Design and Construction of an Automatic Temperature Controller and its Application to Birds' Eggs Incubation Process.

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Dedication

I dedicate this project first to God Almighty for giving me the grace and wisdom to successfully carry out this project. Secondly, to my lovely family for their unending love and support. Lastly, to the memory of my late uncle, Mr. Oppong Mensah.

Declaration

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

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Abstract

This project presents the design and construction of an automatic temperature controller and its application to birds' eggs incubation process. The main features of this device are: temperature sensor, microcontroller, relays, analog to digital converter (ADC) and a 3-digit 7-segment display unit. The analog output from the sensor is converted to its digital equivalent by the ADC and fed into the microcontroller, the microcontroller is programmed to compare this value to the preset value and then initiate a control action (i.e. heating or cooling) as the case may be. The sensor detects temperature values between 0-100°C, as such; the preset values could be adjusted within this range. Temperature values (sensed and preset) as well as relay failure massages are displayed on the display unit as the case may be. The device could also be used for many other processes which require some degree of temperature control.

Table of Contents

List of Figures

List of Tables

Chapter One

General Introduction

1.1 Historical Background

Temperature is by far the most measured parameter [1]. It impacts the physical, chemical and biological world in so many ways. Intuitively, people have known about temperature for a very long time: for instance, no one needs to be told that fire is hot and snow is cold. As man attempted to work with metals through the bronze and iron ages, greater knowledge was gained [2]. Some of the technological processes required a degree of control over temperature; also, man needed to control temperature in some of his daily domestic activities such as cooking, food preservation, processing of medicinal herbs etc.

It is evident that the need to control temperature has been an important topic of discussion and research to man, right from the early generations up until the present. To properly understand this topic (i.e. Temperature control), some relevant questions need to be asked:

What is temperature control? Temperature control refers to the adjustment or regulation of temperature (i.e. cold or hot), to a desired point suitable for a particular process. This could be done either by increasing or decreasing the process temperature.

How can temperature be controlled? Temperature, whether in domestic or industrial applications can be controlled by using temperature control devices. These devices could be cooling fans, air conditioners, heaters etc. However, these devices need effective control systems to regulate their modes of operation. These control systems determine when and how control devices operate. For instance, if the temperature of a particular process needs to be increased or decreased, the control system can be set or programmed in such a way that the respective control devices, i.e. heating and cooling devices, operate as at when desired.

How important is temperature control? In our world today, temperature control is unarguably very important as it is employed in so many ways: In homes, offices and other dwelling places, fans and air conditioners are usually used during hot weather, in order to reduce temperature and hence improve comfort. Similarly, room heaters are used during cold weather. In order to properly preserve delicate items such as foods and drugs, refrigerators and freezers are usually used. Ovens which operate at relatively high temperatures are also used for cooking. These are a few amongst several domestic applications of temperature control.

In the field of agriculture, temperature control is very necessary in green houses and incubators which are used for the cultivation of tender plants and artificial incubation of eggs respectively. We shall however be more interested in the application of temperature control for birds' eggs incubation process; a case study of ostrich eggs incubation shall be considered for the purpose of explaining the role of this project (automatic temperature controller) in the incubation process.

Before going any further, it will be necessary to define what incubation as well as an incubator is. Incubation can be defined as the process of keeping birds' eggs warm to develop to the stage at which the young come out [3], while an incubator is a device which keeps birds' eggs at the correct temperature to enable the young develop until they break out of the shell [4]. From the above definitions, it is very clear that the entire incubation process is a very temperature sensitive and dependent one. The incubation process of ostrich eggs for instance, comprises a number of steps which are all temperature sensitive: first, the eggs are collected after being laid and stored at 12-18°C in a dry clean room for a few days [4]. Secondly, they are taken to the incubation room where the temperature of both the room and the incubator itself must be controllable. This device can be of immense help in this case. Usually for ostrich eggs, the temperature in the incubator is required to be kept at between 36.1-36.7°C [4,5]. From the incubator, the eggs are transferred to the hatchery, the temperature required in the hatchery is a bit lower than that of the incubator since the embryo also produces heat at that stage of development [4,5]. The eggs are left in the hatchery until they are completely dry [4,5]. After they are taken out of the hatchery, the chicks are placed in a restricted area with temperature control, 30-34°C during the first days and gradually adjusted to the normal temperature of the environment over a two month period [4,5].

The steps explained above which are all temperature sensitive, are to a great extent the same for the incubation of other birds' eggs. Thus, the design of this project is aimed at achieving incubation of eggs at proper temperatures. But it may also be important to state that this device can also be used for many other applications, e.g. greenhouses, laboratory experiments, industrial processes etc.

1.2 Project Motivation, Aims and Objectives

Over the years, man's need to control temperature for various processes has brought about the development of several temperature control systems and devices which have been used in homes, offices, farms, laboratories, hospitals and industries etc.

The design and construction of this project, was stimulated by the need to effectively control the temperature of birds' eggs incubation process. The aims and objectives of this project are as listed below:

i. To build a system that will effectively control the temperature of birds' eggs incubation process.

ii. To reduce electricity cost which would have otherwise been high, if cooling or heating systems were left to operate always.

iii. To improve the efficiency of processes that are highly temperature sensitive

iv. To cut down on production losses due to unfavourable temperature in the case of processes which are temperature sensitive.

v. To further promote indigenous initiatives in providing engineering solutions.

1.3 Scope Of Project

The system is made up of six basic units: the power supply unit, which supplies power to the entire circuit; the temperature sensory unit, whose task is to measure or sense the actual temperature around the sensor; the analog to digital converter, whose function is to convert the analog signal from the sensory unit to a digital signal which the microcontroller would be able to handle.

Then there is the control unit which consists of a programmed microcontroller which serves as the brain of the unit: the microcontroller is responsible for determining the operational output of the system, i.e. cooling or heating. It also sends messages to be displayed by the display unit of the system. The display unit simply displays messages received by it from the microcontroller; these messages include: the preset temperature value, sensed temperature value as well as load switch error messages; i.e. an error massage is displayed when ever a particular relay fails. Lastly, we have the external equipment drive unit which consists of two relays that switch either of the external control devices (cooling or heating device) On or Off as determined by the microcontroller-based control unit.

The function of this system is to maintain the temperature of an incubation process at a preset value. It offers users the opportunity of presetting temperature values within the range of 0-100°C, this flexibility enables its application for several other processes other than incubation as mentioned earlier. Depending on the desired temperature of the incubation process, the external equipment drive unit energizes the external cooling or heating device connected to it when the temperature of the process goes higher or lower than the preset temperature value respectively.

1.4 Methodology

In order to arrive at the design and construction of this system, many steps were taken to ensure that success was achieved. These include: research carried out on the internet which served as the major source of information on the project; previous works of other people which had to do with temperature measurement and control were also studied.

In choosing the components, the characteristics as well as performance of each of them were carefully considered in order to come up with the most suitable components for the system. For instance, the LM35DZ temperature sensor was chosen because of its relatively high accuracy and standard calibration (i.e. 10mV for every 0°C).

In order to simplify the construction of the system, it was initially subdivided into various modules which were later coupled together to form the main system.

1.5 Project Layout

This project report is comprised of five chapters: Chapter one presents a general introduction of the project, the aims and objectives, scope of work and methodology. Chapter two presents a theoretical background as well as review of related literature of the project, review of previous works of other people as it relates to this project.

Chapter three of this report comprises the presentation of the major work of this project i.e. steps taken in the design, components used, design calculations, circuit diagrams etc. In chapter four of this report, the steps taken to test the device, the results obtained from these tests as well as the discussion of these results are all presented.

Finally, chapter five comprises a summary of the work done, problems encountered as well as recommendations for possible improvement on the system.

Chapter Two

Literature Review

2.1 Brief History of Temperature Measurement

In the early generations, temperature measurement was very subjective [6]. In the case of hot metals, the colour of the glow was good enough to indicate the temperature [7]. For intermediate temperatures, the impact on various materials could be determined. For example, some of the questions that were asked were: whether the temperature could melt sulphur, lead or wax or even boil water [6]?

In about 1592, Galileo invented the first documented thermometer [6,7] which was an air thermometer consisting of a glass bulb with a long tube attached. This thermometer was sensitive, but was affected by changes in atmospheric pressure.

In 1714, Daniel Gabriel Fahrenheit invented both the mercury and the alcohol thermometer [6,7]. Although the mercury thermometer was not as sensitive as Galileo's air thermometer, it was not affected by atmospheric pressure. Also, mercury freezes at -39°C [6] which means that it can not be used to measure temperatures below this point. Alcohol on the other hand, freezes at -113°C [6], allowing much lower temperatures to be measured.

In 1821, T.J. Seeback discovered that a current could be produced by unequally heating two junctions of two dissimilar metals [6], giving birth to the thermocouple. Also in 1821, Sir Humphrey Davy discovered that all metals have a positive temperature coefficient of resistance [6] and that platinum could be used as an excellent temperature detector (RTD) [6,8]. These two discoveries marked the beginning of serious electrical sensors.

The late 19th century saw the introduction of bimetallic temperature sensors [6]. These thermometers contain no liquid but operate on the principle of unequal expansion between two metals [9]. Although not as accurate as liquid in glass thermometers, bimetallic thermometers are handier, easy to read and have a wider span, making them ideal for many industrial applications. The 20th century has seen the discovery of semiconductor devices [6], such as: the thermistor, the integrated circuit sensor, a range of non-contact sensors and also fibre-optic temperature sensors.

2.2 Early Breakthrough: The Thermostat

Once early scientists were able to design devices that could measure temperature, they determined that anything that could be measured could as well be controlled [10]. This led to another round of research with the aim of designing a device that could govern the temperature of a system, but it was not until around 1660 that a major breakthrough was recorded with the invention of the thermostat [10,11]. Named from the Greek words for "constant temperature", the thermostat was invented by Dutch scientist Cornelius Drebbel [10,11]. His device, used to regulate the temperature within a duck and chicken-egg incubator, was actually an elegant combination of several different technologies. Placed above a furnace, the incubator was surrounded by a water-filled jacket. Inside the incubator was a container of alcohol that would expand as it was heated, this expansion pushed down on a U-shaped tube filled with mercury, and as one end of the U was pushed down, the other end would rise up, raising with it a rod. The rising rod would raise a lever connected to the furnace's flue, so that the airway would be partially closed and the temperature would begin to fall. When the temperature fell beyond a certain point, the alcohol once again contracted, thus releasing the mercury, lowering the lever, and re-opening the furnace's airway. This type of thermostat underwent a series of modifications over the next two centuries before it found its way into industry [10].

Thermostats were an important part of the industrial revolution [10] and today are widely incorporated in heating and air-conditioning systems of homes, automobiles and heavy machinery. Modern thermostats fall into two general categories: metallic and electronic.

2.2.1 Metallic Thermostats

The metallic thermostat has at its heart a bimetallic strip- a thin strip of two metals fused together. The two metals have different coefficients of thermal expansion; i.e. they expand and contract by different amounts as the temperature rises or falls. When a bimetallic strip is heated, it will bend to one side. In thermostat [12], that bending can be used to push a lever or a valve, or to complete an electrical circuit. Many household thermostats use a bimetallic strip.

2.2.2 Electronic Thermostats

The thermostat that is becoming common is the electrical thermostat. In electronics, the resistance of most metals will increase as the temperature does [12,13]. By running an electrical current through a circuit, temperature can be measured by observing the change in the circuit's resistance. This type of thermostat is particularly useful when very precise temperatures must be maintained, such as in scientific laboratories and hospitals. Modern electronics are further combined with thermostats to produce programmable thermostats which are essentially small microcomputers that control the temperature. Such units keep full track of the time and date, they have digital display readout and can be preset to change to certain temperatures.

2.3 Review of Modern Temperature Controllers

Modern temperature controllers are mostly fully automatic. A large number of them are microprocessor-based which makes them more accurate in effecting temperature control. A typical modern day temperature control system is as shown in fig.2.1 [14] below; it relies upon a controller, which accepts a temperature sensor such as a thermocouple, RTD or I.C. sensor as input. It then compares the actual temperature to the desired temperature or setpoint and provides an output to an external control element, such as a fan or heater.

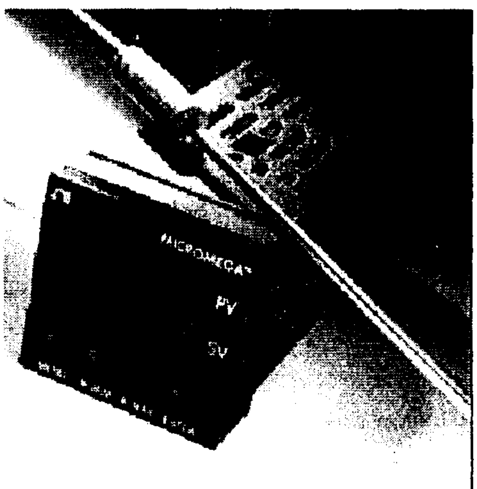

Fig. 2.1 microprocessor-based temperature controller

The controller is one part of the entire control system and the whole system should be analyzed in selecting the proper controller. A number of items should be considered when selecting a controller, these include the following:

1. Type of input sensor and temperature range.
2. Type of output required [electromechanical relay, solid state relay (SSR)].
3. Control algorithm (On/Off, proportional, PID).
4. Number and type of outputs (heat, cool).

Basically, there are three types of controllers; they include the On/Off, proportional and PID controllers. The acronym PID stands for: Proportional with integral and derivative.

2.3.1 On/Off Controllers

An On/Off controller is the simplest form of temperature control device [14]. The output from the device is either On or Off, with no middle state. An On/Off control will switch the output only when the temperature crosses the setpoint. For instance, for heating control, the output is On when the temperature is below the setpoint, and Off when it is above the setpoint.

Since the temperature causes the setpoint to change the out state, the process temperature will be cycling continually, going from below setpoint to above, and back below. In cases where this cycling occurs rapidly, in order to prevent damage to contactor and valves, an on-off differential or "hyteresis", is added to the controller operations [14]. This differential requires that the temperature exceeds setpoint by a certain amount before the out put will turn on or off as the case ~~way~~ may be; i.e. if the setpoint is maybe 20°C, the differential may be set to ± 5°C so that the output is switched on or off only when the sensed temperature reaches 15°C and below or 25°C and above.

The usefulness of on-off differential is that it prevents the output from "chattering" [14](i.e. engaging in fast, continual switching if the temperature's cycling above and below the setpoint is very rapid).

One major disadvantage of on-off control is that it cannot be used where a precise temperature control is needed. The switching characteristics of an On-Off controller when applied for heating control is shown in fig 2.2 [14] below.

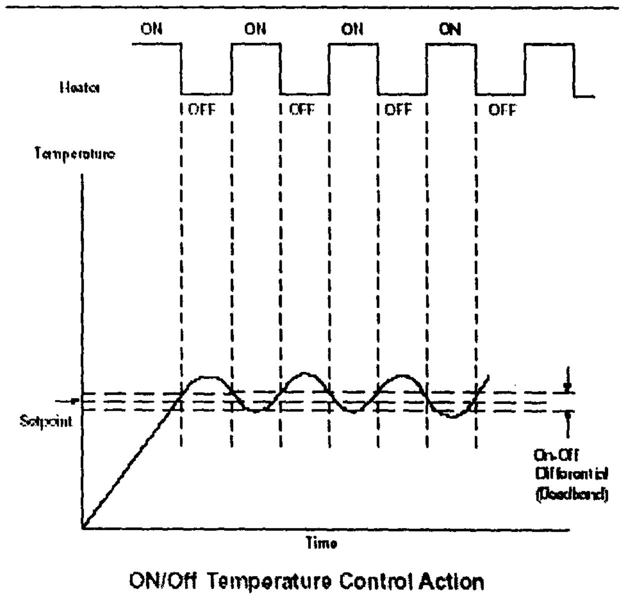

Fig 2.2: on /off temperature control action controls

2.3.2 Proportional Controls

Proportional controls are designed to eliminate the cycling associated with on-off control. A proportional controller decreases the average power being supplied to the output as the temperature approaches setpoint [15].

This has the effect of slowing down the output so that it will not overshoot the setpoint but will approach the set point and maintain a stable temperature. This proportioning action can be accomplished by turning the output on and off for short intervals.

This time proportioning varies the ratio of 'on' time to 'off' time to control the temperature. Fig 2.3 [14] below shows how time proportioning is achieved for a 20 seconds cycle time. The proportioning action occurs within a proportional band around the setpoint temperature. Outside this band, the controller functions as an On/Off unit, with the output either fully On or fully Off. However, within the band, the output is turned On and Off in the ratio of the measurement difference from the setpoint. At the setpoint (midpoint of the proportional band), the output On:Off ratio is 1:1, i.e. the On-time and Off-time are equal. If the temperature is further from the setpoint, the On and Off-times vary in proportion to the temperature difference. In the case of cooling control for instance, if the temperature is above setpoint, the output will be on longer; if the temperature is too low, the output will be Off longer.

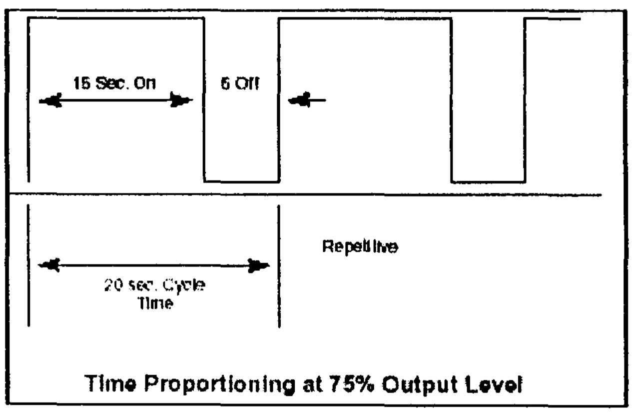

Fig 2.3 illustration of time proportioning at 75% output level

The proportional band is usually expressed as a percent of full scale, or degrees. It may also be referred to as gain, which is the reciprocal of the band. It should be noted that in time proportioning control, full power is applied to the output, but is cycled On and Off [14], so the average time is varied. In most units, the cycle time and/or proportional band are adjustable, so that the controller may better match a particular process. Table 2.1 [14] below is a tabulated illustration of time proportioning for heating control with setpoint of 500°F, cycle time of 20 seconds and proportional band of 80°F(i.e. ±40°F).

One of the advantages of proportional control is its simplicity of operation. It may require an operator to make a small adjustment (may be manual reset) to bring the temperature to setpoint on initial start up, or if the process conditions change significantly.

Table 2.1 proportioning for heating control at 500°F

Time Proportional			
Percent On	On Time Seconds	Off Time Seconds	Temp (°F)
0.0	0.0	20.0	over 540
0.0	0.0	20.0	540.0
12.5	2.5	17.5	530.0
25.0	5.0	15.0	520.0
37.5	7.5	12.5	510.0
50.0	10.0	10.0	500.0
62.5	12.5	7.5	490.0
75.0	15.0	5.0	480.0
87.5	17.5	2.5	470.0
100.0	20.0	0.0	460.0
100.0	20.0	0.0	under 460

2.3.3 PID Controls

This third type of controller provides proportional with integral and derivative control (PID). This controller combines proportional control with two additional adjustments, which help the unit automatically compensate for changes in the system [14,15]. These adjustments, integral and derivative, are expressed in time-based units; they are also referred to by their reciprocals, RESET and RATE respectively [14].

Rate and reset are methods used by controllers to compensate for offsets and shifts in temperature. When using a proportional controller, it is very rare that the heat or cool input to maintain the setpoint temperature will be 50%; the temperature will either increase or decrease from the setpoint, until a stable temperature is obtained. The difference between this stable temperature and the setpoint is called Offset. This Offset can be compensated for manually or automatically. Using manual reset, the user will shift the proportional band so that the process will stabilize at the setpoint temperature. Automatic reset, also known as integral, will integrate the deviation signal with ~~the~~ respect to time and the integral is summed with the deviation signal to shift the proportional band. The output power is thus automatically increased or decreased to bring the process temperature back to setpoint. An illustration of a process with temperature offset is shown in Fig 2.4 [14] below.

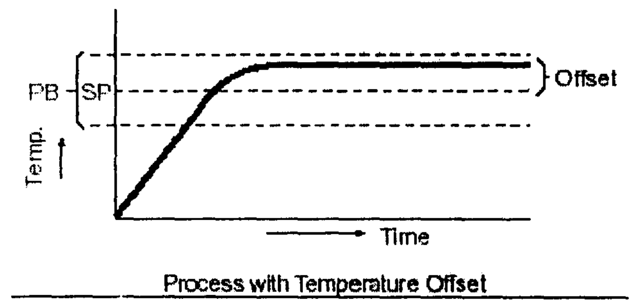

Fig 2.4 process with temperature offset

The rate or derivative function provides the controller with the ability to shift the proportional band to compensate for rapidly changing temperature. The amount of shift is proportional to the rate of temperature change.

PID controllers provide the most accurate and stable control of the three controller types [14]. It is best used in systems which have a relatively small mass, those which react quickly to changes in energy added to the process. It is highly recommended in systems where the load changes often and the controller is expected to compensate automatically due to frequent changes in setpoint, amount of energy available, or the mass to be controlled.

2.3.4 Types of Output for Controllers

The type of output from a controller may take one of several forms. The most common forms are time proportional and analog proportional.

A time proportional output applies power to the load for a percentage of a fixed cycle time. For example, with a 10 second cycle time, if the controller output were set for 60%, the relay would be energized (closed, power applied) for 6 seconds and de-energized(open, no power applied) for 4 seconds. Time proportional outputs are available in three different forms: electromechanical relay, triac or ac solid state relay, or a dc voltage pulse (to drive an external solid state relay).

The electromechanical relay is generally the most economical type, and is usually chosen for ~~on~~ systems with cycle times greater than 10 seconds, and relatively small loads.

An ac solid state relay or dc voltage pulse is chosen for reliability, since they contain no moving parts. They are recommended for processes requiring short cycle times; they need an additional relay, external to the controller, to handle the typical load required by a heating element. These external solid state relays are usually used with an ac control signal for ac solid state relay output controllers, or with a dc control signal for dc voltage pulse output controllers.

An analog proportional output is usually an analog voltage (0 to 5 Vdc) or current (4 to 20 mA). The output level from this output type is also set by the controller; if the output were set at 60%, the output level would be 60% of 5 V, i.e. 3 V. With a 4 to 20 mA output (a 16 mA span), 60% is equal to (0.6 x 16) + 4, i.e. 13.6 mA. These controllers are usually used with proportioning valves or power controllers.

Chapter Three

Design and Implementation

3.1 Basic Building Block

This chapter gives a complete description of the various modules that make up the automatic temperature controller. A block diagram showing the various modules of the system is as shown below:

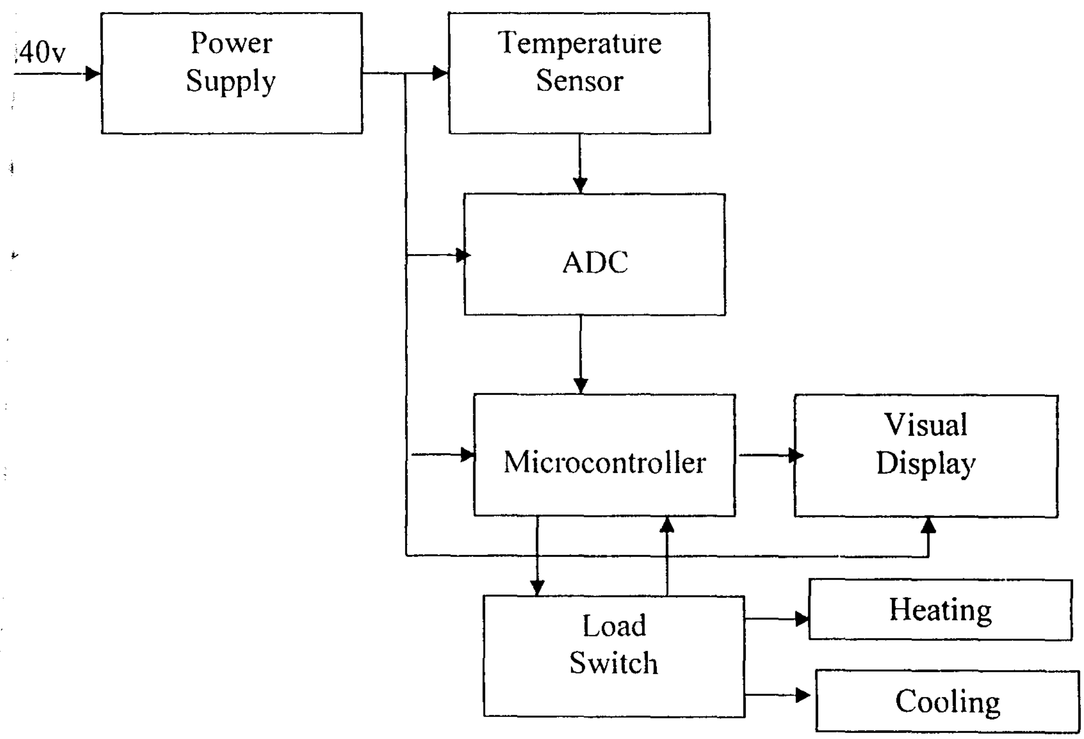

Fig 3.1 Block Diagram of Automatic Temperature Controller

From the block diagram above, it can be seen that the system comprises the following units:

i. Power supply unit

ii. Temperature sensory unit (LM35DZ)

iii. Analog to digital converter (ADC 0804)

iv. Microcontroller unit (AT89C51)

v. Visual display unit (3-digit 7-segment display)

vi. Load switch unit (2 Relays)

3.2 Mode of Operation

The mode of operation of this system is quite simple:

i. The power supply unit which has a regulated DC output, supplies a +5V to the digital circuit comprising the temperature sensor, ADC, microcontroller, visual display unit and the switching transistors for the relays.

ii. The temperature sensor senses the temperature around it and its output is fed into the ADC.

iii. The output of the sensor being an analog signal is converted to its digital equivalent by the ADC and fed into the microcontroller.

iv. The microcontroller sends the value of the sensed temperature to be displayed on the visual display unit. The microcontroller also compares the sensed temperature with the preset value and simulates the appropriate control condition (heating or cooling); i.e. if the sensed temperature exceeds the preset value, then the microcontroller initiates an action to switch on the cooling unit. However, if the reverse is the case, then the microcontroller initiates an action to switch on the heating unit. The respective control units are switched off when the temperature falls between the range of the preset value. The preset value can be adjusted by using the buttons provided on the device; the modes available are low and high temperature limits.

v. In the event of either of the two relays failing, a status feedback signal is transmitted from the load switch to the microcontroller. The microcontroller then sends the error message to be displayed on the display unit either as "ER1" [for Relay1 (heating) failure] or "ER2" [for Relay2 (cooling) failure]. The display unit also displays the preset values.

3.3 Description and Analysis of Components

In this section, the various components that were used in the construction of the device will be theoretically described and analyzed, as well as their interconnections. However, it is of importance to state that the choice of most of the components used for the construction of this device were based on similar-familiar technique.

3.3.1 Power supply unit

This unit comprises a step down transformer (12V,0.5A) which steps mains voltage of 240V down to 12V; full wave bridge rectifier, 2200μF capacitor, voltage regulator (7805) and 1000μF capacitor. The main function of this unit is to convert AC supply to an equivalent DC voltage.

The rectification was realized by connecting the secondary terminal of the transformer to the full-wave bridge rectifier as shown in the figure below:

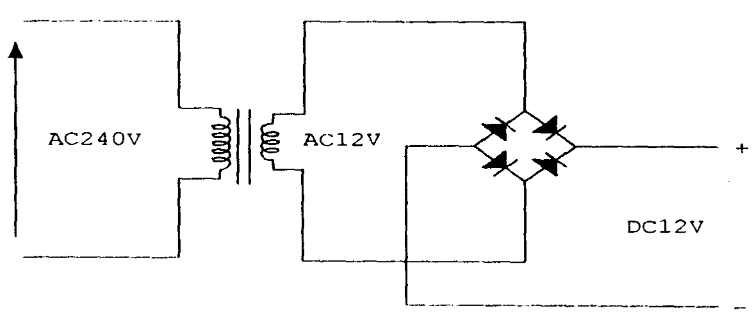

Fig. 3.2 AC-DC Voltage Rectification

The corresponding output waveform [16] of the rectification process is as shown in Fig 3.3 below:

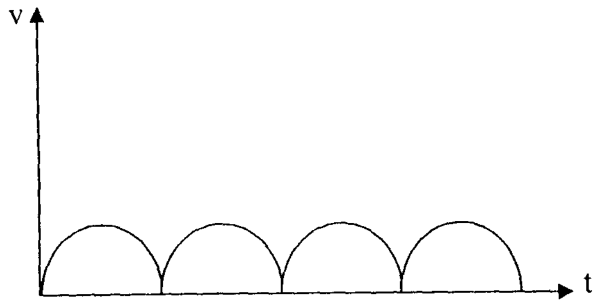

Fig. 3.3 output waveform of full-wave rectifier

The DC output voltage is a pulsating waveform which has peak amplitude expressed as follows:

$V_{peak} = (V_{rms}\sqrt{2}) - 1.4$ - 3·1

Where V_{rms} = 12V; hence, $V_{peak} = (12\sqrt{2}) - 1.4 = 15.57V$

The 2200μF capacitor was used to remove the AC ripples in the DC voltage of the rectifier output, this filtered 12V DC was then fed into the 7805 (5V,1A) voltage regulator which regulated the DC voltage down to +5V.

The +5V was used for powering the digital circuit. However, the 1000μF capacitor was used to stabilize the +5V output of the voltage regulator.

The figure below shows how the regulator and capacitors were connected to the rectifier output.

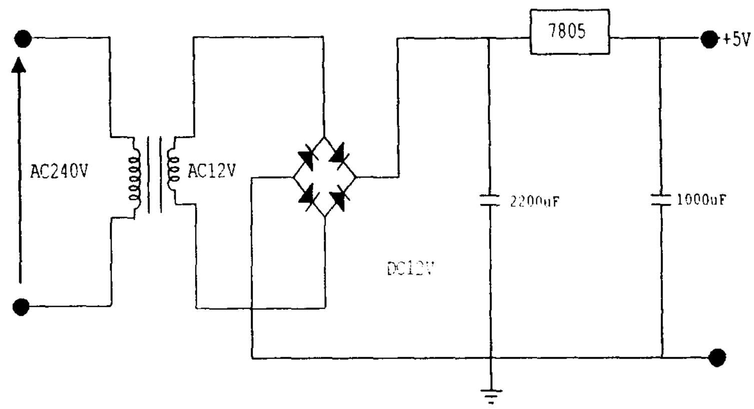

Fig. 3.4 DC Voltage regulation

3.3.2 Temperature Sensor

The temperature sensor used in this system is an IC type, LM35DZ. It can measure temperatures within the range of 0-100°C. The output of the sensor goes up by 10mV for every 0°C raise in temperature [8]. A 10µF capacitor was connected at the output of the sensor in order to stabilize its output. This particular sensor was chosen for its efficiency and reliability.

3.3.3 Analog to Digital Converter (ADC)

The ADC was used to convert the temperature sensor's analog output to its digital equivalent. This was done so that the microcontroller could manipulate the sensor's output.

The ADC used is an 8-bit successive approximation register converter. The device has a maximum clock frequency of 1.46MHz and converts typically in about 100µS [17]. It features a pin-out that makes it suitable for interfacing with processors, PIAs, and converters.

The essential pins of the ADC0804 [17] are as shown below:

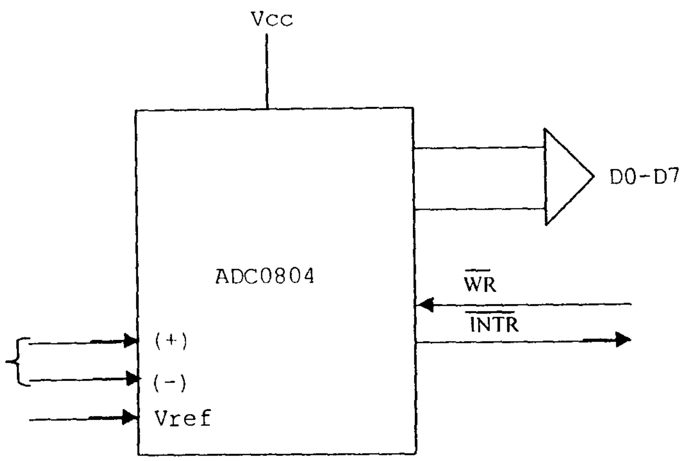

Fig 3.5 simplified schematic of ADC0804

The ADC was interfaced to the microcontroller via ports P1, P2.2 and P2.3 of the microcontroller. Port P1 receives the converted data, P2.2 and P2.3 control the INTR and WR pins of the ADC respectively under software control.

The LM35DZ sensor was connected to the ADC via pin6 (+ input) and a reference voltage (Vref) of about 1.22V was applied to the Vref input of the ADC in order to establish correspondence between the input analog voltage and the digital output equivalent. A one on one correspondence was received; hence, a Vref (Vspan/2) of 1.28V was applied to pin9 of the ADC.

The full span voltage was therefore 2.56V, at which the digital output equivalent is 0FF (255). A typical conversion cycle is initiated as follows:

i. Take WR low

ii. Take WR high

iii. Delay until INTR = 0

iv. Read converted data from ADC

v. Process data

vi. Go to i

3.3.4 Microcontroller Unit

The microcontroller used in this system is an AT89C51 8-bit microcontroller. It has 4KB of on-chip flash memory and 128 bytes of internal RAM [18]. It was run on a clock frequency of 12MHz, yielding an instruction cycle of 1μS. This clock frequency was provided by an external crystal. The microcontroller coordinates system operations such as:

i. Initializing I/O ports.

ii. Controlling ADC

iii. Manipulating converted data

iv. Writing data to display unit

v. Switching load according to outcome of logical operations.

The microcontroller executes a small set of instructions which consist mainly of a mainline block involving other routines to achieve overall system functionality. Typically, the microcontroller configures the system, enables interrupts and goes into a loop consisting of a set of operations such as:

i. Display refresh

ii. Temperature conversion and manipulation

iii. Load switching

It also responds to user inputs via key presses, as interrupts are enabled. By way of pressing the buttons, the high and low limits of the temperature range to be maintained can be adjusted and preset.

The system initializes with a default low limit temperature of 20°C and a high limit temperature of 40°C; hence, adjustments proceed from these two points.

The microcontroller was connected to other system components as shown below:

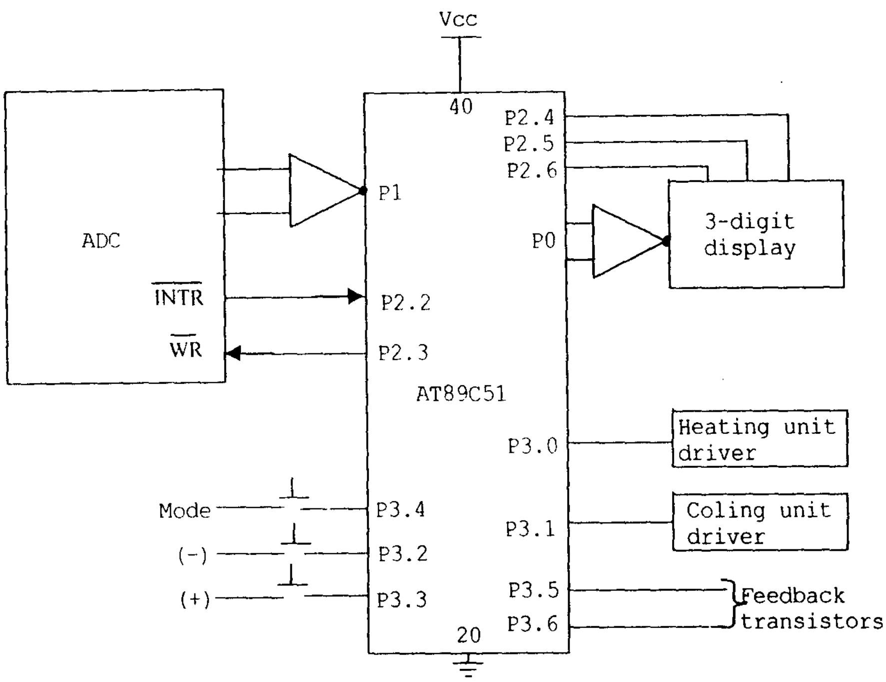

Fig. 3.6 connection of microcontroller to other system components

The microcontroller displays the value of the converted temperature (actual temperature around LM35DZ sensor) on a 3-digit 7-segment display unit. The microcontroller executes the embedded software as a sequential flow, taking jumps and invoking routines as needed.

A flow chart of the basic operations of the system is as shown in Fig 3.7

The converted temperature is displayed using bit patterning on the 3-digit display since a dedicated 7-segment decoder is not used. Bit patterning [19] involves sending the 8-bit pattern of the digits to the segment, after the temperature has been converted to BCD equivalent.

A look-up table in program memory is accessed based on the BCD value. Since a 3-digit display was used for this device, using separate 7-segment connections would have required a minimum of 22 separate I/O pins on the microcontroller. To reduce wiring complexity and also save on I/O pins, display multiplexing was used. Display multiplexing involves switching digits on and off in sequence at a rate greater than the eyes can discern [19], usually above 50Hz.

A typical display multiplex scheme is of the format shown below:

i. Switch all digits off
ii. Set data for digit 1 on common output port
iii. Switch digit 1 on
iv. Delay for persistence
v. Switch digit 1 off
vi. Set data for digit 2 on common output port
vii. Repeat steps ii to vi until all digits have been addressed
viii. Go to i

The refresh rate was fixed at 60Hz in software by generating a time delay using special function registers.

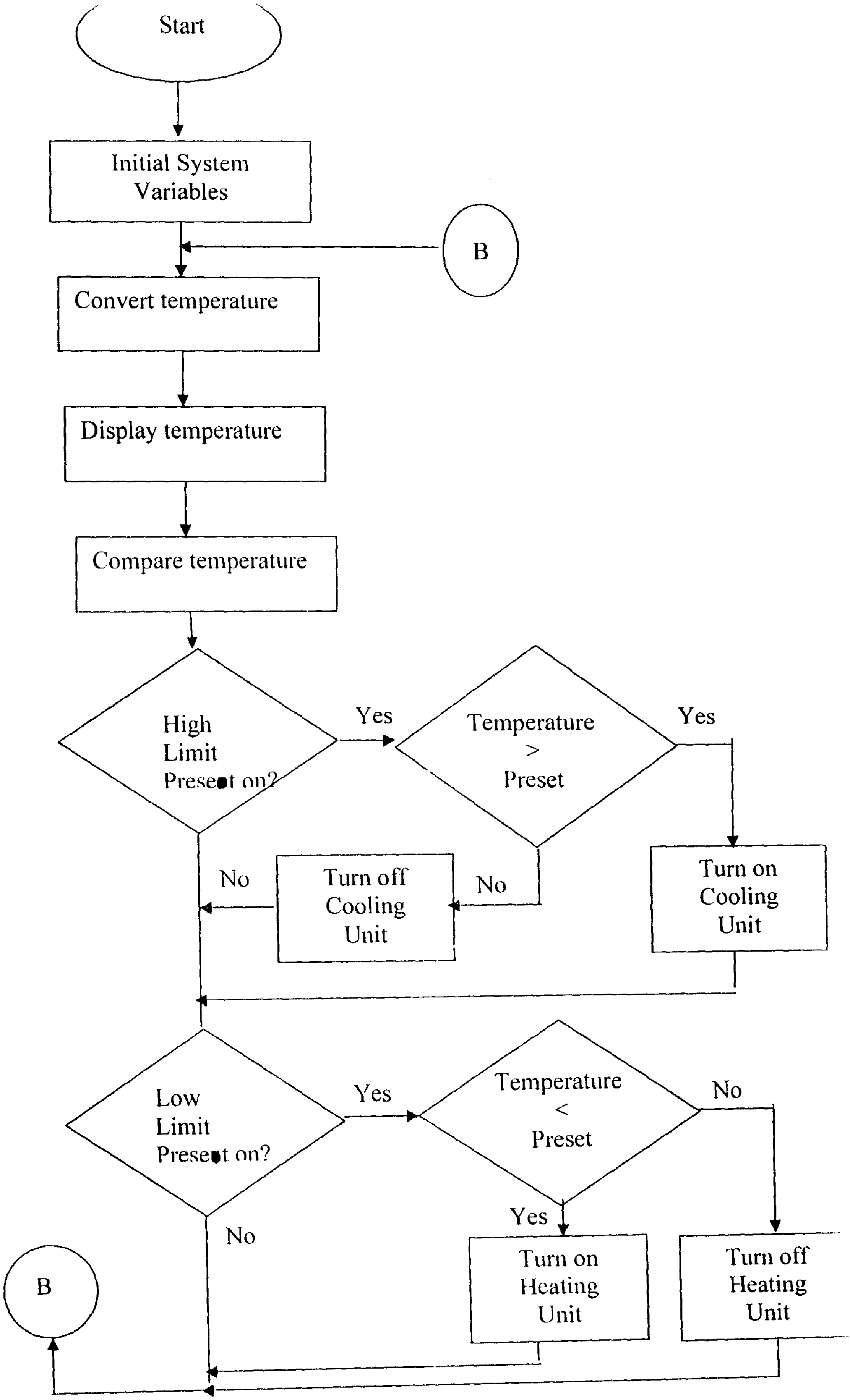

Fig. 3.7 flow chart of system operation

3.3.5 Visual Display Unit

The 3-digit 7-segment display unit used in this project is illustrated with its connections as shown in Fig 3.8.

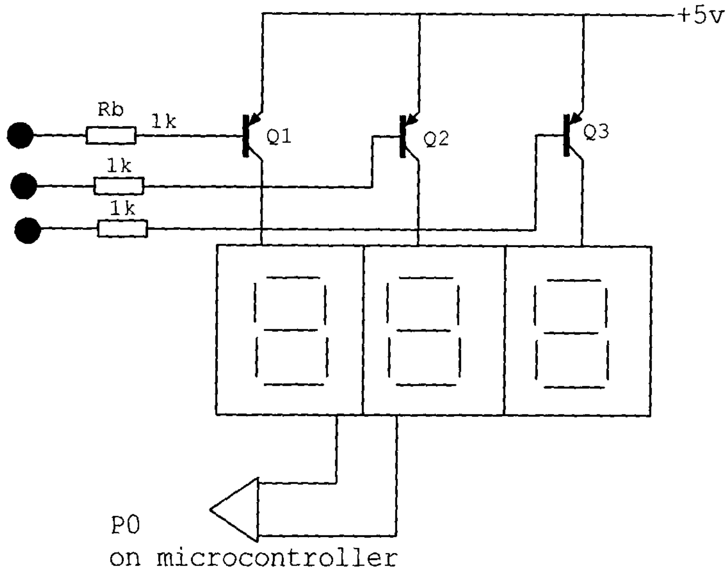

Fig. 3.8 3-digit 7-segment display unit

Each digit has an associated PNP digit driver that switches pulsed 5V into driven digit. The expression for calculating the base resistance is shown below:

$$R_B = (V_{CC} - V_{BE} - V_{0L}) / I_{digit} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where $V_{CC} = 5V$, $V_{BE} = 0.7V$, V_{0L} = logic 0 output voltage level on the microcontroller, and I_{digit} = digit current.

When the displays are multiplexed, the current supplied to each segment is made equal to the number of digits multiplied by the segment current[19]; for example, if the nominal segment current is 10mA, for the three digits being addressed, the segment current is increased to

)mA×3=30mA. Hence, the total segment current for the three digits being addressed will be

.0mA, i.e. 3×7×10mA.

alculation of R_B:

he nominal segment current for the 7-segment display used was 30mA.

ence, for the 3-digit display, the required segment current was: 3×30mA=90mA

or 7-segment activation,

$_C = 7\times 90\text{mA} = 630\text{mA}$

But $I_C = \beta I_B$, where β= gain of PNP transistor................................3.3

} is typically 200.

Hence, $I_B = \frac{I_C}{\beta} = \frac{0.63}{200} = 0.00315$

Therefore, $I_B = 3.15mA$

Hence, from eq.3.2, the value of R_B can be gotten as follows:

$R_B = \frac{V_{CC} - V_{BE} - V_{OL}}{I_B}$ where $V_{CC} = 5V$, $V_{BE} = 0.7V$, $V_{OL} = 0.02$

$R_B = \frac{5 - 0.7 - 0.02}{3.15 \times 10^{-3}} = 1.4K\Omega \approx 1K\Omega$

Thus, to provide the peak digit current of 0.63A, base resistances of 1KΩ were used for the transistors. The overall circuit diagram of the system is as shown in Fig 3.9.

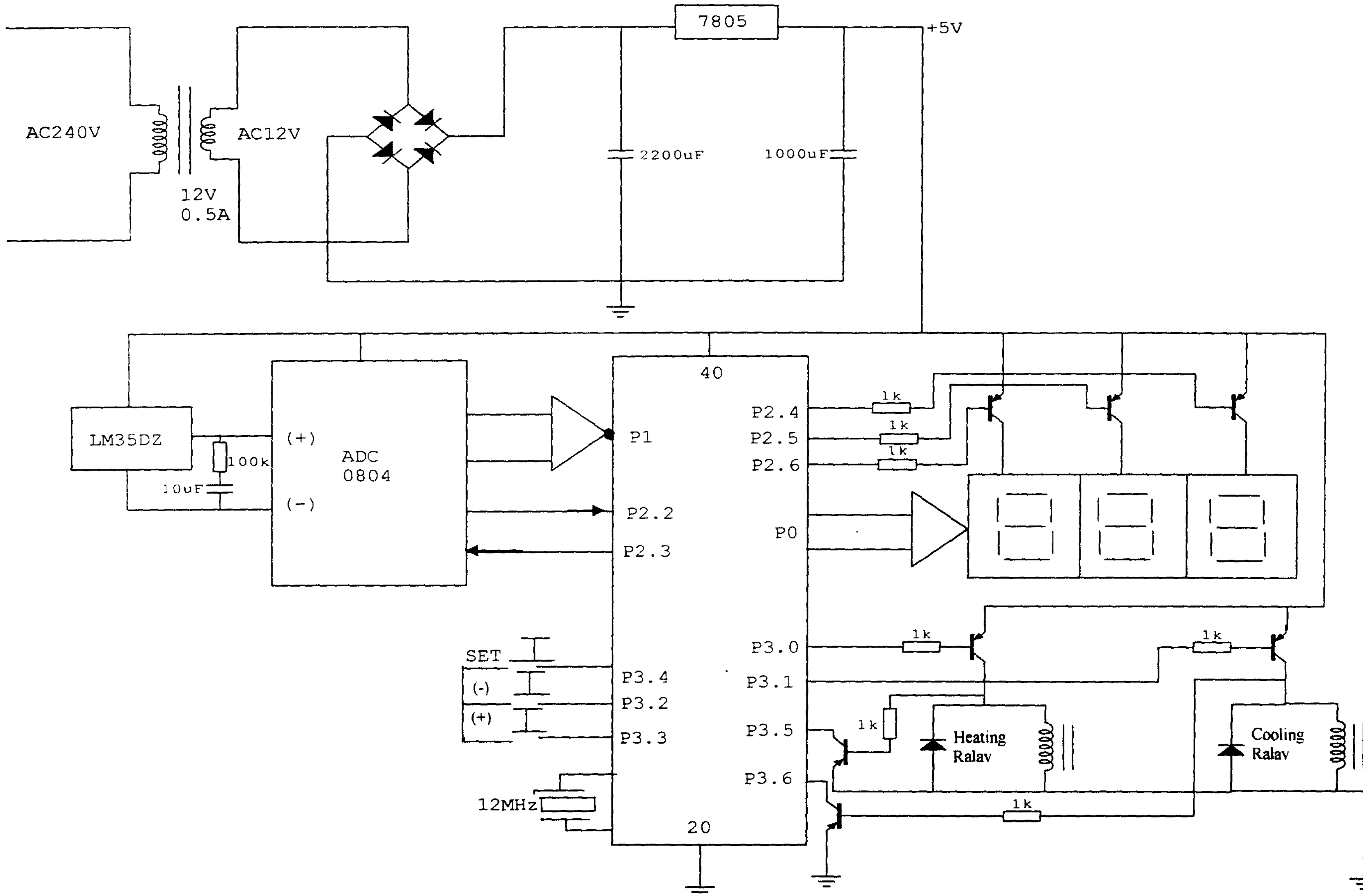

Fig 2.0 Circuit Diagram of Automatic Temperature Controller

Chapter Four

Tests, Results and Discussion

4.1 Tests

In order to ensure reliability of the device, a number of tests were carried out before the final packaging of the device. The tests carried out include the following:

1. Testing of power supply unit: An AC supply of 240V was fed to the primary of the step-down transformer, the output of the secondary was then measured using a digital multimeter and found to be 12V.
2. Confirmation of +5V voltage regulation: The output of the 7805 voltage regulator was measured using a digital multimeter and found to be +5V, thus making it appropriate for the digital circuit.
3. Testing of temperature sensor and ADC operation: The operation of the temperature sensor and the ADC were tested only after coupling all the units together. The seven segment display unit was able to display the numerical value of the temperature around the sensor. Hence, confirming the ability of the ADC to properly carry out analog to digital conversion.
4. Testing of microcontroller operation: In order to test the operation of the microcontroller, the following steps were taken:
    a) The temperature sensor was inserted into an enclosed box and the temperature inside the box was displayed as 32°C.
    b) Two different light bulbs (red and green) were connected to the outputs of the relays. The red bulb was connected to the relay that controls the

heating unit while the green bulb was connected to the relay that controls the cooling unit.

c) In order to test the microcontroller's output to the relays, the low temperature limit was set to 29°C and the high temperature limit was set to 31°C. The result of this was that the microcontroller had to activate the cooling relay so as to bring down the temperature of the enclosed box from 32°C to between 29-31°C, as such the green bulb was lit indicating that cooling was taking place. The box was then opened a bit to allow air flow into it, as soon as the temperature dropped below 31°C, the green bulb went off. The same procedure was followed in testing the microcontroller's output to the heating unit relay, only that in this case, the temperature limits were set to 33-35°C for low and high limits respectively. An artificial heat was provided in the box and the red bulb went on and off respectively as expected. This action of the bulbs going on and off in each case, confirmed that the microcontroller was in good and efficient operational condition. Hence, confirming the ability of the device to effectively control temperature within a user specified range.

4.2 Results and Discussion

The results obtained from the testing of the microcontroller are as shown in table 4.1

Table 4.1 Testing of microcontroller operation

Sensed Temperature in box (°C)	Preset Temperature (°C)	Relay1 (heating) Status	Relay2 (cooling) Status	Activated Control Action
32	29-31	OFF	ON	Cooling
31	29-31	OFF	OFF	Nil
30	29-31	OFF	OFF	Nil
29	29-31	OFF	OFF	Nil
32	33-35	ON	OFF	Heating
33	33-35	OFF	OFF	Nil
34	33-35	OFF	OFF	Nil
35	33-35	OFF	OFF	Nil

Again, from the table above, it can be seen clearly that the device will activate the cooling unit whenever the sensed temperature exceeds the preset value and will likewise activate the heating unit whenever the sensed temperature goes below the preset value.

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

This project has been successfully carried out. Components used for the construction of the device were carefully chosen with great emphasis on their availability and reliability. The design was reviewed over a number of times until the present one was arrived at. Every section of the device has been duly tested to ascertain reliability.

From the results obtained from testing, it can be seen that the device is able to give the desired operational output. However, the success of this project was not achieved without some challenges, the greatest of which was the programming of the microcontroller.

5.2 Recommendations

A temporary casing was provided for the device, to this end, there would be need to improve on the casing. Other improvements could be made as well.

I would like to make the following recommendations for future improvement of the device:

i. A proper metallic casing with adequate ventilation could be provided for the device.

ii. Provision could be made for an audible alarm in addition to the error messages displayed in the event of either of the relays failing.

iii. The number of temperature sensors could be increased so that the device could operate more effectively when used over larger surfaces or in more complex processes

References

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