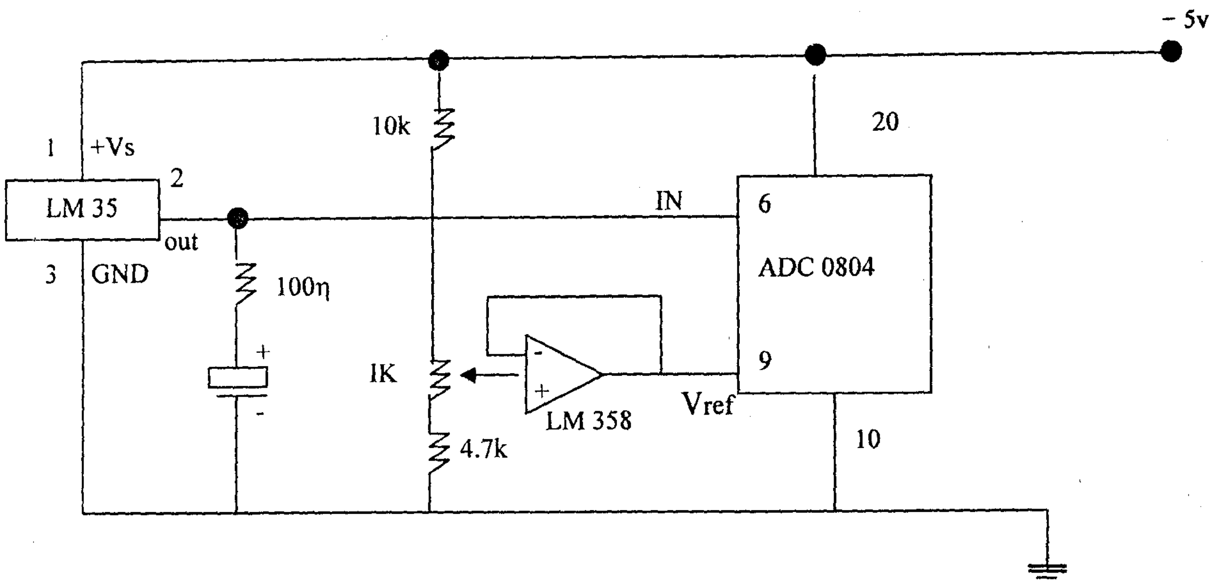


Fig 3.3. Wiring of LM 35 as temperature-to-digital converter.

The inclusion of the series R-C at the output of the LM 35 in this design is to provide easy isolation, decoupling, or damping of heavy loads. Because this project work is intended to drive a very heavy load, e.g. a heating element, this provision greatly compensated for the limited ability of the LM35 device (like most micro-power circuits) to drive heavy loads.

3.2 DESIGN OF ANALOGUE-TO-DIGITAL CONVERSION MODULE

The design of this module followed a very careful selection of a suitable analogue-to-digital converter capable of performing the required conversion functions. To achieve the required conversion purposes, the ADC 0804 IC chip analogue to-digital converter was used in this project work.

The ADC0804 is a CMOS, 8-bit successive approximation analogue-to-digital converter that uses a differential potentiometric ladder. This converter is designed to allow operation with the NSC 800 and IN 8080A derivative control bus with TRI-State output latches directly driving the data bus. It appears like a memory location or input/output (I/0) port to the microprocessor and require no interfacing logic.

In addition, the reference voltage input can be adjusted to allow the encoding of any smaller analogue voltage span to the full 8 bits of resolution [19]

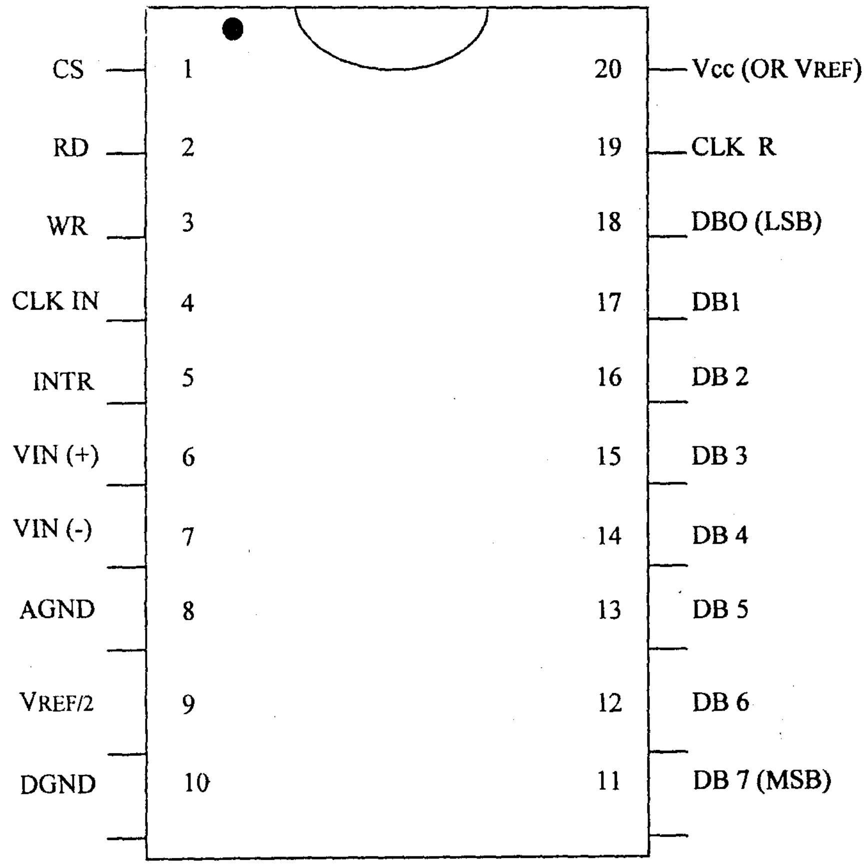


Fig 3.4. Connection diagram of the ADC 0804 IC Package [19].

3.2.1 DESIGN CONSIDERATIONS AND SPECIFICATIONS

The choice and subsequent application of this converter in this project was necessitated by a number of outstanding features it posses as well as other numerous capabilities it offers, which include the following:

i. It is compatible with 8080 microprocessor derivatives, and requires no interfacing logic.

ii. Easy interface to all microprocessors, or can operate “stand alone”

iii. Logic inputs and outputs meet both CMOS and TTL voltage level specifications.

iv. It has on-chip clock generator

v. It can use 0V to 5V analogue input voltage range with single 5V supply.

vi. No zero adjust required

The converter has the following key design specifications.

i. Resolution – 8 bits

ii. Total error - + 1LSB

iii. Conversion time-100υs.

3.2.2 DESIGN IMPLEMENTATION

For the purpose of this project, the module was designed and applied as computer-software interfaced temperature–to-digital converter. To achieve this objective, the ADC 0804 chip was wired as shown below.

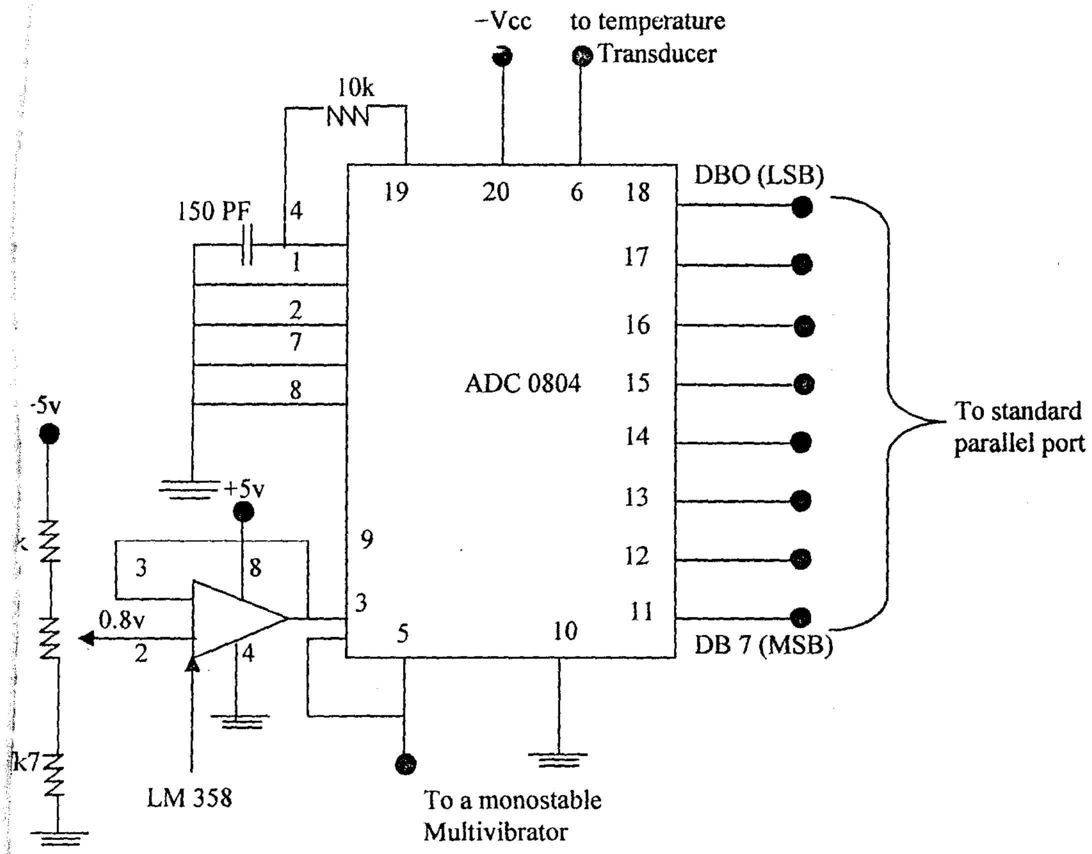


Fig 3.5 An ADC0804 chip wired as a temperature-to-voltage converter.

The inclusion of the LM358 voltage comparator circuitry in the design is to provide the desired reference voltage input to the ADC to allow the encoding of any smaller analogue voltage span to achieve the required full 8 bits resolution.

3.3 DESIGN OF SWITCH CONTROL MODULE

One of the main objectives of this project is to effectively control the operation of the cooking device between set temperature values. This objective necessitated the design and inclusion of a form of control in the project designs. The design of this module or unit was achieved mainly by the use of an electromagnetic relay connected through the collector of an npn transistor to pin 16 of a standard DB connector. An electromagnetic relay has been defined as a type of switch, which uses the magnetic effect of a current to open and close contacts. However, the decision to employ a relay in this project to achieve the required control function was influenced by the following two main purposes of a relay.

i. To enable a large current to be controlled by a small current. It is therefore a sensitive switch, so that a small current can control devices, which use heavier currents, such as cooking devices, as in the case of this project.

ii. To enable the control circuit to be isolated from the controlled circuits. It is this complete isolation between the controlled circuit and the control circuit that makes the relay so useful in this project, where a low-power equipment such as a micro computer is required to operate a high power device such as a cooking device.

To achieve the desired control function in this project, the relay was connected as shown in the figure below.

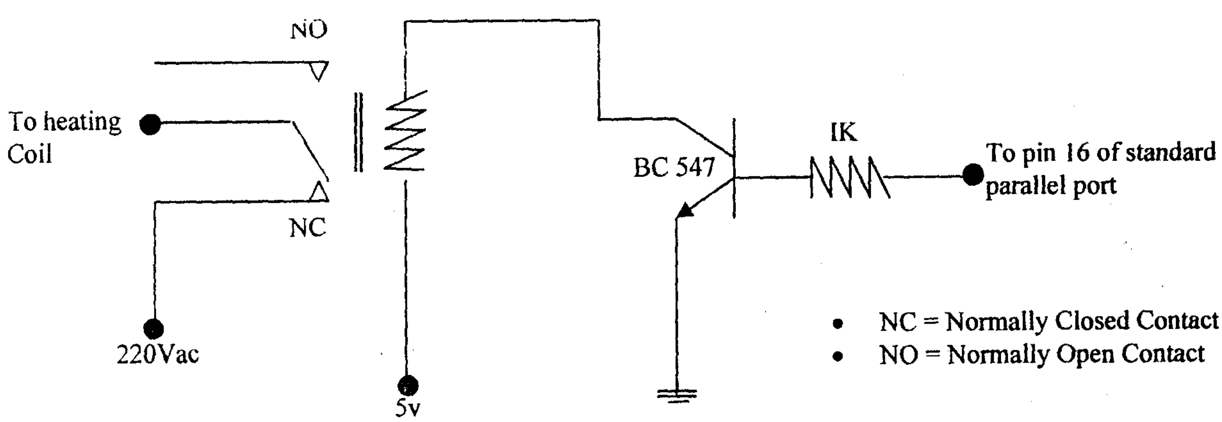


Fig 3.6 Design of Switch Control Unit.

In the standard DB 25 connector, pin 16 is a control pin [16] and performs control functions. Control signal at this pin, usually written to it by manipulating the control register in a specialized program designed for that purpose, is delivered through the BC547 npn transistor to the electromagnetic relay. The function of the transistor is to drive the relay. The controlling current flows through the large number of turns of the coil of the relay so that it can produce a magnetic field strong enough to operate electrical contacts of the relay, which either cuts off the supply to the heating element or maintains it in operation.

3.4 DESIGN OF POWER SUPPLY MODULE

All the IC (Integrated circuit) chips used in this project required a 5V dc, steady power supply to power and make them operational. As such, the need to design and incorporate a power supply module capable of supplying the required 5V steady power became very necessary. The simple, practical dc power supply circuit diagram shown in the figure below was used to realize this objective.

3.5 DESIGN OF POWER SUPPLY MODULE

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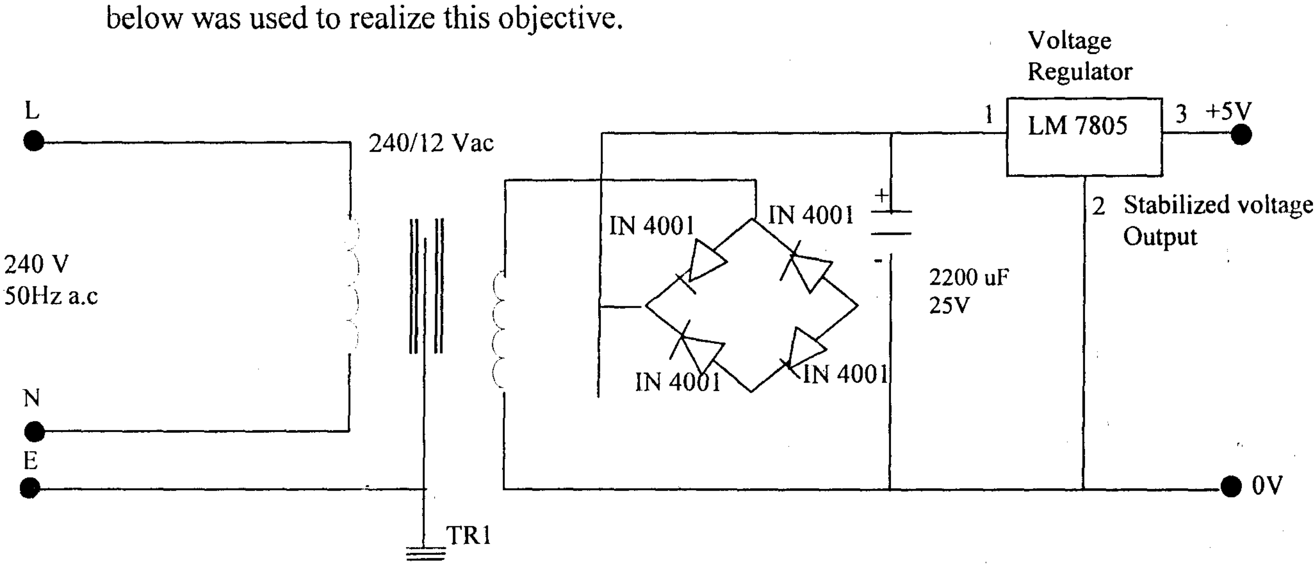

Fig 3.7 Circuit Diagram of a practical 5V dc power supply.

TR1 is a 12V low voltage transformer capable of accepting a 240 Vac from the mains supply at 50Hz frequency into its primary side and stepping it down to 12 Vac, at its secondary side. This varying voltage at the secondary windings of the transformer is fed to a full- wave bridge rectifier circuit made up of four IN4001 type diodes. The function of the rectifier circuit is to remove the ripple frequency produced by the sinusoidal voltage, thereby converting it to a dc voltage.

The electrolytic capacitor serves to couple the unstabilized voltage output from the rectifier to the voltage regulator. It also provides smoothening of the rectified voltage to approach a more linear form. To aid the stability of the circuits, the capacitor was mounted physically as close to the regulator IC as possible [20]. This also ensures that the voltage regulator is stable in operation.

The essence of the power supply unit is to provide a stabilized 5V dc power to the various chips used in the project. To achieve this, however, a 5V, LM7805 voltage regulator IC was included in the design. The LM7805 voltage regulator accepts an unstabilized dc voltage at its pin 1 terminal and produces a stabilized voltage of 5V at its pin 3 terminal. The pin 2 terminal is the common, and it is grounded. Thus, the stabilized voltage of 5V is collected between the pins 2 and 3 terminals.

3.6 DESIGN OF SOFTWARE MODULE

The software module is the 'heart' of the project work as it forms the basis for performing the monitoring, control and timing functions of the device by simply manipulating the desired parameters or variable in program.

The application software package is a specialized computer program designed specifically to achieve the desired objectives of the project by way of effectively carrying out the above stated functions. In accomplishing this all-important unit, a visual basic programming language, version 6.0 was used.

Visual basic, often called VB for short, is a high level programming language evolved from the earlier DOS (Disk Operating System) version called BASIC which stands for Beginners' All-purpose Symbolic Instruction Code. Visual Basic is a visual and event driven programming language, in which programming is done in a graphical environment [21]. The desire to adopt the Visual Basic Programming Language, in the design of the software package for this project was necessitated by the following advantages that if offers.

i. The syntax of Visual Basic Program codes is almost like the normal English Language, and as such it is a fairly easy programming language to learn.

ii. A Visual Basic Program can be made up of many sub programs, each has its own program codes, and each can be linked together in one way or another.For this project, which was realized first in different modules and then put together to achieve the complete work, the ability of Visual Basic to offer the second advantage stated above proved very helpful in writing the application package. This Visual Basic capability provided the needed convenience, simplicity, and flexibility in event programming.

In creating the Visual Basic Application for this project, three basic steps [21] were generally employed.

Step 1: Designing the Interface

This is the first step in constructing a Visual Basic Program, and it involves creating an attractive and user-friendly interface through which the user can effectively communicate with the system. This step involves changing the caption of existing labels to names that best suit the designer, creating text boxes, and inserting command buttons. All these were achieved at the properties window of the Visual Basic environment.

Step 2: Setting Properties of the control

Before writing an event procedure for the control to respond to a user's input, certain properties have to be set for the control to determine its appearance and how it would work with the event procedure. Controls are tools such as textbox, command button, label, combo box, picture box, image box, timer and other objects that can be dragged and drawn on a Visual Basic form to perform certain tasks according to the events associated with them. Setting the properties of the controls was done in the properties window of the Visual Basic environment. This was achieved by highlighting the items in the right column of the window and then changing them by typing or selecting the options available.

Step 3: Writing the events' procedures

This step involves writing the program code for an event so that an action or a series of actions can be performed. As mentioned earlier, Visual Basic uses English like syntax in writing its codes. This makes it fairly easier and convenient to write. The event procedures are usually written in between the beginning and the end statements. For example, the program code for the event of clicking a command button would have the general format shown below:

Private sub command 1_ click

(Key in program code here)

End sub

The statements *"private sub command 1_click"* and *"end sub"* are the beginning and the end statements respectively. Sub actually stands for sub procedure that made up a part of all the procedures in a program.

For a project with more than one event, as with this project, an event procedure needs to be written for each event. The program code is made up of a number of statements that set certain properties or trigger some actions. As an example, let us examine the sample subprogram below [21]:

Private sub command 1_click

Label 1. Visible = False

Label 2. Visible = True

```
Text 1. Text = "You are Correct!"
End sub.
```

From the sample program above, clicking on the command button will make label 1 become invisible and label 2 become visible; and the text *"you are correct"* will appear in textbox 1. As a further example, a section of codes of the program for this project are presented below:

```
Private Sub Form _ load ()
   Out Val (&H37A), 32
   Label 8. Visible = False
   Label 9. Visible = False
  T1. Text = Time$
  T2. Text = Date$
End sub.
```

The entire program code for the project is presented in the appendix.

3.7 BOARD IMPLEMENTATION

The implementation of this project was done in two stages. At first, the circuit was realized on a project board by connecting up the various components as in the circuit diagram. Faulty components where detected and removed and the connection ascertained to conform to circuit design utilizing links where necessary. When the system was powered, it was observed that it worked within design parameters and specifications.

Thereafter, the entire circuit arrangement was transferred to a veroboard for permanent connections using the soldering technique.

3.8 DESCRIPTION OF SYSTEM OPERATION

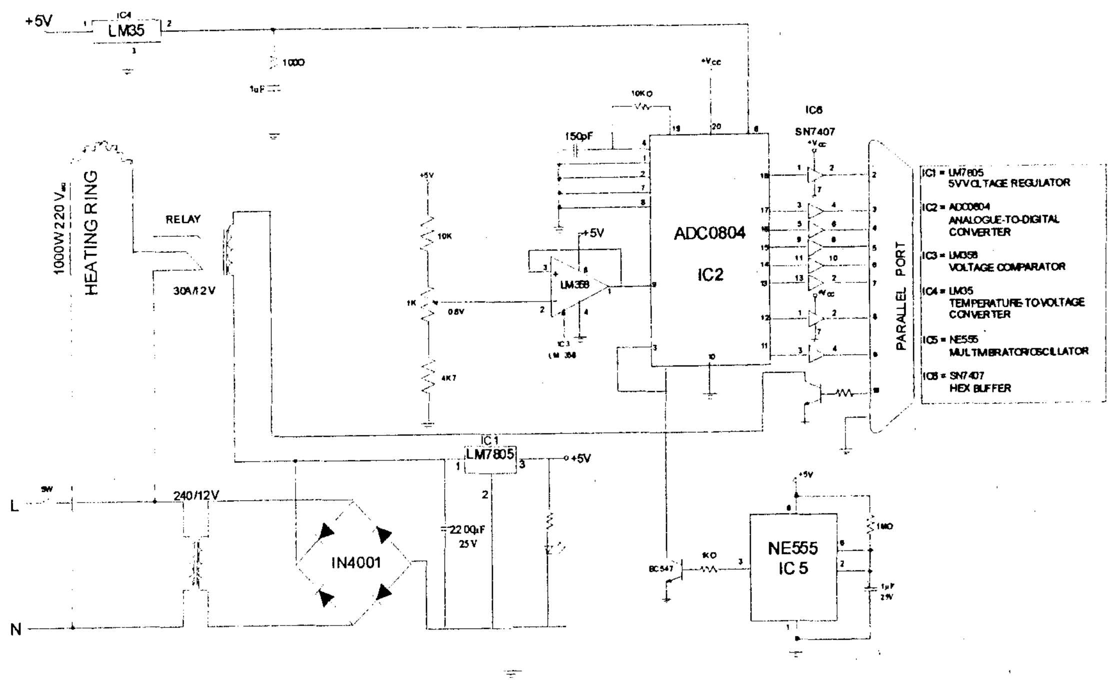

FIG 3.8: SYSTEM CIRCUIT DIAGRAM

Fig 3.8 SYSTEM CIRCUIT DIAGRAM

The system circuit diagram shown above consists mainly of an ADC 0804 IC chip, LM35 (a temperature-to-voltage converter IC package), LM358 (a voltage comparator), LM7805 (a 5V voltage regulator), a 1000W 220 Vac heating element, a standard parallel port cable, capacitors and resistors.

When the system is powered, desired values of temperature and time at which baking is to be carried out are input into the computer via the user interface, and the system program is run, electric power flows to the 1000Watts heating element and baking begins. The temperature at which baking operation is taking place is sensed and converted to electrical voltage by the LM35 temperature to voltage converter. This analogue voltage is then delivered to the ADC 0804, which converts it to binary format. To ensure continuous conversion, the ADC is connected to a 555 IC chip wired as a monostable multivibrator.

The LM 358 voltage comparator provides the required reference voltage to the ADC for its operation [22]. The binary value equivalent of the analogue voltage is then fed into the computer via the data lines of the parallel port. The SN7407 hex buffer between the ADC and the parallel port serves not only to latch the binary output of the ADC to the parallel port, but also to ensure that minimal current is drawn from the port.

The computer, with the aid of a specialized system application program, compares the values of the desired temperature and the system temperature. If these values are equal, the computer system sends control signal via the control lines of the parallel port to disconnect the heating element by energizing an electromagnetic relay directly connected to the heating element. Then, the system temperature tends to remain constant for a while and then begins to fall. Once the temperature falls slightly below the desired temperature, the computer sends control signal to the relay to reconnect the heating element and heating continues. This temperature monitoring and control process continues until the desired time at which baking is expected to be completed elapses. When this happens, power is permanently cut off from reaching the element and baking is over. It is worth noting however, that during the intermittent disconnection and reconnection of power to the element, baking will still be in progress.

The system makes provision for changing the values of the desired temperature and time, the user simply clicks on the "change value" command button on the user interface and the process is immediately halted. He then enters new values and clicks on the "OK" command button, and the system resumes the baking process.

CHAPTER FOUR

4.0 TESTING AND RESULTS

After completing any engineering design and construction, as in this project work, testing the resulting device plays a vital role in ascertaining the functionality or workability of the system. It also helps to ensure whether the resulting device is functioning satisfactorily within design specifications as to achieve design objectives. In this project work, testing of the device was carried out in two stages: hardware testing and system testing.

4.1 HARDWARE TESTING

Having completed the construction of the circuit, which forms the system hardware, the resulting device was powered from a 220/240 Vac mains supply and found operational. This was observed, when after switching on the device, the indicator light lit up and the element began dissipating heat. It was also observed that the heat dissipation became intense as it was left in operation over time. When the device was switched off thereby cutting off electric power supply, the device stopped functioning and the element started cooling down. It is relevant therefore to state here that the device functions satisfactorily according to design objectives and specifications.

4.2 SYSTEM TESTING

Having completed the design and building of the application software, the overall system was also tested to establish its functionality. To accomplish this, the application software was installed into a reliable computer system and interfaced to the hardware unit via the PC's parallel port with the aid of a parallel port cable and the user interface page was opened. Thereafter the system was powered from a 220/240Vac mains supply, the hardware unit switched on, and the element started heating up. When this was done, the PC immediately displayed the prevailing system temperature, current date, and time.

A desired time of three minutes and temperature of 70°C were keyed into the system through the user interface, and the "OK" button was clicked. When this action was carried out, the time value started counting in seconds down and the computer system started comparing the system and desired temperature values. When the system temperature equalled the desired temperature, a 'pop' sound was heard, indicating the automatic disengagement of the element from the source of power. At this time, the element stopped heating; and after a little while, the system temperature started to drop.

When the value of the system temperature was slightly below the desired temperature (i.e. 69°C), another 'pop' sound was heard, indicating reconnection of the element to power source and the element was observed to have started heating again. This monitoring and control process continued until the desired time elapsed (i.e. 0sec) when the element was disconnected and the message "baking is over" displayed on the screen of the PC. Again, it is relevant to state here that the system functions satisfactorily according to design objectives and specifications.

4.3 GENERAL TEST AND OPERATING PROCEDURES

A general step by step procedure for using the system presented below:

i. Get a reliable computer system

ii. Install into the system, the specialized Visual Basic application software.

iii. Open the application software user interface

iv. Interface the hardware unit to the computer system via its parallel port.

v. Plug hardware unit to a 220/240 Vac mains supply.

vi. Power the system by operating the switch on the hardware unit.

vii. Enter desired values for time and temperature.

viii. Click on the "Start" button.

If during the process, it is wished to change the desired values for time and temperature then, proceed as follows:

ix. Click on the "Change Values" button.

x. A message box will be displayed, then click on "Yes" to clear existing values.

xi. Enter new values for time and temperature.

xii. Click on the "Start" button.

xiii. When the baking process is completed, an alert message "baking is over" will be displayed, then click on "OK".

xiv. Close user interface.

xv. Switch off and unplug hardware unit.

xvi. Disconnect hardware and software interface.

4.4 OPERATING INSTRUCTIONS

This device should only be used as intended and within the design parameters by suitably qualified and trained personnel who must have read through the various sections of this report. The user is also required to exhibit basic safety precautions at all times to avoid the possibility of accidents.

However, the designer will neither accept any responsibility for the operation of the system within a range outside the stated design limits, or any consequential loss, damage or injury that may result from such operation thereof. In view of this, when in doubt regarding the correct use of the system, or require any technical information, the intending user should contact the designer or the supervisor of this project, or other qualified hands of the Department of Electrical and Computer Engineering of the Federal University of Technology, Minna.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 CONCLUSIONS

There are a number of possible solutions for the automation of industrial process monitoring and control such as a baking oven, but the computer software-controlled baking oven seems to be the most viable alternative as it provides for extensive technical capabilities, operational convenience, accuracy, and flexibility. The computer-controlled baking oven, as implemented in this project work, is indeed a revolutionary concept in modern baking or cooking because it is aimed at keeping with the growing pace of computer usage that has revolutionized nearly every sector of our modern day society.

Besides the fast, convenient and effective way of baking that it provides, it equally reduces to the barest minimum, the immense economic losses incurred daily in the baking and confectionery industry due to the use of ovens that are characterized by high level of human and analogue control mechanisms. The reason is that human action and analogue controls are prone to errors, and as a result, such systems are generally unreliable and inefficient.

Moreover, considering the fact that the operation of the system because of its flexibility can be reprogrammed to handle the operation of high temperature industrial equipment such as glass furnaces, iron melting and smelting plants, compressors, turbines as well as a variety of other high temperature systems used for industrial applications, its relevance to societal, industrial, economic and national growth cannot be overemphasized.

5.1 RECOMMENDATIONS

I strongly believe that a lot of improvement can be done on this prototype design to enhance its usability, efficiency, flexibility and performance. For these reasons, I wish to recommend the followings:

i. This design does not include a means of cooling within the system. It only provided a means of minimizing the heat generated by the heating element from damaging the electronic components by including ladding protection. It is therefore recommended that future designers should attempt to incorporate effective means of cooling to reduce oven temperature within the system.

ii. Although the use of Visual Basic Programming Language provided the expected result in this design, I believe that the use of more specialized high level programming languages such as C^{++}, Java, Oracle, Python, C# etc in the design of the application software would enhance the performance and flexibility of the system to achieve probably, better monitoring and control objectives.

iii. Future designers should also attempt a means of automation that can enable more than one computer system that has the application software installed to be used to monitor

iv. and control the same device or process. The designer strongly believes that by extending the design to include control of the baking device by several computers connected in a

v. network, it is possible to control the device from quite a distance. This feature, the present design did not incorporate.

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APPENDIX

Program Codes

```
'Declaration of Variables

Public a

'Set data line of the parallel port as an input

Private Sub Form _Load ()

Out Val (& H37A), 32

Label 8.Visible = False

Label 9. Visible = false

T1.Text = Time$

T2. Text = Date$


End Sub


'Setting messages for input boxes

Private Sub Change_Click ()

Dim changevaluesmsg As integer

Changevaluesmsg = MsgBox ("Do you want to change values?", vb YesNoCancel
+VbExclamation, "Change Values")

If changevaluesmsg = 6 Then

t. Text = " "


Text 2. Text = " "
```

```
Timer 2. Enabled = False

Timer 5. Enabled = False


Else

End If

End sub

‘ Setting message when there is no hardware connected to the system

Private Sub hardware _Timer ()

If Text3.Text = 255 Then

msg=MsgBox(“Hardware removed”, vbCritical, “Hardware fault”)

hardware.Enabled =False

End If

End sub


Private Sub quit_Click ()

Dim exitmsg As Integer

exitmsg = MsgBox (“ Do you want to quit?”, vbYesNoCancel + vbExclamation, “Exit”)

If exitmsg = 6 Then

End

Else

End if

End sub

Private Sub Start_ Click ()

‘Setting the data line of the parallel port as an input

Out Val (& H37A), 32
```

```
If t. Text = ' ' ' ' Or Text2.Text = ' ' ' ' Then   ' if there is no value for time and temperature for cooking, go back
msg= MsgBox ("Please, go back and key in values for TIME and TEMP.", vbOKOnly, " Go back").
End If
If msg = 1 Then


Else
Timer 2.Enabled = True
Label 8.Visible        = True
Label 3.Visible = False
Label 6.Visible = False
Label 9.Visible = True
Text 1.Text = t.Text * 60
Timer 5.Enabled = True
hardware.Enabled=True
End If
End Sub
Private Sub Timer 1_Timer ()
T1.Text = Time$
a= Text 1.Text

End Sub


Private Sub Timer2_Timer ()
```

```
If Label 4.BackColor = vbGreen Then
Label 4.BackColor = vbRed
a= a-1
Text1.Text = Str$(a)
Else
Label 4.BackColor = vbGreen
End If
End Sub
Private Sub Timer 5_ Timer ( )
'set the data line of the parallel port as an input
Out (&H37A), 32
'give the input at test3
Text3.Text = Inp(&H378)
'If the oven temperature = the required temperature, stop heating
If Text2.Text – Text3.Test <= 0 Then
Out (&H37A), 191 'set pin 16 of pp HIGH, stop heating
Else
Out (&H37A), 0 'set pin 16 of pp LOW, start heating
End If
If Text1.Text = 0 Then
Timer 2.Enabled = False
Out (&H37A), 191 'stop heating
msg = MsgBox("Baking is over")
End
End If
```

End Sub.