DESIGN OF AN AUTOMATED

TEMPERATURE STORING DEVICE

BY

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IN

MECHANICAL ENGINEERING

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DECLARATION

I hereby declare that this project on "Design of an Automated Temperature Storing Device" is an original work done by me under the supervision of Dr. J.O. Dirisu. I also solemnly declare to the best of my knowledge, that this report has not been submitted here or elsewhere for award of a bachelor's degree. All sources of knowledge used have been duly acknowledged.

(Signature & Date)

Nwakile Olisemeka

(15CM03163)

CERTIFICATION

This is to certify that NWAKILE OLISEMEKA NNABUIFE carried out this project titled **Design of an Automated Temperature Storing Device** under supervision, in the Department of Mechanical Engineering, Covenant University, Ota, Ogun State.

_________________ _________________

Dr. J.O. Dirisu

Supervisor Date

_________________ _________________

Prof. J.O. Okeniyi

Head of Department Date

DEDICATION

This project work is dedicated to God Almighty, the King of kings and Lord of lords, for all the guidance, wisdom, and good health bestowed upon me throughout the journey to the completion of my bachelor's degree program. I also want to dedicate this study to my family for their love and support throughout this project. Special recognition to my amazing mother, Mrs. Uzonwanne Nwakile, for continually pushing me always to be my best.

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My first and foremost gratitude is to Almighty God, who has been with me through it all, motivating me when all hope was lost and supernatural strength to complete this project.

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Special appreciation also to my lovely Parents for financial, moral, and spiritual support throughout my academic journey. Also, my siblings Chisolum and Kosisochukwu for all their support and love.

ABSTRACT

The current existing methods for measuring the thermal conductivity of specimens always require full human operation in taking the readings, which errors are highly inevitable. It is noted that errors obtained from reading collection will lead to errors in the final calculation of thermal conductivity. This study uses an automated system, a temperature data logger connected with two temperature sensors and a heater to carry out the experiment and record the values gotten at different intervals. The temperature device is embedded with a PIC microcontroller that acts as the brain of the system. The temperature data logger sensors are attached to two brass discs via grooves bored into the disc. The first batch of data is stored for 60 minutes when 50˚C temperature threshold is reached when the heater is switched on, and the specimen has been setup. The heater switches off after 60 minutes, during the next 40 minutes, when the whole experimental setup cools down via normal environmental convection. During the cooling downstage, the PIC microcontroller also stores the temperature of both brass discs, which the temperature sensors are inserted into.

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CHAPTER ONE

1 INTRODUCTION

1.1 BACKGROUND

Nowadays, the innovative group of devices, namely the microcontrollers and specialized central processing unit-based microcomputers, are readily accessible for purchase. Microcontrollers are widely introduced as single board computers and draw attention from a variety of occupations such as informatics, engineers, and researchers; this is mostly because of the beneficial features: being portable, powerful, inexpensive, reliable, and easy to program. In a recent trend, microcontrollers are now being cost-effectively used in many research fields. Microcontrollers outspread the possibilities of developing new automated systems or modifying a manual system and converting the manual system into an automatic system. A microcontroller connected with a sensor then becomes a data logger due to the availability of the sensor to collect data and a microcontroller to interpret data from the sensor. (Pasquali, D'Alessandro, Gualtieri, & Leccese, 2017). This project aims to grow, build, and examine a temperature data logger at a relatively low cost that will be modified to also be able to measure thermal conductivity.

First and foremost, a data logger has to be simple, easy to set up the hardware, and also have a good feedback system for the operator. The technology used to measure temperature has grown from the vintage liquid-in-glass, which depend on an increase of fluid as it is heated, to current electronic recording devices and measurement. The growth of this temperature measurement technology has directly led to simplicity in operation, dependability of device, security, and accuracy of the device. A temperature data logger is the main instrument for learning heat infiltration in foods. Data loggers used to measure temperatures can be used in either a laboratory or industry and can be grouped into two primary forms "wireless" and "wired." In a "wired" system, the temperature sensors (normally thermocouples) are connected directly to a recording device that is equipped with required electronics to make temperature readings and store the data. The wired temperature data logger system continuously monitors, displays, and record data as its fed into the sensors.

Typically, it is linked to a personal computer (PC) for the display of information and programming of the automated system. In a "wireless" temperature data logger system, in this system, it is simply a self-sustaining system with a DC operated recording and measurement devices are used that have the required memory, microprocessor, and required sensor. Wireless temperature data logger systems are programmed to collect data at a specified rate and time, while that data can be displayed on a liquid crystal display screen (LCD) attached directly to the system or read into a personal computer (PC). It is noticed that instruments that measure temperature are made up of two main primary components, namely which are: the electronic components and the sensors. In the majority of research being carried out that concerns the use of a temperature data logger system, use a "wireless" system mainly because of the ease in which the system can be setup, and no additional adjustment is required for its components. (Sullivan, 2008)

The phenomenon by which heat is transmitted through a material, when a temperature difference is applied between two opposite sides, is called thermal conduction, while thermal conductivity is the attribute that indicates the capacity of materials to transmit heat. Knowing the thermal properties of various materials is very important in applications, especially in a field that deals with thermal insulation where the heat exchange with surroundings is an important issue. (Flori, Putan, & Vilceanu, 2017).

The thermal properties of materials are very in engineering solutions for heat transfer problems. Measurement of the thermal features of heterogenous and porous materials by the conventional methods usually leads to large errors. (Ukrainczyk, 2015). Thermal conductivity is well described as the attribute of a material capacity to transmit heat; this is done as the end consequence of the temperature difference below steady state boundary conditions. (Philip & Fagbenle, 2014).

Thermal conductivity is measured very often in the industry via various methods that have been documented. One of the earliest forms of thermal conductivity measurement of mainly solid materials of lower conductivity than metals, such as materials like soils and clay, is known as the hot-plate method. The steady-state hot-plate technique is made up of a small cylindrical mold of the sample, the ends of the apparatus that bound the sample consist of metal slabs of higher conductivity. The steady-state technique performs a measurement when the temperature of the sample, which is being measured, remains constant over a certain amount of time. A solid sample of the material is placed between two plates in a steady-state covered hot-plate here. One plate is going to be heated while the additional plate will be left untouched. Until they are constant, the temperatures of the plates are registered. To measure thermal conductivity, the steady-state temperature, the heat input going into the hot plate are used, and the thickness of the sample is regarded and used to quantify thermal conductivity. The disadvantage of using a steady-state method is that it requires a well-engineered experimental setup. (Von Herzen & Maxwell, 1923). The setup is commonly in an upright position with the metallic plate, which is usually made of bronze is placed at the top with the specimen placed in between and the cold bronze plate placed under the sample. Heat is then provided at the top of the plate and is properly insulated and made to move down to stop convection in the sample. Measurements are recorded after the sample has attained a steady-state this usually takes some time, on average, about 30minutes. Other forms of steady-state procedures for poor conductors of heat, Lee's disc apparatus process can be used, while for good conductors of heat, the Searle's bar method can be used.

Searle's bar method, christened after George Fredrick Charles Searle, is a simple experimental procedure used to determine the thermal conductivity of materials. It is simply a block of material being heated at the top by steam, and the bottom of the material is then cooled down with water, while the extent of the block is thermally insulated. (Adamu, Muhammad, & Shitu, 2017). A steady heating device, stopwatch, a measuring cylinder, and steam generator, which is used to pass steam through the steam chest to the four thermometers present during Searle's bar method called T1, T2, T3, and T4 were used. T1 and T2 measured the temperatures at a stage on the bar, while the other two thermometers were used to measure the temperature value of thermometers T3 and T4 that were used for measuring the temperature of the water entering and exiting the spiral. Postulating there was no loss during the process, variables will now be determined and put into a formula to derive after the experiment has been carried out manually. (Ushie *et al.*, 2014)

Lee's disc is another apparatus used in determining the value of thermal conductivity but with a major focus on bad thermal conductors, for example, glass or plastic in the form of a disc. Apparatus that are to be used for this experiment include two thermometers, a stopwatch, boiler, heater, steam chest, and two brass discs of the same diameter and thickness. The material under investigation, usually rubber, glass, or ebonite, is situated in between two brass discs: brass disc one and brass disc 2. the steam chest is attached to the brass disc one that is positioned on top of the material. The steam chest is a vacuous enclosure in which dual tubes are made available for the outflow and inflow of steam. Dual thermometers T1 and T2 are put into two holes in the dual brass discs, respectively. The complete setup is done with a clamp stand. When the steam streams for a while, the temperatures that are recorded bit by bit become steady after some time. This is called a steady-state; when the apparatus is in its steady-state, the rate of heat conduction into the brass disc 2 is identical to the rate of heat loss from it. Thermal conductivity is now calculated from the variables gotten from the experiment. (Philip & Fagbenle, 2014)

Another popular technique utilized to calculate the thermal conductivity of materials is known as the Transient hot wire method. It is very popular because of its accuracy and exact technique to method the thermal conductivity of liquids, gasses, refrigerants, and nanofluids in an extensive temperature and pressure variety. In this method, a single, thin platinum wire is used as both a temperature sensor and a constant power heater. The wire is then plunged in a fluid, and due to the little measuring time (one second), there is no convection existing in the measurements, and only the thermal conductivity of the fluid is measured with very superior precision. (Merckx, Dudoignon, Garnier, & Marchand, 2014)

Transient plane source method is also used to quantify the thermal conductivities of different varieties of materials. A sensor combined with a distinct mathematical model is used in outlining heat conductivity and, when corresponding with electronics, allows the before mentioned method to measure various thermal transport properties that also includes thermal conductivity. The Transient plane source method uses a slender disk-shaped temperature-dependent resistor simultaneously as the sensor for temperature and heat source for thermal diffusivity and thermal conductivity measurements; in between dual specimen halves, that is where the sensor is located. From this setup, a direct current now travels through the sensor that is significantly big enough to increase also the sensor temperature; as a result of this temperature addition, the resistance of the sensor will vary, and there will be an equivalent detection in voltage drop over the sensor as a whole. Therefore, in this method, by storing the voltage disparity and current disparity in the sensor over some time from the start of heating current, it is then possible to obtain accurate data on the heat flow between the sensor and the material under investigation; this is how various thermal properties of a material is determined. The flat sensor is made up of a dual spiral of electrically conducting metal, which is nickel engraved out of a thin foil. The spiral made of nickel is positioned in between two layers of a very slim blocks of polyimide known as Kapton. The Kapton film offers mechanical stability and also electrical insulation to the sensor. (Log & Gustafsson, 1995)

Another method that can be used in the calculation of thermal conductivity of materials is the improved transient plane method. This was first established by Dr. Nancy Mathis. This method makes use of a sensor that is one-sided, interfacial, and is a heat reflectance sensor. The major distinctness between the transient and modified method is that the heating element is aided by providing electrical insulation, thermal insulation, and also mechanical support. The performance of the modified transient plane method with utilization to the heat transfer fluids was diagnosed, and it was concluded that this method offers consistent data in harmony with the literature value for thermal conductivity of materials. This ultimately advises that this is a dependable way to measure the thermal properties of fluids. (Harris, Kazachenko, Emanuel, Bateman, & Nickerson, 2014)

Most of these other methods of measurement of thermal conductivity are either manually operated, and hence human errors are likely to occur, such as systematic errors, random errors, and outright blunders. Systematic errors have an identifiable cause and can be eliminated. Types of systematic errors include:

I. Instrumental error: When the instrument used for taking readings are flawed and cannot be easily detected by the user and thus provides inaccurate readings.
II. Observational error: When the observer reads a measurement incorrectly.
III. Environmental error: When the immediate surroundings are in a laboratory, cold room, etc., lead to inaccurate readings.
IV. Theoretical error: When experimental procedures, for instance, a model system or equations, for instance, create an inaccurate result. This normally is a result of neglect of a very sensitive parameter or process in the experimental method.

Random errors occur during manually operated experiments, and readings taken will, in turn, be inaccurate. These errors are mainly caused by unknown changes in the environment often do not have sources that are often identifiable. Random errors are further divided into two major types:

I. Observational error: Observational error under random error occurs simply when the observer's ability to take reading leads to a random error rather than consistent accuracies in the total readings taken as a whole.
II. Environmental error: Simply when there are unpredictable changes in environmental conditions such as mechanical vibrations and temperature.

Blunders in science can be easily described as an outright mistake. Although blunders are similar to random errors and systemic errors, blunders can easily be identified because they are not consistent.

The temperature data logger to be designed and constructed will easily be able to avoid these types of human errors because the system will be fully automated. The temperature data logger does not require and operator in most cases, a scientist to be present throughout the process of data collection once the experiment has begun. The thermal conductivity of various samples can be conducted in a controlled environment due to the compartment in which the temperature data logger is housed.

The temperature data logger easily stores temperature readings from the sample that is currently being tested; these readings are made to be easily retrieved by the operator of the temperature data and can be used in the calculation of thermal conductivity *k* of materials.

1.2 PROBLEM STATEMENT

I. The various existing methods for measurement of thermal conductivities of specimens (good conductors and bad conductors of heat) requires full human operation in taking the readings (temperature-time data) during the experiment.

II. It has been noted humans are inherently fallible, and errors are highly inevitable. Therefore, there are high possibilities for errors gotten from data taken during the experiment will lead to errors in the calculation to get the thermal conductivity. (Reason, 1990).

1.3 AIM AND OBJECTIVES

1.3.1 Aim

The study aims to design a temperature data logger that will be used to determine the thermal conductivity of various insulating materials. The design of the temperature data logger was done as a modern mechatronic system to reduce all forms of human error and also to make the system fully automated.

1.3.2 Objectives

I. To design a functional circuit board using Proteus ISIS 7 professional software.

II. To synchronize the electrical components with the machined components being added to the system and ensure they are working ideally.

III. To design a system to efficiently and effectively measure temperature and stores the data in relation to time.

IV. To determine the effectiveness of the system by comparing the final results to already determined standard results of the same materials.

1.4 SCOPE

I. The project provides a simple and accurate method that can be used to work out the thermal conductivity of materials.

II. The project is aimed at using a fully mechatronic system that successfully measures and record temperature data from the temperature sensors embedded in the system.

III. The study was based on a circuit board design.

1.5 LIMITATIONS

I. The thermal property that can be determined from the project is limited to thermal conductivity only.

II. The band greater had to be imported from China.

1.6 JUSTIFICATION

There has been a renewed interest in developing new methods of determining the thermal conductivity of materials in recent years. This is a result of the rapid advances of technology in particular material technology and the several new applications of all kinds of materials at various wide temperatures, either elevated temperature or low temperatures. The project, the temperature data logger is able to measure important parameters needed for thermal conductivity calculations. (Parker, Jenkins, Butler, & Abbott, 1961).

Also, there will be a reduction in stress, fatigue, and distraction resulting in long term human presence during the operation of the device.

1.7 OVERVIEW OF THE STUDY

This project report is organized into five chapters, and they are:
Chapter 1 – Introduction
Chapter 2 – Literature Review
Chapter 3 – Materials and Methods
Chapter 4 – Results and Discussions
Chapter 5 – Conclusions and Recommendation

CHAPTER TWO

2 LITERATURE REVIEW

2.1 INTRODUCTION

Characteristics of various materials when subjected under mechanical and thermal loading is described by a group of physical features, which can be differentiated into four main groups. The first group of characteristics include thermal conductivity, melting point and specific heat capacities. The first group of characteristics are used to aid in the description of a material under thermal load without relation to their mechanical properties. The second group of characteristics include yield constants, elastic modulus etc., the second group of characteristics aid in the description of material behavior under mechanical load without experiencing fracture. The third group of characteristics include thermal expansion, density etc., the third group of characteristics aid in the description of thermo-mechanical behavior of material. The fourth group simply talks about the fracture behavior of materials. Thermal and mechanical properties of material are highly rated in the production industry and are mainly studied in research and development centers of both institutions and cooperate bodies. The study of the thermo mechanical properties are carried out for the prediction of material behavior in wide range of scenarios. (Marchenko, n.d.)

Thermal conductivity is also highly vital in the conception of engineering structures where both thermal stress and temperature are of concern. To this day, various measurement methods are used for measurement of bulk and thin film solid state materials with a very wide variety of temperature. (Zhao, Qian, Gu, Jajja, & Yang, 2016).

Data loggers are simple and largely cheap electronic devices which robotically observe and store environmental parameters of the data logger. A typical data logger comprises of a sensor to obtain the data and a computer chip to aid in the storage of the data collected. The data that is now collected from the data logger is then reassigned into a computer for investigation. (Gemini Data Loggers, 2020).

In this chapter, we are discussing the integration of a customized data logger that can be used to take readings of temperature of specimens under study. Comparisons of the automated data logger method to more natural manual methods of thermal conductivity. In this chapter, insights into a new and revised lee disc apparatus for thermal conductivity is considered.

2.2 APPLICATIONS OF MECHANTRONICS IN INDUSTRIES

Mechatronics is a very new branch in engineering. The rapid growth and development in this information age most especially computer technology and microchips also. This has massively helped the increase of demand of system that combine control, mechanical and electronic engineering. Mechatronics is a relatively new term generated first in the year 1969 by a certain Testura Mori while he was engaged in work at a company known as Yaskawa Electric Corporation.(Mohamed, 2016) Foundation of mechatronics include mechanical engineering, computer/information systems, computer engineering and electronics engineering. In mechatronics when a product is produced that requires various inputs from more than one discipline it can be classified as multi-disciplinary, inter-disciplinary or cross-disciplinary. This project focuses on a multi-disciplinary combination of mechanical engineering, electrical engineering and also computer engineering.

In the application of mechatronics in engineering problems it is also approached in the same manner. Mechatronics design process is divided into three simple parts; namely

I. Modelling or Simulation
II. Prototyping
III. Development or Life cycle

(Kunzel, 2005)

2.2.1 Key elements of a mechatronic system

Elements of mechatronics include all the various disciplines that make up a mechatronic system. As mentioned in the section above. Mechanical elements in area of mechatronics include things like hydraulic structure, thermo-fluid that makes up the system. In mechatronics it is noted that it's the mechanical elements within the system that acts with the environment directly. Mechanical elements involve physical power to create force, motion, heat, etc. Electromechanical elements in area of mechatronics include objects like sensors and actuators. A sensor is a device that can be used to measure physical variables examples are measure light via a photo-resistor, stress and pressure measurement using a strain gauge etc., An actuator is a part of a machine that is responsible for moving and regulating a device or system, a simple example is opening a valve. Electrical elements refer to electrical components used to assemble a mechatronic system examples are resistor, capacitor, transformer, and electric circuits. Electronic elements are one of the most important in mechatronic system because they aid in the interface of electromechanical sensors and actuators to the computing hardware. Facilities such as analog-to - digital converter, digital-to - analog converter, digital input / output, timers, microprocessor, counters, data acquisition and control board and digital signal processing board are referred to by computing hardware components. A control algorithm using sensor measurements is implemented by computing hardware elements to quantify control behavior to be applied by the actuator. (Onwubolu, 2005). Integrating different technologies to achieve the best solution to a given technical problem is the core of the discipline known as mechatronics. It is noted that electronics, digital control, actuators and sensors, and information technology are the core elements of a mechatronic system. In order to generate a specific product that is of practical value to the people or the issue at hand, all these components are brought together. The figure below illustrates the major branches of mechatronics.

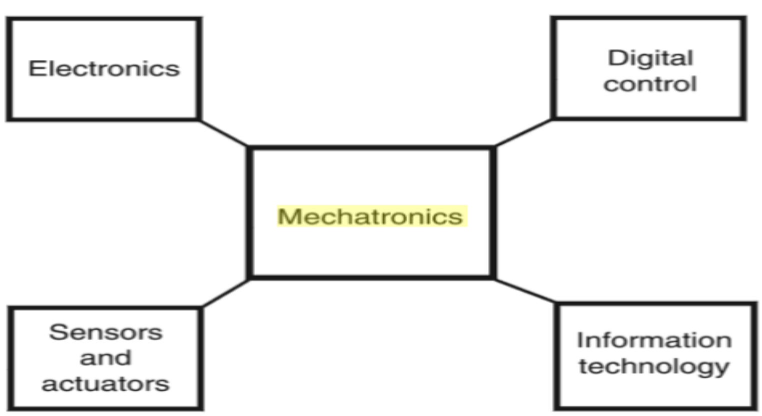

Figure 2.1: Branches of mechatronics

2.2.1.1 Electronics

Since the 1950s, semiconductor devices, such as diodes and transistors, have modified and influenced human lives, with silicon and germanium being the two most widely used semiconductors in electronic devices to date. Semiconductor chips, however, are not made of only one compound, but impurities are often added to the germanium or silicon base. The types of impurities added here are very high purified tetravalent atoms examples are; aluminum, boron and also pentavalent atoms examples of these are; antimony, phosphorus they are called doping materials. Unbonded electrons and empty bonds in pentavalent and tetravalent atoms are the final target of the doping of semiconductor base materials. An n-type semiconductor is one with an excess number of electrons, whereas a purified semiconductor material is then doped with a tetravalent product, so the reverse occurs since electrons are now deficient. A p-type semiconductor is the type of material produced It has been noted that by joining an n-type and p-type semiconductor together as a p-n junction, a semiconductor diode is formed. While transistors are active elements of the circuit and are naturally composed of germanium and silicon, they come in two kinds. Bipolar junction transistors and field effect transistors are two types of transistors.

2.2.1.2 Digital control

A mechatronic system's transfer function describes the relationship between the inputs to a system and its outputs. Normally, the transfer function is expressed as the domain of frequency. The To map the time domain representation into the frequency domain representation, the Laplace transform is used. Closed loop system in mechatronics deals with the setup and programming of the electrical parts of the system and the interaction with its mechanical aspects. Closed loop system in mechatronic system comprises of feedback. The output from the mechatronic device is now feedback from the device input through a controller. The control behavior of the controller depends on the desired and real process variable in a closed loop control system. Closed loop controllers have been noted to contain a feedback loop that essentially ensures that the controller exercises a control action to control a process variable at the same value as the set point. Closed loop controllers are sometimes called feedback controllers for this purpose.(Di Steffano, Stubberud, & Williams, 1967) Forward loop system in a mechatronic system is also a part of the control system. It is an element or pathway within a control that passes a controlling signal from the origin in its external environment to a load elsewhere in the identical environment. This signal is obtained from an external operator much of the time. A control device that only has a predefined response to the results of sensors. A control variable modification is not error-based in a forward loop system. Instead, it is based in the form of a mathematical model on knowledge of the entire method. (Haugen, 2009)

An open loop system is an unregulated system, a system with no feedback. The control operation of the controller in this scheme is independent of the process output, which is the managed process variable. This method does not use feedback to decide whether the desired target of the input command or process "set point" has been reached by its output. (Di Steffano.,1967)

2.2.1.3 Sensors and actuators

Sensors are elements used to track machine and process performance. The common classification of sensor data that can be captured are: distance, movement, proximity, stress, force, strain, and temperature. Many commercial sensors are being developed and prepared for production. Some types of sensors are: sensor for proximity, sensor for temperature, sensor for illumination, sensor for ultrasound, sensor for smoke, sensors for humidity, and many more. The signal output from a sensor is converted into a digital form for display on a device or another type of display unit, such as a liquid crystal display, under normal conditions. The computer controlling the sensor output for a display in a digital form is referred to as a measuring instrument. The figure below is a characteristic computer-based measuring system. Figure 2.2 below shows a flowchart of computer based measuring system.

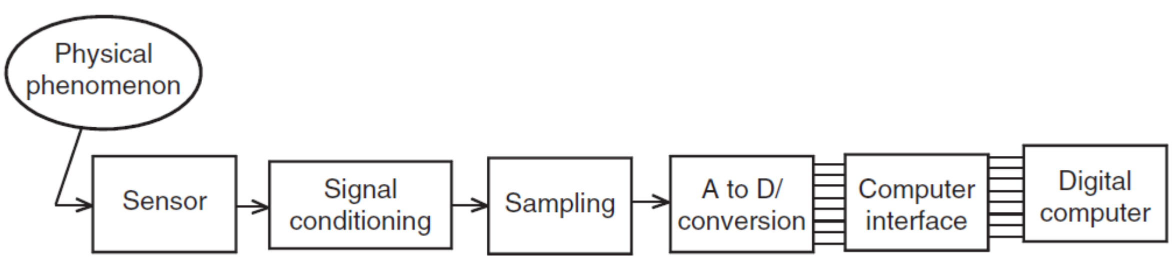

Figure 2.2: Computer based measuring system

Integrated sensors offer so many advantages when used for mechatronic systems such as: high reliability, low cost, small size, and system combability. The explanation behind these described benefits is the ability to preprocess and amplify the transducer signals before presenting them to the microcomputers via the jumper cables. They have the ability to use the transduction element's tiny signals. Integrated electronics offer excellent possibilities, such as the reduction of total transduction components, the removal of unwanted additional contacts and the land area of the electronic circuit. More sensitive and maintenance-free properties are needed in the real-life applications of these sensors, which are clearly the characteristics of integrated sensors. Integrated sensors are designed to provide enhanced temperature performance, sensitivity and long-term stability. (Powner & Yalcinkaya, 1995)

Electrical actuators are equipment that can transform electrical energy into mechanical energy. Both actuators are transducers, essentially because one source of energy is transformed into another form of energy. Some sensors, though not all, are also transducers. Actuators are used to produce motion or action, such as angular motion or linear motions. Solenoids, relays and electric motors are some of the main electrical actuators used in most mechatronic systems. In mechatronic systems, these actuators are of great importance when moving physical objects. The actuating force / torque can be supplied by an electric actuator in one of many ways. A motor that transforms electrical energy into mechanical torque can also be powered by electromechanical forces. A second solution is an electro-hydraulic actuator, where the electric motor remains the prime mover, but also generates torque to drive the hydraulic accumulator at the same time, which is then used to transfer actuation force in much the same way as diesel engines and diesel hydraulics are usually used in heavy machinery. When an actuator is fitted to control the flow of fluid through a valve a brake is then installed closely above the motor, this is to prevent the fluid pressure forcing open the valve. The main significance of brakes being installed with actuators that deal with the opening and closing of valves containing fluids is to avoid damage to actuators. (Oliver, 2019).

Mechanical actuators are classified simply as transducers which convert mechanical energy to electrical energy. Pneumatic cylinders, hydraulic cylinders, piezoelectric actuators, pneumatic actuators, and mechanical linear actuators are also some of the significant mechanical actuators that can be used in a mechatronic system.

2.2.1.4 Information technology

Communication: It is known that for communication to occur between a mechatronic system and a computer a form of communication must be established. This form of communication is established through transfer of signals to and fro from the devices. Normal conditions when computer is connected to a peripheral device it is done so through the computer's serial and parallel ports, where signals are being transferred. The parallel port has the ability to send and receive data. This parallel port contains five status lines, four control lines, and eight data lines. Standardized parallel port protocols under the IEEE 1284 normal for all types of parallel port manufactured. (Onwubolu, 2005)

2.3 EXAMPLES OF MECHATRONIC SYSTEMS

Mechatronic devices today are mainly used in daily aspects of life in workplaces, households, stores , schools and, of course, industrial applications. Examples of mechatronics systems being used for industrial applications are: Rockwell Automation, which is one of the world's largest industrial automation and information firms. Therefore, it can be said that the principals of mechatronic systems aid this company in design of products that are being offered to their consumers. In the development of some of their products focus is placed on these disciplines

I. Control systems
II. Motor control devices
III. Sensing devices
IV. Visualization and human-machine interface (HMI)

Mechatronic systems are also found present at entertainment service centers like Disney land. From the early hydraulic automations seen at the 1964 New York World Fair to the modern day globe containing theme parks, this has always been present in this industry. Disney land has always been a front runner for the implementation of all forms of engineering to their industry which is entertainment. Disneyland has a world-famous motto which reads "happiest place on earth", the whole idea of the theme park would not be attainable without mechatronics. Each year, the combination of computer controls, sound, fluid mechanics and light with intricate mechanical androids has helped to delight millions of adults and kids. Mechatronics applications keep getting better and are even used for out of this world purposes. A major organization is the National Aeronautics and Space Administration is set to launch officially unnamed "Mars 2020 Rover" a brand new completely remotely controlled vehicle that will be used for scientific expeditions to

Mars. The ten-foot-long, nine-foot-wide, seven-foot-tall vehicle will be designed as a computer that can simulate operating it with a human onboard. It will be equipped with temperature sensors for recording data of machine and immediate environment, computers to process information, powerful antennae for constant communication with earth and camera acting as eyes plus other sensors mounted on its mechanical head and neck. (Hunter, 2015)

2.3.1 Precision in mechatronic measurement

All existing steady state test methods for measuring solids' thermal conductivity are limited to applying heat flux in one direction. For these various procedures the additive errors such as reading errors from the sensor, error when recording data and also errors that result from a thermal contact resistance between samples and probes. In this paper with the aid of a mechatronic device we aim to reduce the error gotten during measurement.(Zhang, Shi, Xuan, & Li, 2013).

2.4 MICROCONTROLLERS

Microcontrollers and microcomputers since the beginning of the early 1970s era has been known to develop at a very quick rate since that time to this present day. Microcontrollers have developed from the point that before a single chip was designed with a functionality of one calculator alone, but now in these present times a single-chip microcontroller (SOCs) are able to perform multiple functions on all electronic systems. Microcontrollers that have a 16-bit processor or an 8-bit processor are often preferred and widely used for their ease of implementation and low-cost price. These microcontroller devices are now able to meet all types of needs and also have a better processing capacity of 64 bits and also 32 bits(Güven, Coşgun, Kocaoğlu, Ezİcİ, & Yilmazlar, 2017). The development process of some microcontrollers is shown in the table below:

Table 2.1: Development process of microcontrollers

Microcontroller	Processor	Bit Length	Clock Frequency	Year
TMS1802	Intel 4004	4 bit	740 KHz	1971
68HC05	Motorola 6800	8 bit	2 MHz	1974
MCS-48	Intel 8048	8 bit	11 MHz	1976
MSP430	Intel 8096	16 bit	12 MHz	1982
AT89C51	Intel 8051	8 bit	24 MHz	1986
Am29000	Intel 80186	32 bit	25 MHz	1995
AT91SAM3X8E	Cortex-M3	32 bit	84 MHz	2004
LPC3000	Cortex-M4	32 bit	250 MHz	2010

Programmable integrated circuits that can perform both logical and mathematical operations on digital inputs are microprocessors. Microprocessors consist basically of a single chip that typically contains the register areas necessary for the operations, as well as the input / output units and the data paths between them, as well as the transistor-based structure not to be overlooked. (Güven *et al*., 2017). The figure 2.3 shows below the basic architecture in a microcomputer.

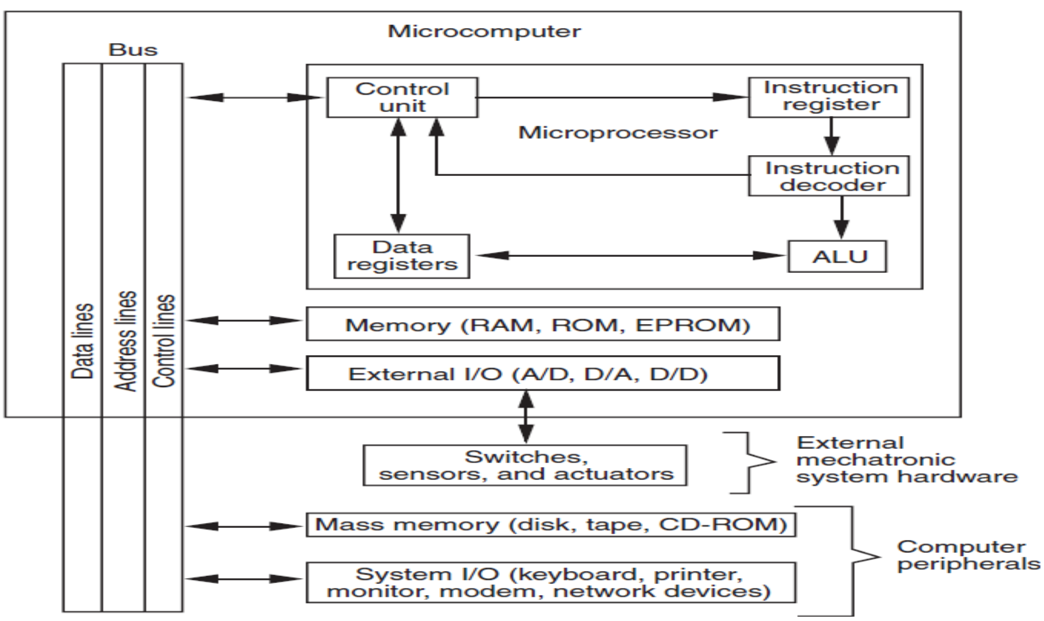

Figure 2.3: Microcomputer architecture

2.5 PROPERTIES OF ENGINEERING MATERIALS

Engineering materials as we know are very vital in day to day life because of their multipurpose structural features. Apart from these features, they also do show a very significant role because of their physical properties. Top physical quantities in question are: optical properties, thermal properties, magnetic properties and electrical properties. Choice of materials for use at high temperatures and perceived temperature variations will then require an expert such as an engineer to understand and know their thermal features.(Bohac, 2017).

2.5.1 Electrical properties of materials

Electrical properties are the skill to transmit electrical current. Several electrical properties are as follows electrical conductivity, resistivity, dielectric strength and thermoelectricity amongst others.

A few of the electrical properties are briefly described below:

Electrical resistivity: This is a characteristic of the material which negates the movement of electric current through material. Described as a give and receive of conductivity. The numbers of electrical resistivity are measured in micro ohm centimeters.

Electrical conductivity: This is a characteristic of a material that allows movement of electrical current through the body. It can be also described as current density to electric field strength. Electrical conductivity quantifies how well the material houses motion of an electric charge. Electrical conductivity is a very useful property since data gotten from the measurement also aids in checking for heat treatment of metals and also heat damage in some metals amongst other advantageous uses.

Temperature coefficient of resistance: This attribute of a material specifies change in resistance of material and alteration in temperature. It is noted that resistance of a conductor changes with change in temperature. Therefore, it has been noted that conductivity of materials reduces as temperature rises.

Thermoelectricity: If a relation is created by the connection to two metals and is heated, a small voltage of millivolt is fashioned. This consequence is known as thermoelectricity. This devises the foundation of operation of thermocouples.

2.5.2 Magnetic properties of materials

The magnetic properties of materials are primarily due to the electron-circling magnetic moments of their atoms. Usually, the magnetic moments of the nuclei of atoms are thousands of times smaller than the magnetic moments of electrons, so they are insignificant in the sense of material magnetization.

2.6 INSULATING MATERIALS

There are very basic and necessary specifications for insulating materials in every industry dealing with various heat transfer device operations. Insulating materials are very necessary to in the food and dairy industry to sustain the temperature of the steam being supplied, chilled water, storage of products at various temperatures in tanks or other forms of storage and also the transfer of finished products at low temperatures. The simple purpose of insulation is to interrupt the rate of heat flow in order to minimize the temperature change of the device or the room. Fifty percent of the energy used in daily industry studies is in the heating and cooling of milk.(Latham, 2010). As both these industries involve several units for operations, either at lower temperature or higher temperature as when compared to the ambient conditions of the air. Then the use of insulating materials in the diary and food industries are inevitable for the conservation of energy.

Thermal insulation can be described as a material or a material mixture that, when applied, delays heat flow and can be adapted to any form , size and surface. The insulation is therefore the product of the method of thermally isolating the device using different insulating materials to significantly reduce the heat transfer rate between the device and the adjacent body or the environment. The term known as "thermal insulation" is applied to temperatures ranging from minus seventy-five degrees Celsius to eight hundred and fifteen degrees Celsius. This is because applications of temperature below minus seventy-five degrees Celsius are termed as cryogenic and cryogenics are defined as the production and behavior of materials at very low temperatures. Although temperatures above eight hundred and fifteen degrees Celsius are considered refractory, any material that has a high melting point and also retains its structural properties at very high temperatures can be classified as refractory. Thermal insulators, which are used to reduce heat gain or heat loss, are weak heat conductors with very low thermal conductivity. Examples of such materials are typically porous, with a significant number of air cells commonly used as insulating materials, such as wool, glass and polyurethane foam...(Deshmukh, Preeti, Rupesh, & Saurabh, 2017)

2.6.1 Advantages of Insulating Materials

For energy efficiency, the main function of insulation is to avoid or mitigate thermal energy losses. Insulation, however, helps to accomplish this feat by adopting the methods highlighted below:

I. It avoids condensation and the resulting corrosion on cold surfaces.
II. It leads to energy savings and the elimination of green house gases (GHGs) in the atmosphere.
III. It offers more detailed monitoring of process temperatures and product safety.
IV. It also aids in providing additional fire protection and absorbs vibrations also.
V. It minimizes the building up of condensate in steam pipeline and other similar problems.

There have also been numerous direct and indirect benefits of insulation reported. Enhanced thermal protection of products are the most cost-effective way of reducing energy loss and at the same time operational costs. Large amounts of heat energy are wasted in industrial plants nationwide because of uninsulated, under maintained or under insulated heated or cooled surfaces on different machineries. So properly designed and installed insulating systems reduce the use of energy in the system. New findings have been able to confirm that the application of thermal insulation might result in cooling and heating energy savings as high as 25%. More studies have also indicated that, depending on certain external factors, such as air temperature, insulation materials also have the ability to minimize energy consumption by 18-34 percent..(Deshmukh *et al.*, 2017)

2.6.2 Important Properties of Insulating Materials

There are numerous properties of insulating materials which make them very significant to contemplate for the selection of insulating materials for particular projects. The final selection of insulating material for use depends on its properties but also at the same time depends on basis of structural and economic considerations. The top properties that an insulating material is expected to excel at are five in number they are compressive strength, service temperature range, water absorption, thermal conductivity and thickness tolerance. Also ideal insulating materials should also fulfil this various standards such as non-corrosive, non-flammable, low thermal conductivity, non-toxic and exhibit little or no decomposition at long period of time. The compressive strength of most insulating materials decrease as temperature increases this is why compressive strength of such materials are always considered at the service temperature. Thermal conductivity(K) is classed as the most significant in the quest to find out a materials ability to resist the flow of heat.(Deshmukh *et al.,* 2017).

2.7 INSULATING MATERIALS USED IN BUILDING

Building insulation is generally regarded as a simple but highly efficient energy solution that can now be useful for the commercial, industrial and residential sectors. A thermal insulator is typically composed of composite materials that naturally have desirable characteristics , such as high thermal resistance, which demonstrates the ability to minimize the heat flow rate.(Al-Homoud, 2005). As a consequence of this insulation in houses, it is able to maintain the cool or heat in a specific building and therefore avoids heat flux that would usually go on to the surrounding area. As insulators, various materials such as mineral wool, foam, fiberglass and many other materials are used. The biggest benefit of building insulation is undoubtedly the cost savings. This is possible because insulation in buildings helps the positive net energy balance by a greater amount of energy saved by this cost-saving application than the energy needed to create the insulation material itself. Moreover, the use of thermal insulation materials results in the various other benefits, including personal comfort, sound control, fire protection, and condensation. One of the simple and effectual ways of energy conservation technologies that are available today is by way of building insulation. The thermal conductivity will then be reduced by increasing the insulation thickness, while the insulation cost will be increased until it exceeds the savings identified for it, which will not bring any economic benefit from this additional thickness. Therefore, the ideal insulation thickness only exists when the savings start to drop as a result of the increase of the insulation thickness. As previously noted, insulating materials used in a building are also a way of saving energy and that the negative environmental effects of greenhouse gas emissions from the building.(Aditya *et al*., 2017).

CHAPTER THREE

3 METHODOLOGY

3.1 INTRODUCTION

This chapter presents a detailed insight into the materials that were utilized to carry out the project and also the technical and systematic approach used while giving reasons for the choice of each component and the methods used.

The chapter now further advances with a detailed description of each material and also components, a brief overview of coding used in PIC controller, various schematic diagrams also of materials used.

3.2 MATERIALS

3.2.1 Materials and Component Description

3.2.1.1 Brass disc

Brass, because of its hardness and workability, is a zinc and copper alloy of great importance. Because of its strong electrical conductivity, the metal was picked. The size of the brass disc was machined to 50mm in diameter and 20mm thick. The specific heat capacity of brass is 0.38 KJ/W ˚c the faces were also smoothened with sandpaper for good thermal contact. The figure 3.1 below shows a picture of the machined brass disc that was used during the production

Figure 3.1: Brass disc

3.2.1.2 Transformer

A transformer is a fixed electrical device that conveys electrical energy sometimes between two or more circuits by way of electromagnetic induction.

This transformer used in the project is a step-down transformer. This device converts the 220V supplied directly from the power supply unit to 18V which will now be supplied to the rest of electrical components.

3.2.1.3 Power Supply Unit

A power supply unit or PSU is a device that as the name implies supplies power to a computer. The temperature data logger contains a microcontroller hence the need for the PSU. The main job of PSU is to convert mains AC to a low voltage regulated DC power for the internal components of the temperature data logger which includes the microcontroller. This device also is able to function by providing a rectified, filtered and regulated DC to all other subunits of the rest of the device.

This can be represented by the flow diagram below in figure 3.2.

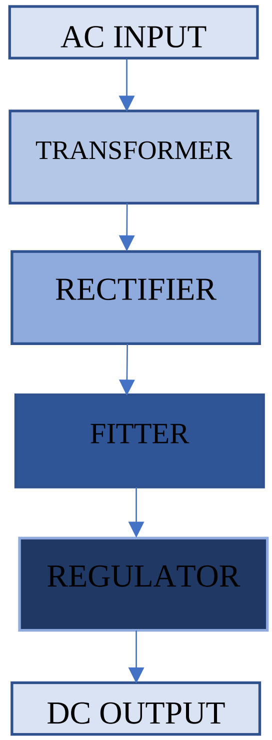

Figure 3.2: Flow chart of current in the temperature data logger

3.2.1.4 Rectifier

A rectifier is a simple electrical device that converts low voltage Alternating Current (AC) which is known mostly for reversing direction occasionally, to direct current (DC), which flows in only one direction. A rectifier is just a single diode or group of diodes. Diodes that aid in the conversion of AC current into DC current are known as rectifiers. Rectifiers are commonly grouped into two main types: half wave rectifier and full wave rectifier. The temperature data logger makes use of a full wave rectifier because we intend to achieve a smoother output DC voltage, which can only be realized by using full wave rectifier. The type of full wave rectifier that we used was a bridge rectifier for improved efficiency in the conversion of current and also helping to cut cost and good in space management. The bridge rectifier contains four diodes or sometimes more diodes in a bridge circuit configuration.

3.2.1.5 Fitter

This device is normally used in bridge rectifier and is connected after the rectifier diodes. A fitter is a simple device that allows dc components and also blocks all ac components that are products of the rectifier output. Fitter simply smoothens the signal by removing ripples from ac components still present. The fitter used was an electrolytic capacitor fitter connected to the circuit

3.2.1.6 Regulator

A regulator is designed primarily to maintain a constant voltage at a point or throughout a circuit irrespective of the input voltage. This device is needed to retain voltages within the given range that can be tolerated by the electrical components such as microcontrollers and sensors that will be using the particular voltage. The temperature data logger makes use of two regulators namely a 7805V and 7812V regulators which are both integrated circuits. The 7805-voltage regulator is connected to rest of components, while the 7812 voltage regulators is connected to the relay which is then connected to heater because of the large amount of voltage that is supplied to the heater. The 7805-voltage regulator has minimum input voltage of 7 V and maximum input of 25 V and operating current is 5mA and is available at low cost.

The 7812-voltage regulator is an integrated circuit belonging to the 78xx voltage family also. The 7812-voltage regulator has an output voltage of 12 V and is available at low cost.

3.2.1.7 Relay switch circuit

This is an electromagnetic switch which can be used to change high current or voltage via the use of low power circuits. Relay helps by isolating low power from the high-power circuits. Relays are easily connected with microcontrollers with the aid of a transistor. The transistor used in the particular circuit was an NPN transistor. The relay in the temperature data logger was used to pass current through the heater to heat the heat sink and after 60 minutes the microcontroller will stop energizing the relay therefore cutting of supply to the heater and that is when the cooling recording process will begin.

3.2.1.8 NPN transistor

An NPN transistor is one in which a p-type material is put in between two weak n-type materials. This transistor is the device that sends current flow through the relay. When the pin of the PIC microcontroller goes high the transistor is activated and the current then flows through the relay. There are three terminals for the NPN transistor, namely the emitter, base and collector. Although the base is connected to the negative supply to control the switching on and off stages of the transistor, the collector is still connected to the positive supply.

3.2.1.9 Temperature sensor

Temperature sensor is an electrical device thats basically a thermocouple or resistance temperature detector, that allows for temperature measurement via an electrical signal. LM35 temperature sensor was the electrical component used to take temperature readings of the heat sink, it is an integrated circuit with high precision, it is a semiconductor-based contact temperature sensor because it. Major advantage of using LM35 sensors are very cheap cost for an integrated circuit and also the very economical size. LM35 temperature sensors are able to measure temperature between -55*C to 150*C. LM35 sensors are easily connected to any microcontroller that has an analog to digital converter function. This electrical component has three types of pin configurations namely: a Vcc(5V) input, Analog Output that reads 10mV per degree Celsius and the last pin is the ground pin. The Vcc pin serves as where the input voltage of 5V flows through. The Analog Out pin is the pin that is connected to the temperature sensor head and is used to measure the output temperature via increase in electrical signal which is voltage and the last pin is the ground pin which is naturally connected to the ground of the circuit.

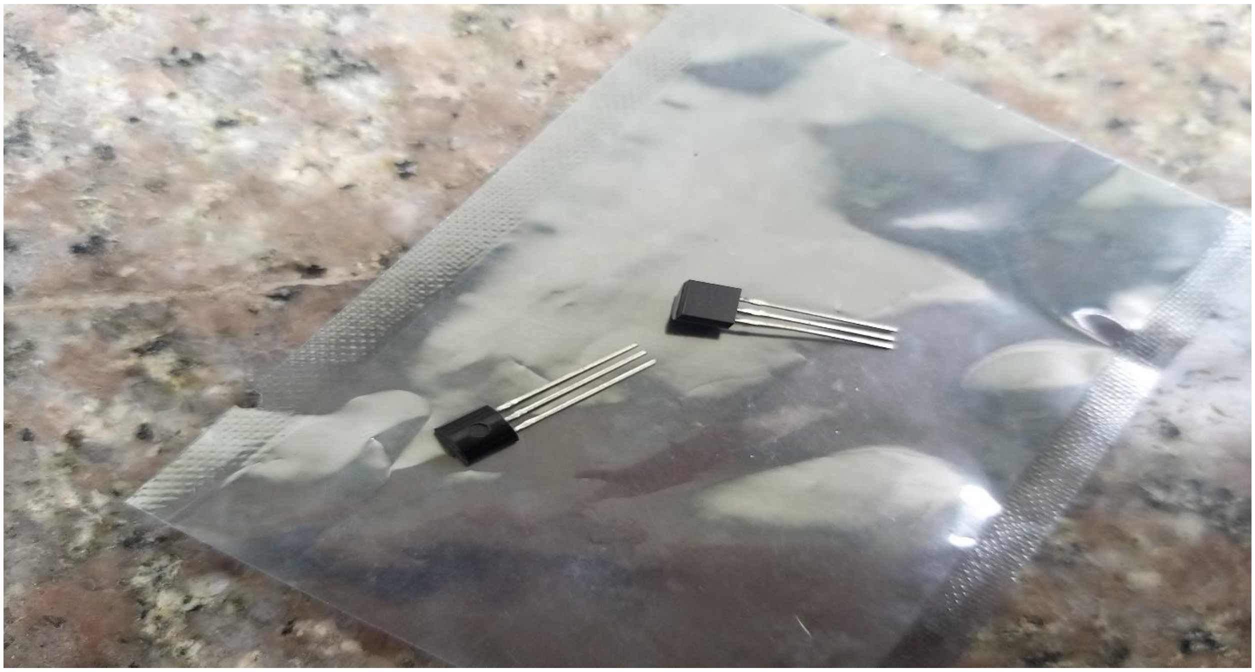

Figure 3.3: LM35 temperature sensor

3.2.1.10 PIC Microcontroller

Microcontroller can be simply described as a small computer on a single chip. It is intended to govern a particular operation in an embedded system. It is a compact integrated circuit that includes a memory, processor and input/output (I/O) peripherals. This device is fixed inside of a system to dictate singular functions. It carries out such functions by decoding data that is being received from its input/output peripherals using the central processor embedded also within the microprocessor. The microcontroller that was used for the temperature data logger was a PIC18F4620 microcontroller. PIC stands for Programable Interface Controllers. PIC18F4620 microcontrollers have a pin count of 40 which are also known as peripherals, safe operation voltage range of 2 volts to 5.5 volts hence the importance of the voltage regulator. The microcontroller PIC18F4620 is fitted with flash type of memory which means it can be reprogrammed multiple type making the whole mechatronic system very versatile in its application.

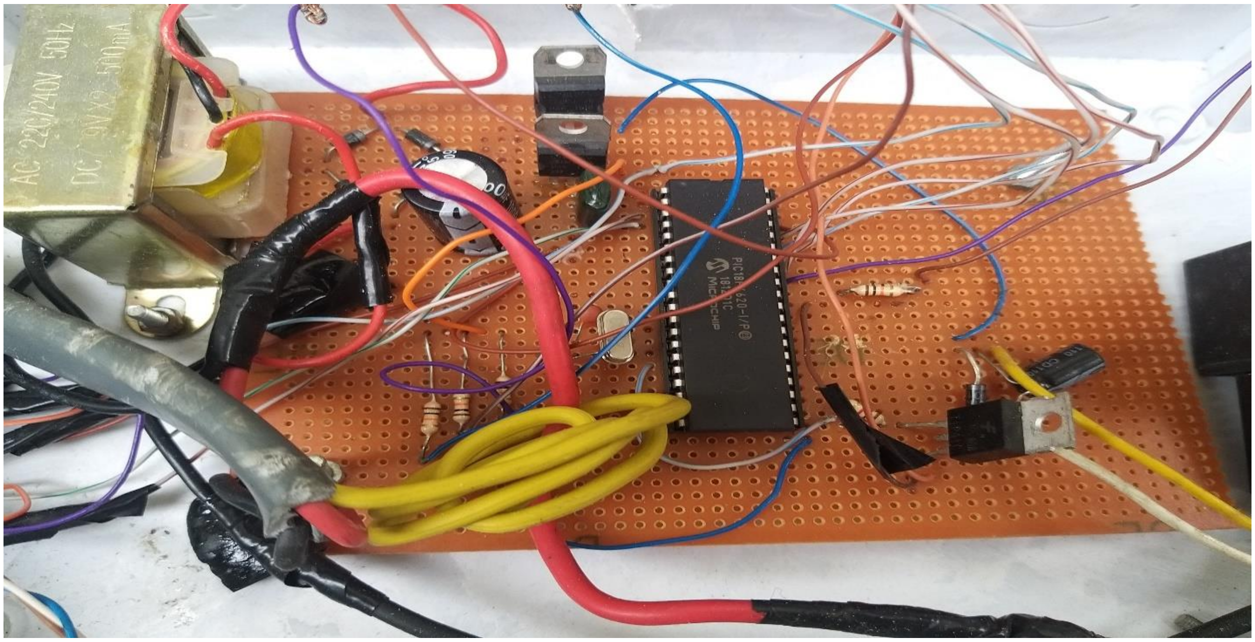

Figure 3.4: PLC microcontroller

3.2.1.11 Crystal oscillator

The type of oscillator found in PIC18F4620 microcontroller is a 4MHz internal crystal oscillator. Internal oscillator circuit is used to generate the clock of the device. Further explained it is used to generate clock pulses required for the synchronization of all internal operations of the device.

3.2.1.12 Liquid crystal display

LCD which stands for Liquid Crystal Display is a type of flat panel display which operates via the use of liquid crystals. The liquid crystals are what is used to produce visible images. The liquid crystal display is very important when being used in microcontroller projects because it helps to display results immediately when the process starts so that you can quickly correct errors in programming instead of having to use a debugger each time which is quite difficult. The type of liquid crystal display screen that was used was the LM44L which has 14 pins where 8 pins are classified as data pins (from D0 to D7). Three other pins are classified as LCD control pins namely: RS (Register Select), RW(Read-Write) and E (Enable). Two other pins are classified as LCD power pins namely the VDD(+5v) and VSS (Gnd). The last pin is the LCD contrast pin (VEE).

3.2.1.13 Push button switches

In an embedded system used in very basic to highly complex systems, push buttons are basic input devices. They are basically mechanical on-off buttons which act as control devices. It short circuits the line when force is applied down on the push button and opens when force is withdrawn.

The type of push button used for this project were the spdt push button. Push button is connected to a microcontroller through a resistor to reduce and control the sourcing current. In the temperature data logger three push buttons were utilized the first push button was labelled next, the second push button was labelled reset and the last push button was labelled previous.

3.2.1.14 Mica band heat sink

Mica band heaters are simple devices which offer economical and efficient heating solutions to pipes, tubes and blocks that require indirect external heating. These heaters are used to heat-up the external surface of drums, pipes or blocks for gradual heat transfer process.

The mica band heater that was used was a 50mm diameter by 30mm height operating on a 220volts AC current. Figure 3.5 shows a Mica band heater used.

Figure 3.5: Mica band heat sink

3.2.1.15 Electrical cables

These simply provide wired connections between all electrical components.

3.2.1.16 Software

The microcontroller is programmed using embedded C language. The complier used was the Mikro C compiler. Mikro C can be used to provide an interface to write the program and then compile the code into the component. The Hex code generated after building the program is transferred to the PIC18F4620 via a PIC program using mplab software

3.2.2 Specification of Components

Temperature Sensor

Features of LM35 temperature sensor

- Operates from 4 volts to a 30 volts limit
- Low cost due to water-level trimming
- Suitable for remote applications
- Low impedance output, 0.1Ω for 1-Ma load
- Calibrated directly in Celsius

Table 3.1: Pin specifications on the LM35 temperature sensor

PIN NUMBER	PIN NAME	PIN TYPE	DESCRIPTION
1	$+V_S$	POWER	Positive power supply pin
2	GND	GROUND	Device ground pin, connect to power supply negative terminal
3	V_{OUT}	O	Temperature sensor, Analog output

Microcontroller

Table 3.2: Operating parameters of the LM35 temperature sensor

S/N	PARAMETER	VALUE
1.	Operating Frequency	DC – 40 MHz
2.	Program Memory (bytes)	65536
3.	Program Memory (instructions)	32768
4.	Data Memory (bytes)	3968

5.	Data EEPROM Memory (bytes)	1024
6.	Interrupt Sources	20
7.	I/O Ports	5 Ports- A, B, C, D, E
8.	Timers	4
9.	Analog-to Digital Module	13 Input Channels
10.	Instruction Set	75 Instructions
11.	Parallel Communications (PSP)	Yes

Table 3.3: Description of pins in the PIC18F4620 microcontroller

PIN NUMBER	PIN TYPE	PIN NAME	DESCRIPTION
1		MCLR/V_{PP}/RE3	Master clear (input) or programming voltage (input).
	I	MCLR	Master Clear (reset) input. This pin is an active low. Resets the device.
	P	V_{PP}	Programming voltage input
	I	RE3	Digital input
2		RA0/AN0	
	I/O	RA0	Digital I/O
	I	AN0	Analog input 0
3		RA1/AN1	
	I/O	RA1	Digital I/O
	I	AN1	Analog input 1
15		RC0/1OSO/T13CKI	
	I/O	RC0	Digital I/O
	O	1OSO	Timer1 oscillator output
	I	T13CKI	Timer1/Timer3 external clock input
19		RD0/PSP0	
	I/O	RD0	Digital I/O
	I/O	PSP0	Parallel slave port data
20		RD1/PSP1	
	I/O	RD1	Digital I/O
	I/O	PSP1	Parallel slave port data
21		RD2/PSP2	
	I/O	RD2	Digital I/O
	I/O	PSP2	Parallel slave port data
33		RB0/INT0/FL0/AN12	
	I/O	RB0	Digital I/O
	I	INT0	External interrupt 0
	I	FL0	PWM fault input for enhanced CCP1

	I	AN12	Analog input 12
34		RB1/INT1/AN10	
	I/O	RB1	Digital I/O
	I	INT1	External interrupt 1
	I	AN10	Analog input 10
35		RB2/INT2/AN8	
	I/O	RB2	Digital I/O
	I	INT2	External interrupt 2
	I	AN8	Analog input 8
36		RB3/AN9/CCP2	
	I/O	RB3	Digital I/O
	I	AN9	Analog input 9
	I/O	CCP2	Capture 2 input
37		RB4/KBI0/AN11	
	I/O	RB4	Digital I/O
	I	KBI0	Interrupt on
	I	AN11	
38		RB5/KBI1/PGM	
	I/O	RB5	Digital I/O
	I	KBI1	Interrupt on change pin
	I/O	PGM	Low voltage ICSP™ Programming enable pin

Liquid Crystal Display

Table 3.4: Operating parameters of liquid crystal display

S/N	PARAMETEER	VALUE
1.	Input Voltage	2.2/5V
2.	Supply Current	2.5-4.0 mA
3.	Output Voltage	0.2-2.2 V
5	Operating temperature	0-50˚C

Table 3.5: Function of pin in the liquid crystal display

S/N	SYMBOL	FUNCTION
1.	VSS	GND,0V
2.	VDD	+5V
3.	VEE	For LCD Drive
4.	RS	Function Select
5.	RW	Read or Write
6.	E	Enable Signal
7.	DBO	Data Bus Line
8.	DB1	Data Bus Line
9.	DB2	Data Bus Line
10.	DB3	Data Bus
11.	DB4	Data Bus
12.	DB5	Data Bus

13.	DB6	Data Bus
14.	DB7	Data Bus

Mica band heater

Table 3.6: Operating parameters of mica band heater

S/N	PARAMETER	VALUE
1.	Voltage	220V
2.	Power	150W
3.	Diameter x Height	50mm * 30mm

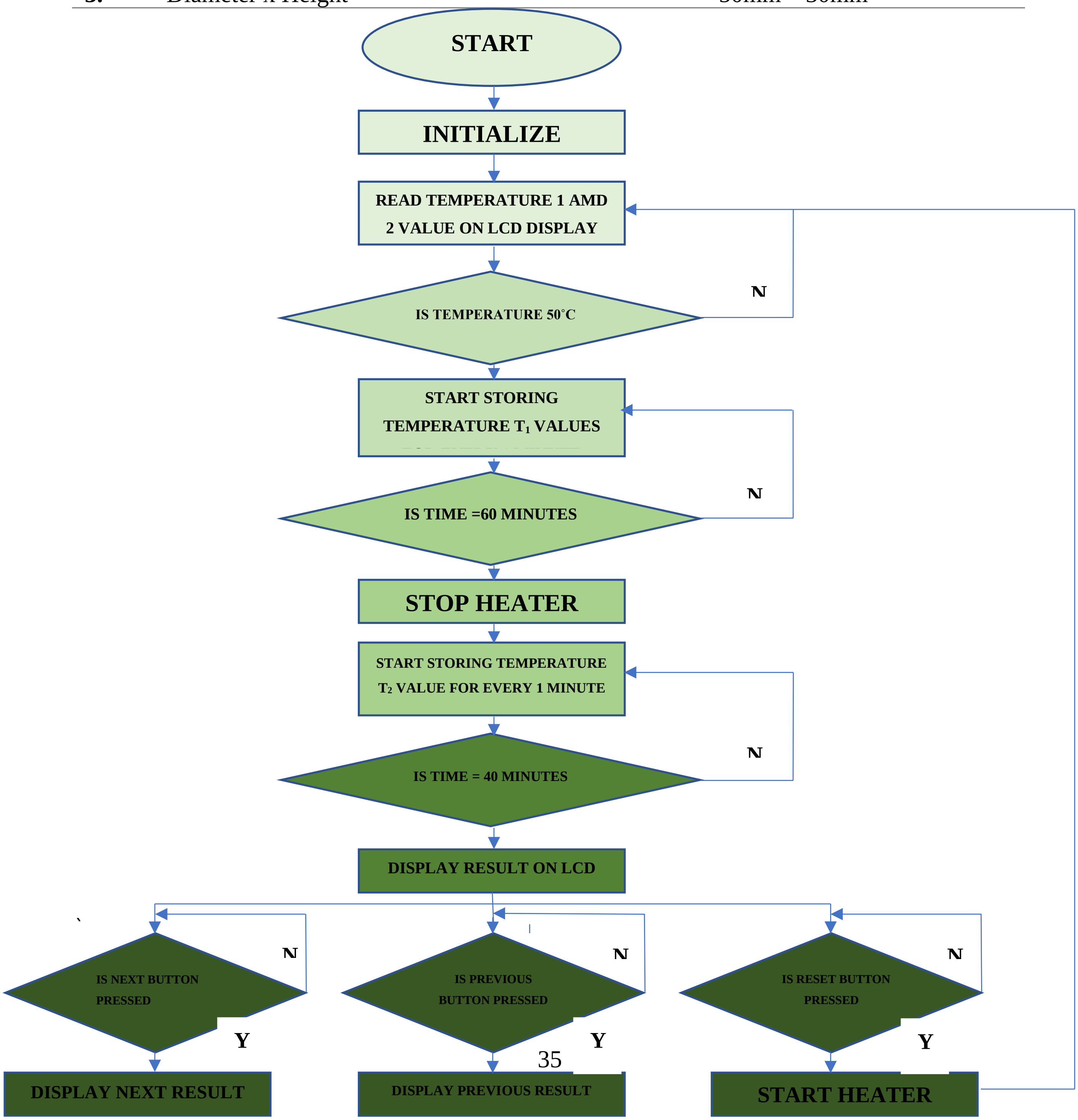

Figure 3.6: Flowchart of Temperature data logging process

3.3 METHODS

This section reveals the procedure in the project setup and will be explained under the different segments of the system:

Section A – Logical function of the system

Section B – Electrical system

Section C – Circuit diagram

Section D – Power supply connections

3.3.1 Section A-Logical function of the system

This section describes the function of the temperature data logger in lay man terms explaining the instructions that is carried out by the PIC microcontroller.

Simple description of uses of the two temperature sensors Heater sensor (T1) and Heat sink (T2) will be a focus in this section.

Note that both the sensors T1 and T2 are already inserted into their respective brass discs.

For simplicity the functionality is divided into three sections:

- Heating the brass disc attached to T1 to 50˚c
- Capturing of data for 60 minutes after brass disc attached to T1 has reached the 50˚c
- Capturing of data for 40 minutes during cooling

3.3.1.1 Heating the brass disc attached to T1 to 50˚c

Here the microcontroller will send signal to the relay switching circuit which will in turn mean the relay switch will closed, therefore current will pass through relay switch before getting to heater. This will mean the heater will increase gradually until it reaches the checkpoint of 50˚c.

At the value of 50˚c the PIC microcontroller will begin to store data of readings gotten from our two sensors T1(heater sensor) and T2(heating sink sensor).

3.3.1.2 Capturing of data for 60 minutes after brass disc attached to T1 has reached the 50˚c

Here the microcontroller processes the input signals gotten from the sensors with the help of its Central Processing Unit (CPU). With particular focus on the Heater sensor (T1) after the sensor read a temperature of 50˚c the CPU located in the PIC microcontroller will interpret the input signal gotten from the sensor and will now store the information as data in its Random-Access Memory (RAM). The data will be interpreted to the operator via the LED (Light Emitting Diode) screen.

The data storing will be done at 60 second/1-minute intervals for 60 minutes after 50˚c temperature value was attained.

Data readings that are being stored are the data of both of the temperature sensors that is Heater sensor (T1) and Heat sink (T2) in the RAM of the microcontroller.

- Software algorithm for this process:

```
 if(flag2 == 1)
   {
   LCD1_cmd(clear);
   while(flag2)
      {
      if(PORTD.B0 == 0) if(_ii==60); else _ii++;
      if(PORTD.B1 == 0) if(_ii==1);  else _ii--;
      if(PORTD.B2 == 0) {for(_ii=0; _ii<60; _ii++){heater_A[_ii] =0;  heater_B[_ii]=0;
sink_A[_ii]=0;  sink_B[_ii]=0;} _ii=0; flag2=0; flag1=0; flag =0; PortC.B0 =0 ;}
          LCD_writeText(1,1,"T1-");
          inttostr(_ii+1, txt);
          LCD_writeTextCP(Ltrim(txt));
          LCD_writeTextCP("a: ");
          floattostr(heater_A[_ii], txt);
          txt[4]=0;
          LCD_writeTextCP(Ltrim(txt));
```

```
CustomChar(1,13);
lcd_chr_cp('C');

LCD_writeText(2,1,"T2-");
inttostr(_ii+1, txt);
LCD_writeTextCP(Ltrim(txt));
LCD_writeTextCP("a: ");
floattostr(sink_A[_ii], txt);
txt[4]=0;
LCD_writeTextCP(Ltrim(txt));
CustomChar(2,13);
lcd_chr_cp('C');

if(_ii<40)
{
LCD_OUT(3,1,"T1-");
inttostr(_ii+1, txt);
LCD_writeTextCP(Ltrim(txt));
LCD_writeTextCP("b: ");
floattostr(heater_B[_ii], txt);
txt[4]=0;
LCD_writeTextCP(Ltrim(txt));
CustomChar(3,13);
lcd_chr_cp('C');

LCD_OUT(4,1,"T2-");
inttostr(_ii+1, txt);
LCD_writeTextCP(Ltrim(txt));
LCD_writeTextCP("b: ");
floattostr(sink_B[_ii], txt);
txt[4]=0;
```

```
LCD_writeTextCP(Ltrim(txt));
CustomChar(4,13);
lcd_chr_cp('C');
}
```

3.3.1.3 Capturing of data for T1 andT2 temperature sensor during 40 minutes of cooling

Here the microcontroller will send signal to the relay switch circuit after 60 minutes which then opens the relay switch, therefore current that was previously being supplied to the heater is now cut off. Hence the cooling process begins and the two temperature sensors begin to take readings for cooling T1 and T2 for 40 minutes. The storage of data will be chiefly orchestrated by the microcontroller.

- Software algorithm for this process:

```
else if(flag1==0)
  {
  if (temp1>= 50.0)  flag =1;
  }
  else
  {
     Lcd_writeText(4,1,"capturing...");
     heater_B[_ii] = temp1;
     sink_B[_ii] = temp2;
     _ii++;

     if(_ii > 39)    {flag = 0;    flag1=0; _ii=0;    flag2=1; LCD1_cmd(clear);
Lcd_writeText(4,1,"Cooling stopped"); }
    delay_ms(60000);        //ESURE IT IS delay_ms(60000);
    LCD1_cmd(clear);

  }
```

```
    if(flag==1)
      {
         Lcd_writeText(4,1,"capturing...");
         heater_A[_ii] = temp1;
         sink_A[_ii] = temp2;
         _ii++;

         if(_ii >59)    {flag = 0;   flag1=1; _ii=0; LCD1_cmd(clear); Lcd_writeText(4,1,"Heating stopped"); PortC.B0 =1 ; }
         delay_ms(60000);   // ENSURE delay_ms(60000);
         LCD1_cmd(clear);
      }
      else  {delay_ms(1000);  //LCD1_cmd(clear);
      }
    }
}
```

3.3.2 Section B - Electrical system

Electrical systems are groups of electrical components typically connected to perform such tasks. Based on the wiring, electrical systems may be as simple or complex. To ensure that they are safe, economical and efficient, electrical designs are used to solve design and development-related challenges. Design of an electrical system is very important because of the consequence of wellbeing of human life that can be a result of faulty electrical connections. An electrical engineer was contracted to ensure that the electrical components found in the Data Logger were properly connected with regards to safety rules and regulations.

The electrical design system of the Data logger runs on 12 volts DC. The 12 volts current is going to be regulated around the system this 12 volts is going to be regulated by a process called rectification. The normal voltage gotten from plugging an electrical component into a wall socket is 230 volts AC. There is a transformer located inside the Data logger that steps down 230 volts AC to a 12 volts AC, and the 12 volts AC is now passed through the rectifier bridge. The rectifier bridge is a combination of diodes shaped in a diamond form. The rectifier converts the 12 volts AC to 12 volts DC. The waveform of the current passing through the rectifier diodes contain some ripples in them and may be harmful to the rest of the electrical components in the Data Logger. Capacitor was introduced in particular a smoothing capacitor; the capacitor reduces the ripples in the DC voltage coming from the rectifier so that the current can resemble a steady waveform coming from a DC battery. Located in front of the smoothing capacitors we have the voltage regulators, which mainly are tasked to supply fixed amount of voltage to the rest of the device.

The voltage regulators integrated into the data logger are rated as 12 volts. Now the 12 volts from the voltage regulator goes into the relay. A relay is an electric switch that uses electromagnetism to convert small electrical stimuli into larger currents. These conversions occur when electrical input activate electromagnets to either form or break existing circuits. The relay works if a certain condition is met, for example in this project if the relay switch is energized with a 12 volt current the relay then completes the circuit. The current now flows through relay switch to the integrated circuit (IC)/ PIC controller.

3.3.3 Section C- Circuit design

A circuit diagram/electronic schematic is simply a graphical representation of an electrical circuit. Schematic designs are more detailed than pictorial representations and are widely used for engineering projects. The schematic design shows the interconnections and components of the circuit using the standard symbolic representations. In most instances the arrangement of the actual components physically does not correspond exactly with the interconnections represented on the schematic circuit diagram.

The software that was used to draw, design and simulate circuit diagrams in real time in the duration of the project was Proteus ISIS Professional. Figure 3.7 below shows a circuit diagram of data logger.

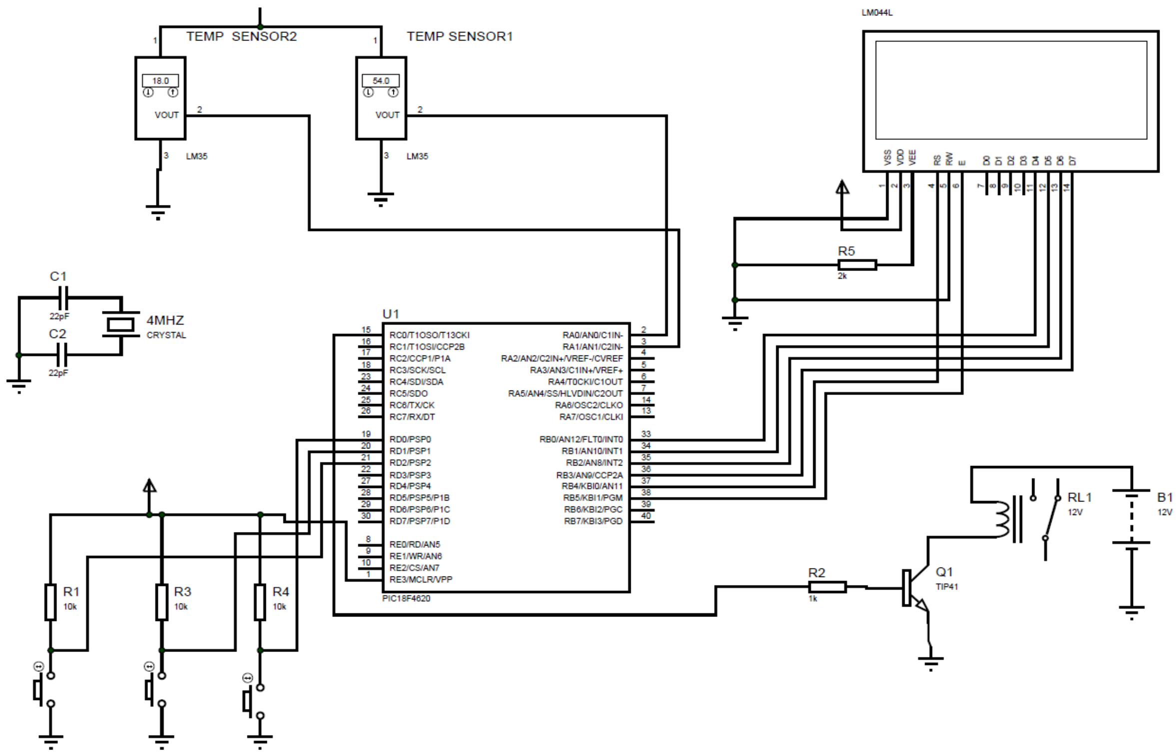

Fig 3.7: Circuit diagram of the data logger

From the Circuit diagram we can see the PIC microcontroller at the center of the diagram acting as the brain for the Data logger with various logic gates that are patched together and carry out various functions.

From the circuit diagram at the bottom right of the image the symbol of a battery can be identified which represents a power source be it Alternating current or Direct current which is ground. Power supply is designated as 12 volts hence in the circuit diagram no safety precaution is necessary by adding rectifiers, diodes. The battery hence is therefore connected to a 12-volt rated relay switch. The current entering the relay switch is adequate and safe enough the relay switch now closes which allows current pass through it. The current now flows from the relay switch to a silicon NPN power transistor. A transistor is a simply a semiconductor device used to amplify electrical power or also function as an electronic switch, more specifically the power transistor is designed to work at power levels meaning the power transistors are very capable of handling large voltage and current. The NPN power transistor is connected to a metal base that acts as a heat sink to dispose excess power. The power transistor only does switch and conversion of electrical power and has nothing to do with amplifying. Current moves from the transistor and enters into a resistor. A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. It is well known that in electric circuits, resistors are used to reduce current flow, adjust signal levels. Resistors are common elements of an electric network. The current then flows through the resistor into the PIC microcontroller at pin 15 which is a Digital I/O pin that stands for digital input and output. The pin is configured as an input pin because it instructs the microcontroller that the required voltage to power the system safely has been met. The data bus ports found in the LCD are connected to the microcontroller via pin 33,34,35,36. Data bus can transfer data to and from the memory of a computer/microcontroller. Pin number 33,34,35,36 all contain Analog input pins which is an input that can read a variable voltage, typically from zero volts to the maximum voltage that powers the microcontroller itself. Data pins 37 and 38 are connected to the RS and E pin of the LCD screen respectively. RS pin is the function select pin while the E pin is the enable select pin. The function select pin in the LCD toggles among a command and data register, used to connect a microcontroller unit pin and also obtains either a 1 or 0. Where the 0 stands for "data mode" and the 1 stands for "command mode". The enable pin on the LCD screen, it is used to execute read/write process and it is connected to the microcontroller unit and constantly held high. While pin 11,12,13,14 are all classified as data pins on the LCD screen. The function of the data pins is that they are used to send data from the microcontroller. The VDD pin on the LCD screen represents the voltage supply pin of the display screen, it is used to connect the supply pin of the power. The VSS pin on the LCD screen represents the ground pin, it is used to connect the ground terminal of the microcontroller or the power source. The logic gate pins 19,20,21 of the PIC microcontroller is patched to the three push buttons of the Data logger representing the reset, next and previous functions of the device. The push buttons patched to the microcontrollers are through parallel port slave ports. These specialized ports allow data transfer measured in bits between the PIC microcontroller and external device which are the push buttons in this setup. Notice the number 1 pin labelled on the microcontroller is patched onto the reset push button. When the reset push button is closed, current flows through and sends a signal to logic pin 1 on the microcontroller which in turn resets the device and begins to take readings again from the beginning.

3.3.4 Section D- Power supply connection

The system is powered by an Alternating Current of Nigerian rating 230V. The transformer steps down the voltage from 230V to 12V. where other devices embedded in the system convert 12V alternating current into a 12V direct current.

Table 3.7: Power rating

COMPONENT	QUANTITY	CURRNET RATING (A)	TOTAL CURRENT (A)
PIC18F4620 MICROCONTROLLER	1	0.025	0.025
LM 35 TEMPERATURE SENSOR	2	0.00006	0.00006

CHAPTER FOUR

4 RESULTS & DISCUSSIONS

4.1 INTRODUCTION

This chapter presents the results of the design work and the discussion of the overall working of the system that has been fully constructed and designed making it fully operational.

4.2 RESULTS

This section presents the pictorial results of the design work.

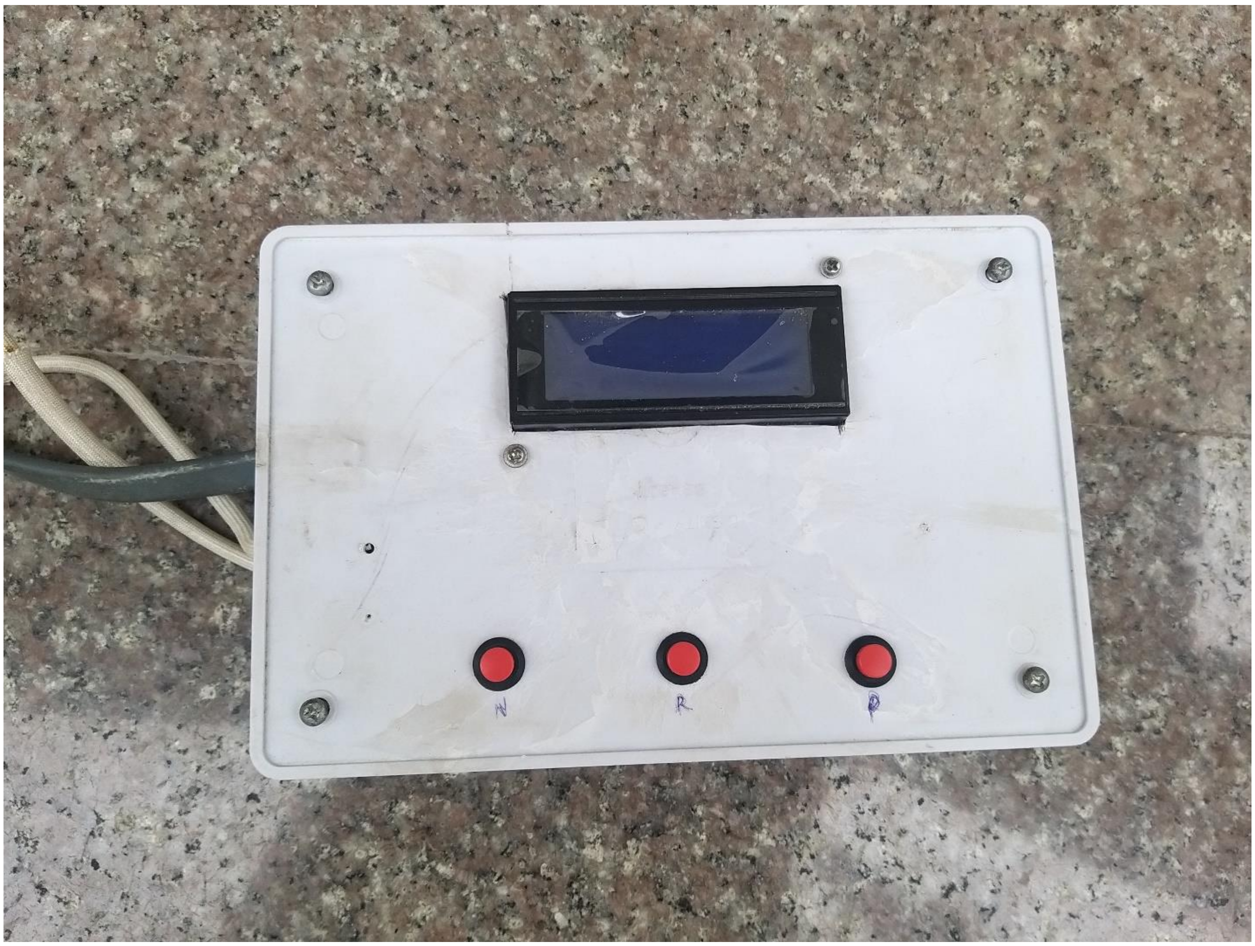

Figure 4.1: Temperature data logger

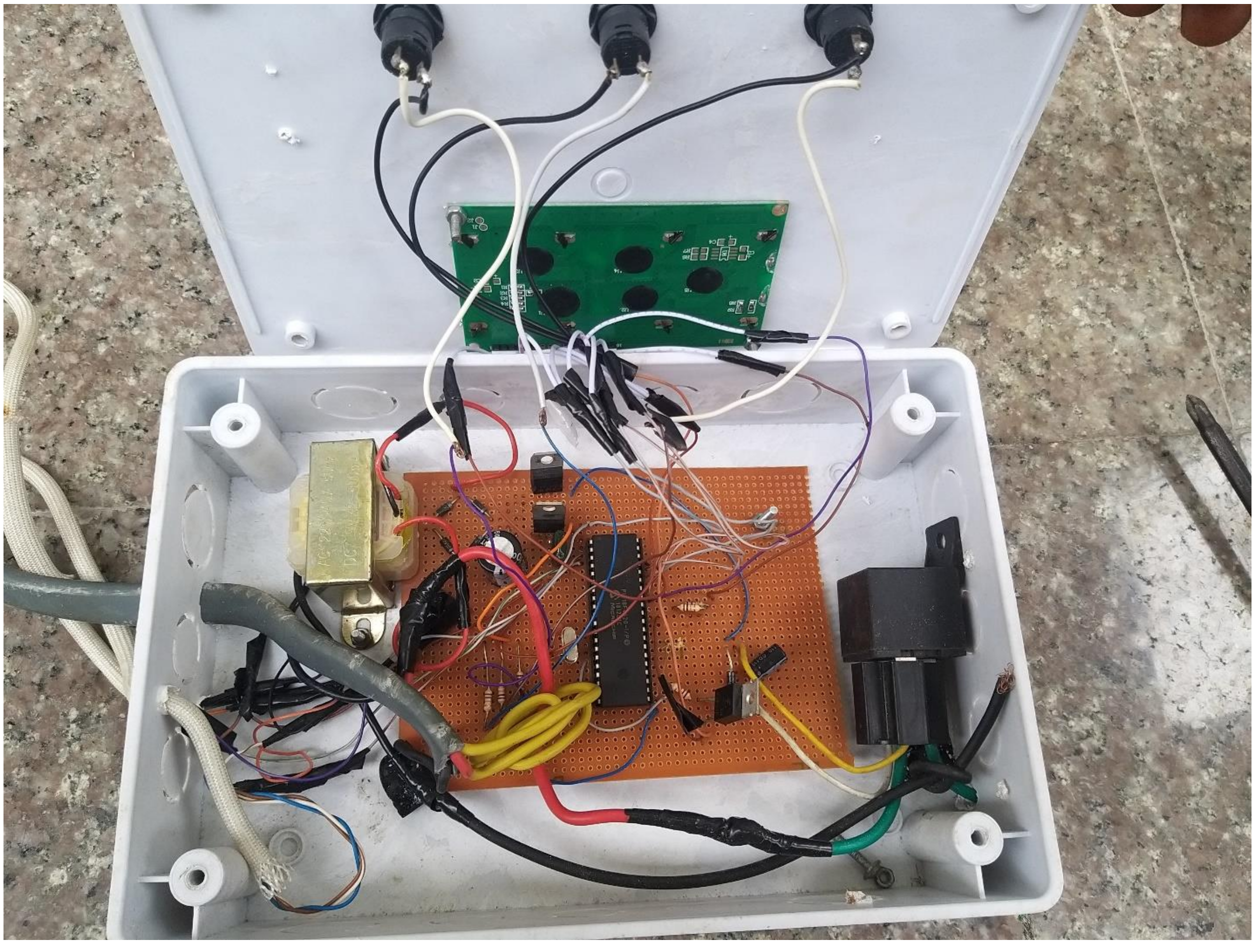

Figure 4.2: Internal components of the temperature data logger

4.3 DISCUSSION

The data logger as seen above in the various pictures has been constructed to operate by taking the temperature readings of brass disc attached to the temperature sensors. These temperature readings are taken in batches and the microcontroller imbedded inside the data logger stores the data. The first batch of data that would be stored is when the heater reaches a temperature of 50˚C, the microcontroller then stores both readings from the two sensors for 60 minutes after which the current being sent to the heater is open which cuts off power to heater. After this the microcontroller also stores the temperature data from the sensors for 40 minutes when the cooling of heater now occurs. These readings are displayed on the LCD screen of the data logger for the users viewing pleasure, push buttons are also present to help the user navigate the numerous data values presented by the device.

The setting up of the data logger is quite straight forward. Firstly, the temperature sensors are coupled together with the brass discs via holes machined into the discs. The heating chamber is then coupled together with a brass disc and is place on top of the specimen due for thermal conductivity reading. The specimen is already placed on top of the second brass disc. The whole setup is now fastened together via a hose clamp to ensure maximum surface contact between the brass discs and the specimen subject under test. The temperature readings are carried out automatically and stored by the data logger.

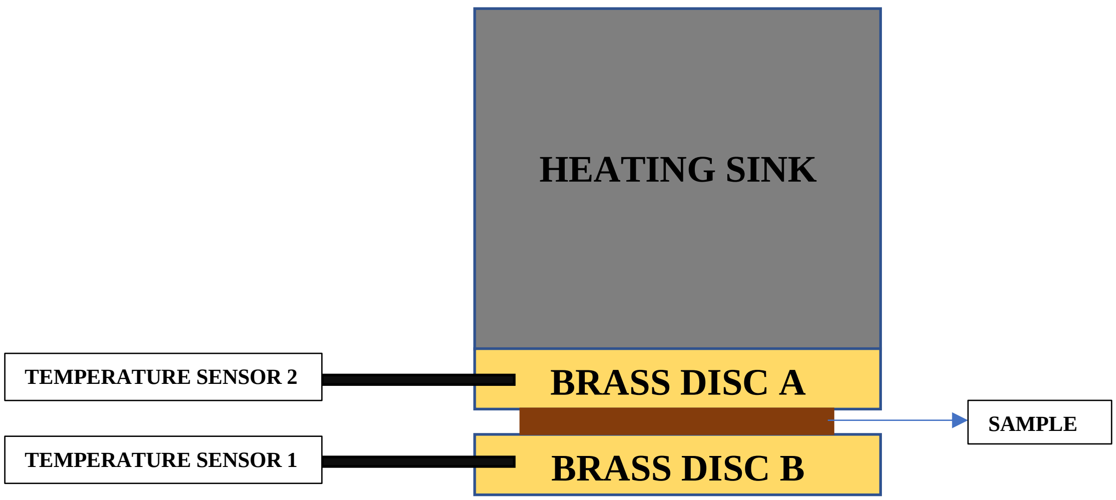

Figure 4.3: Sample setup

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

Nowadays, a new generation of devices, such as microcontrollers are now made available, with the introduction of this device and also with its numerous advantageous features that have been used extensively in field of engineers, researchers and informatics. A manual system can be completely modified with the aid of said microcontrollers that converts the system into an automated system with the aid of various other components connected to the microcontroller. The microcontroller is known to act as the brain box of the system. Thermal conductivity of materials is highly rated in design and construction of engineering structures where temperature and thermal structures are worrisome factors. Various methods for measurements are used in the measurement of different solid-state materials at very wide range of temperatures. A microcontroller-based data logger has been designed to efficiently to run all activities in thermal conductivity test using lee's disc method. The experiment using the data logger is run automatically as the system heats the sample and also takes readings during heating and cooling process.

5.2 CONCLUSION

From the results of the design of the data logger, mechatronics has been able to be applied in both industrial and tertiary institution uses. The system was successfully designed and furthermore developed by integrating several software features and hardware which has been tested successfully. The designed system was able to accomplish the following:

- Measure the temperature of both brass disc during heating and cooling of sample
- Storage of data gotten from temperature sensors during the experiment at a one-minute interval
- Display of data gotten from temperature data logger after the experiment has been concluded on the LCD
- Ability of the deliver-controlled current to the heat sink

5.3 RECOMMENDATIONS

Based on the outcome of this project, further work to be put into consideration include the following recommendations:

- The system should be fitted with an alternate source of power such as a battery, such as to overcome the issue of epileptic power supply in Nigeria
- Time switches should be used in the system and programmed in sync to the microcontroller to control current delivery to the heat sink
- A program can be created on a personal computer that connects to the data logger and calculates the thermal conductivity of the samples.
- The use of temperature sensors with a high rate of measurement rating to be able to carry out simultaneous experiments without worry of damaging the sensors.
- The system can be designed in such a way that the clamp used should not affect the result.

APPENDIX

Each micro-controller is programmed in the C++ language using the MPLAB Integrated Development Environment. The C++ language was chosen because of its dynamic interaction with hardware, speed, memory allocation and flow algorithm.

```
// Lcd pinout settings
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D7 at RB3_bit;
sbit LCD_D6 at RB2_bit;
sbit LCD_D5 at RB1_bit;
sbit LCD_D4 at RB0_bit;

// Pin direction
sbit LCD_RS_Direction at TRISB4_bit;
sbit LCD_EN_Direction at TRISB5_bit;
sbit LCD_D7_Direction at TRISB3_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D4_Direction at TRISB0_bit;



#define clear              0x01
#define returnHome         0x02
#define moveCursorRight    0x14
#define moveCursorLeft     0x10
#define shiftDisplayRight  0x1C
#define shiftDisplayLeft   0x18
#define cursorBlink        0x0F
#define cursorOff          0x0C
```

```
#define cursorOn            0x0E
#define Function_set_4bit   0x28
#define Function_set_8bit   0x38
#define Entry_mode          0x06
#define Function_8_bit      0x32

char ENN, RSS, D44, D55, D66, D77, roww, coll;

#define RS PORTB.B4
#define EN PORTB.B5
#define D7 PORTB.B3
#define D6 PORTB.B2
#define D5 PORTB.B1
#define D4 PORTB.B0

LCD_DISP(unsigned char MSB1,unsigned char LSB1){

            D4 =  MSB1 & 1;
            MSB1 = MSB1 >> 1;  D5 = MSB1 & 1;
            MSB1 = MSB1 >> 1;  D6 = MSB1 & 1;
            MSB1 = MSB1 >> 1;  D7 = MSB1 & 1;
            EN = 1 ; delay_ms(2);  EN = 0;



            D4 = LSB1 & 1;
            LSB1 = LSB1 >> 1;  D5 = LSB1 & 1;
            LSB1 = LSB1 >> 1;  D6 = LSB1 & 1;
            LSB1 = LSB1 >> 1;  D7 = LSB1 & 1;
            EN = 1;  delay_ms(2);    EN = 0;

            }
```

```
void LCD1_cmd(unsigned char comd){
        unsigned char MSB2 , LSB2 ;
            RS = 0;
            MSB2 = (comd & 0xF0) >> 4; LSB2 = comd & 0x0F ;
            LCD_DISP(MSB2,LSB2);
          }

void LCD_writeCP(unsigned char chr){
            unsigned char MSB,LSB;
            RS = 1 ;
            MSB = (chr & 0xF0) >> 4; LSB = chr& 0x0F ;
             LCD_DISP(MSB,LSB);
                      coll++;
            }

LCD_write(unsigned char row,unsigned char col,unsigned char chr){
         unsigned char MSB , LSB ;
               coll = col;
               roww = row;
        if(row==1) LCD1_cmd(0x80 + (col-1));
        if(row==2) LCD1_cmd(0xC0 + (col-1));
         if(row==3) LCD1_cmd(0x94 + (col-1));
        if(row==4) LCD1_cmd(0xD4 + (col-1));
        LCD_WriteCP(chr);
}

LCD_writeTextCP(unsigned char *s){
            unsigned char pnt=0;

             while(s[pnt] != '\0'){
```

```
                LCD_WriteCP(s[pnt]);
                pnt++;
                delay_ms(1);
                }
          }
LCD_setCursor(unsigned char row, unsigned char col){
            if(row==1) LCD1_cmd(0x80 + (col-1));
            if(row==2) LCD1_cmd(0xC0 + (col-1));
            if(row==3) LCD1_cmd(0x94 +(col-1));
            if(row==4) LCD1_cmd(0xD4 + (col-1));
}

LCD_writeText(unsigned char row, unsigned char col, char *s){
           unsigned char MSB , LSB ,chr;  char pnt;
                        coll = col;
                    roww = row;
            if(row==1) LCD1_cmd(0x80 + (col-1));
            if(row==2) LCD1_cmd(0xC0 + (col-1));
            if(row==3) LCD1_cmd(0x94 +(col-1));
            if(row==4) LCD1_cmd(0xD4 + (col-1));
                  pnt =0;
             while(s[pnt] != '\0'){
                LCD_WriteCP(s[pnt]);
                pnt++;
               delay_ms(1);
                }
}

Start_cmd(){
      LCD1_cmd(0x33);
      delay_ms(2);
```

```
        LCD1_cmd(0x32);
         delay_ms(2);
        LCD1_cmd(0x28);
        delay_ms(2);
        LCD1_cmd(0x08);
        delay_ms(2);
        LCD1_cmd(0x0C);
        delay_ms(2);
        LCD1_cmd(0x06);
        delay_ms(2);
}



void LCD_setting(){
   Start_cmd();
    }

void LCD_writeCustomChar(unsigned char addressCGRAM, unsigned char row, unsigned char
col, const char *customCharArray) {
   unsigned char i;
   LCD1_cmd(64 + (addressCGRAM *  8));
   for (i = 0; i <= 7; i++)
      LCD_writeCP(customCharArray[i]);
   LCD1_cmd(returnHome);

   if((!row) && (!col))
         LCD_write(roww, coll-8, addressCGRAM);
   else
      LCD_write(row, col, addressCGRAM);
 }
```

```
unsigned char rec;
float temp1;
float temp2;
unsigned char txt[6];
//unsigned char txt2[4];

const char character[] = {6,9,9,6,0,0,0,0};

void CustomChar(char pos_row, char pos_char) {
  char i;
    Lcd1_Cmd(64);
    for (i = 0; i<=7; i++) Lcd_WriteCP(character[i]);
    Lcd1_Cmd(_LCD_RETURN_HOME);
    Lcd_write(pos_row, pos_char, 0);
}
     float heater_A[60], sink_A[60], heater_B[40], sink_B[40];
     char flag=0,flag1=0,flag2=0,_ii=0;
void main() {
//TRISA=0xFF;

ADCON1 = 0x07;
CMCON=0x07;
TRISB=0x00;
TRISC=0x00;
TRISD=0xFF;
TRISE=0x00;
PORTA=0x00;
PORTB=0x00;
```

```
PORTC=0x00;
PORTD=0x00;
PORTE=0x00;

LCD_setting();
//Lcd_Init();
LCD1_cmd(clear);
LCD1_cmd(cursorOff);

Lcd_writeText(1,3,"TEMPERATURE DATA");
Lcd_writeText(2,7,"LOGGER");
delay_ms(1000);

LCD1_cmd(clear);
Lcd_writeText(1,9,"2019");
//Lcd_writeText(2,1,"PROJECT");
delay_ms(1000);
LCD1_cmd(clear);


while(1)  {
//Lcd_CMD(_LCD_CLEAR);
Lcd_writeText(1,4,"OPERATION MODE");
temp1=ADC_read(0);
temp1=temp1*500/1024;
floattostr(temp1,txt);
txt[4]=0;
Lcd_writeText(2,1,"T1= ");
Lcd_writeTextCP(txt);
CustomChar(2,9);
LCD_writeCP('C');
```

```
LCD1_cmd(returnHome);
temp2=ADC_read(1);
temp2=temp2*500/1024;
floattostr(temp2,txt);
txt[4]=0;
Lcd_writeText(3,1,"T2= ");
Lcd_writeTextCP(txt);
CustomChar(3,9);
lcd_chr_cp('C');

   if(flag2 == 1)
   {
   LCD1_cmd(clear);
   while(flag2)
     {
     if(PORTD.B0 == 0) if(_ii==60); else _ii++;
     if(PORTD.B1 == 0) if(_ii==1);  else _ii--;
     if(PORTD.B2 == 0) {for(_ii=0; _ii<60; _ii++){heater_A[_ii] =0;  heater_B[_ii]=0;
sink_A[_ii]=0;  sink_B[_ii]=0;} _ii=0; flag2=0; flag1=0; flag =0; PortC.B0 =0 ;}
        LCD_writeText(1,1,"T1-");
        inttostr(_ii+1, txt);
        LCD_writeTextCP(Ltrim(txt));
        LCD_writeTextCP("a: ");
        floattostr(heater_A[_ii], txt);
        txt[4]=0;
        LCD_writeTextCP(Ltrim(txt));
        CustomChar(1,13);
        lcd_chr_cp('C');

        LCD_writeText(2,1,"T2-");
```

```
inttostr(_ii+1, txt);
LCD_writeTextCP(Ltrim(txt));
LCD_writeTextCP("a: ");
floattostr(sink_A[_ii], txt);
txt[4]=0;
LCD_writeTextCP(Ltrim(txt));
CustomChar(2,13);
lcd_chr_cp('C');

if(_ii<40)
{
LCD_OUT(3,1,"T1-");
inttostr(_ii+1, txt);
LCD_writeTextCP(Ltrim(txt));
LCD_writeTextCP("b: ");
floattostr(heater_B[_ii], txt);
txt[4]=0;
LCD_writeTextCP(Ltrim(txt));
CustomChar(3,13);
lcd_chr_cp('C');

LCD_OUT(4,1,"T2-");
inttostr(_ii+1, txt);
LCD_writeTextCP(Ltrim(txt));
LCD_writeTextCP("b: ");
floattostr(sink_B[_ii], txt);
txt[4]=0;
LCD_writeTextCP(Ltrim(txt));
CustomChar(4,13);
lcd_chr_cp('C');
}
```

```
 }
}
else if(flag1==0)
{
if (temp1>= 50.0)  flag =1;
}
else
{
    Lcd_writeText(4,1,"capturing...");
    heater_B[_ii] = temp1;
    sink_B[_ii] = temp2;
    _ii++;

    if(_ii > 39)   {flag = 0;  flag1=0; _ii=0;  flag2=1; LCD1_cmd(clear);
Lcd_writeText(4,1,"Cooling stopped"); }
   delay_ms(60000);           //ESURE IT IS delay_ms(60000);
   LCD1_cmd(clear);

}
if(flag==1)
  {
    Lcd_writeText(4,1,"capturing...");
    heater_A[_ii] = temp1;
    sink_A[_ii] = temp2;
    _ii++;

    if(_ii >59)   {flag = 0;  flag1=1; _ii=0; LCD1_cmd(clear); Lcd_writeText(4,1,"Heating
stopped"); PortC.B0 =1 ; }
    delay_ms(60000);   // ENSURE delay_ms(60000);
    LCD1_cmd(clear);
  }
```

```
      else  {delay_ms(1000);  //LCD1_cmd(clear);
      }
    }
}
```

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