DESIGN AND CONSTRUCTION OF A DIGITALLY PROGRAMMABLE THERMOSTAT

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DEDICATION

I here by dedicate this project to Almighty God who had been a very present help in my time of need, all through my stay in this institution.

I would also love to dedicate this work to my Parents Mr. and Mrs. P. K. Katugwa, Sisters, Brothers, Cousins, Uncles, Aunties and Friends who have contributed to my progress. May the Almighty reward them.

ATTESTATION

I KATUGWA SOKOYEBOM. ALBERT 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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ACKNOWLEDGEMENT

My most profound gratitude goes to God for his innumerable assistance in making this project a success. Also, I would love to specially thank my Parents Mr. and Mrs. P. K. Katuwa, My Uncle and his Wife Chief and Dcns. James A. M. Katugwa, My Aunt and her Husband Mr. and Mrs. Agada for their moral and financial encouragement.

I cannot forget my supervisor Engr. E. M. Eronu who has not only been a guide, but also a mentor. I also appreciate the efforts of Mr. E. M Katugwa. May God establish and make all of them reference points.

ABSTRACT

The design and construction of a Digitally Programmable Thermostat is aimed at providing thermostatic control to various temperature related devices or system. However, in this project the application is limited to a heating element. The project was constructed as a model. (i.e. Its application could be expanded). Heat energy is converted into an equivalent Electrical energy via a transducer (sensor) called Lm 35. The resulting analogue signal is converted to digital signals via an Analogue-to-digital Converter. The digital signal, which are often in binary form , are converted to decimal form and displayed on a seven segment dual display. The project consists of a preset counter which enables the user to set the device at a desired temperature. The comparator unit compares temperature and sends logical output to output switching unit. Hence thermostatic control is achieved.

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CHAPTER ONE

INTRODUCTION

Most heating and cooling system operate on the principle of temperature regulation. This is achieved by the use of a temperature regulating device present in the system. A typical example of this device is a thermostat.

A thermostat is a device for maintaining the temperature of a system within a defined range by controlling, directly or indirectly, the flow of heat energy into or out of the system [8.] There are various types of thermostat. Each type depends on the system it has been designed for. For example, Bimetallic - strip, wax – pellet thermostat mainly for Mechanical systems, line voltage, simple two – wire thermostat, digital thermostat for Electrical system. [8.]

A digital programmable thermostat is one which could be adopted to maintain and regulate any system via an electronic circuit that operates digitally. The design concept adopt a means of comparing a preset fixed value [Temperature Ready] with a varying one from a sensor, once the preset temperature is attained, a switch is activated to trigger on or off the device it has been connected with. For this project a heating element is adapted.

1.1OBJECTIVES

The aim of this project is to design and construct a Digitally Programmable Thermostat, which could be used for regulating temperature in an incubator, oven, a Refrigerator, Air – conditioner, etc. The application of this device could be expanded. Basically, in this project, the application is limited to a heating element/device. Which could be part of an oven or an incubator. The project is small, flexible and portable as a model.

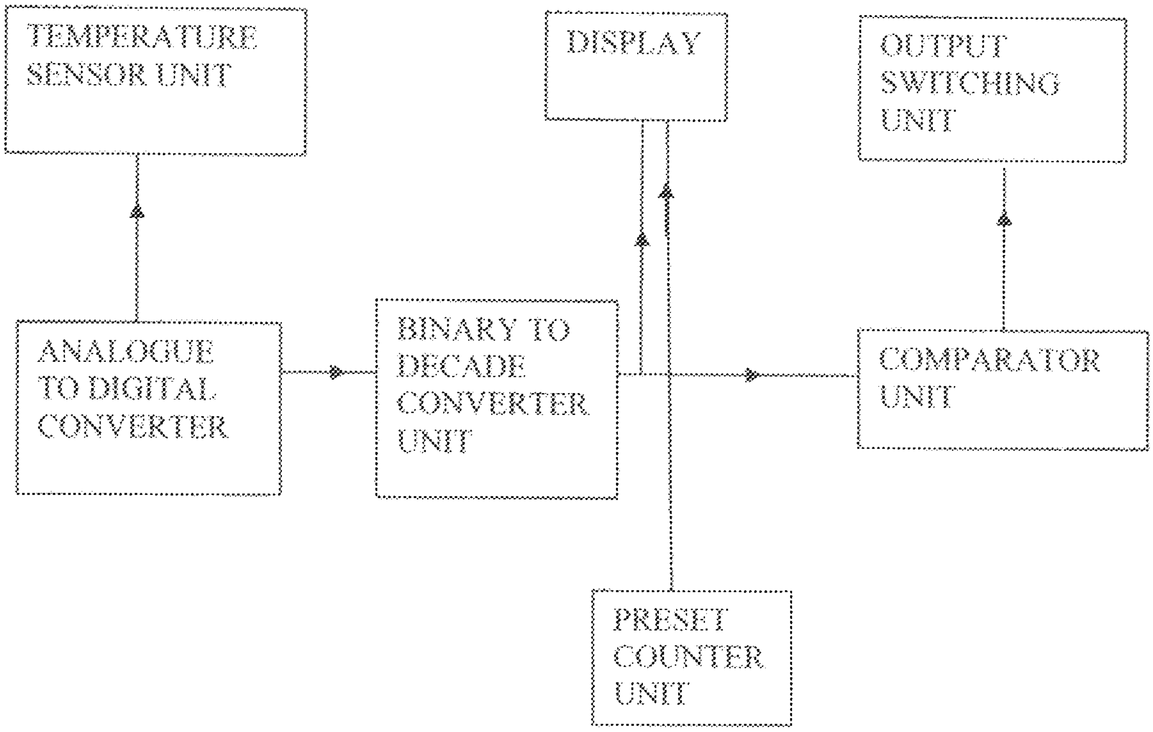

Fig. 1.1 Block Diagram

1.2 METHODOLOGY

The circuit diagram for this project was test runed via simulation process. The materials and tools used were purchased subsequently. Construction of the project commenced immediately.

From the block diagram, the input device is a temperature sensor,. The LM35 is a linear precision temperature sensor.

It is designed with an Analogue output that defines the temperature at which it is subjected. This output is connected to an Analogue – to – Digital Converter. This unit converts the signal from the sensor into corresponding base two or 8 – bit digital format. Subsequently, a binary to decade converter units is required to allow the information to be displayed on a 7 – segment Dual – Display panel. The temperature display unit is designed to relay a visual temperature reading. The programmable ability of the thermostat is achieved by comparing an input temperature with that being read by the sensor. Consequently. The output heating process can be controlled through the temperature information feedback from the sensor at the heating corners.

Moreover, from the block diagram, the comparator unit receives digital signal from BCD (Binary to decade counters) on both the preset temperature and the temperature being sensed by the sensor.

The result form unit determines the state of the heating element (i.e. whether it is off or on). Whenever the comparator output is '0', the heating element is enabled. But when it is a ` 1`, it indicates that the reading and preset temperature are the same. Hence, the heating process is stopped.

This process is controlled by an output switching unit. This unit consists of an SR-Latch – Relay of 12V. The latch helps to hold a particular result of the comparing process, than it switches the relay circuit on or off along side the result of the comparator. The relay circuit is in series with the heating elements so it acts as a switch.

CHAPTER 2

LITERATURE REVIEW

Temperature can be simply defined as the physical property of a system which underlies the common notions of "hot" and "cold"; the material with the higher temperature is said to be hotter. Physically, temperature is a measure of the random agitation of matter and ambient photons, under the effect of thermal fluctuations. It is a fundamental parameter in thermodynamics and it is conjugate to entropy.

Generally, thermostats do two things as related to temperature:

(1) Compare the thermometer reading of a particular surrounding to the "ideal" thermostat temperature required or selected temperature

(2) Give start-and-stop commands to the heating or cooling system in order to achieve a specific temperature range that is as close to the selected or preset thermostat setting as possible. By doing those two things, a thermostat plays the role temperature regulation. [8.]

The project involves a programmable thermostat type .The big advantage of programmable thermostats is that the temperature range can be adjusted or programmed into many desired temperatures within a particular range for different times of the day or night, or for different days of the week. They are often made in digital form. The main parts of such typical device are temperature measuring instrument (a thermometer) and a heating element under a control mechanism.

The history of thermometer is related to the subject. This is because thermometer is a temperature measuring device which serves as an input or a feed-back of any programmable thermostat.

Temperature measurement using modern scientific thermometers and temperature scales goes back at least as far as the early 18th century, when Gabriel Fahrenheit adapted a thermometer (switching to mercury) and a scale both developed by Ole Christensen Røemer. Fahrenheit's scale is still in use, alongside the Celsius scale and the Kelvin scale. Many methods have been developed for measuring temperature. Most of these rely on measuring some physical property of a working material that varies with temperature. One of the most common devices for measuring temperature is the glass thermometer. This consists of a glass tube filled with mercury or some other liquid, which acts as the working fluid. Temperature increases, cause the fluid to expand, so the temperature can be determined by measuring the volume of the fluid. Such thermometers are usually calibrated, so that one can read the temperature, simply by observing the level of the fluid in the thermometer. This instrument was invented years after man developed interest in temperature measurement.

The first thermometers were called thermoscopes and while several inventors invented a version of the thermoscope at the same time, Italian inventor Santorio Santorio was the first inventor to put a numerical scale on the instrument. Galileo Galilei invented a rudimentary water thermometer in 1593 which, for the first time, allowed temperature variations to be measured. In 1714, Gabriel Fahrenheit invented the first mercury thermometer, the modern thermometer. Another type of thermometer that is not really used much in practice, but is important from a theoretical standpoint is the gas thermometer. Most modern thermometer are quite digital in operation .They provide accurate result through the application of semiconductor technology .The most evident advantages of such instrument are compatibility and economy. [3], [8]

2.1 THEORETICAL BACKGROUND

A typical thermostat is any device used to maintain a desired temperature in a system like refrigerator, air-conditioner, cold room, oven and iron and in a number of devices. Old, but still in use, thermostats work on the principle of thermal expansion of solid materials. A good example is the bimetallic thermostat.

A bimetallic thermostat device consists of a strip of two different metals having different coefficients of linear expansion. The bimetallic strip works as an electric contact breaker in an electric heating circuit. The circuit is broken when the desired temperature is reached. Due to difference in the coefficients of linear expansion of two metals, the bimetallic strip bends in the form of a downward curve and the circuit is broken. The metallic strip is in contact with a screw when it becomes hot, bends downward and electric conduction to the heating part or contact is broken. Thus the current stops flowing through the heating coil. When the temperature falls, the strip contracts and the contact is restored .At this moment, electricity flows to the heating element which again raises the temperature towards the edge of the involved temperature range before the contact is again broken. The operation turns into a circle. The temperature of the leading system is merely regulated within an acceptable narrow range through the periodic switching on and off of the involved heating medium. The device is merely more mechanical in operation.

Modern thermostats, especially for air conditioners and ovens, are often incorporated with digital control for temperature regulation. They are often referred to as "Programmable thermostat". The preset temperature is digitally adjustable within a specific range the involved temperatures are digitally displayed on either LED or LCD displays. Advanced versions feature automatic temperature regulation with time. Such function is evident in new domestic air conditioner designs.

As earlier defined, the project involves a simple programmable thermostat. It is merely designed to regulate temperature within 0-100 degree Celsius range. The range is determined by the involved temperature sensor. Temperature sensors are important input and feedback devices for any electronic programmable thermostat.

2.1.1 Temperature measuring techniques for programmable thermostat

Of all digital thermometers applicable for digital programmable thermostat, thermocouple thermometers reach and display the final temperature the fastest - within 2 to 5 seconds. The temperature is indicated on a digital display. A thermocouple measures temperature at the junction of two fine wires located in the tip of the probe. Thermocouples used in scientific laboratories have very thin probes, similar to hypodermic needles, while others may have a thickness of 1/16 of an inch. Thermocouple thermometers respond so rapidly to temperature variations. The temperature range is indeed high. But, the technology is expensive. Thermistor-style thermometers use a resistor (a ceramic semiconductor bonded in the tip with temperature-sensitive epoxy) to measure temperature. The thickness of most probes is approximately 1/ 8 of an inch and takes roughly 10 seconds to register the temperature. Simple thermistor-based set-point thermostat or controller applications can be implemented with very few components – just the thermistor, a comparator, and a few resistors will do the job.

Silicon Temperature Sensors and Integrated circuit temperature sensors differ significantly from the other types in a couple of important ways. The first is operating temperature range. A temperature sensor IC can operate over the nominal IC temperature range of -55°C to +150°C. Some devices go beyond this range, while others, because of package or cost constraints, operate over a narrower range. The second major difference is functionality. A silicon temperature sensor is an integrated circuit, and can therefore include extensive signal processing circuitry within the same package as the sensor. There is no need to design cold-junction compensation or linearization circuits for temperature sensor ICs, and unless you have extremely specialized system requirements, there is no need to design comparator or ADC circuits to convert their analog outputs to logic levels or digital codes. Those functions are already built into several commercial ICs.

Simpler silicon temperature sensors, such as LM35and LM34, hold temperature-voltage relationship. Their outputs are quite calibrated into the conventional temperature scale. Therefore, they are easily incorporated into temperature related circuits. [6.]

The project is all about a simple silicon temperature sensor, LM35. It is well calibrated into the Celsius temperature scale. It possesses 1 degree Celsius to 10mV relationship.

CHAPTER THREE

DESIGN ANALYSIS AND IMPLEMENTATION

The project involves seven major parts: They are given below:

i. Power unit

ii. Temperature sensor unit

iii. Analogue – to – Digital Converter (ADC) unit

iv. Binary to Decade Converter Unit

v. Display Unit

vi. Preset control Unit

vii. Comparator unit

viii. Output switching Unit

3.1 Power unit

The power unit involves the common or weel know transformer - bridge rectifier circuit. The unit supplies 5v and 12v to the complete circuit. A 24v A.C output transformer is required to step-down the regulatory high voltage A.C mains down to 24V.A.C. The voltage is connected to a bridge rectifier which involves the groups of diodes. The result is a rectified or D.C. output at 24v. Thus the voltage is attributed to considerable ripple effect or small A.C component. The unwanted effect is reduced or removed through the use of a filter (or a latch) parallel to the output, the regulating voltage is then passed on to both 7812 and 7805 voltage regulators which produce regulated 12v and 5v respectively.5v from the regulating 24V is intended for all logic device while 12v serves the output (relay switching)

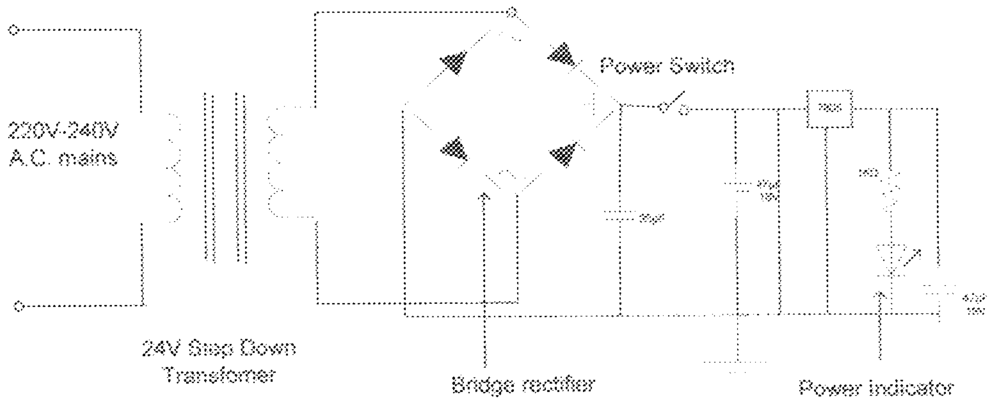

Fig 3.1 Power unit circuit [9]

Moreover, a 22v out 35v capacitor is used for the output filtration – The value can be within 1000 – 470v out. The 35v rating allows protection for the capacitor beyond the normal operating voltage.

A power switch is incorporated into the circuit for opening and closing inverted flow. A resistor LED circuit is designed to indicate power supply in the circuit. The circuit is supplied with 5v. 2.7v is expected across the LED. With a current of 3mA.

$R_p = (5\text{-}2.7)\ V/(3\times10^{-3})$ 3.1

$= 766.6\Omega$

1000Ω is used in the circuit. The resistor provides reasonable LED intensity to the circuit.

3.2 Temperature sensor unit

The heat of the temperature sensor unit is an Lm35 precision or linear silicon temperature sensor. It is designed with three terminals. Two are for power supply. While, the other one produces a particular voltage in accordance with the device`s subjected output works with a temperature-voltage relationship of 1C -10mV. That is, a temperature of say 30°C is corresponding to 30x10=300mV at the sensor's output. In this way, temperature is converted into electrical or analogue signal. The temperature sensor has a temperature range of 0 - 100° with 1°C error.

This device is quite suitable for the input if the device. This is simply based on level of output linearity. The device is supplied with 5V and its output is connected to the Analogue to Digital converter (ADC) unit.

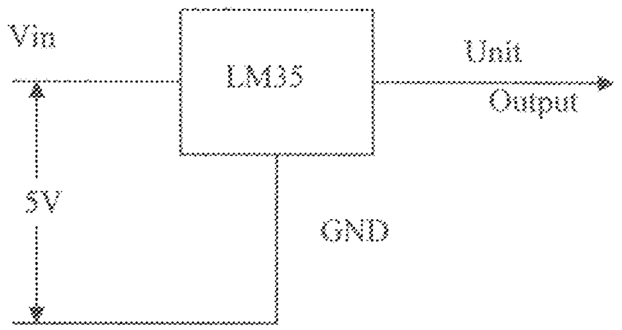

Fig. 3.2 The structural diagram of the LM35

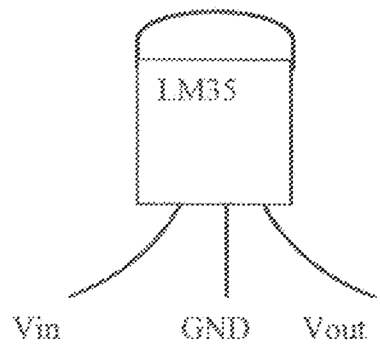

Fig. 3.3 The pin layout of the lm35

3.3 The Analogue- to- digital converter (ADC) unit.

The Analogue – to – digital converter (ADC) unit comprises the ADC 0804 integrated circuit. It is an 8-bit type ADC. That is it involves the recognition of input analogue signals through 256 codes. The integrated circuit is 10 pins dip. The ADC is incorporated into the circuit to convert the voltage level from the temperature sensor into digital codes for better recognition.

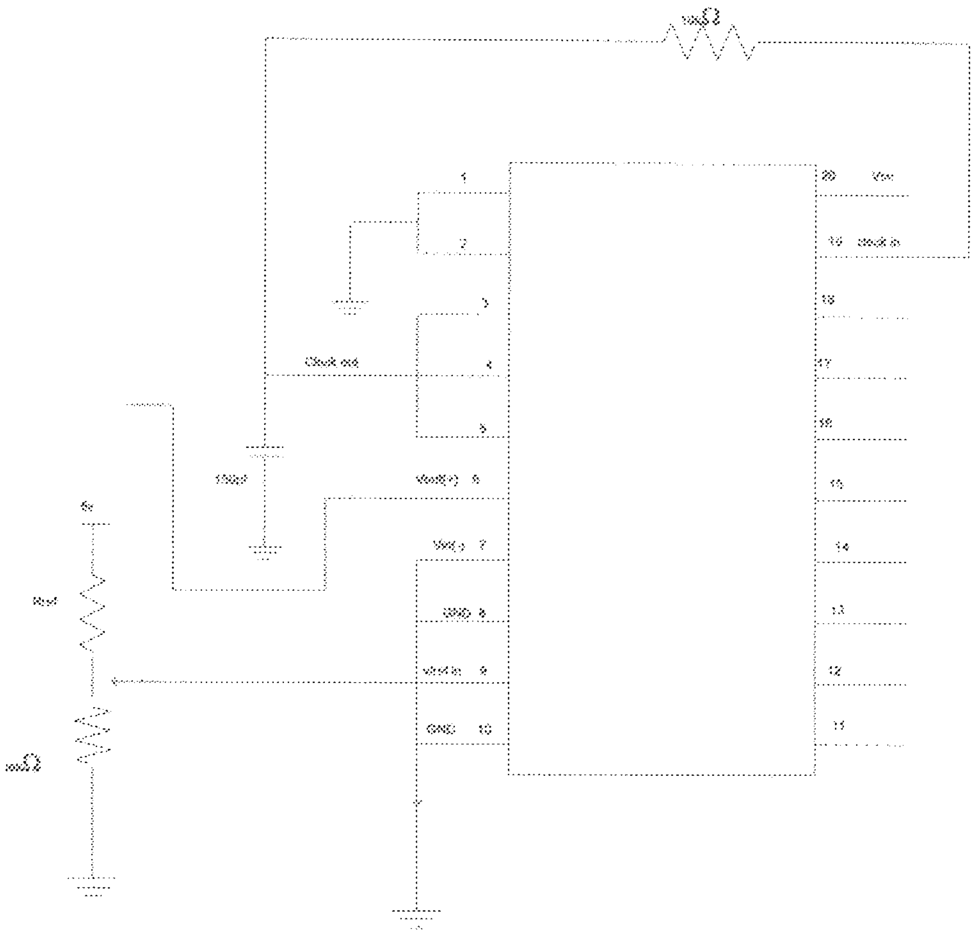

Fig. 3.4 The Analogue- to- Digital Converter Unit.

The circuit of the ADC unit is specified by the manufacturer's data sheet. [10.] Pins 4 and 19 deal with the operating speed or frequency of the integrated circuit.

The connection between these terminals involves a capacitor (150pf) and resistor (10KΩ). The two components are related with a frequency formula that is given below.

F = 1/RC 3.2

R = 10KΩ, C = 150pf

F = 1/ (10×10^3 100x 10^{-12})

= 666,666.7Hz. Or 666.7kΩ

T = 1/f 3.3

= 1/666.7 kHz = 1.54 Sec.

The ADC device operates with a speed if 666.7kHz and corresponding period of 1.54s

This signal is used for coordinating the entire operation of the circuit.

Moreover, the involved temperature range is 0 - 100°C. That is, based on the temperature – voltage relationship of the sensor, a voltage of 0 – 1000mv is produced within the temperature range.

The device manufacturer's datasheet stated that the reference voltage at pin 9 must be half the expected full voltage range into the input of the device. The Normal sensitivity of the expected of the ADC is given below:-

Expected full voltage/255 ....3.4

= 5/255 = 19.61mv. (The reference is 2.5V)

So as to make the ADC work in accordance with the temperature sensor, with a sensivity of 10mV. The expected full voltage must be manipulated.

So that, 10mv x 255 = expected full voltage

Expected full voltage = 2.55v. The corresponding reference voltage for the ADC current with the particular temperature sensor is given below: -

Expected full voltage = 2.55/2 = 1.275v.

The adjustment is done with a 10kΩ monitor and R_{ref}. For easily adjustment of such low voltage, a voltage of like 2v is required across the 10KΩ variable sensor. That is, 3V to required across R_{ref}

The current in the sensor connected resistors is given below,

$I_{ref} = (5/10+ R_{ref}) \times 10$ 3.5

$(10 + R_{ref})2 = 50$

$20 + R_{ref} = 50$

$R_{ref} = R_{ref}$

With these settings on the ADC circuit, the analogue signal from the temperature ssensor is converted into 8 – bit code in binary from. A temperature of say 30°C corresponds to a voltage of 300 mV at the output of the ADC. The ADC simply converts the input temperature into corresponding binary number. The value of the temperature and weight of the binary output from the ADC are one and the same.

3.4 Binary- to- Decade converter unit

The binary to decade converter is designed to covert the binary output of the ADC into a visible format which is normally in decade or base 10. The leading subject is system or unit compatibility.

The main component in this unit is the 40103B. It is a jammable down 8 – bit counter with a zero detector output. This is used for sampling a particular 8 bit input. In fact, the eight jam input of the device is connected to the 8-bit input of ADC 0804.

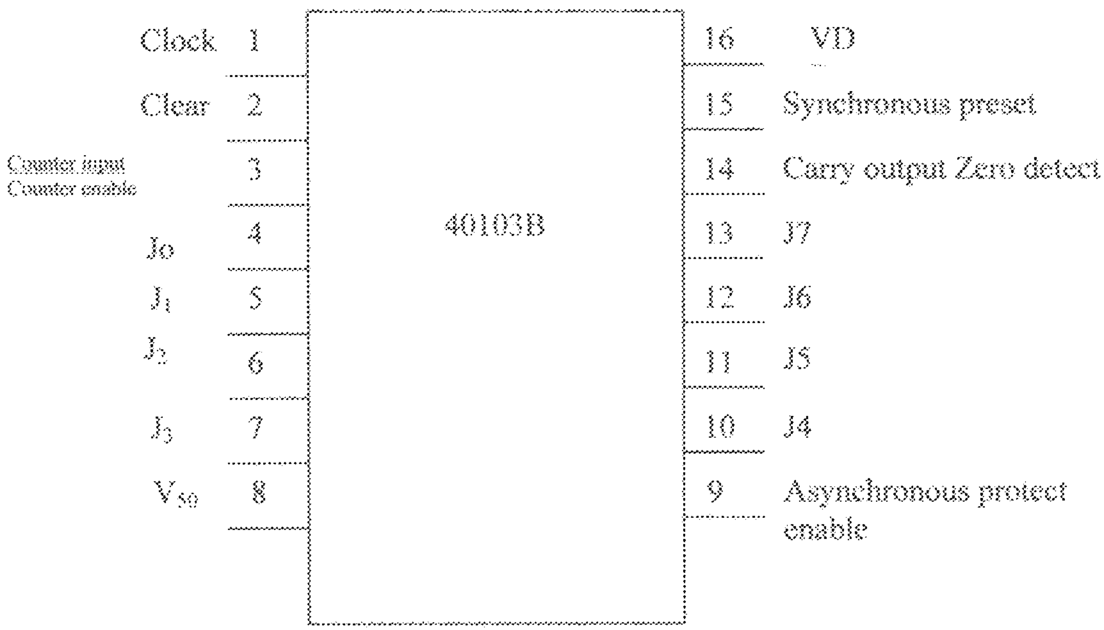

Fig. 3.5 Pin assignment of the 40103B

The 40103B is a monolithic integrated circuit which consists of an 8 – stage synchronous down counter with a single output which is active when configured as a single 8 – bit binary counter. All control inputs and the CARRY – OUT/ZERO – DETECT Output are active – low logic. In normal operation, the counter is decremented by one count to each positive transition of the clock. Counting is inhibited when the carry – in/counter enable (CI/CE) input is high. The carry – out/zero detect (CO/ZO) output gives low when the count reaches zero. This occurs if the CI/CE input is low for a full clock period.[11]

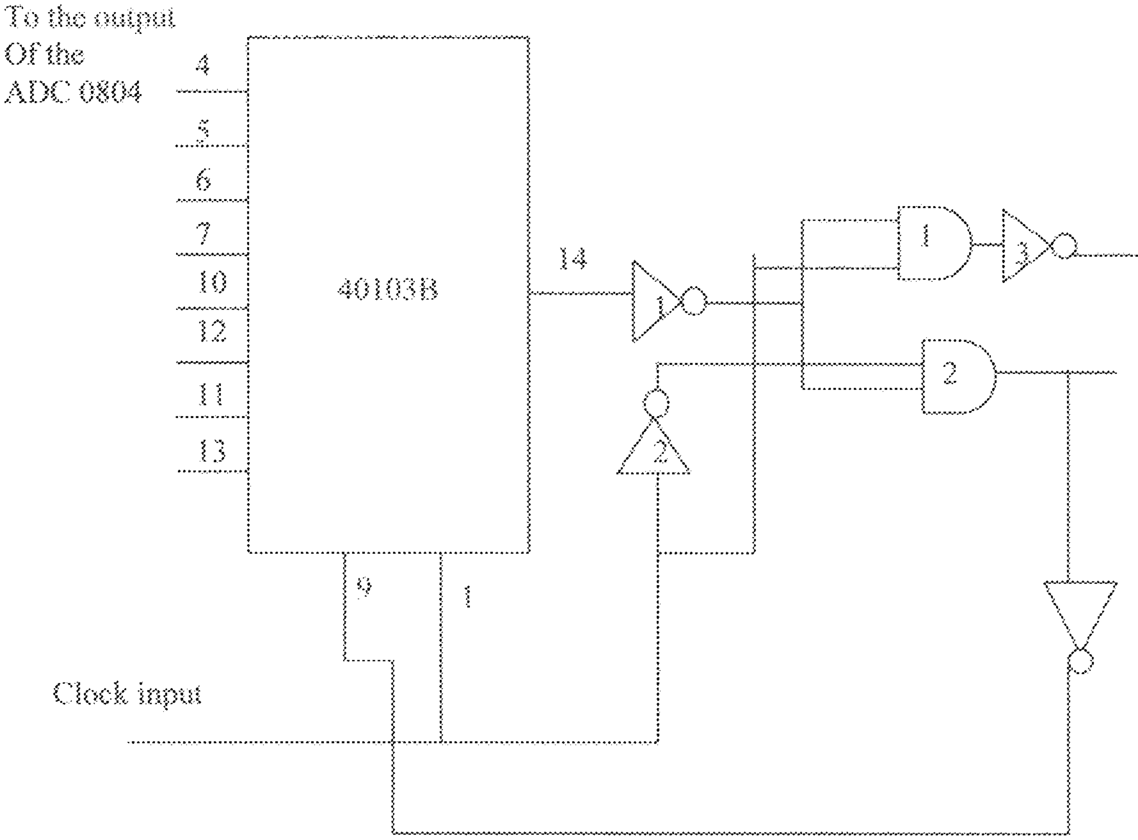

Fig.3.6 Binary-to-Decade Counter Unit [11]

The device works along side a small circuit consisting of 4 NOT and 2 input AND gate. The 40103B provides two control signals for displaying of corresponding digit on 7 segment display panel. The signals control three up-counters and 7 segment display decoders.

The main operation of the 40103B is to jam and count down the 8 –bit output from ADC, at a high speed of conversion. The zero output of the 40103B is hard for achieving latch reset operation on the display decoders and up BCD counter, for necessary temperature display. Terminals A and B are used for resetting and latching application of high speed. The 2 input AND and NOT gates are derived from 4081B and 4069VB their functional diagrams are given below.

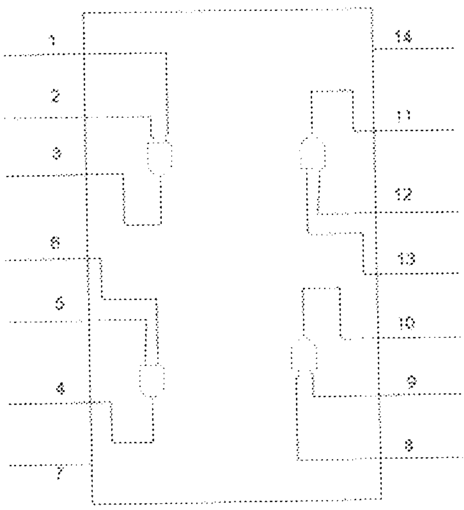

Fig. 3.7 Pin Configuration of the 4081B.

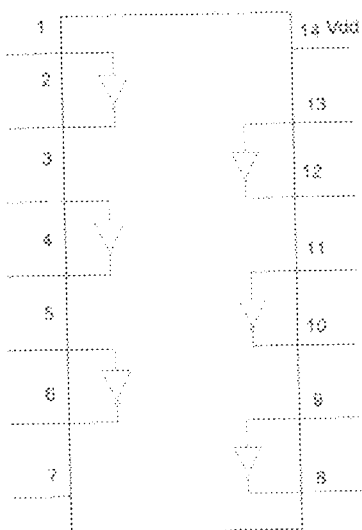

Fig. 3.8 Pin Configuration of the 4069VB

3.5 Display unit

The display unit involves both 4518B (dual up BCD counter) and 4511B (7-segment decoder). They receive necessary signals from terminals A and B of the binary to decade converter unit. The basic operation of the units is merely to display the corresponding temperature of the input sensor.

The 4518B is a dual BCD up – counter each consist of two identical, internally synchronous 4 – stage counters for single – unit operation. The enable input is maintained high and the counter advances on each positive going transition of the clock. The counters are cleared by high level on their reset line. This terminal is controlled by A's output from binary to decade converter unit.

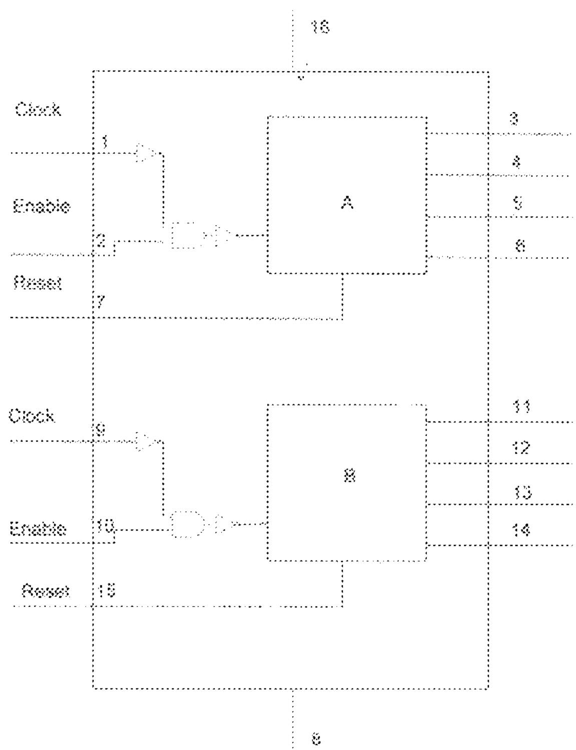

Fig. 3.9 functional diagram of the 4518B

The 4511B is a 7 –segment decoder. It is designed to convert BCD codes into 7 segment equivalent. The device works with common cathode 7 –segment displays.

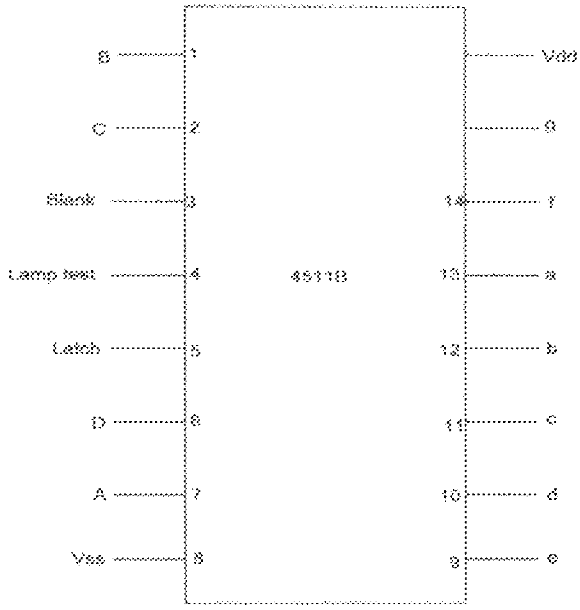

Fig.3.10 The Pin Configuration of the 4511B

Pin 3 and 4 are usually put at positive terminal. Two 4511B are used in the design. Their latch inputs are connected together to terminal A of the Binary- to- Decade converter unit.[7]

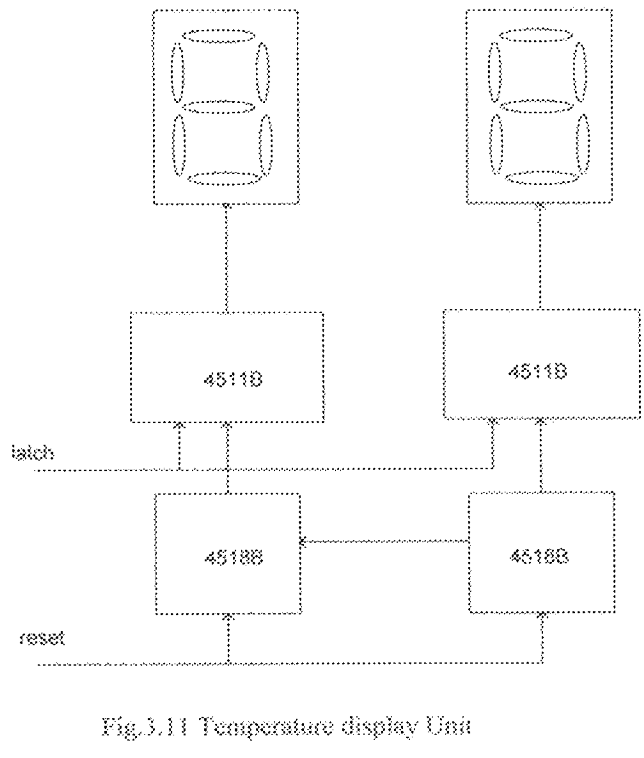

Fig.3.11 Temperature display Unit

3.6 Preset Counter Unit

The preset counter unit is made also of the 4518B and 4511B integrated circuits. They are connected the same way as the temperature display unit. The differences are that the latch and reset inputs are made logically 0. The unit is used to compare the temperature reading at the output so that necessary switching is done at the output. The output of this unit is incremented by a soft touch button.

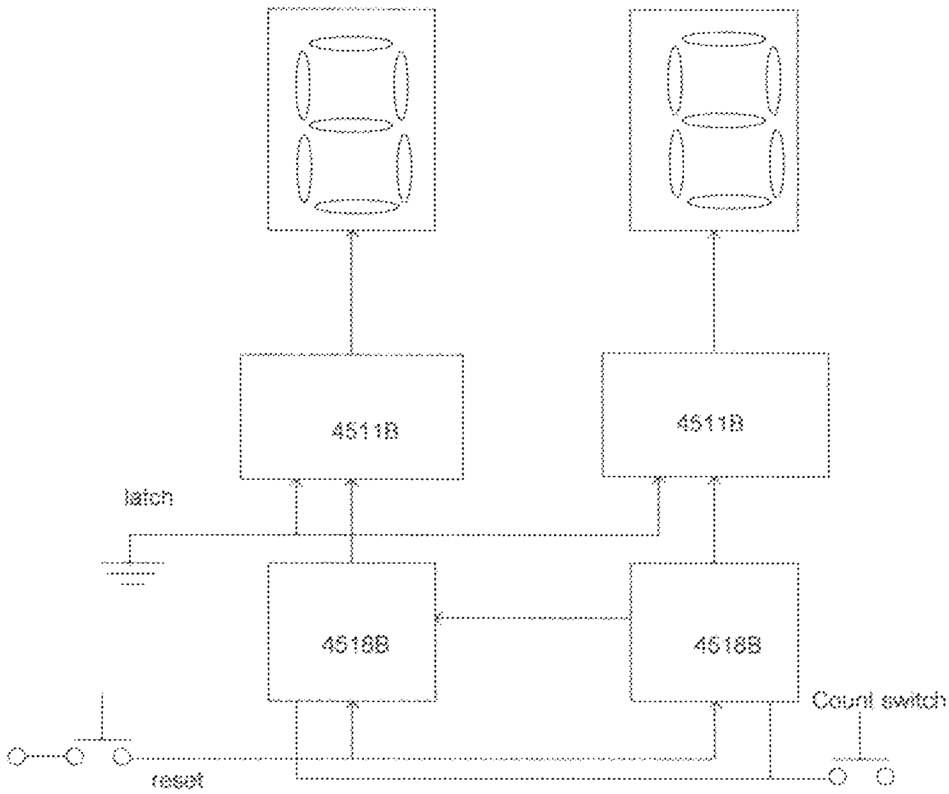

Fig. 3.12 functional diagram of the preset counter unit

3.7 Comparator Unit

The comparator unit is made mainly of the 4030B exclusive OR gate integrated circuit. In a manner to compare the BCD codes from both the temperature and preset counter unit. The technique is that whenever the reading temperature is lower than the present one, the output of the comparator unit allows heating at the output. But, the moment the two temperatures are the same or the reading temperature is about going beyond the preset value, the heating is stopped. In this unit, additional integrated circuit such as 4013B and 4060B are connected to the output of the 4030B designed comparator. The 4013B is a dual D-type latch. Its input operates at the high logical levels.

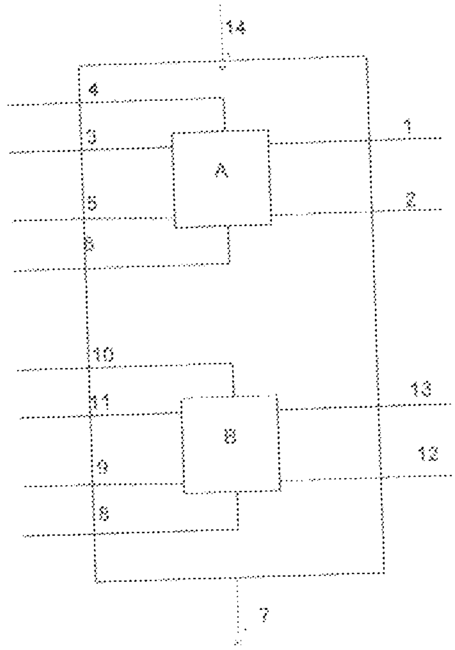

Fig. 3.13 The Pin Configuration of the 4013B

4060B is configured as a RC timer which is incorporated into the design to reset a latch some moment after it was set by the comparator. [9]

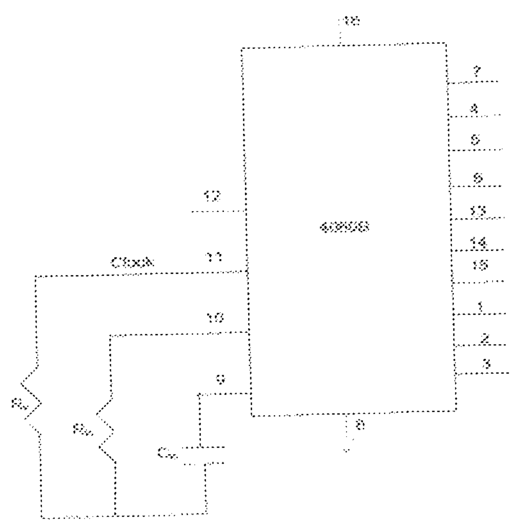

Fig. 3.14 The Functional diagram of the 4060B

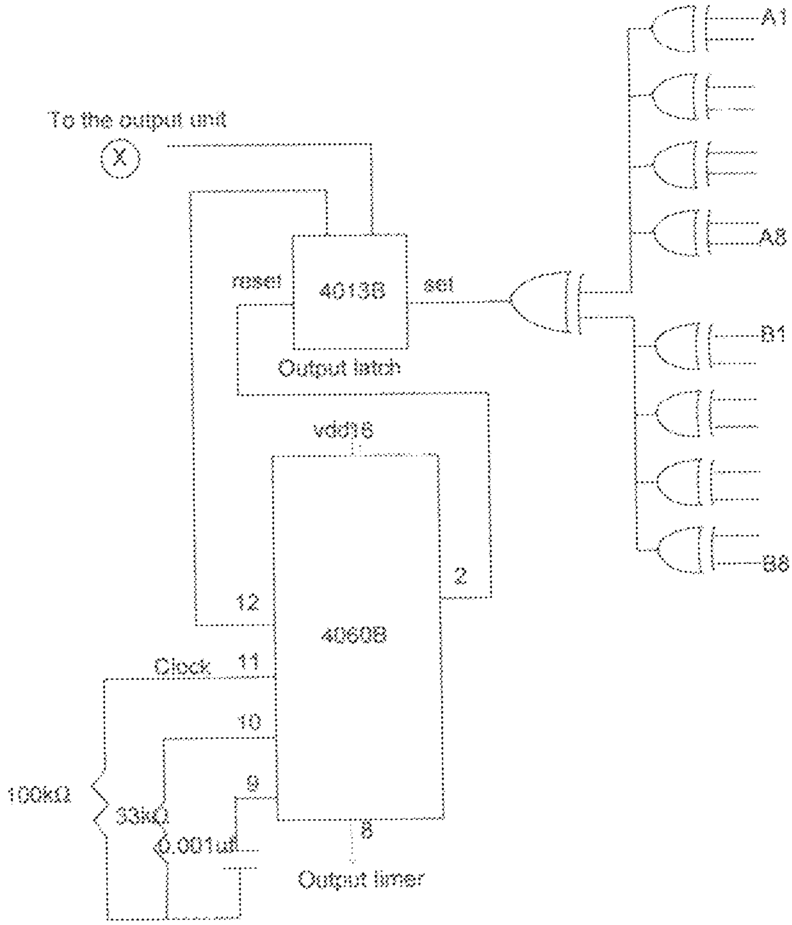

Fig.3.15 The comparator unit

The 4030B integrated circuits are used in this unit. They are used to compare all the output of one set of counter with the other. Through the dynamic nature of the one concern with the temperature, a latch (4013B) is required to hold the control terminal intended for the output control. The output timer periodically refreshes the output state. The output timer (4060B) produces a periodic high logical level original at its pin 2. The signal is based on the RC constant of the device.

Based on the 4060B integrated circuit specification the output pulse at pin 2 with respect to its RC constant is given by the following equation

$$\text{Frequency output from pin 2 } (Fq_{13}) = \frac{1/(2.3 \times 100\times 10^{3} \times 0.001 \times 10^{-6})}{2^{13}}$$

$$Fq_{13} = \frac{13.2 \times 10^3}{2^{13}}$$

Period of the signal at pin 2 is given by = $1/Fq_{13}$ 3.3

The timing allows automatic refreshing of the output from the output latch. This output is connected to the output switching units. [9]

3.8 Output Switching Unit

The output switching unit allows the signal from the comparator unit to be used for heat switching or regulation purposes. This unit contains a transistor- relay circuit.

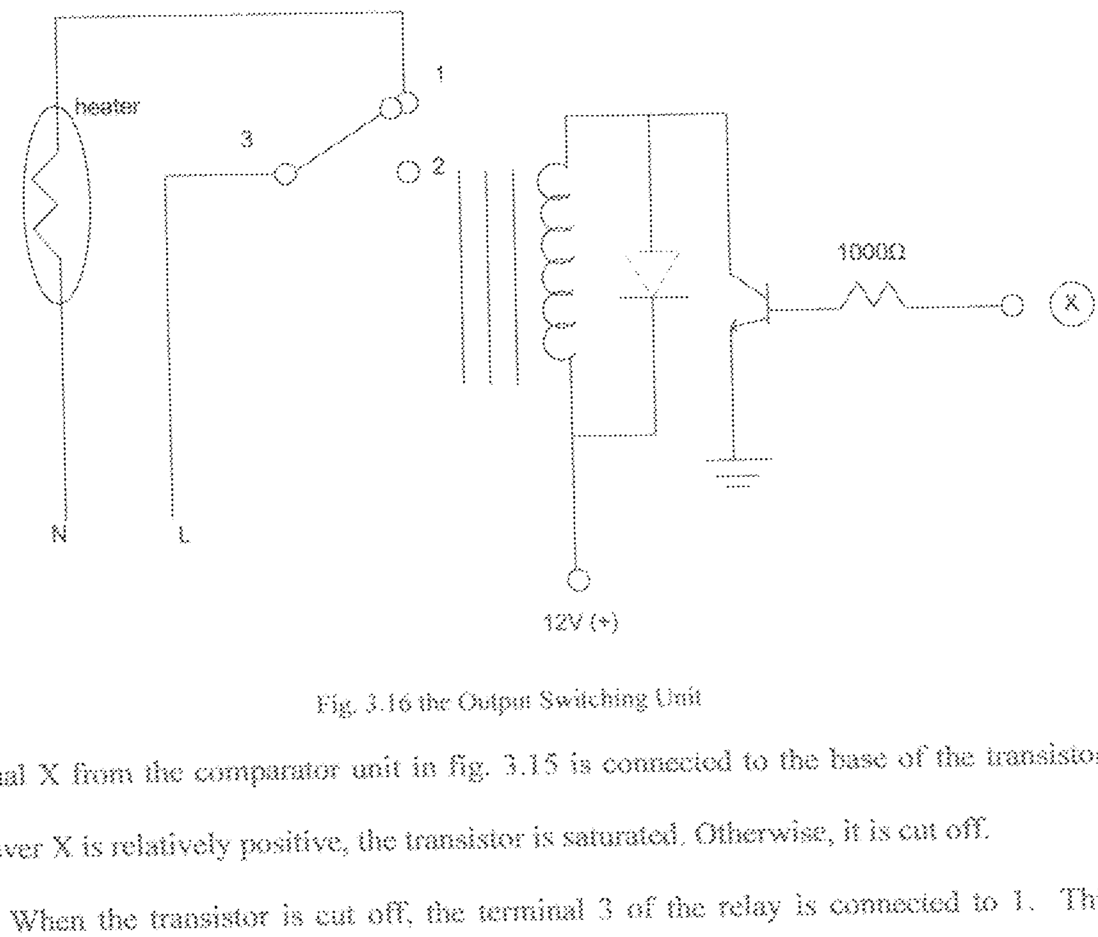

Fig. 3.16 the Output Switching Unit

Terminal X from the comparator unit in fig. 3.15 is connected to the base of the transistor. Whenever X is relatively positive, the transistor is saturated. Otherwise, it is cut off.

When the transistor is cut off, the terminal 3 of the relay is connected to 1. This allows electric current through the heater. In so doing the heater is working. But when the transistor's saturated as a result of X at logic 1, the relay is energized and its terminal 3 joined to 2.The heater works whenever the reading temperature is below that of the preset. Its stops whenever the two involved temperatures are the same. The two operations sum up to become the heart of the together regulating feature of the device.[5]

3.9 PICTORIAL VIEW OF THE VARIOUS UNITS AND PACKAGE OF THE PROJECT

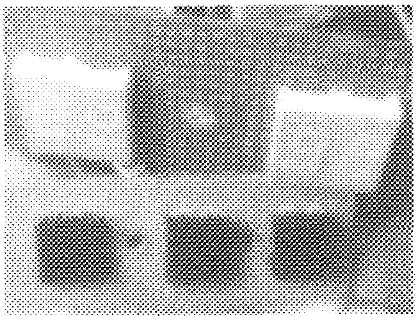

Fig.3.17 display unit

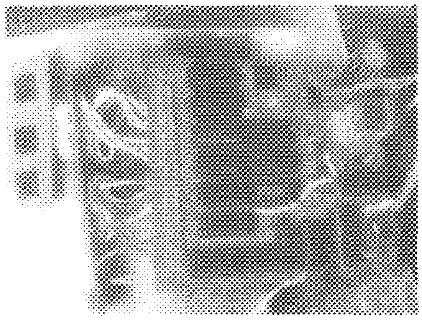

Fig.3.18 entire unit showing all ICs used

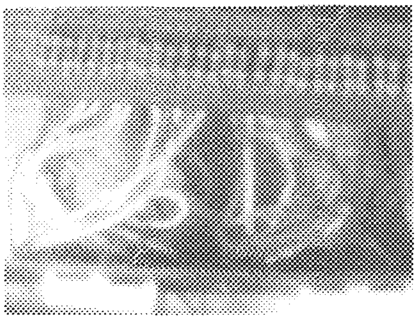

Fig. 3.19 showing the internal circuitry of the Display unit

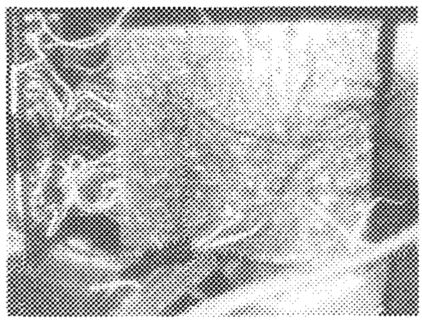

Fig. 3.20 showing how wires were soldered

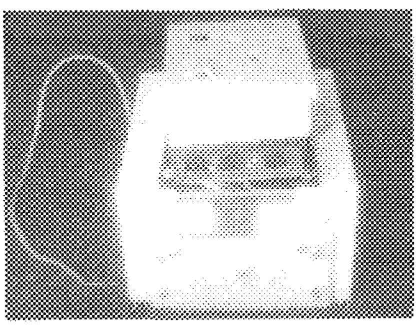

Fig. 3.21 showing already packaged project

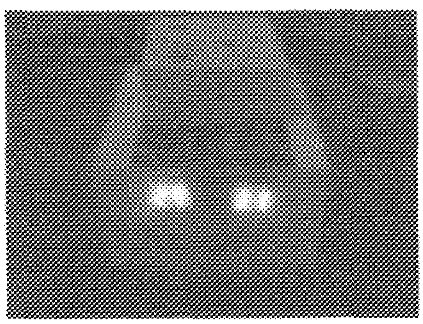

Fig. 3.22 showing an activated display

CHAPTER FOUR

CONSTRUCTION, TESTING AND RESULT

4.1 CONSTRUCTION

The construction involved two parts; the circuit and casing constructions. The circuit construction involves the assembling of the related components together as shown the circuit diagram. The casing construction involves the packaging of the completed circuit.

The circuit's construction was done on a Vero board. The platform allowed the related components to be connected together through wires and other means of connectors. The Vero board was sectioned into modules to allow easy construction and trouble shooting..

The power unit was first constructed. The ADC related parts were done next, followed by the counter units. The output unit which involved the heat control switch mechanism was constructed last. The sub-circuits were carefully configured together for the desired function.

4.1.1 The List of Some of the Items Used For the Construction;

- Soldering Iron
- Soldering Lead
- Cutter
- Glue

4.1.2 Casing construction

The casing was made from plastic casing originally designed to house wiring application. The casing was merely modified for the purpose of the project. Additional materials such as aluminum and transparent plastic were used in the modification.

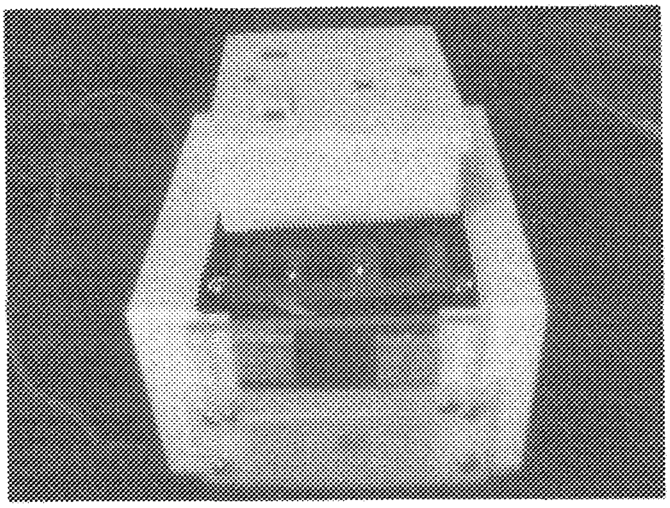

Fig 4.1Casing

4.2 TESTING

The testing was effected by setting a particular preset temperature input and allowing the heater to increase the temperature of the particular sensor. Numerous inputs were used within the temperature range of 0-99°C. The test was carried out several times to check the reliability of the output`s response.

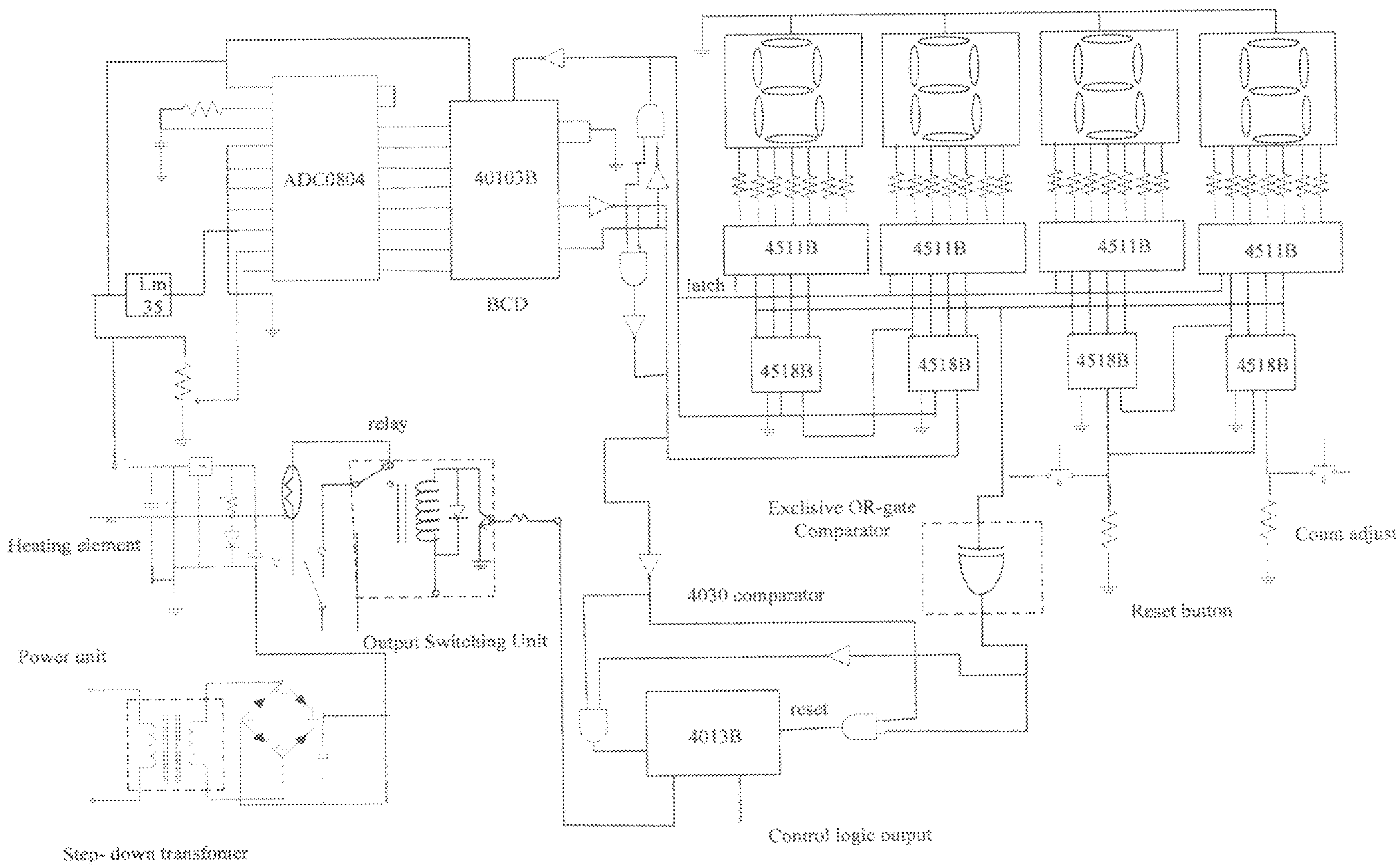

Fig 4.2 Circuit diagram for a digitally programmable thermostat

4.3 RESULTS

The result was quite strange. Only odd number preset temperature inputs worked according to the design. The Even ones provided reasonable switching error. The error was due to the instability of the LSB output of the Analogue to Digital Converter (ADC).

Table 4.1 the table shows the output response of the device.

S/NO	Preset Temperature (°C)	Maximum Temperature reading (°C)	Minimum Temperature reading (°C)
1	41	42	41
2	49	48	50
3	63	62	64
4	71	70	73
5	85	84	88

The table shows that the temperature regulation is relatively unstable at higher temperature setting than lower ones. The wide regulating effect is due to the circulation or flow of heat within the temperature sensor and heating region.

CHAPTER FIVE

CONCLUSION

5.1 CONCLUSION

The design and construction of this project was not an easy task as various problems were encountered. The proper functioning of the device for only Odd number preset temperatures was not intended. This was due to the instability of the low significant bit of the Analogue to digital converter.

However, the thermostatic control was achieved with minimum error.

5.2 RECOMMENDATIONS

The temperature range of the device could be expanded through the application of more advanced sensors such as thermocouple, thermistor and the use of three seven segment LEDs .Microcontroller could replace some of the involved integrated circuits for more accuracy, compatibility and simplicity.

A remote control feature could be incorporated in the design for more ease in operation. An alarm feature could be incorporated into the design to signify critical temperatures. The design could be modified for oven, air conditioning application.

Stronger switching relay could be incorporated for heavier loads.

The display could be modified to Light Crystal Display (LCD) for less power consumption as compared to the used LEDs

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