

**DESIGN AND CONSTRUCTION OF A DIGITALLY PROGRAMMABLE
TEMPERATURE / TIME - BASED CONTROL SYSTEM FOR A LABORATORY
WATER BATH**

BY

Eberechukwu Caleb ODUNZE

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CERTIFICATION

This Masters thesis entitled "Design And Construction Of A Digitally Programmable Temperature/Time Based Control System For A Laboratory Water Bath" by ODUNZE EBERECHUKWU CALEB is approved for the degree of Masters in Physics Electronics.

Prof. S.O. Azi
(Supervisor)

Date

Prof. O.D. Osahon
(Head of Department)

Date

(External Examiner)

Date

DEDICATION

To God Almighty

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ABSTRACT

The Digitally Programmable Temperature/Time-Based Control System puts forth a system which enables users to choose the preferred temperature for the water to be heated while the device is in the temperature mode. The design is built with the objective of implementing a digital temperature monitoring circuit that will collect the temperature of water and send the value, digitally to a microcontroller and to create an alerting mechanism that will be in the form of an audio alarm and a visual display to alert the operator that an operation is done. By also providing precise temperature regulation and accurate timing the water heater will turn on when the user sets the desired temperature via the input switches, and the screen will begin counting down from the chosen time to zero. A signal from the microcontroller will be sent to the transistor's base through the resistor when the water reaches the specified temperature, cutting off the power to the heater. In order to activate the relay, the transistor must become saturated. Given that the heater is linked to the relay's typically open contact, the water heater will be turned off. The flow chart were established, which helped with the proper circuit diagram design and simulations utilizing electrical simulation software like PROTEUS ISIS. The MIDE-written assembly language program was translated to machine code using TOPWIN6, and then burnt into the microcontroller IC using a universal programmer. The 555 timer, which is connected in the Astable mode, will be activated at the same moment by the microcontroller depending on the written program stored in its ROM. This will enable the buzzer to pulse and an alarm to sound with an LED flashing. The complete system operates on a 5 volts power supply which is obtained from the public mains. This design makes use of an efficient and low-cost technology for controlling the appliances thus minimizing the power wastage. The results showed that the developed system provided accurate temperature control with a deviation of less than 1°C, and precise timing control with a deviation of less than 5 seconds.

CHAPTER ONE

1.0 INTRODUCTION

This project puts forth the equipment that will replace the analog control of the existing water bath in the department of physics, university of Benin by converting it to a Digitally Programmable Temperature/Time Based Control System. The world operations are being slowly replaced with digital devices as its becoming obvious that digital devices and equipment are easier to control, faster in operations and readily modifiable, than analog systems. To this effect, this project will be based on the design and construction of a digitally programmable temperature and time based control system for a laboratory water bath equipment. This means that a user can set the control of the water heater in the bath to either run on temperature control mode or timing control mode. This system will ensure that a user, using control switches, can control the water heater in the bath, either by setting the tripping temperature of the water bath or based on timing the duration of the heating. Over the years technology has been ever evolving, and as a result, new means are being developed for easier and safer control of electrical devices for more efficient power management at homes and workplaces as there has been an increasing technology and digitization demands for a low-cost and efficient system. The proposed design makes use of an efficient and low-cost technology for controlling the appliances thus minimizing the power wastage.

The laboratory water bath is a system that is used in the sterilizing of equipment and tools before they can be used for practical experiments and it can also be used to raise the temperature of some chemicals to a known level also for the use in the laboratory. A need to be able to control the temperature of the water bath either based on the degree of rise (or fall) of the water

temperature, or with the use of timing, turns out to be very crucial in the utilization of this laboratory water bath.

1.1 INTRODUCTION TO LABORATORY WATER BATH



Fig. 1.1 One Chamber Water Bath (Mettler, 2022)

A water bath is laboratory equipment made from a container filled with heated water. It is used to incubate samples in water at a constant temperature in the microbiological laboratory over a long period of time (WHO, 2008). All water baths have a digital or an analogue interface to allow users to set a desired temperature (Hasim et al., 2011) from experimental observation, when the water bath reaches the set temperature, it will cycle on and off to maintain constant temperature. Most water baths have a second control called the safety. This control is set at the maximum temperature the water bath should attain. It is usually set just above the temperature control. Often an indicator light is associated with the safety control. If the water bath reaches the temperature that the safety control is set at, the light will go on. It will be impossible for the water bath to heat higher than the safety setting even when the temperature setting is higher. If in any circumstance, the water bath temperature is lower than the temperature control setting, it is advisable to increase the safety control setting in order to increase the water bath temperature. It

is worthy of note that at the same temperature, heat transfer in liquids are more efficient when compared to air chambers. This is because the thermal capacity of water is greater than that of air. It is however important to use water as the heated fluid because water is an excellent liquid, cheap, safe and readily available (Ibrahim et al., 2014).

A laboratory bath is also a device that is used to maintain a set temperature by means of indirect heating or cooling, the laboratory bath has an enclosed container in which the temperature in it is constant. This container is where the specimen or whatever needs to be kept at a constant temperature. (Hasim et al., 2011) opined submit that a Laboratory bath is a preferred heat source for heating flammable chemicals instead of an open flame to prevent ignition.

The Water heated bath are also utilized for warming of reagents, melting of substrates, incubation of cell cultures and to enable certain chemical reactions to occur at high temperature. It is reported that the growth of many microorganism requires a temperature controlled environment and most enzymatic reactions occurs at 37oC as their optimal temperature. Although many chemical reactions can be accelerated with changes in temperature ranges, some biochemical procedures require strict temperature control (Berry and Foegeding, 1997). Water heated bath has different types. They include; circulating water baths, also called stirrers are ideal for applications when temperature uniformity and consistency are critical, noncirculating water baths that relies primarily on convection instead of water being uniformly heated and the shaking water baths that has extra control for shaking, which moves liquids around (WHO, 2008). And reliable cooling and heating are used everywhere, from organic synthesis distillation towers to mass spectrometer vacuum diffusion pumps (Michael and Felton, 2004).

In addition, baths and circulators are essential for those who frequently need to heat in order to maintain a certain temperature or cool experiments to effect a reaction (Shukla and Kulkarni, 2017).

Water-Bath temperature control is one of the major control process and has numerous applications in both food process industries and medical centers i-e Nestle, F&N, Yeoh Hiop Seng, General district hospital Kifisia Greece etc. (Om et al., 2012; Lochaitis et al., 1992).

Laboratory baths vary according to their uses, heating medium, sizes and specifications. They are classified according to the actions they perform or meant to perform. Examples are heating baths that heat up the laboratory bath to a certain temperature above room temperature and remains constant at that temperature, and the cooling baths that cools a liquid mixture which is used to maintain low temperatures typically between -12°C and -78°C (Jensen and Lee, 2000).

According to (WHO, 2008). A water bath is laboratory equipment made from a container filled with heated water. It is used to incubate samples in water at a constant temperature in the microbiological laboratory over a long period of time.

Temperature sensors are used for a wide variety of industrial, scientific, medical and domestic purposes, and they differ by design and/or operating principles to better suit their given application. The global market size for these sensors was estimated at USD 6.3 billion in 2020 with a projected annual growth of 4.8% to 2027 (: <https://www.marketsandmarkets.com/Market-Reports/temperature-sensormarket-522.html> (accessed on 20 January 2023)). For many applications, using a single temperature sensor is sufficient, but sometimes a group of sensors is required to optimise, for example, the design of a refrigerator or room ventilation (Shinoda et al., 2021).

The accuracy of temperature sensors after manufacture is specified by their vendors; variation might range from as low as $\pm 0.25^{\circ}\text{C}$ up to $\pm 2^{\circ}\text{C}$ (https://en.wikipedia.org/wiki/List_of_temperature_sensors (accessed on 20 January 2023)).

A study on thermistors found that their accuracy deteriorated very little over time (Lawton et al., 2001), and this should hold for both RTDs and integrated circuit temperature sensors that have been manufactured from materials of high purity.

Temperature control is an important factor in many process control system. Water-Bath temperature control is one of the most important and widely used applications of non-linear control system (Nisha et al., 2011) in process control industry and its application, in the production of a variety of drinks products such as chocolate drink, strawberry milk products etc. The process industries which use Water-Bath temperature control are Nestle, Yeoh Hiop Seng, F&N, etc. If the temperature is out of the given range, the final product is badly affected. Therefore, it is necessary to reach at desired temperature points quickly within specified time period and to avoid large overshoot (Bakhtiar I.Saeed, 2011). Since the process-control systems are often non-linear and tend to change in an unpredictable way, they are not easy to control accurately.

1.1.1 Statement of Problem

In physics, materials behavioral characteristics are largely dependent on a whole lot of physical and chemical properties. One of the most significant property that changes or alters the behavioral characteristic of materials, is temperature. In many laboratory experiments, there is always a need to control the temperature of a given experiment, either to maintain it to a certain level, to increase (or decrease) it to a known level. A laboratory water bath is one of such equipment that can be used to achieve this aim.

However, when a water heater is activated, the temperature of the water in the bath can rise up to a very high temperature and the control of the temperature, can spiral out of control when not corrected. And as such, a form of thermometer needs to be included into the water bath, so that a

user can manually monitor the rise in temperature and cut it off when it gets to an undesirable level.

Unfortunately, there are a whole lot of problems that can arise from when an operation as sensitive as temperature control is controlled or monitored manually. Another point of problem that was considered in the design of this system is that, due to human negligence or distractions with other engagement, an operator can start a monitoring or control process and due to distractions, can fail to notice when the whole process is completed. As such a form of automated measurement, monitor, control and notification, can be put in place to totally eliminate the error due to manual collection of data result, negligence and other unforeseen factors. Which could also help moderate energy wastage.

1.2 Aim and Objectives

This aim of this study is to: design a Digitally Programmable Temperature / Time Based Control System for a Laboratory Water Bath in Physics Department.

The objectives are to:

- 1) to construct a suitable interface that will enable the system to be properly installed in the existing analog system that is in the department of physics, university of Benin
- 2) to design and implement a digital temperature monitoring circuit that will collect the temperature of water and send the value, digitally to a microcontroller.
- 3) to create an alerting mechanism that will be in the form of an audio alarm and a visual display to alert the operator that an operation is done
- 4) to install a digital display unit to enable the user to view the status and operation of the system, real time

5) to design an electronic circuit that will carry out these operations, with the use of a programmable integrated circuit using Atmega328 microcontroller.

6) to simulate the operation of the complete system using proteus simulation software.

1.3 Scope of Study

In this project, the diagram will range from simple block diagrams to complex circuit diagrams which will comprise mostly of common electrical and electronics symbols. Some of the diagrams that will feature in this report will be used as the main block on which certain parameters will be explained upon. Relevant components will also be shown and described.

This project report will also contain an outline of the circuit diagram as it is seen physically. Furthermore, this research is focused on the designing a control switching system that will enable a user to set the mode for the operation of the system, either to temperature monitoring mode or timing based mode. And also, when in timing mode, to enable the user to set the time duration of the operation for a laboratory water bath, thereby converting it from its original analog control to digital control to be executed in the built diagram.

CHAPTER TWO

LITERATUREREVIEW

2.0 Water Bath System

This chapter reviews briefly some related work on water bath temperature control system that has been done, various methods used as well as virtual laboratory environment and water bath fabrication with locally sourced materials.

Hasim *et al.* (2011), designed and developed a water bath control system using a virtual laboratory environment. The study included instructions for developing a water bath control system in a virtual lab environment. The recommended system was created using LABVIEW 8.6. This project is divided into three parts. The first stage of hardware development is the establishment of an interface circuit that enables communication between the computer and the plant. The fuzzy set and rule base are used in the second stage of developing the fuzzy logic controller using the LABVIEW application. The final stage is to make the GUI module accessible online for real-time remote control. The internet-based GUI model environment of a water bath temperature control system has been successfully developed using the LABVIEW software and uploaded to the web, where it can be completely controlled and monitored by any user, regardless of location, as long as they have access to a computer with a web browser and an internet connection. This will therefore ensure a better and clearer understanding of a number of things, especially the control system. With such a facility, lab supplies can be shared online, experiments can be carried out off-site and outside of typical business hours, and the control topic may be taught to the students in a way that is more applicable and efficient.

Chakraborty *et al.* (2018), worked on temperature measurement and transmission to a remote receiver must be taken very seriously by every plant activity that employs various types of

thermometer circuits. Without employing a genuine thermometer, an experimentally confirmed straightforward temperature monitoring and transmission system for an electric heater-operated water bath is devised. As the steady-state temperature of a water bath heated by an electric heater only depends on heater current if we disregard a small change in the ambient temperature, this approach uses heater current as a temperature measurement parameter.

Experimentally derived and given are the characteristic curves of the prototype temperature transmitter unit. There were created the mathematical relationships describing how the suggested temperature monitoring and transmission system functions. The curves are found to follow the mathematical correlations identified during the investigation.

Khairunnas *et al.* (2018), reported that the use of hot water for bathing is one use of recently developed technology. By using water heater equipment, one may get water at a higher temperature. Nevertheless, it takes a long time for the water heater to heat the water to the proper temperature and fill the tub for usage. With the use of temperature sensors, ultrasonic sensors, and water pumps, this technology has produced an autonomous faucet that can be switched on or off based on the temperature of the water in the main tub. An Android microcontroller operating on an Arduino Mega2560-based Arduino board controls the MQTT protocols-based machine-to-machine system that is utilized by both sensors. The main tube's average performance time to achieve the target temperature is 18 minutes 30 seconds, and the test results show that the accuracy of the temperature obtained is 97.60%. The primary tub utilized in the test has a 12.320 cm³ capacity for the volume of water that can be filled and a 9.240 cm³ capacity for the volume of hot water that can be provided. The type of pump utilized, how much energy the water heater uses, and the size of the main tubing container used as a container for mixing hot water temperatures and regular water temperatures are other elements that affect how long it takes to reach the target temperature.

Furthermore, Zhang, Z.Y., and Guo, T. (2012), worked on a water bath temperature control system based on DS18B20 the design introduce the single-wire digital temperature sensor DS18B20's features and operation. The water bath temperature management system is created using the single chip microcontroller AT89C51 and is based on DS18B20. The study also provides information on the hardware device's construction, the software's primary design, and the DS18B20 C51 program. The testing findings ultimately demonstrate that the DS18B20 system has a greater accuracy.

Ren-xiu, L. (2011), and also Chakraborty *et al* (2018), developed a hardware and software of the MSP430F133-based high-precision constant temperature controller for the water bath in accordance with the controller's operating theory. The high-precision analog comparator with chip MSP430F133, the thermal stability capacitor, the high-precision reference resistor, and the high-precision thermal resistance were used to monitor the temperature of the water bath. It didn't need any more chips. The temperature was controlled using an incremental PID algorithm to ensure accuracy. The controller had a low-complexity, high-precision circuit. Similarly,

Hasim *et al.* (2012), worked on the creation of a water bath temperature control system to regulate the temperature of the liquid in the water bath was shown. MATLAB fuzzy logic toolbox was used to construct the water bath temperature control system. Based on the information gathered from the thermal transducer sensor, the fuzzy logic controller (FLC) is intended to regulate the temperature of the water. The Max-min (Mamdani) approach and the center of gravity methodology for defuzzification are the inference engines that are employed. In this research, the 4 4 matrix rules for the controller was applied. Additionally, the MATLAB program and real-time application was linked via the USB NI-DAQ card as an xPC target. Based on the simulation's temperature, which the user originally sets, the real-time output temperature

is confirmed. It may be said that the simulation result and the performance of the real-time investigation are comparable.

Electric heater current is taken as a temperature measuring parameter since the steady-state temperature of electric heater operated water bath depends on heater current only if we ignore a small variation of atmospheric temperature. The mathematical relations describing the operation of the proposed temperature measurement and transmission system are determined. The characteristic curves of the prototype unit of the proposed temperature transmitter are derived experimentally. The curves are found to follow the mathematical relations derived.

In intelligent temperature controller for water bath system, Om *et al.* (2012) noted that traditional controllers often needed a prior understanding of the process mathematical modeling, particularly for non-linear and complicated control problems, the process performance suffers from inaccurate mathematical modeling. The method employed is the most popular and somewhat nonlinear Water-Bath system. In order to prevent overshoot and absolute inaccuracy in a water-bath system, it is essential to reach the target temperature within a predetermined window of time. This requires superior temperature tracking capabilities. Intelligent controllers, such fuzzy logic (FL) and the Adaptive Neuro-Fuzzy Inference System (ANFIS) were employed to address the aforementioned challenges. The linguistic control rules that make up knowledge are intended to be used by the fuzzy controller. Nevertheless, the incorporation of these linguistic guidelines into the fuzzy set theory framework depends on the selection of a few parameters for which there is no formal technique. A fuzzy inference system and a neural network with learning capabilities are coupled to create an ANFIS. According to analysis, ANFIS is the most suited system for the aforesaid system's adaptive temperature control. Unlike PID and FLC, ANFIS generates a steady control signal. Better temperature tracking is available.

The ANFIS is a modified TSK (Takagi-SugenoKang)-type fuzzy rule-based model with learning capabilities derived from neural networks. The ANFIS does not originally have any rules, in contrast to the general Adaptive Neuro-Fuzzy-Inference Systems, where the rules must be chosen beforehand before parameter learning is carried out. We may draw the conclusion that ANFIS not only solves the PID and fuzzy controller issue, but also offers greater control over the water-bath temperature management system. ANFIS Controller can be more effective than a traditional PID Controller in critical systems.

Sohaib *et al.* (2016), worked on utilizing MPC to manage the temperature of a water-bath system although there are limitations MPC is implemented using an optimizer and system modeling. The term "optimizer" refers to a mathematical function that minimizes the cost function while taking restrictions into account in order to optimize the control signal. The optimizer receives the discrepancies between the expected output and reference value in the form of errors and optimizes the subsequent input; this process will continue. The wattage power of an immersion rod determines its capability for heating. Aqua therapy is used in medical facilities to treat a variety of ailments, and MPC-based Water-Bath temperature controllers have been created for this purpose. The simulation results of MPC have been evaluated in three modes of temperature control without constraints, with input constraints, and with output constraints since PID is a basic structural control approach but it cannot effectively cope with input and output constraints. MPC successfully controls the temperature in all three modes while abiding by the limitations. It also demonstrates to be a reliable control method that efficiently controls the target temperature of the Water-Bath system in a dynamic environment with variable intake flow rate. Future MPC implementation on embedded devices might assess the operation of the water-bath temperature management system in real time. Moreover, research could be done to improve the system's durability and energy efficiency.

Furthermore, Oussama *et al.* (2013), in Review of water-heating systems: General selection approach based on energy and environmental aspects, noted that water heating contributes an important proportion of residential energy consumption all around the world. Different kinds of domestic hot-water production systems exist. The operational cost, environmental effect and performance of these systems differ according to various energy sources, climates, system types and system designs. Hence, the proper choice of a domestic hot-water system could save energy, protect nature and reduce operational costs, significantly, This research illustrates, to the best of the author's knowledge, the existing water-heating systems all along with the principle, advantages, disadvantages and state-of-the-art for each. Six different categories were presented, namely wood, oil/gas, electric, heat pump, solar and instantaneous systems. The heat-pump systems were further classified into several groups, namely air source, ground source, solar assisted, ground source-solar assisted, photovoltaic thermal and gas-engine driven systems. In addition, concerning solar water heating, different types of systems and collectors were presented and reviewed. The reviewer concluded that water heating contributes to a large amount of residential energy consumption all around the world, and thus, the proper choice of a domestic hot-water system can significantly save energy, protect nature and reduce operational costs.

Also, Balogun and coworkers reported the development of a temperature controlled water heated bath for Science Laboratories in Nigeria with locally available materials, designing the electrical circuit and controlling it, fabricating the frame out of metal, fabricating the bath cover, and fabricating the tank are the four components that make up the design and development approach for the water bath in their work. Using materials readily available in Nigeria, the project's goal was to create a temperature-controlled water heated bath that would keep lab specimens at a set temperature for an extended length of time. This was accomplished by developing and creating a temperature-controlled, water-heated bath, and then performing a

performance assessment on the finished product. Theoretical investigation indicated that the temperature of water within the water bath could be increased from 10oC to 100oC within 2 - 3 minutes. Experimental validation demonstrated that the water in the bath reached the boiling point of 100oC at around 3 minutes. Their findings demonstrate a relationship between the elevated temperature and the observed bath water content. This further demonstrates that the produced water bath, which has a lower production cost when compared to the price of the imported water heated baths, can be used to keep laboratory specimens at a consistent temperature for a period of time. Balogun *et al.* (2020)

2.1. Temperature Control System

Nasser, *et al.* (2021) in new cost effective design of PCR heating cyclers system using Peltier plate without the conventional heating block showed that for effective DNA amplification in PCR, temperature management is a key element. The major goal is to create a portable, economical PCR system with tight control and a high rate of heating and cooling. The speed relies on the thermal mass of the PCR heating component being reduced. Improvements in the device structural design and the selection of a better heating and cooling mechanism with a reliable controller are the usual techniques utilized to reduce the device's thermal mass or heating/cooling time. An excellent temperature distribution is achieved on the heater surface by increasing thermal mass, but the heat transmission is delayed. The controller must work harder to ensure a high temperature uniformity distribution on the Peltier surface as a result of the removal of thermal mass. The work offers a low-cost Peltier-based PCR heating/cooling system. Using adaptive FLC and bang-bang as a hybrid controller, this system is managed to deliver high precision at the fastest rate of temperature change possible. The findings indicate that while the adaptive FLC with bang-bang controller is 20% quicker in cooling than the typical PD-like FLC, it is 5–10% faster in heating. At the denaturation and annealing processes, the adaptive FLC

offered steady state errors that were 3% and 1.5% smaller, respectively, than the standard FLC. Using a thermal camera, temperature distribution is evaluated. Conventional PCR is used to verify the device. When the amplification product was electro phoretically separated on a 1.5% agarose gel and then stained with ethidium bromide, the results showed that the amplification had been effective.

Also, Dinca *et al.* (2009), worked on Fast and accurate temperature control of a PCR micro system with a disposable reactor which displays a micro polymerase chain reaction (PCR) equipment made out of a disposable PDMS component with a 1 l chamber and a tiny thermal cyclor with Pt thin layers used as heaters and temperature sensors, screen-printed on a ceramic plate. The gadget can deliver a heating rate of 7.7 °C s⁻¹ while consuming just 0.3 W of heating power at 95 °C and 1.5 W during heating transitions. An anti-windup method was used with a two-degree-of-freedom proportional-integral-derivative controller to manage temperature. The obtained performances are better than those that have been previously reported, including the use of the maximum/minimum power level for nearly the entire transition time, overshoots and undershoots below 0.1 °C, a very short settling time without oscillation, steady error less than 0.05 °C, and excellent robustness against process changes. In compared to other controllers that have been previously described, the suggested controller is also more easier to construct and adjust. The disparity between the sensor and chamber temperatures is dynamically corrected, and a number of set-point shaping profiles are suggested and contrasted. The inverse of the related transfer function-based delayed pre shaped profile was discovered to produce the greatest outcomes. When forced convection cooling is used as a heat switch, the low power consumption for heating is maintained while a cooling rate of 6.6 °C s⁻¹ is achieved. If the dwell times are ignored, the device described

can achieve cycle times of 12 s. In less than 25 minutes, 32 cycles of PCR amplification were completed successfully.

An innovative gyroscope prototype that has an on-chip heater and temperature sensor keeps the gyroscope independent of the outside temperature was carried out by Lu xu *et al.* (2011). It initially described the gyroscope's operation and determined how temperature affected it in order to determine how sensitive performances were to temperature. It turns out that when the operating temperature of a gyroscope changes by 50K, capacitive sensitivity changes by 13.5. The performance of the on-chip temperature-controlled gyroscope prototype was then presented, and it was theoretically and quantitatively examined. Moreover, a manufacturing technique based on Silicon-On-Glass (SOG) technology was developed. According to simulation results, the power consumption increases from 0.011W to 0.213W when the ambient temperature lowers from 55°F to -40°F in order to maintain the gyroscope's temperature at 60°F with a temperature differential between the center mass and anchor below 1.6°F. When consumption power is 0.0884W and the ambient temperature is 20, a gyroscope can achieve its equilibrium condition of 60 from 20 in under 20 seconds. The maximum tensile or compressive strength of each material is greater than the stress intensities inside the gyroscope. The prototype satisfies the three requirements of low power consumption, even temperature distribution, and rapid thermal response, according to this theoretical demonstration. The prototype should eventually be produced and put to use.

Purwanto *et al.* (2018). Worked on design of server room temperature and humidity control system using fuzzy logic based on microcontroller looking at the condition of the server room, including its temperature, humidity, power, and all of its IT equipment, and empathised that it should always be monitored in real time. The server room is a very important asset for a

company because it houses servers that house applications and company databases that are very valuable for the sustainability of a company. Using an Internet of Things (IoT)-based system is one technique to regulate and keep track of the temperature and humidity of the server room. This study suggested a method for controlling the temperature and humidity of server rooms using fuzzy logic, based on the Wemos D1 microcontroller, as an infrared transmitter remote control to regulate temperature and mode setting in Air Conditioners. The server room's temperature and humidity were successfully controlled using fuzzy logic based on microcontrollers. Simulation test results using Matlab were used to obtain values that matched the microcontroller's results, which had average AC Temperature Set output deviations of 0.03500 and average AC Mode Set output deviations of 0.01225. Moreover, the system is made to be able to monitor data such as temperature, humidity, and power voltage online via a website and to send out early warning messages using social media like Twitter.

Microgyroscope Temperature Effects and Compensation-Control Methods was worked on by Dunzhu *et al.* (2009), and deposited that the resonant frequency of the microgyroscope declines linearly with temperature as it rises, and the quality factor changes significantly at low temperatures, according to an examination of how temperature affects the performance of microgyroscopes. Moreover, temperature differences significantly alter the zero bias. There are several temperature compensation-control ways to lessen the impact of temperature on the microgyroscope. Then, a BP (Back Propagation) neural network and polynomial fitting are used to construct the microgyroscope's temperature model. The temperature control system then adopts an integral-separated PID (Proportion Integration Differentiation) control method, which may stabilize the temperature within the microgyroscope in pursuit of its best performance. The combination of microgyroscope temperature compensation and control techniques is both

feasible and successful in a prototype downsized microgyroscope, according to experimental data. The temperature compensation system uses piecewise polynomial fitting due to its simplicity and real-time needs.

Furthermore, Aaron *et al.* (2020), worked on Design and Analysis of a Closed-Loop Temperature Engineering Control System using MikroC and Proteus. The task focuses on creating a script in MikroC PRO, which will then be transferred to a PIC18F45K22 microcontroller and programmed using Proteus, where the circuit will also be developed and simulated. The concept would be put to the test to see whether it works and if it can manage the temperature based on feedback from sensors that show the ambient room temperature as well as the user's preferred temperature. The system was able to modify the temperature based on the user's requested temperature and the ambient room temperature, demonstrating the effectiveness of the simulation. This is advantageous since the user can just set the temperature once and then completely forget about the thermostat, saving them from having to manually adjust the temperature every time it becomes too cold or hot.

The PIC18F46K22 is the system's most crucial part. This component was chosen not just for its specs but also for its adaptability and simplicity of usage. It can be easily programmed and reprogrammed by the user thanks to its 1024 bytes of Electronically Erasable Programmable Read-Only Memory (EEPROM), allowing for reuse and repurposing. Suggestion for further work as given stating that comparable projects can be worked on in a variety of ways. This is due to the fact that fuzzy logic controllers often work with a hazy set of rules that are specified between logic 0 and 1. By using fuzzy logic, a machine may think more as a person would.

Fuzzy logic-based control systems can therefore be claimed to be more accurate than conventional ones. It does have its limitations. For instance, simpler fuzzy logic systems may not be as accurate; to improve accuracy, one must make the system more sophisticated or include

more variables. While a more complicated system will be more accurate, interpretability will suffer.

In the design and simulation of automatic temperature control and alert system based PIC16F887. Jabbar (2017) noted that an embedded system was used in the design and modeling of an automatic temperature control system to automate the temperature-dependent regulation of several appliances. Ventilation, cooling, heating, and alerting are the equipment that will be regulated. Aimed at decreasing or eliminating human involvement and boost system dependability. The likelihood of relying on a human factor operator in industries, warehouses, and labs is reduced or eliminated through this automation procedure, which also enhances the working and performance environment. The system in this study used the microcontroller PIC16F887 as the main control unit, LM35 temperature sensor as a temperature source, 16x2 LCD as an indicator to show various system working statuses in addition to some drivers, relay, and light emitting diodes (LED) as indicators to show the corresponding working appliance driver. Proteus professional software version 8.0 was used for the system's implementation and simulation.

CHAPTER THREE

MATERIALS AND METHOD

3.0 INTRODUCTION

In this chapter, the design of the programmable temperature/time based control system for a laboratory, is done. The block diagram is presented as well as all the components of the block. The complete work is broken down into smaller units and analyzed separately. In each unit, the circuit diagram is drawn, all the calculations on how to obtain the rating of the components was shown and presented. The concluding articles is on the full circuit diagram as well and the mode of operation of the system.

3.1 MATERIALS (HAREDWARE AND SOFTWARE COMPONENTS ANALYSIS)

i. Capacitor

A capacitor is an electrical device that can store energy in the electric field between a pair of closely spaced conductors (called plate). Electric charges with opposing polarity and equal magnitude accumulate on each plate of the capacitor when voltage is supplied.

Capacitors serve as energy-storage components in electrical circuits. They are helpful in electrical filters because they can distinguish between high-frequency signals.

Condensers are a term that can be used to describe capacitors. With a specific potential difference or voltage (V) that emerges between the plates, the capacitor's capacitance (C) is a measurement of the amount of charge (Q) stored on each plate:

$$C=Q/V \tag{3.0}$$

When one coulomb of charge results in a potential difference of one volt between the plates, a capacitor has a capacitance of one fared (in SI units). Values of capacitors are typically given in microfarads (F), nanofarads (nF), or picofarads because the farad is a relatively big unit (pF).

The capacitor is inversely related to the distance between the plates and directly proportional to the surface area of the conducting plate. Also, it varies in direct proportion to the permittivity of the dielectric material—a nonconductive material—that separates the plates.

ii. Stored energy

Due to the separation of charges, contrary charges build up on a capacitor's plates, and as they do, an electric field created by these opposed charges causes a voltage to form across the capacitor. When more charge is separated, ever-increasing effort must be done to counteract this ever-increasing electric field. The effort necessary to establish the voltage across the capacitor and, consequently, the electric field, is equal to the energy (expressed in joules, in SI) that is stored in a capacitor.

This energy expression can be put in three equivalent forms by just permutations based on the definition of capacitance $C=Q/V$.

$$U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} QV = \frac{1}{2} CV^2 \quad (3.1)$$

Where V is the voltage across the capacitor.

iii. Circuit with DC source

Electrical cannot readily move straight from one capacitor plate to the other over the dielectric because the dielectric is deliberately selected to be a good insulator. In a capacitor, electrons collect on one plate while being eliminated from the other plate when there is a current flowing through it. Despite the fact that the capacitor is always electrically neutral, this process is sometimes referred to as charging it. In actuality, rather than causing a buildup of electric charge, the current flowing through the capacitor causes the separation of electric charge. Because to this charge separation, an electric field forms between the capacitor's plates, resulting in voltage across the plate.

iv. Diode

A diode is a two-terminal electrical component used in electronics that conducts mostly in one way (asymmetric conductance); it has a low resistance to the flow of current in one direction (preferably zero) and a large resistance in the other direction (ideally infinite). A crystalline piece of semiconductor material with a p-n junction attached to two electrical terminals is a semiconductor diode, the most used form today. A heated cathode and a plate (anode) make up the two electrodes of a vacuum tube diode. The earliest semiconductor-based electronic devices were semiconductor diodes. German scientist Ferdinand Braunin discovered crystals' ability to correct errors in 1874. The first semiconductor diodes, called cat's whisker diodes, developed around 1906, were made of mineral crystals such as galena. Today, most diodes are made of silicon, but other semiconductors such as selenium and germanium are sometimes used.

Main functions of diode

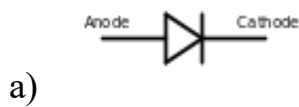
A diode's most common use is to let electric current to flow in one direction (known as the diode's forward direction) while obstructing current flow in the opposing direction (the reverse direction). As a result, the diode may be thought of as an electrical check valve. Rectification is the process of converting alternating current (AC) to direct current (DC), which includes extracting the modulation from radio signals in radio receivers. Rectifiers include diodes, which exhibit this unidirectional characteristic.

Diodes, however, may behave in ways that are more complex than just switching on and off, because to their nonlinear current-voltage characteristics. Only in the presence of a specific threshold voltage, also known as a cut-in voltage, in the forward direction do semiconductor diodes start conducting electricity (a state in which the diode is said to be forward-biased). It is possible to utilize this effect as a voltage reference or a temperature sensor since the voltage drop across a forward-biased diode changes very little with current and is dependent on temperature. By choosing the semiconductor materials and the doping impurities added to the materials during fabrication, it is possible to customize the current-voltage characteristic of a semiconductor diode. Special-purpose diodes are produced using these methods and can be utilized for a variety of tasks. For instance, Zener diodes are used to control voltage. Avalanche diodes are used to safeguard circuits against high voltage surges. Varactor diodes are used to electronically tune radio and TV sets (light-emitting diodes). Negative resistance, which is advantageous in switching and microwave circuits, is exhibited by Tunnel, Gunn, and IMPATT diodes.

Shot-noise generators may be made from vacuum and semiconductor diodes.

v. **Electronic symbols**

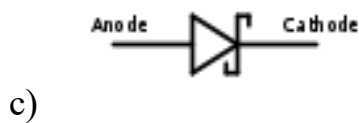
The symbol used for a semiconductor diode in a circuit diagram specifies the type of diode. There are alternative symbols for some types of diodes, though the differences are minor. The triangle in the symbols points to the forward direction, i.e. in the direction of conventional current flow.



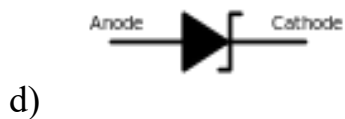
Diode



Light-emitting diode (LED)



Schottky diode



Zener diode

vi) Resistor

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors have a variety of purposes in electronic circuits, including lowering current flow, adjusting signal levels, dividing voltages, biasing active components, and terminating transmission lines. High-power resistors that can generate several watts of heat instead of electrical energy can be utilized as test loads for generators, power distribution systems, and motor controllers. With temperature, time, or operating voltage changes, fixed resistors' resistances very minimally fluctuate. Variable resistors can be used as sensors for heat, light, humidity, force, or chemical activity as well as to alter circuit components (such a volume control or a lamp dimmer).

Resistors are widely used in electronic equipment and are typical components of electrical networks and electronic circuits. Practical resistors can be made of a variety of materials and shapes as discrete components. Additionally, integrated circuits incorporate resistors.

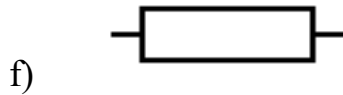
The resistance of a resistor determines its electrical purpose; typical commercial resistors are produced over a range of more than nine orders of magnitude. The nominal value of the resistance is within the component's stated manufacturing tolerance.

Electronic symbol and notation

Two typical schematic diagram symbols are as follows:



(a) Resistor, (b) Rheostat (variable resistor), and (c) Potentiometer



IEC resistor symbol

Theory of operation

Ohm's law

The behavior of an ideal resistor is dictated by the relationship specified by Ohm's law:

$$V = IR \tag{3.2}$$

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I), where the constant of proportionality is the resistance (R). For example, if a 300 ohm resistor is attached across the terminals of a 12 volt battery, then a current of $12 / 300 = 0.04$ amperes flows through that resistor.

Practical resistors also have some inductance and capacitance which affect the relation between voltage and current in alternating current circuits

Resistor values – the resistor color code

Resistance is measured in ohms, the symbol of ohm is an omega Ω . 1Ω quite small so resistor values are often given in $k\Omega$ and $M\Omega$. $1k\Omega = 1000\Omega$ and $M\Omega = 1000000\Omega$.

Resistor values are normally shown using colored bands. Each color represents a number as shown below.

Most resistors have four bands:

- The first band gives the first digit
- The second band gives the second digit
- The third band indicates the number of zeros
- The fourth band is used to show the tolerance of the resistor, this may be ignored for 4 almost all circuits but further details are given

vii) Transistor

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It has at least three terminals to connect to an external circuit and is often made of semiconductor material. The current flowing through one pair of terminals on the transistor is controlled by the voltage or current applied to that pair. A transistor may magnify a signal because the regulated (output) power and controlling (input) power can both be greater. While many more transistors are now found incorporated in integrated circuits, some still come in discrete packaging.

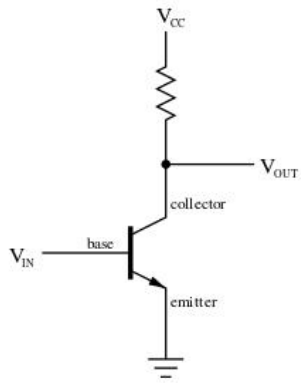


Fig. 3.0

A simple circuit diagram to show the labels of a n-p-n bipolar transistor.



Fig. 3.1 Assorted discrete transistors.

Packages in order from top to bottom: TO-3, TO-126, TO-92, SOT-23. (About Electronic, 2022).

Operation

The essential usefulness of a transistor comes from its ability to use a small signal applied between one pair of its terminals to control a much larger signal at another pair of terminals. This property is called gain. It can produce a stronger output signal, a voltage or current, which is proportional to a weaker input signal; that is, it can act as an amplifier. Alternatively, the transistor can be used to turn current on or off in a circuit as an electrically controlled switch, where the amount of current is determined by other circuit elements.

There are two types of transistors, which have slight differences in how they are used in a circuit. A bipolar transistor has terminals labeled base, collector, and emitter. A small current at the base terminal (that is, flowing between the base and the emitter) can control or switch a much larger current between the collector and emitter terminals. For a field-effect transistor, the terminals are labeled gate, source, and drain, and a voltage at the gate can control a current between source and drain.

The image represents a typical bipolar transistor in a circuit. Charge will flow between emitter and collector terminals depending on the current in the base. Because internally the base and emitter connections behave like a semiconductor diode, a voltage drop develops between base and emitter while the base current exists. The amount of this voltage depends on the material the transistor is made from, and is referred to as V_{BE}

Transistor as an amplifier

The common-emitter amplifier is designed so that a small change in voltage (V_{in}) changes the small current through the base of the transistor; the transistor's current amplification combined with the properties of the circuit means that small swings in V_{in} produce large changes in V_{out} .

Various configurations of single transistor amplifier are possible, with some providing current gain, some voltage gain, and some both.

Transistor as a switch

In digital circuits, transistors are frequently employed as electrical switches that may be in either a "on" or "off" state, both for high-power applications like switched-mode power supply and for low-power applications like logic gates. The voltage handled, the current switched, and the switching speed—defined by the rise and fall times—are all crucial characteristics for this application.

Relay

Relays are switches that run on electricity. A switch is mechanically operated by an electromagnet in many relays; however there are other relays that function using solid-state technology. When more than one circuit has to be controlled by a single signal or when a separate low-power signal is required, relays are utilized. The original relays served as amplifiers in long-distance telegraph circuits by repeating the signal arriving from one circuit and retransmitting it on a different circuit. Early computers and telephone exchanges both made heavy use of relays to carry out logical processes.

A contactor is a particular kind of relay that can manage the high power necessary to directly operate an electric motor or other loads. With no moving components and switching performed by a semiconductor chip, solid-state relays regulate power circuits. Electrical circuits are protected from overload or defects by relays with calibrated operating characteristics and occasionally numerous operational coils; in contemporary electric power systems, digital instruments still serve as protective relays for these

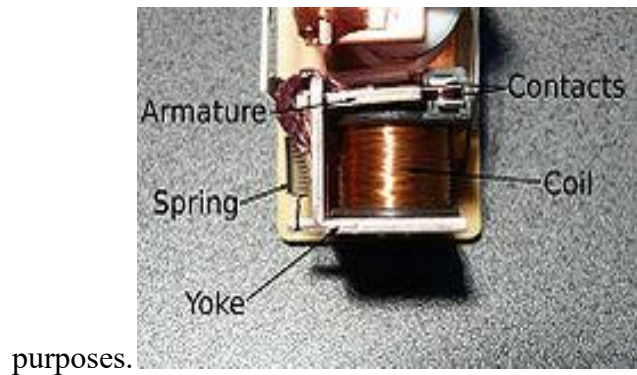


Fig. 3.2 Simple electromechanical relay.

Source: (https://commons.wikimedia.org/wiki/File:Relay_Parts.jpg)

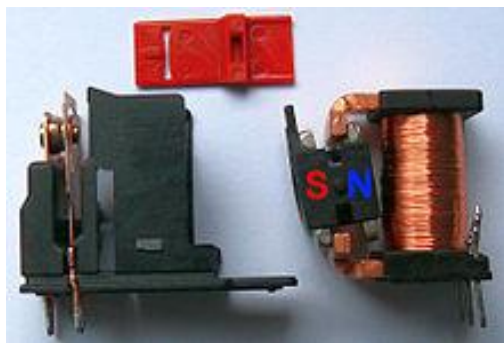


Fig. 3.3 Latching relay with permanent magnet

Source: (https://commons.wikimedia.org/wiki/File:Relay_Parts.jpg)

Operation of relay

A basic electromagnetic relay is made up of an iron yoke that works as a low-reluctance conduit for magnetic flux, an iron coil of wire wrapped around a soft iron core, a moveable iron armature, and one or more sets of contacts (there are two contacts in the relay pictured). The yoke and one or more sets of moving contacts are mechanically connected to the armature, which is hinged to it. A spring holds the armature in place so that when the relay is de-energized, the magnetic circuit has an air gap. One of the two sets of contacts in the relay shown in this situation is closed, while the other set is open. Depending on how they are used, other relays may have more or fewer sets of connections. Moreover, the relay in the image has a wire joining the armature to the yoke. Via the yoke, which is connected to the printed circuit board (PCB), this maintains circuit continuity between the moving contacts on the armature and the circuit track.

As an electric current flows through the coil, it creates a magnetic field that activates the armature. As a result, the moveable contact moves and, depending on how it was built, either creates or destroys a connection with a fixed contact. The action opens the contacts and breaks the connection if the set of contacts was closed when the relay was de-energized, and vice versa if the contacts were open. The armature is restored to its relaxed state by a force that is roughly half as strong as the magnetic force when the current to the coil is shut off. In industrial motor starters, a spring is typically employed to create this force, but gravity is also frequently used. The majority of relays are made to function rapidly. This lessens noise in low-voltage applications and arcing in high-voltage or current applications.

In order to dissipate the energy from the collapsing magnetic field upon deactivation, which would otherwise cause a voltage spike risky to semiconductor circuit components, a diode is

frequently installed across the coil while the coil is powered with direct current. When transistors were utilized as relay drivers, such diodes were not often used, but they quickly spread since early germanium transistors were easily damaged by this surge. Within the relay casing of certain automobile relays is a diode.

Surge currents surrounding the relay output contacts may also be an issue if the relay is driving a big or particularly reactive load. A snubber circuit (a capacitor and resistor connected in series) between the contacts may be able to tame the surge in this situation. For this typical application, suitably rated capacitors and the corresponding resistor are offered as a single packed component.

A technique is used to divide the flux into two out-of-phase components that add up to increase the minimum draw on the armature during the AC cycle if the coil is intended to be powered by alternating current (AC). This is often accomplished by crimping a thin copper "shading ring" around a section of the core that produces the delayed, out-of-phase component and retains the contacts during the control voltage's zero crossings.

3.2 Electronics Vs Electrical Devices.

Although both electrical and electronic equipment use electricity, there is a little difference in how it is used. While the majority of electrical equipment (such as fans and lights) run on AC power, electronics require DC electricity to operate (television, my project). Because of this, circuit boards are used for electronic connections whereas thick cables are used for electrical connections.

3.3 Types of Circuit Boards and Properties

(a). **Project Board or Bread Board:** Prior to switching to a permanent board, this is mostly used to organize components. Because of how the board was made, this is conceivable. Both horizontally and vertically, the row is continuously continuous. It is not necessary to solder components since they will "stuck" to the holes supplied and continue to conduct. The parts may be reused several times and the assembly is quick.

(b). **Matrix Board:** This is similar to a breadboard in the sense that components could be assembled quickly. It has pins sticking out of it and the components are easy just as they look on paper (circuit diagram)

(c). **Vero Board:** This is a more "serious" sort of board where the components will really be soldered on using either parallel or occasionally non-parallel continuous technology. It is taken care not to cross any of its lines.

(d). **Printed Circuit Board (PCB):** This type of board is included in the majority of electrical equipment. The parts are positioned exactly as needed, and the arrangement is captured on camera while taking connection into account. After then, a corrosive chemical will "burn" away the undesirable conductor. As it is simple to create in large quantities, it is less expensive overall. It is therefore well-liked by the majority of producers.

3.4 The Soldering

Soldering is a method of joining metal parts using an alloy of low melting point filler material (solder) which has a melting temperature below 450 °C (800 °F). By using a filler metal that melts at a lower temperature than the base metal, soldering differs from brazing whereas welding uses molten base metal. In the soldering process, heat is provided to the metal components, and the alloy metal is forced against the junction, melts, and is pulled into the joint by capillary

action and around the materials to be connected by "wetting action". While the resultant joints are not as robust as the base metal after cooling, they are nevertheless strong enough, electrically conductive, and watertight for many applications. An age-old method known as soldering has been in use for almost as long as people have been producing metal objects.

Lead: This is a metal alloy having a low melting point. It ensures that components “stay” on the Vero board and maintain connectivity between them.

Casing: For proper presentation the whole project was enclosed in a plastic casing. I choose plastic because it is cheap and available and so that my components do not bridge and handlers do not get electrocuted.

3.5 **Block Diagram**

The block diagram components for the project are as listed below

- Power Supply Unit
- Real Time Clock Unit
- Temp And Timing Input Unit
- Display Unit
- Alerting Unit
- Control Relay Unit
- Status Led
- Temperature Sensor
- Microcontroller Unit

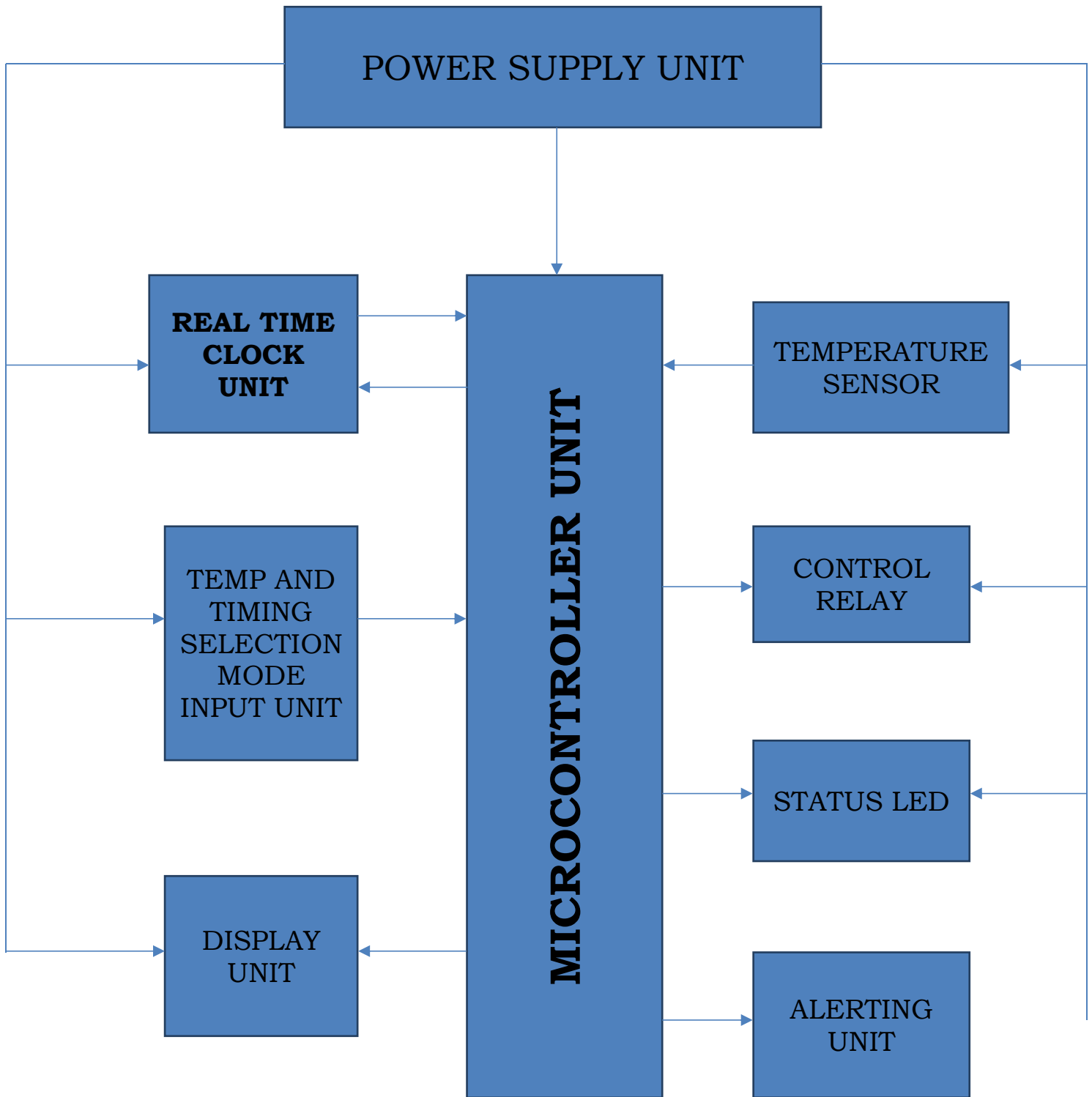


Fig. 3.4 Block Diagram of the System

3.5.1 Power Supply Unit

This is the unit that supplies power to the whole circuit. The system uses 5 volts dc for its operation. It also needs 12 volts dc for the powering of the buzzer and the large relays involved in the system as well as 220 volts ac for the powering of the power supply itself. The power supply unit will have the ability to produce such system. The power supply unit will use power from the national grid as its own primary source of power.

The circuit diagram and subsequent calculations is as shown below.

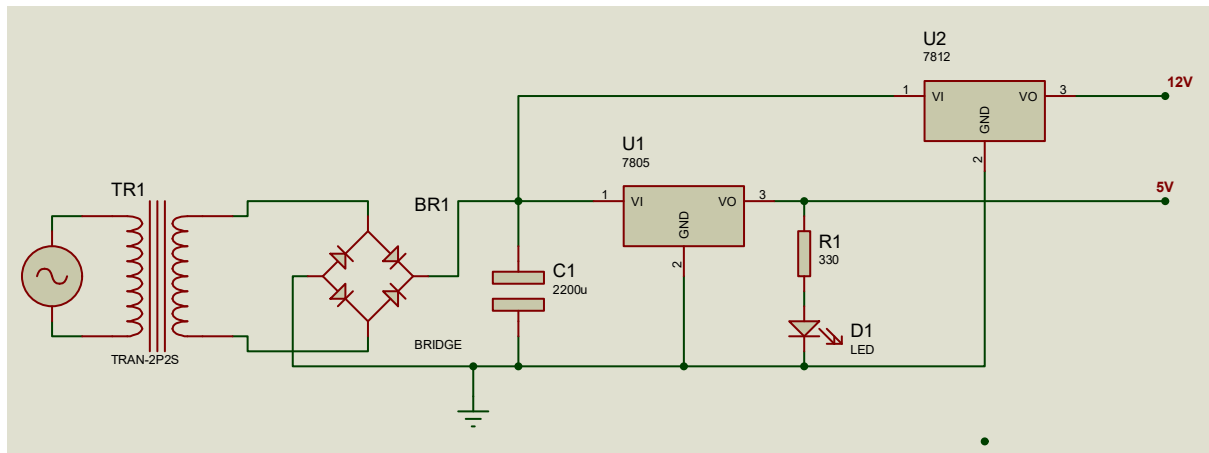


Fig 3.5: The Power Supply Unit

TR1: This is the step down transformer. A transformer voltage of 12Vac or above is required. The current should be enough to supply the requirement of the circuit.

The transformer (T1) chosen is

12Vac@300mA.

D1-D4: These are the rectifier circuit. The diodes chosen must have a peak inverse voltage (PIV) that must be able to withstand twice the peak voltage (V_p) of the

transformers output and a forward current (D_c) of 1.5 times the output current of the transformer.

$$V_p = \sqrt{2} V_{rms} \dots \dots \dots (3.3)$$

Where V_p is the peak voltage of the transformer output.

V_{rms} is the actual output voltage from the transformer = 12Vac

$$V_p = \sqrt{2} \times 12$$

$$V_p = 1.414 \times 12$$

$$V_p = 16.97 \text{Vac}$$

$$D_{(piv)} = 2 \times V_p \dots \dots \dots (3.4)$$

Where $D_{(piv)}$ is the PIV of the rectifier diode

Therefore, $D_{(piv)} = 2 \times 16.97$

$$D_{(piv)} = 33.94.$$

And $D_c = 1.5 \times 300 \times 10^{-3}$

$$D_c = 0.45 \text{A}$$

Therefore the required diode must have a:

$$PIV \geq 33.94 \text{V}$$

$$D_c \geq 0.45 \text{A}$$

From diode catalogue, the IN4007 has the following characteristics:

$$PIV = 50 \text{V}$$

$$D_c = 1 \text{A}$$

Consequently, the diode chosen is the IN4007

$$D_1-D_4 = \text{IN4007}$$

C₁: This is the filter capacitor. Electrolytic capacitors come with a capacitance and a voltage rating.

3.5.2 Voltage Rating

The voltage of the capacitor (V_c) must be able to withstand 150% of the output voltage from the diode.

$$V_C = 150\% \text{ of } V_{DP} \dots\dots\dots (3.5)$$

Where V_{DP} is the peak output voltage from the diodes

But V_{DP} is given as

$$V_{DP} = V_p - V_D \dots\dots\dots (3.6)$$

Where V_p is the peak voltage of the transformer

V_D is the voltage drop of the diodes (0.7×2)

$$V_{DP} = 16.97 - 1.4$$

$$V_{DP} = 15.57V$$

$$\therefore V_C = 1.5 \times V_{DP} \dots\dots\dots (3.7)$$

V_c is the voltage rating of the capacitor

$$V_c = 1.5 \times 15.57$$

$$V_c = 23.6V$$

3.5.3 Capacitance Rating

The capacitance of the capacitor must be such that it could reduce the ripple voltage (V_R) to about 30% of the output peak voltage from the diodes.

$$V_R = 30\% \text{ of } V_{DP} \dots\dots\dots (3.7)$$

From eqn 3.6, V_{DP} is given as 15.57

$$\therefore V_R = \frac{30}{100} \times 15.57$$

$$V_R = 4.67V \dots\dots\dots (3.7.1)$$

From the ripple voltage equation, we could get the capacitance

$$V_R = \frac{I_{max}}{2 \times f \times C_1} \dots\dots\dots (3.8)$$

Where V_R is the ripple voltage

I_{max} is the maximum current from the diodes/ transformers (300mA)

f is the frequency of supply (50Hz)

C is the capacitance of the capacitor in Farads.

$$V_R = 4.67V \text{ (from eqn 3.6.1)}$$

$$\therefore V_R (2FC) = I_{max}$$

$$C_1 = \frac{I_{max}}{V_R \times 2 \times f} \dots\dots\dots (3.9)$$

Substituting,

$$C_1 = \frac{300 \times 10^{-3}}{4.67 \times 2 \times 50}$$

$$C_1 = \frac{0.3}{467}$$

$$C_1 = 6.42 \times 10^{-4} \text{ F}$$

Converting to μF

$$C_1 = \frac{6.42 \times 10^{-4}}{10^{-6}}$$

$$C_1 = 642.4 \mu\text{F}$$

$$= 642.4\mu\text{F}$$

This value cannot be obtained in the market and due to the fact that we require a highly filtered circuit, a capacitor with a high than calculated capacitance can be chosen. Therefore the capacitance chosen is:

$$C_1 = 1000\mu\text{F @}35\text{V}$$

U1: This is the voltage regulator.

Regulator specifications I:

- Maximum input voltage = 30V
- Maximum output voltage = 5.5V
- Operating temperature = 0%- 150%

For effective Voltage regulation, the minimum input voltage should be:

$$V_{\min} = V_{\text{out}} + V_{\text{ref}} \dots\dots\dots (3.10)$$

V_{\min} – Minimum input voltage

V_{out} – required output voltage: 5V

V_{ref} – Datasheet Stipulated reference voltage; 3V

$$V_{\min} = 5 + 3$$

$$V_{\min} = 8V$$

The output voltage after the capacitor is 15.57 volts. This is enough to supply the minimum input voltage (8 volts) Therefore, the voltage regulator could be comfortably used. The regulator chosen is

$$U_1 = 7805$$

Regulator specifications II3:

- Maximum input voltage = 30V
- Maximum output voltage = 12.5V
- Operating temperature = 0%- 150%

For effective Voltage regulation, the minimum input voltage should be:

$$V_{\min} = V_{\text{out}} + V_{\text{ref}} \dots\dots\dots (3.11)$$

V_{\min} – Minimum input voltage

V_{out} – required output voltage: 12V

V_{ref} – Datasheet Stipulated reference voltage; 2V

$$V_{\min} = 12 + 2$$

$$V_{\min} = 14V$$

The output voltage after the capacitor is 15.57 volts. This is enough to supply the minimum input voltage (14 volts) Therefore, the voltage regulator could be comfortably used. The regulator chosen is

$$U_1 = 7812$$

C_2 is a transient capacitor. The rating is stipulated in the 78XX voltage regulator's data sheet as 0.1uF

Hence,

$$C_2=0.1\mu\text{F}$$

This capacitor helps for smoothening of the output from the voltage regulator. It is also to prevent spikes in the DC output voltage waveform in the event of transient disturbances. It is known as a buffer capacitor whose value is gotten from the data sheet of the regulator.

Current limiting resistor calculation:

$$R_1 = \frac{V_S - V_D}{I_D} \dots\dots\dots (3.12)$$

$$R_1 = \frac{5 - 2}{10 \times 10^{-3}}$$

$$R_1 = 300\Omega$$

This value of resistor is not in the market, so the appropriate value to use is:

$$R_1=330\Omega$$

Light emitting diode characteristics:

Forward current of..... $10 \times 10^{-3}\text{A}$ to $10 \times 10^{-3}\text{A}$

Voltage drop of.....2V

3.5.4. Temperature and Timing Input Unit

This is the unit that the system uses to set the desired response temperature for the water bath. It also uses this same circuit to set the timing of the system. It is comprised of push button buttons and pull up resistors. The circuit diagram is as shown below.

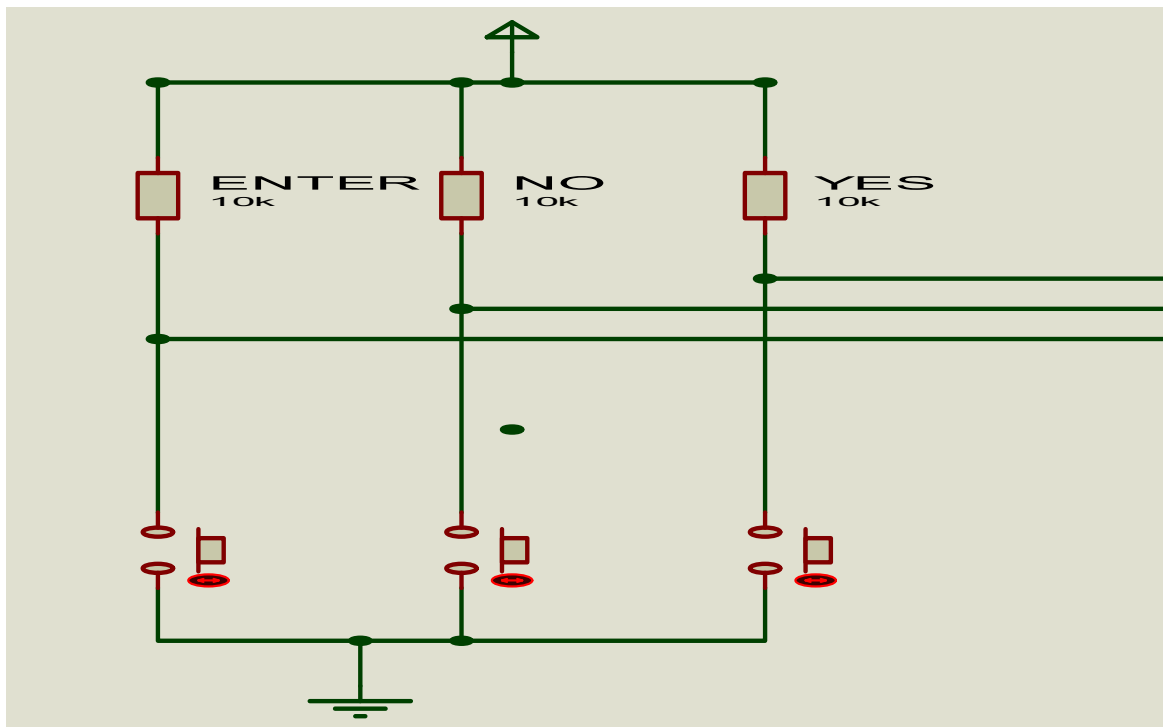


Fig. 3.6 Temperature and Timing Input Unit

R: these are pull up resistors. Pull up resistors are always given a range of values from

470 Ω to 22k Ω

For the sake of our project, the value chosen for the pull up resistors values are

R = 10k Ω each

3.5.5 Display Unit

This is the user interface unit. It's the part of the system that the user uses to interface with the system. All the activities that is carried out in the circuit, is displayed on the screen. The screen used is a 16 by 2 liquid crystal display (LCD) that displays alphanumeric data.

The circuit diagram and subsequent calculations is as follows

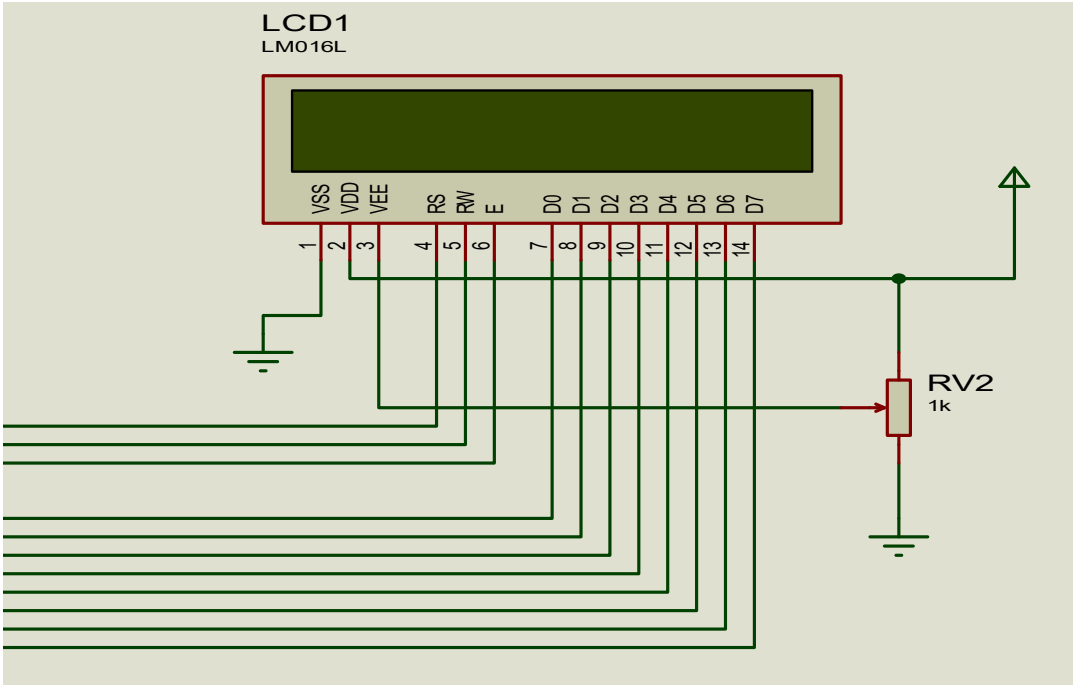


Fig. 3.7 Display Unit

The LCD is 16 x 2 screen display. This means that it can display 16 alphanumeric characters on 2 lines.

RV2: is a resistor to set the contrast of the display.

A 1kΩ variable resistor is the usual value used

3.5.6 Alerting Unit

This is the part of the system that sends alert to the user that the set temperature is reached. It is designed using an Astable mode connected multi vibrator integrated circuit, the 555 timer. It is designed for an output frequency of one hertz while its output terminal is connected to an LED and a buzzer. To this effect, the unit has the ability to turn on the buzzer and LED, on and off, each second thereby creating a unique pulsating effect of an audio and visual alerting mechanism.

The circuit diagram and subsequent calculations is as follows

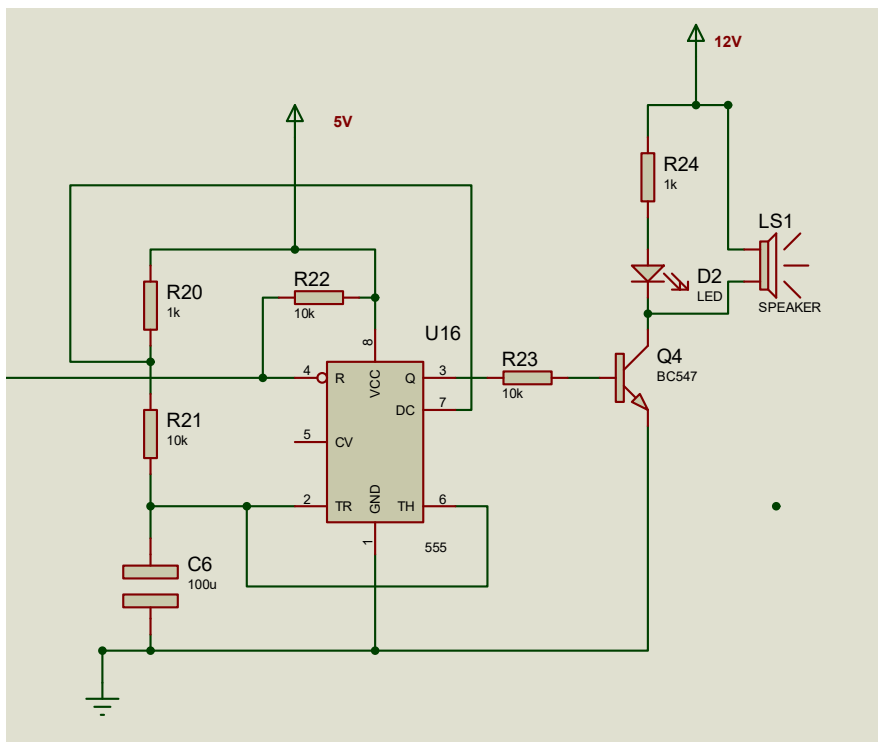


Fig. 3.8 Alerting Unit

The outputs of the multi vibrator is set to a frequency of 1Hz such that the alarm connected to it will turn on for one second and off for another one second continuously as long as the microcontroller allows it to.

U16 - This is a 555 timer biased in an Astable multi vibrator mode. R_{20} , R_{21} and C_6 are used to set the output frequency. The relationship is given thus;

$$f = \frac{1.44}{(2R_{21} + R_{20})C_6} \quad (3.13)$$

A frequency of 1 Hz is desired. Since we are looking for three unknown, we chose values for two and calculate for the third one. Choosing;

$$C_6 = 47\mu\text{F} \text{ and } R_{21} = 10\text{K}\Omega$$

Calculating R_{20} as follows

$$f(2R_{21} + R_{20})C_6 = 1.44$$

$$(2fR_{21} + fR_{20})C_6 = 1.44$$

$$2fR_{21}C_6 + fR_{20}C_6 = 1.44$$

$$fR_{20}C_6 = 1.44 - 2fR_{21}C_6$$

$$R_{20} = \frac{1.44 - 2R_{21}C_6}{f \times C_6}$$

$$R_{20} = \frac{1.44 - (2 \times 1 \times 10000 \times 47 \times 10^{-6})}{1 \times 47 \times 10^{-6}}$$

$$R_{20} = 10638.29\Omega$$

This value of resistor is not in the market, so the value of the resistor used is

$$R_{20} = 12K\Omega$$

R_{24} : this is a current limiting resistor for the LED and the value is given as thus

$$R_x = \frac{V_s - V_{ir}}{I_{ir}} \quad (3.14)$$

Where

V_{ir} – voltage drop of the LED: 2V

I_{ir} – current of the LED: taken as 10mA

V_s – voltage from the source: 12v

$$R_x = \frac{12-2}{10\text{mA}}$$

$$R_x = \frac{10}{10 \times 10^{-3}}$$

$$R_x = 1000\Omega$$

$$\therefore R_{24} = 1k\Omega$$

In this circuit, this resistor is also known as the collector resistor: R_C

R_{23} is the base resistor for the transistor R_C . For effective switching, the collector current should be about 10 times the base current.

$$I_c = 10 \times I_B$$

$$\therefore R_B = 10 \times R_C$$

$$R_C = 1000\Omega \text{ (from previous calculations)}$$

$$\therefore R_B = 10 \times 1000$$

$$= 10000$$

$$R_{23} = 10k\Omega$$

3.5.7 Control Relay Unit

This is the unit that the system uses to control the relay that turns on and off the water heater. When the system desires to turn on the water heater, it will send a digitally high signal to the control relay unit and when it desires to turn it off, it sends a digitally low signal. The circuit is made up of Triacs, opto Triacs, resistors and transistor. The circuit diagram is as shown below

The circuit diagram is as shown below

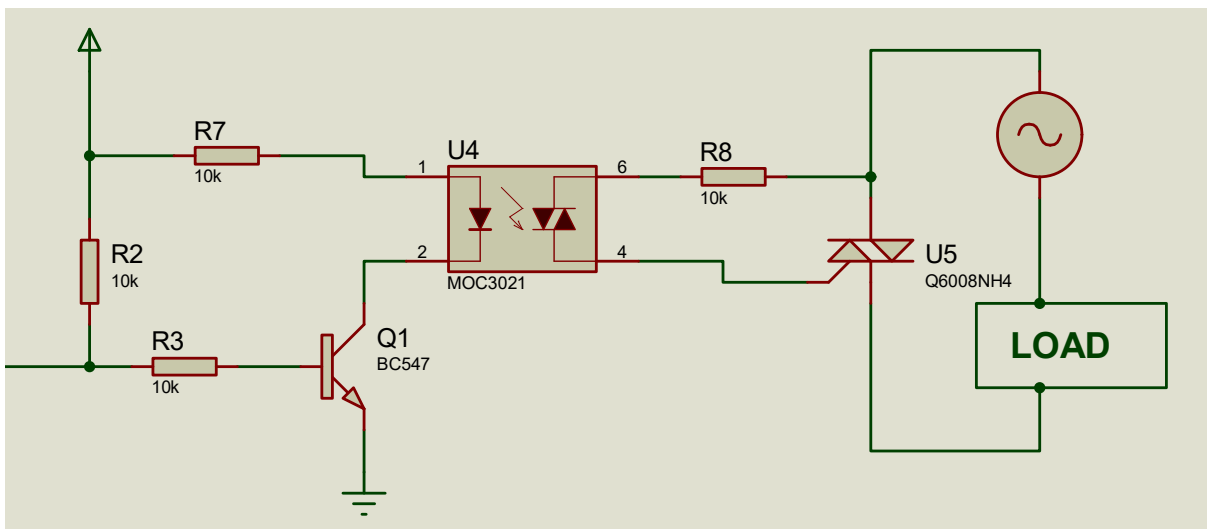


Fig. 3.9 Control Relay Unit

The control part of the load actually turns it off or on. This is basically a switch that is built around a static relay using a triac fired by another triac based opto-

isolator. An NPN transistor is used to control the low voltage side of the isolator from signals transmitted from a microcontroller terminal.

R_{12} = a pull up resistor. This is a resistor that is basically used to set a terminal temporarily high. The value is usually from a range of

$$470\Omega \text{ to } 10,000\Omega$$

For this circuit, the value of $1,000\Omega$ was used.

R_{14} = this is a current limiting resistor for the light emitting diode inside the low voltage side of the Optoisolator. The formula to calculate the value of current limiting resistors is given thus

$$R_{14} = \frac{V_S - V_D}{I_D} \quad (3.14)$$

From the MOC3021 datasheet, the following characteristics of the low voltage side light emitting diode is given as

Forward current, $I_D = 10 \text{ mA}$

Voltage drop $V_D = 2\text{V}$

While the supply voltage for the system is $V_S = 5\text{V}$

$$R_{14} = \frac{5 - 2}{10 \times 10^{-3}}$$

$$R_{14} = 300\Omega$$

This value of resistor is not in the market, so the appropriate value to use is:

$$R_{14} = 330\Omega$$

R_{13} = this is the biasing resistor for the NPN transistor. For the transistor to work in the saturation mode, we use the equation

$$R_B = 10 \times R_C$$

Where R_B is base resistor R_{13} , and R_C is collector resistor R_{14} (330Ω)

Substituting

$$R_B = 10 \times 330\Omega$$

$$R_{14} = 3300\Omega$$

R_{15} = snubber resistor for the triac on inductive loads

Datasheet stipulates the collective resistance to $1k\Omega$

Therefore

$$R_{15} = 1,000\Omega$$

3.5.8 Status Led

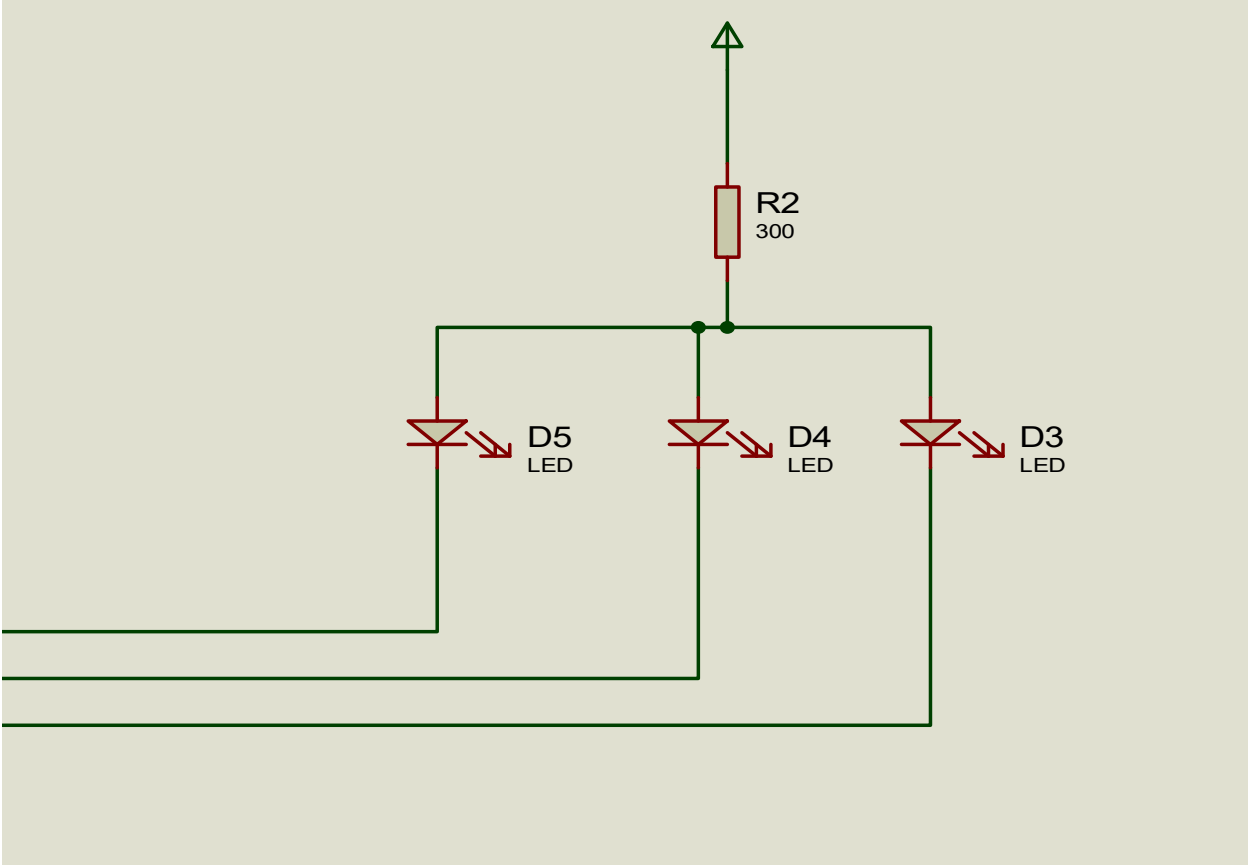


Fig. 3.10 Status Led

Current limiting resistor calculation:

$$R_2 = \frac{V_S - V_D}{I_D} \dots\dots\dots (3.15)$$

$$R_2 = \frac{5 - 2}{10 \times 10^{-3}}$$

$$R_2 = 300\Omega$$

This value of resistor is not in the market, so the appropriate value to use is:

$$R_2 = 330\Omega$$

Light emitting diode characteristics:

Forward current of..... $10 \times 10^{-3} \text{A}$ to $10 \times 10^{-3} \text{A}$

Voltage drop of.....2V

3.5.9 Temperature Sensor

With is unit, the temperature of the water bath is monitored. The sensor is placed inside the water bath and its temperature is digitally sent to the microcontroller for subsequent reading and display and activation/deactivation respectively.

The unit circuit diagram and subsequent calculations is as shown below:

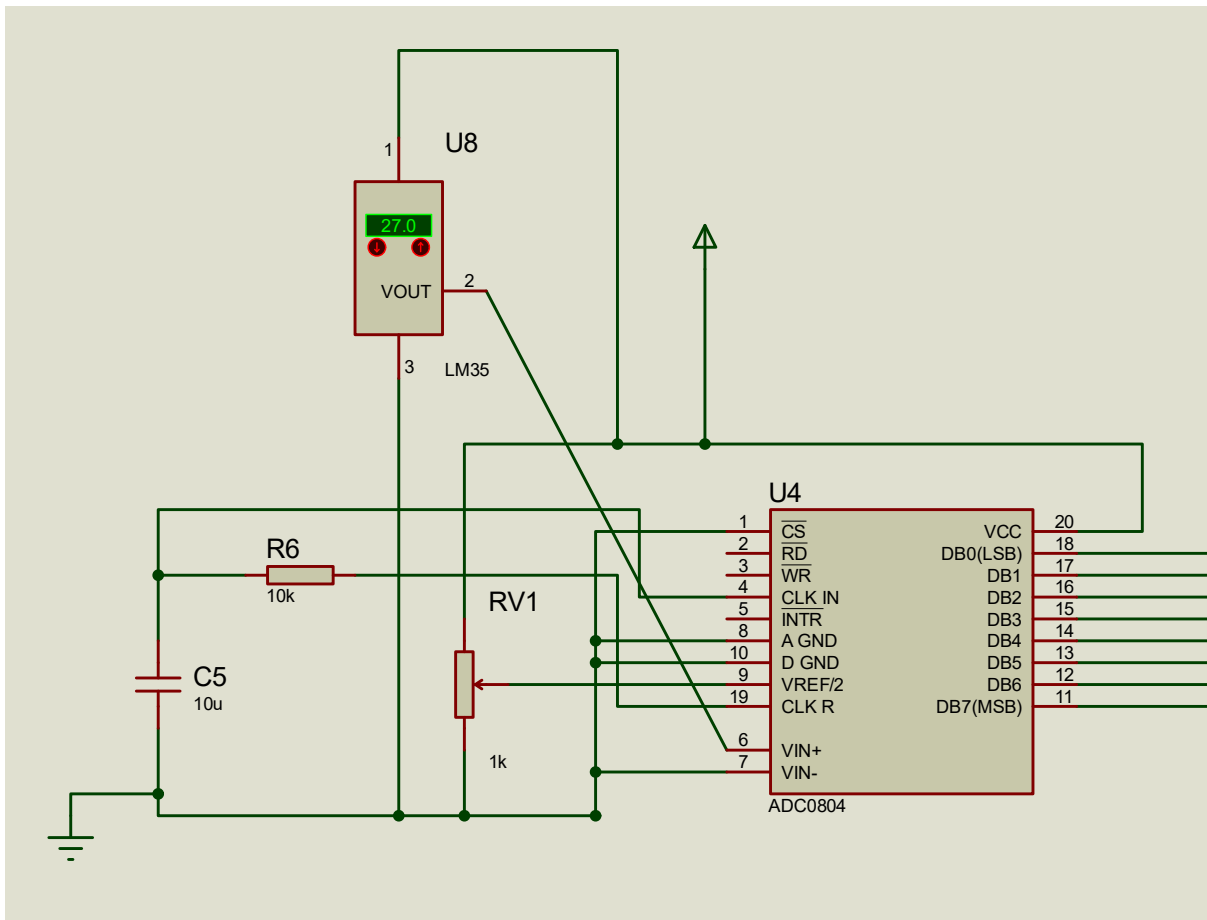


Fig. 3.11 Temperature Sensor

U8: this is a temperature sensor and it has the following general description and features from the data sheet

General description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to

obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of $\pm 1/4^{\circ}\text{C}$ at room temperature and $\pm 3/4^{\circ}\text{C}$ over a full -55 to $+150^{\circ}\text{C}$ temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only $60\ \mu\text{A}$ from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a -55° to $+150^{\circ}\text{C}$ temperature range, while the LM35C is rated for a -40° to $+110^{\circ}\text{C}$ range (-10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in $^{\circ}\text{C}$ elsius (Centigrade)
- Linear $+ 10.0\ \text{mV}/^{\circ}\text{C}$ scale factor n 0.5°C accuracy guaranteeable (at $+25^{\circ}\text{C}$)
- Rated for full -55° to $+150^{\circ}\text{C}$ range n Suitable for remote applications
- Low cost due to wafer-level trimming n Operates from 4 to 30 volts
- Less than $60\ \mu\text{A}$ current drain

- Low self-heating, 0.08°C in still air
- Nonlinearity only $\pm 1/4^\circ\text{C}$ typical
- Low impedance output, 0.1 Ω for 1 mA load

U4: this is the analogue to digital converter integrated circuit.

Table 1: Analogue to digital converter integrated circuit

Pin No	Function	Name
1	Activates ADC; Active low	Chip select
2	Input pin; High to low pulse brings the data from internal registers to the output pins after conversion	Read
3	Input pin; Low to high pulse is given to start the conversion	Write
4	Clock Input pin; to give external clock.	Clock IN
5	Output pin; Goes low when conversion is complete	Interrupt
6	Analog non-inverting input	Vin(+)
7	Analog inverting Input; normally ground	Vin(-)

8	Ground(0V)	Analog Ground	
9	Input pin; sets the reference voltage for analog input	Vref/2	
10	Ground(0V)	Digital Ground	
11		D7	
12		D6	
13		D5	
14		D4	
15		D3	
16		D2	
17		D1	
18		D0	
19	Used with Clock IN pin when internal clock source is used	Clock R	

R6 and C5: these are the discrete components of the CLK IN and the CLK R terminals. These terminals are for the use of the internal clock of the ADC

CLK IN is an input pin connected to an external clock source. To use the internal clock generator (also called self-clocking), CLK IN and CLK R pins are connected to a capacitor and a resistor, and the clock frequency is determined by

$$F = \frac{1}{1.1 RC} \quad (1.16)$$

As always, mathematically, when faced with two unknowns, we assume one and calculate for the other. Meanwhile the data sheet of the ADC 0804 stipulated the clocking frequency to be about 110μs.

Therefore

$$F = 110 \times 10^{-6}$$

$$R = 10 \times 10^3$$

$$C = \frac{1}{1.1 RF}$$

$$C = \frac{1}{1.1 \times 10 \times 10^3 \times 110 \times 10^{-6}}$$

$$C = 150 \times 10^{-12}$$

$$C = 150\text{Pf}$$

RV1: for the Vref/2 terminal of the ADC, It is used for the reference voltage *f*If this pin is open (not connected), the analog input voltage is in the range of 0 to 5 volts (the same as the Vccpin) *f*If the analog input range needs to be 0 to 4 volts, Vref/2 is connected to 2 volts

$V_{REF}/2$ Relation to V_{IN} Range

$V_{REF}/2$ (v)	V_{IN} (V)	Step Size (mV)
Not connected*	0 to 5	$5/256=19.53$
2.0	0 to 4	$4/255=15.62$
1.5	0 to 3	$3/256=11.71$
1.28	0 to 2.56	$2.56/256=10$
1.0	0 to 2	$2/256=7.81$
0.5	0 to 1	$1/256=3.90$

Step size is the smallest change can be discerned by an ADC

For the case of connecting an LM35 to an ADC804. Since the ADC804 has 8-bit resolution with a maximum of 256 steps and the LM35 produces 10 mV for every degree of temperature change, we can condition V_{IN} of the ADC804 to produce a V_{OUT} of 2560 mV full-scale output. Therefore, in order to produce the full scale V_{OUT} of 2.56 V

for the ADC804, We need to set

$$\frac{V_{REF}}{2} = 1.28$$

This makes V_{OUT} of the ADC804 correspond directly to the temperature as monitored by the LM35.

To this effect, we need RV1 to be a variable resistor. Therefore,

$$RV1 = 10k\Omega$$

3.5.10 Microcontroller Unit

The microcontroller unit circuit is the heart of the project. This is where the program for the control part of the project is written and burned using assembly language and a universal programmer, respectively. The circuit diagram is as shown below

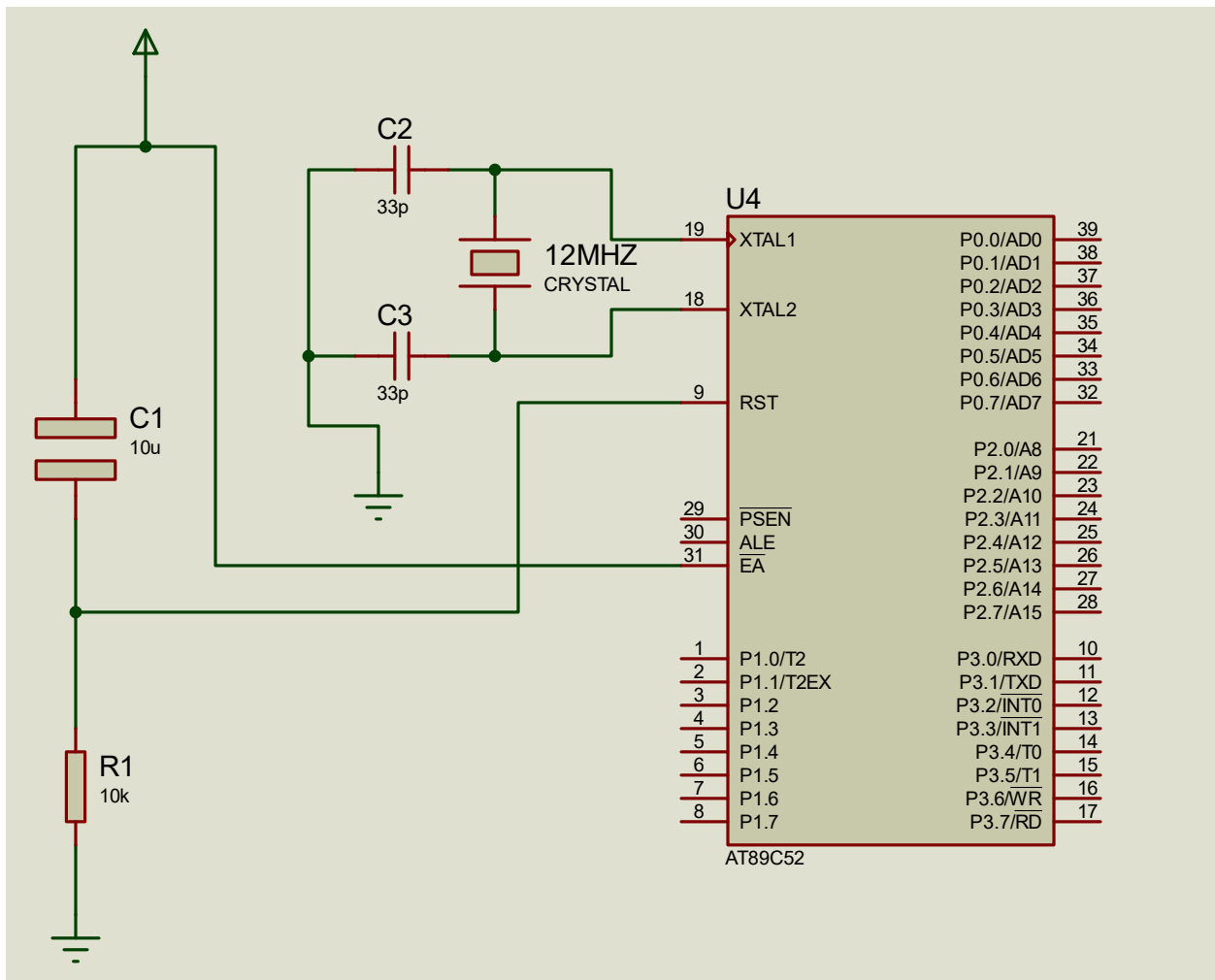


Fig. 3.12 Circuit Diagram for the Microcontroller Unit

The 8052 microcontroller hardware circuit is usually a very flexible one and all the surrounding components are given a recommended range of values, by the datasheet but the actual values can be chosen by the programmer.

The ranges of values given for the 8052 microcontroller hardware are as follows

- Reset capacitor: 4.7 μ F to 10 μ F
- Reset resistor: 8.2K Ω to 15 K Ω
- Crystal oscillator: 4MHz to 32MHz
- Crystal capacitors: 27pF to 47pF

For the programming of the digitally programmable temperature/time based control system for a laboratory water bath equipment in physics department, university of Benin, the chosen values are as follows

- Reset capacitor (C_1): 10 μ F
- Reset resistor (R_1): 10 K Ω
- Crystal oscillator (X_1): 12MHz
- Crystal capacitors (C_2 & C_3): 33pF

The program codes for the circuit is as follows

```
#include <LiquidCrystal.h>
```

```
#include <DallasTemperature.h>
```

```
#include <OneWire.h>
```

```
#include <DS18B20.h>
```

```

#define oneWireBus A5

OneWireoneWire(oneWireBus);

DallasTemperaturesensors(&oneWire);

//13,11,5,6,7,8

LiquidCrystalled (8, 9, 10, 11, 12, 13);

constint button1 = 2;

constint button2 = 3;

constint button3 = 4;

constint buzzer = 10;

constint relay = 9;

intTarget_temp = 0;

int R = 2;

int J=0;

intRw=12;

intdebounce = 100;

//int * ptr = &R;

DS18B20 ds(oneWireBus);

void setup() {

```

```
pinMode(button1, INPUT);  
pinMode(button2, INPUT);  
pinMode(button3, INPUT);  
pinMode(relay, OUTPUT);  
pinMode(buzzer, OUTPUT);  
pinMode(Rw, OUTPUT);  
lcd.begin(16, 2);  
sensors.begin();  
    //Serial.begin(9600);  
digitalWrite(Rw,LOW);  
digitalWrite(buzzer,HIGH);  
delay(1000);  
digitalWrite(buzzer,LOW);  
}  
intGetTemp() {  
    sensors.requestTemperatures();  
    returnsensors.getTempCByIndex(0);  
}  
int temperature = 0;  
int GetTemp2() {
```

```

if (ds.selectNext()) {
    temperature = ds.getTempC();
}
return temperature;
}

void loop() {
    if (digitalRead(button1) == LOW) {
        delay(debounce);
        if (digitalRead(button1) == LOW) {
            R = 2;
        }
        lcd.clear();
    }
}

//Serial.print(R);

if (R == 2) {
    lcd.print("Set Target Temp.");
    lcd.setCursor(7, 1);
    lcd.print(GetTemp2());
    lcd.setCursor(10, 1);
    lcd.print("C");
}

```

```

Target_temp = GetTemp2();

while (R == 2) {

digitalWrite(relay, LOW);

digitalWrite(buzzer, LOW);

if (digitalRead(button1) == LOW) {

delay(debounce);

if (digitalRead(button1) == LOW) {

    R = 3;

lcd.clear();

    }

    }

if (digitalRead(button2) == LOW) {

delay(debounce);

if (digitalRead(button2) == LOW) {

Target_temp++;

    }

    }

if (digitalRead(button3) == LOW) {

delay(debounce);

if (digitalRead(button3) == LOW) {

```

```
Target_temp--;
    }
}

if (Target_temp > 105) {
    Target_temp = 0;
    lcd.clear();
    }

if (Target_temp < 0) {
    Target_temp = 105;
    lcd.clear();
    }

    lcd.print("Set Target Temp.");
    lcd.setCursor(7, 1);
    lcd.print(Target_temp);
    lcd.print(" 'C  ");
    }

while (R == 3) {
    for (inti = 0; i < 1; i++) {
        digitalWrite(buzzer, HIGH);
        delay(1000);
    }
}
```

```
digitalWrite(buzzer, LOW);  
  
    //delay(1000);  
  
    }  
  
    R=4;  
  
    }  
  
    }
```

```
int temp = GetTemp2();
```

```
lcd.clear();
```

```
lcd.print("Trgt. temp:");
```

```
lcd.print(Target_temp);
```

```
lcd.print("C");
```

```
lcd.setCursor(0, 1);
```

```
lcd.print("Curr. temp:");
```

```
lcd.print(temp);
```

```
lcd.print("C ");
```

```
if (temp >= Target_temp) {
```

```
digitalWrite(relay, LOW);
```

```
digitalWrite(buzzer, HIGH);
```

```
delay(200);
```

```
digitalWrite(buzzer, LOW);  
  
delay(200);  
  
    J=2;  
  
    }  
  
if ((J==2)&&(temp <= (Target_temp-5))) {  
  
digitalWrite(relay, HIGH);  
  
digitalWrite(buzzer, LOW);  
  
    J=3;  
  
    }  
  
}
```

3.6 Mode of Operation

The operation of the digitally programmable temperature/time based control system for a laboratory water bath is such that when the system is turned on, the LCD displays the initial message, and then the screen prompts the user to select a mode. The options are for temperature mode or for timing mode.

While in the temperature mode, the user will be prompted to set the desired temperature that the water will be heated to, by the use of the input switches. The status LED for temperature mode will come ON. When the water gets to the set desired temperature, the power supplied to the heater will be cut off by the microcontroller sending a signal to the base of the transistor via the resistor. The transistor will saturate and energize the relay. The heater is connected to the normally open contact of the relay and this will ensure that the power to the water heater will be cut off. At the same time, the microcontroller, based on the written program inside its ROM will activate the 555 timer which is connected in the Astable mode. This will allow it to pulsate the buzzer and an alarm will sound with flashing LED.

Meanwhile, in the timing mode, the microcontroller will prompt the user via the LCD, to input the desired duration in seconds, minutes and hours. Once the user uses the input switches to make the setting, the water heater will be activated and the screen will start a countdown operation from the set time to zero. The status LED will show that the system is on timing mode. Once the countdown sequence is done, the system will sound an alarm and flash LEDs, and then turn off the power to the water heater. The concluding operation will be almost the same as when in the temperature mode.

The power to the system will be obtained from the public mains. The power requirements for the system are 220volts ac, 12volts dc and a 5 volts dc. The power supply unit is designed to be able to produce these required powers.

CHAPTER FOUR

RESULTS AND DISCUSSION

SYSTEM TESTING IMPLEMENTATION AND EVALUATION

4.0 System Testing

Testing is a vital process in the development and realization of any design, be it hardware based, software based or both. The various components and their circuitry have to be tested to ensure that all the components on board are certified okay and in good working condition. The components that did not give the required output specification were isolated and troubleshooted to determine the nature and cause of the component failure through careful analysis, that is examination of the working principles of the components.

Here also during the testing analysis, modularization and interface design were also tested. Each module in case of the software were tested to know whether it performs the functions assigned to it and also to know whether each of the module can interact as required by transferring and returning data in form of a signal.

4.1.0 Test Plan

The test plan specifies the steps taken in checking and testing each of the modules that constitute the whole system design. The essence of this is to check for the functionality of the system in question for optimal performance. Some of the steps taken are as follow:

4.1.1 Simulation

The first test carried out is the simulation of the complex work using proteus, an electronics software.

With it, the program is confirmed to be fully functional in its logical decision.

4.1.2 Test Data

The functionality of the system depends to some extent on the correctness of the exact signals being produced by different modules.

Here the test data includes signal that emanates from each module for performing its intended task.

The test data are as follow:

- The signal that comes from the power supply unit
- Test the push buttons
- Test the screen
- Test the dispensing duration
- Test the feeding interval
- Test the dispensing mechanism

The above mentioned test data was used to test for the functionality of the systems.

4.2 Problems Encountered

In the course of the design and implementation of this project, some problems were encountered.

They are:

- Difficulty when writing programs, debugging and interfacing

- Component failures
- Short circuitry
- There were a lot of delicate components involved
- Inadequate and epileptic power supply.

The aforementioned problems were later taken care of during the design processes and implementation of this project.

4.3 The Construction Procedure

The construction procedure for the Digitally Programmable Temperature/Time Based Control System is a set of construction technique that is basically designed for most embedded system.

Firstly the aim and objectives and flow chart was determined which aid in the adequate design of the circuit diagram and suitable simulations using electronic simulation software's such as the PROTEUS ISIS. After the confirmation that the circuit was working perfectly, a step by step process is started. Basically, the following procedure was followed

- The power supply module was first assembled. This consists of the transformer, diodes, capacitor and voltage regulator with its power supply LED indicator.
- Then the switching circuit which comprises of the ten-to-four bit priority encoder and the push button switches, were mounted. However, the switches is intended to be seen outside of the casing so it is extended with wires
- Next the microcontroller circuit is assembled comprises of the microcontroller IC, the crystal oscillator, the filter capacitor and the reset circuit
- The temperature sensor probe was extended out of the casing so that it can be firmly attached into the main water bath. Its probe wires are long enough for this connection and the wires are properly insulated and prepared for insertion into water

- The assembly language program that was written using MIDE was burned into the microcontroller IC using a universal programmer after the codes has been converted to machine codes using TOPWIN6.
- The whole project was powered and tested, corrections made until a suitable working circuit is obtained.

COMPLETE CIRCUIT DIAGRAM

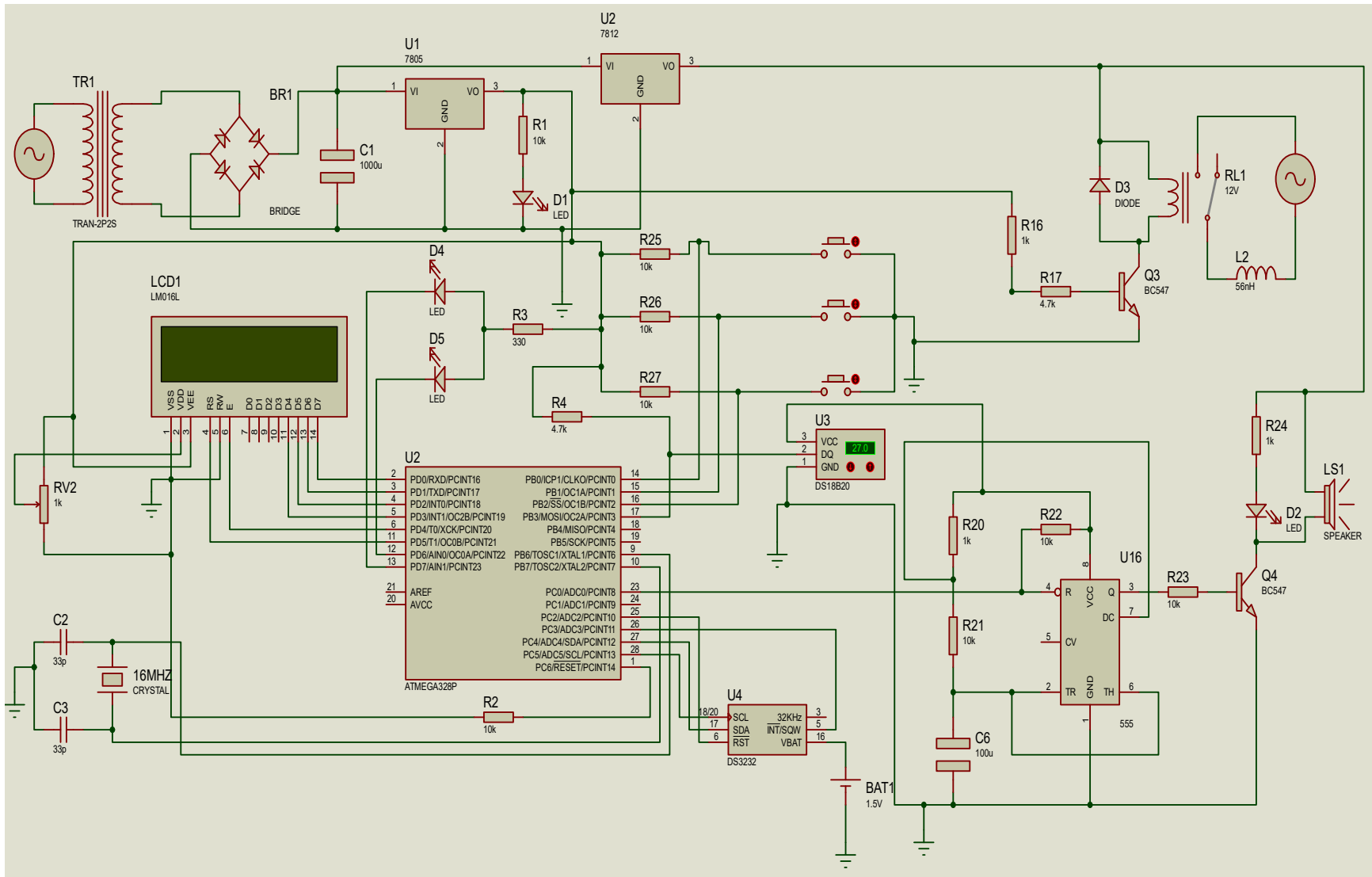


Fig. 4.1 Complete schematics of a Digitally Programmable Temperature / Time Based Control System for Laboratory Water bath

4.4 PRECAUTION

In a project as complex and delicate as this a lot of precaution was observed.

- We were dealing with sensitive components that heat could easily damage so a great care was taken when soldering so that the components could not get damaged by heat.
- Great care was taken to properly identify the cathode anode and other terminals in the components to prevent damage by improper connectivity.
- Care was taken to first assemble the circuit on a breadboard before mounting on the Vero board to avoid mistake on unwarranted de-soldering.
- While soldering, I took precaution so as to avoid bridging and short-circuiting the board.
- The ratings of all the components was carefully verified so as not to damage sensitive components with over voltage.

CHAPTER FIVE

5.0 CONCLUSION

The design is innovative, and its commercial opportunities are numerous. It introduces one to the worldwide trend of the migration from analog systems to digital systems and exposes us to the numerous advantages of the digital system, which are speed, ease of operation, and accuracy. This will be a viable project that will introduce one into the world of IOT systems, which is the future, and eventually, artificial intelligence.

5.1 FINDINGS

A digitally programmable water bath can be designed and fabricated locally at a low cost, which is innovative, and its commercial opportunities are numerous.

5.2 CONTRIBUTIONS TO KNOWLEDGE

The design is viable in the sense that it will go a long way toward reducing unnecessary voltage waste while also introducing one to the global trend of shifting from analog to digital systems.

SUGGESTIONS FOR FURTHER STUDIES

Further work can be undertaken to improve the functionality and efficiency of the water bath, which includes:

- 1) An additional heating element should be added to speed up the heating process.
- 2) A cooling system can also be added to enable rapid cooling of the bath where necessary.

REFERENCES

- Africa, A. D. M.**, Abaluna, D. A. P. , Abello, A. J., and Lalusin, J. M. B. (2020). "Design and Analysis of a Closed-Loop Temperature Engineering Control System using MikroC and Proteus," *International Conference on Decision Aid Sciences and Application (DASA)*, Sakheer, Bahrain, pp. 184-189
- Africa, A.**, Divino, A., and Hartigan-Go, K. (2020). "Fuzzy Logic Temperature Control: A feedback control system implemented by fuzzy logic," *International Journal of Emerging Trends in Engineering Research*, vol. 8, no. 5, pp. 1879–1885.
- Balogun, A. V.**, Edem, I. F., Isitua, C. C., and Fayemi, D. O. (2020). Development of a temperature controlled water heated bath for science laboratories in Nigeria with locally available materials. *Nigeria Journal of Engineering Science Research*, 3(2), pp. 01- 11
- Chakraborty, S.**, Bera, S.K., Bera, S.C., and Mandal, N. (2018). Design of a Simple Temperature Transmitter Circuit of an Electric Heater Operated Water Bath. *IEEE Sensors Journal*, 18, 3140-3151.
- Dinca, M.P.**, Marin, G., Margaret, A., and Paul.G. (2009). "Fast and accurate temperature control of a PCR microsystem with a disposable reactor." *Journal of Micromechanics and Microengineering* 19 (2009): 065009.
- Fadhliana, N.R.**, Suryawan, S.H., and Ariyadi. (2021). "Implementation of Fuzzy Logic on Microcontroller for Quails Coop Temperature Control," *2021 4th International Seminar on Research of Information Technology and Intelligent Systems (ISRITI)*, Yogyakarta, Indonesia, pp. 498-502.
- Gupta J.B** (2004). A course in power systems" S.K KATARIA & SONS 10th Edition July. Part3 pp 198-212.
- Gupta J.B** (2005) Theory and performance of electrical machines" S.K KATARIA & SONS 14th Edition. Part3 pp 1-17.
- Hanah, A.**, Farook, R., Elias, S.J., Rejab, M. R. A., Fadzil M. F. M., and Husin, Z. (2019). "IoT Room Control And Monitoring System Using Rasberry Pi," *2019 4th International Conference and Workshops on Recent Advances and Innovations in Engineering (ICRAIE)*, Kedah, Malaysia, 2019, pp. 1-4,
- Hasim, N.**, Basar, M., and Aras, M. (2011). Design and development of a water bath control system: A virtual laboratory environment, *2011 IEEE Student Conference on Research and Development*, pp. 403-408
- Hasim, N.**, Rashid, M.Z., Aras, M., Kassim, A.M., and Abdullah, S.S. (2012). Development of fuzzy logic water bath temperature controller using MATLAB. *2012 IEEE International Conference on Control System, Computing and Engineering*, 11-16.
- Ibrahim, O.**, Fardoun, F., Younes, R., and Louahlia-Gualous, H. (2014). Review of water-heating systems: General selection approach based on energy and environmental aspects, *Building and Environment*, vol. 72, pp. 59-286.

- Jahlool, S.J.** (2017) "Design and Simulation of Automatic Temperature Control and Alert System Based PIC16F887," *APTIKOM Journal on Computer Science and Information Technologies* Vol. 2, No. 2, 2017, pp. 77~85
- Jensen, C. M.,** and Lee, D. W. (2000). Dry-ice bath based on ethylene glycol mixtures. *Journal of Chemical Education*, 77(5), pp. 629.
- Khairunnas, M.D.,** Ariyanto, E., and Prabowo, S. (2018). Design and Implementation of Smart Bath Water Heater Using Arduino. *2018 6th International Conference on Information and Communication Technology (ICoICT)*, 184-188.
- Lawton, K.M.** and Patterson, S.R. (2001). Long-term relative stability of thermistors. *Precis. Eng.*, 25, 24–28.
- Liu, J.** and Guo, S. (2015). "Resistance Furnace Temperature Control System Based on PIC Single Chip," 2015 8th International Symposium on Computational Intelligence and Design (ISCID), Hangzhou, pp. 34-37, 2015.
- Lu, X.,** Bo Y., Shourong, W., Hongsheng, L. and Libin, H.(2011). "Research on thermal characteristics and on-chip temperature-controlling for silicon micro-gyroscope," 2011 IEEE *International Conference on Information and Automation, Shenzhen*, pp. 807-812,
- Michael** and Felton, J. (2004). Product profile: Baths and circulators. *Today's Chemist at Work. American Chemical Society*, pp.49 - 50.
- Miller, R.** and Miller M.R. (2000). *Electric Motors* Willey 6th Edition pp 338-353.
- Nasser, G.,** Abdel-Mawgood, A., Abouelsoud A., Mohamed, H., Umezu, S., and El-Bab, A.F. (2021). "New cost effective design of PCR heating cyclers system using Peltier plate without the conventional heating block." *Journal of Mechanical Science and Technology* 35 (2021): 3259 - 3268.
- Oo, H. L.,** Anatolii, S., and Ye, K. Z. (2019). "Analysis and Evaluation of the Efficiency of Laser Temperature Control System," *2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus)*, Saint Petersburg and Moscow, Russia, pp. 2180-2182.
- Purwanto, F.H.,** Utami , E., and Pramono, E. (2018). "Design of server room temperature and humidity control system using fuzzy logic based on microcontroller," *International Conference on Information and Communications Technology (ICOIACT)*, Yogyakarta, Indonesia. pp. 390-395,
- Ren-xiu, L.** (2011). A Design on High Precision Constant Temperature Controller of Water-bath. *Journal of Jinhua Polytechnic*.
- Sekhar, N. C.,** Reddy, T. S., and Bhavani, G. (2014). "Implementation of low-cost MEMS based temperature measurement and control system using Lab VIEW and microcontroller," *2014 International Conference on Power, Control and Embedded Systems (ICPCES)*, Allahabad, pp. 1-4.

- Shinoda, J.;** Mylonas, A.; Kazanci, O.B.; Tanabe, S.; Olesen, B.W. (2021). Differences in temperature measurement by commercial room temperature sensors: Effects of room cooling system, loads, sensor type and position. *Energy Build*, 231, 110630.
- Shukla, C. A.,** and Kulkarni, A. A., (2017). Automating multistep flow synthesis: approach and challenges in integrating chemistry, machines and logic. *Beilstein journal of organic chemistry*, 13(1), pp.960-987.
- Sudipta .C.,** Saikat .K.B., and satish .C.B. (2018). “Design of a Simple Temperature Transmitter Circuit of an Electric Heater Operated Water Bath.” *IEEE Sensors Journal* 18 : 3140-3151.
- Tavoosi, J.,** Alaei, M., Jahani, B., and Daneshwar, M.A. (2011). A novel intelligent control system design for water bath temperature control. *Australian Journal of Basic and Applied Sciences*. 5. 1879-1885.
- Theraja, A. K.** and Theraja B. L. (2005).“A Textbook of Electrical Technology” 24th Edition. S. Chand And Company Ltd. New Delhi. pp 214-230, 2071-2075, 357
- World Health Organization (WHO),** (2008). Maintenance manual for laboratory equipment.
- Xia, Dunzhu et al. (2009) “Temperature Effects and Compensation-Control Methods.” *Sensors (Basel, Switzerland)* 9: 8349 - 8376.
- Yang, Z.,** Sun, B., Li, F., and Zhang, L.(2019). “A Temperature Optimal Control Method of Temperature Control System Considering Thermal Inertia,” 2019 Chinese Control Conference (CCC), Guangzhou, China, pp. 5226- 5231.
- Zhang, Z. Y.,** and Guo, T. (2012). Design of Water Bath Temperature Control System Based on DS18B20. *Advanced Materials Research*, 462, 753 - 756.