DESIGN AND CONSTRUCTION OF A MICROCONTROLLER BASED COUNTING AND TEMPERATURE MONITORING SYSTEM

ADEOGUN RAMONI .O.

2001/11910EE

Department of Electrical and Computer Engineering,

Federal University of Technology, Minna, Niger State

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BY

ADEOGUN RAMONI. O.
2001/11910EE

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NOVEMBER, 2007.

DEDICATION

This project work of mine is dedicated to my parents **Mr. Abdulrasheed Adeogun** and **Mrs. Memunat Adeogun.**

DECLARATION

I **ADEOGUN RAMONI.O.**., 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.

ADEOGUN RAMONI.O.

(Name of student)

26/11/007 ....

(Signature and date)

MR. M. DAVID

(Name of supervisor)

26/11/07 ....

(Signature and date)

ENGR. MUSA D. ABDULLAHI

(Name of H.O.D)

....

(Signature and date)

....

(Name of External Examiner)

....

(Signature and date)

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Finally, to all my colleagues and well wishers, thank you all.

ABSTRACT

This project is designed to monitor human inflow and outflow and the temperature of a particular area (room, offices, lecture halls, stadiums, theaters, banks, etc).the circuit establish a limit for both the number of people in the controlled area and the temperature. The maximum number of occupants and temperature are fixed through the PRESET SWITCHES (adjust (+) and adjust (-)). The mode switch is used to select the parameter to be preset. The infrared sensing circuitry generates pulses which are fed to port 3.4 and 3.5 of the microcontroller. Each pulse from the entrance monostable increments the number by one and pulses from the exit monostable decrement the count by one for each pulse. The count decreases and increases until the maximum preset value is reached. At this time, the buzzer sounds and the OVERFLOW LED activated. The temperature sensor (LM35) measures the temperature in the area and the signal generated is converted to digital via the ADC0804. This digital signal enters the microcontroller (AT89C51) through P1.7. The microcontroller keeps comparing the temperature with the preset value until the value is exceeded, the buzzer sounds and the OVERTEMPERATURE LED is activated. This alerts an operator to take a predefined action dependent on the condition that triggers the sounder.

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CHAPTER ONE

1.0 GENERAL INTRODUCTION

Counting is an essential process which is necessary in human day to day activities. It is an avenue of obtaining the number or amount of a particular set of materials, objects or even human beings in an area. It is usually done on a scale of ten or in decimal system. Computers count on a single scale of two or binary system using the digits zero (0) or one (1) [1]. An electronic object counting system is thus a very useful device for industries, traffic monitoring, capacity maintenance in stadiums, classrooms, supermarkets, banks, and other places where counting need to be carried out.

The importance of electronic counting devices in industrial and nation development is highlighted in the society's need for a sound electronic object counting system. The human brain is comparable to a memory module (though with variable limits). Certain factors influence human ability to accurately count or recall data stored in the human brain when needed. Such factors include psychological, social and health problems, volume of materials or object to be counted, age and so on. A number of other factors could interfere with human counting activities and make them loose track of the data (value) obtained before the interference.

These problems necessitate the need for a sound, effective and efficient electronic object counting system which forms the basis of this project design.

Most industrial processes in life involve man, material and machines. Each of these generates heat in different forms. Machines produce heat due to mechanical motion of movable parts and joule losses while human radiate a form of energy termed black body radiation. The effect of the heat radiation is an overall rise in the temperature of the environment\area where the operation is being carried out. It is also known that the number of people in an enclosed area increases the temperature of the area regardless of whatever form of cooling is system used in the area. As a result of this heat generation by human, machines and objects alike, the temperature of every area where operations are carried out need to be kept under control. Consequently, this electronic object counting system inculcate into itself a temperature monitoring unit which keep measuring the temperature of the area and comparing with a preset value.

The microcontroller based Electronic Object counting system with temperature monitor is therefore a miniaturized multipurpose electronic system that can be employed for counting operations and temperature measurement simultaneously. The project utilizes the discoveries in Infrared sensing, generation and transmission, temperature measurement and microelectronics to achieve the desired goal. The adoption of a microcontroller reduced to a great extent the hardware complexity of a typical digital system for this purpose by replacing some hardware components such as counters, comparators, timers and so on with software.

A microcontroller is a single integrated circuit that executes a user program normally for the purpose of controlling some devices hence the name microcontroller [2]. Microcontroller based devices generally deliver better performance at lower cost and with simple construction than do equivalent devices implemented with discrete logic chips and making changes and improvement is often as simple as writing new firmware [3]. In order to derive the aforementioned advantages of microcontroller based systems over other systems, this project utilizes an Atmel89C51 microcontroller. The project basically consists of five hardware sections viz: the user terminal (switches), the sensing section (Infrared and temperature sensors), the analogue to digital conversion (ADC) section, the microcontroller section, and the output section.

The user terminal consists of three switches which allow the user to preset the desired parameters (i.e. differential count and temperature). The first two switches allow the user to increase or decrease the preset temperature and differential count while the third switch is used as the mode select switch. The sensing unit consists of two infrared transmitters and receivers that count the number of entries and exits and a temperature sensor that measures the temperature of the controlled area. The analogue to digital conversion section consist of an analogue to digital converter that convert the generated signal to a form suitable for the microcontroller and the output section consist of four seven segment displays, a buzzer to give an audible output, and two colored LEDs to give visual indications. The user program which is the heart of the project is written in assembly language.

1.1 PROJECT OBJECTIVES

This project 'Design and Construction of Electronic counting system with temperature monitor' was carried out with the aim of meeting the following objectives;

- To study the development in microelectronics and the versatility and efficiency of microcontroller based systems.
- To have a comprehensive knowledge of developing microcontroller based systems
- To design and construct a functional, efficient and cost effective system to aid the manual counting of people in a gathering and to keep the temperature of the area below a maximum presentable value.
- To meet the requirement for the award of bachelor of engineering.

1.2 APPLICATIONS

The project in its design is meant for counting occupants and measuring temperature of areas such as stadiums, conference hall, theaters, supermarkets, lecture halls and so on with the aid of infrared sensors mounted at the entrance and exit of the hall and a temperature sensor placed within the hall. The project is designed with a maximum counting capacity of two hundred and fifty five (255). It can simultaneously count and measure the temperature of the controlled area up to a maximum of sixty-four (64) degree celcius. The project can also be employed in industries to count the number of goods as they move through the conveyor belt.. It is also applicable in counting the number of vehicles that passes through a toll gate.

The project is aimed at employing microcontroller to reduce the hardware complexity of counting devices and to improve the accuracy and efficiency of counting and temperature measurement.

1.3 SIGNIFICANCE OF STUDY

The significance of an electronic counting device can not be overemphasized. This is as a result of the fact that it prevents overcrowding of areas where it is used and it also make production faster in industries. This project also make it possible for people to spend less money on counting compared to when human beings are employed to carry out the counting operation. It also creates a conducive atmosphere for people occupying the controlled area by controlling the temperature.

1.4 MOTIVATIONS

We live in a nation where maintenance culture lacks a lot and this yield a lot of negative effects on the nation particularly human health. The need to exploit the development trends in electronics towards maintaining the capacity of buildings such as classrooms, theaters, stadiums, and so on through accurate counting form the basic motivating factor that lead to the selection of the topic. The fact that every human radiates heat which may lead to rise in the temperature of a populated area and can pose health hazards to people prompted the inclusion of a temperature monitoring unit in the circuit.

1.5 SCOPE AND LIMITATIONS.

This project is limited to the historical background, developments of microelectronics and working principles of various models such as infrared sensing devices, digital counters, magnitude comparators and multivibrators. Materials (circuit components and tools) used for the construction of the project were sourced and put together locally, this makes it possible to mass produce the project. The Electronic object counting systems with temperature monitor can be used in supermarkets, offices, rooms, lecture halls, and so on, to count the number of persons entering and leaving the premises, keep record of the differential count, and monitor the temperature within a presetable limit.

1.6 SOURCES OF INFORMATION.

Information that aids the design of the circuit were sourced from a number of sources including past lecture notes on digital and analogue electronics, Textbooks, Internet, Data sheet of Integrated circuits and microcontrollers. Another vital source of information was consultation with colleagues who offered useful assistance that ensured an effective design and construction of the project.

1.7 THESIS OUTLINE

This thesis report the processes involved in the Design and Construction of an electronic object counting system with temperature monitor and is presented in five chapters as follows;

Chapter one provides a general introduction, discuss the objectives, and outline the scope and limitations, and the sources of information that aided the design.

Chapter two presents the literature review, recent development in line with principles upon which the operation of the project is based and gives the theoretical background which includes the description of basic concepts.

Chapter three presents the design analysis, component selection, and design calculations.

Chapter four outlines the tests and measurements of hardware components and debugging of the software component.

Chapter five present the conclusion, recommendation for improvement on the project, problems encountered during the design and construction of the project.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND

2.1.1 HISTORICAL DEVELOPMENT OF COUTING DEVICES.

Long before the invention of writing, human beings appear to have developed some sense of number. Carvings made on bones found in Africa have been interpreted as a rudimentary means of counting the days for each phase of the moon. Also ancient and nearly universal is the tally stick, a piece of wood on which notches could be carved as animals or objects were counted [4]. Among the first effective counting tools were certainly the fingers and toes of the human body. Virtually every number system known is based on the numbers five (5), ten (10) or twenty (20) [5].

When the human digits were inadequate, heaps of stone were used to represent a correspondence with the elements of another set. Where non-literates used such a scheme, they often pile the stones in group of five (5), for they had become familiar with quintuples through observation of the human hand and foot [6].

The earliest counting tools include a variety of counting boards and abacus which were developed thousand of years ago and are in use in many part of the world. The use of mechanical devices for counting and calculating has been a recurrent thing since the renaissance [7]. John Napier (1550-1617) invented the logarithms which aid calculations. Blasé Pascal (1673-1662) invented an adding machine with numerous rotating cogged wheels. By the end of the19th century, machine that could add, subtract divide and multiply had because popular. Much of time was spent in this century developing a machine called an analytical engine [8]. From the twentieth century to date a lot of improvements have been made in developing an efficient tool for counting. This ranges from the use of large scale integration (LSI) circuits to the use of computer for counting purposes. With the recent development of microelectronic and the versatility of microcontrollers efficient counting devices can be developed using these ultra large scale integration devices called microcontrollers.

2.1.2 HISTORY OF TEMPERATURE MEASURING DEVICES.

The temperature of an object can be described in a qualitative manner as a parameter which determines the sensation of warmth or coldness felt from contact with it [9]. Temperature measurement using modem scientific thermometer and temperature scales goes back as far as the early eighteenth century [10].

The earlier devices used to measure temperature were called thermoscopes which consist of a glass bulb having a long tube extending downward into a container of colored water [11]. In 1701, Ole Roemer made one of the first practical thermometers using red wine as a temperature indicator. His scale was based upon two fixed points; snow (or crushed ice) and the boiling point of water. A good number of modifications were made to Ole Roemer's thermometer by scientists who use different substances as temperature indicator to improve the accuracy of measurement [12].

The early 1800's were very productive in the area of temperature measurement and understanding. William Thompson postulated the existence of an absolute zero. Sir William Hershel discovered that when sunlight was spread into a colour swath using a prism, he could detect an increase in temperature when moving a blackened thermometer across the spectrum of colours [13]. In 1821 T J Seeback discovered that a current could be produced by unequally heating the junctions of two dissimilar metals, the thermocouple effect. Also in 1821, Sir Humphrey David discovered that all metals have a positive temperature coefficient of resistance and that platinum could be used as an excellent temperature detector. These discoveries marked the beginning of serious electrical sensors [14]. Gradually, the scientific world learnt how to measure temperature with greater precision.

The late 19th century saw the introduction of bimetallic temperature thermometers. These thermometers contain no liquid but operate on the principle of unequal expansion between two metals. Since different metals have different coefficient of linear expansion, one metal that is bonded to another will bend in one direction when heated and will bend in the other direction when cooled. This bending motion is transmitted by a suitable mechanical linkage, to a pointer that moves across a calibrated scale. Although not as accurate as liquid in glass thermometers, bimetallic thermometers are handy, easy to read and have a wider span, making them ideal for industrial applications [15].

The twentieth century saw the discovery of semiconductor temperature measuring devices, such as the thermistor, the integrated circuit sensors, a range of non-contact sensors and also fiber optic temperature sensors. The 20th century also saw the refinement of the temperature scale [16].

2.2 CONCEPT OF COMPUTER CONTROL

The application of a microcomputer for control may take many forms and may entail a range of ideas and principles. The simplest approach is to use the microcomputer as an efficient data collector and calculator. This concept is illustrated schematically in fig2.1 where the system is termed a computer monitoring system.

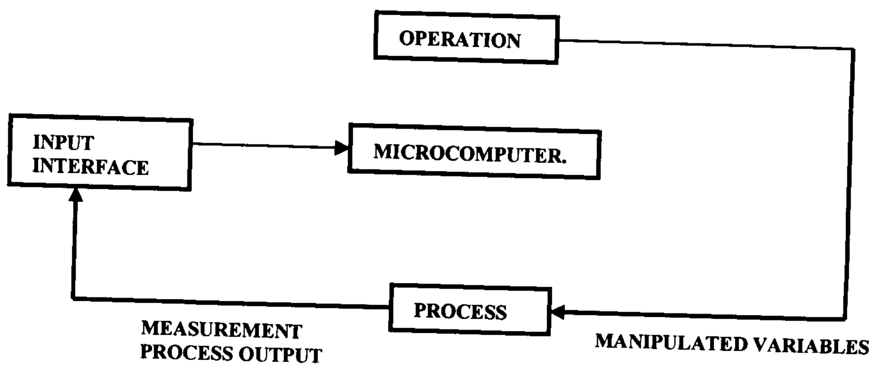

Fig. 2.1 computer monitoring system

In this system human operators manipulate individual process controller directly. The microcomputer simply observes the process via an interface that is capable of detecting physical signal such as analog voltages, temperature and pressure, converting the analog signals to digital words and converting the digital signal into binary information for the microcomputer to process. Operators make decision and take actions on the basis that the computer can be programmed to perform these functions. Application of microcomputer as monitoring system can either be open loop or closed loop.

Another important concept in the application of microcomputer is called the control algorithm process where two distinct operations are performed within the computer and the difference between the operating point and the set point is calculated from the equation: differences =set point – actual output and a corrective action is determined by solving an equation or set of equations that have been established as a desirable way to control the system parameters [17]. This law is referred to as the CONTROL ALGORITHM. These operations are illustrated in the block diagram below:

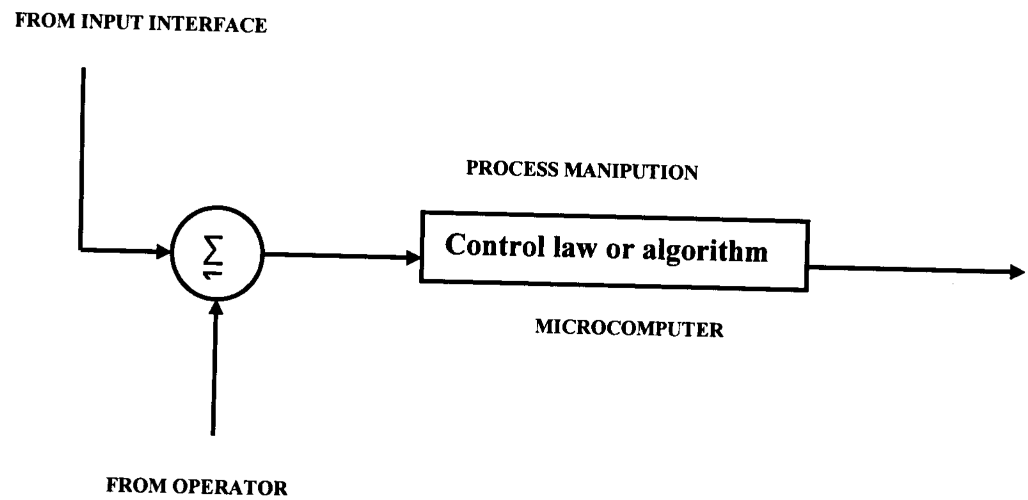

Fig 2.2 microcomputer control Algorithm process

2.3 THEORETICAL BACKGROUND

The basic operation and descriptions of signals, devices, and modules on which the design of the project is based are discussed in the sections below:

2.3.1 CONCEPT OF DIGITAL COUNTING

The operation of electronic counters generally comprise of three distinct stages viz: Sensing or clock generation, proper counting and count display. This is illustrated schematically in the block diagram of figure 2.3

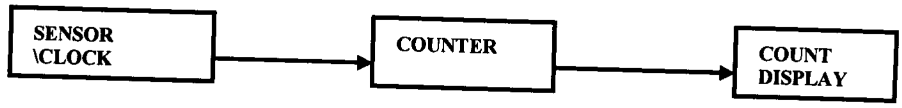

Fig 2.3 Operation of Electronic Counters.or, light dependent resistor (LDR), photodiode, Infrared sensors and so on. The sensor is usually wired with a number of discrete components as an oscillator to generate the clock signal that drives the counting device. Each clock signal causes the count to be incremented or decremented depending on the type of counter viz: whether up counter or down counter or even up-down counter. Most recent digital counters have their sensing circuit designed around a 555 *timer* integrated circuit wired as a multivibrator.

The second stage is the heartbeat of the counter which could be a combination of flip-flops and registers or integrated circuits. The operation of counting can also be implemented using a microcontroller with a set of instruction code written for the purpose of counting [18]. The codes could be written in high level languages (e.g. BASIC, VISUAL BASIC, C++, and FORTRAN) or assembly language depending on the microcontroller and the specific application [19].

The last stage usually comprise of a number of seven segment displays or other digital display devices.

2.3.2 INFRARED SIGNALS\RADIATION.

Infrared (IR) radiation is electromagnetic radiation of wavelength larger than that of invisible light but shorter than that of radio waves, Infrared light lies between the longest visible red (circa 0.7μm) and microwaves (circa 300-1000μm from 400THz to 1THz-300THz).

The infrared spectrum is divided into: near IR band (0.7μm up to 3μm), intermediate IR band (3μm up to 10μm), far IR band (10μm up to 100μm), and Sub millimeter (100μm up to 1mm) [20].

All objects, living or not whose temperature is above absolute zero emit infrared radiation by virtue of their thermal motion (warmth) alone. This radiation is invisible to human eye but can be detected by electronic devices designed for such a purpose. Objects near room temperature emit most of their radiation in the IR band .Even relatively cool objects; however emit some IR radiation, hot objects, such as filaments emit strong IR radiation. This radiation is called black body radiation and such waves are emitted by all natural objects [21].

The discovery of infrared radiation is ascribed to William Herschel who in the early 19^{th} century used a prism to refract light from the sun and detected the infrared. Infrared sensors were used by British American and German forces in the Second World War as night vision aids for snippers [22].

2.3.3 PASSIVE INFRARED SENSORS

Passive infrared sensors (PIRS) are electronic devices which are used to detect motion of an infrared emitting source, usually a human body. Since every object at temperature above absolute zero (-273.15°C or -459.67°C) emit infrared signals, these sensors can therefore be used in counting devices to detect the present of objects and generate a clock signal to the counting devices. This clock signal increase or decrease the count accordingly. The term 'passive' in the passive infrared sensors (PIRs) means the sensors do not emit energy of any form but merely sit "passive" accepting infrared energy through the window in its housing. The heart of the sensors is a solid state chip approximately 1\4 inch square and often from a pyroelectric material mounted on a printed circuit board which also contain the necessary electronics required to interprete the signals from the chip. The actual sensors on the chip is made from natural or artificial pyroelectric material usually in the form of a thin film, out of gallium nitride (GAN) caesium nitrate (CsNO3), polyvinyl fluorides, derivatives of phenylpyrazine, and cobalt phthaloaynine[23].

2.3.4 APPLICATION OF INFRARED RADIATION AND SENSORS

Infrared signal and sensors are applicable in the following areas;

- **Night vision**; infrared is used in night vision equipment when there is insufficient light to see an object.
- **Thermography**; infrared radiation can be used to remotely control the temperature of objects.
- **Heating**; infrared radiation is used in infrared saunas to heat the occupants and to remove ice from the wings of aircraft.
- **Communication;** IR data transmission is employed in short range communication among computer peripherals and personal digital assistants.
- **Spectroscopy**; infrared is used in the study of composition and structure of organic compounds [24].

2.3.5 IR BEAM INTERRUPTION AND REFLECTION.

Infrared beam interruption and beam reflection are two common techniques employed when infrared sensors are used as motion detectors. Infrared sensing circuit normally consist of an infrared emitter (usually an IR LED) wired as an astable multivibrator which continuously generates infrared signal (at frequencies 38KHz, 52KHz or 60KH) and an infrared sensor wired as monostable multivibrator. These two techniques are illustrated in the block diagrams below;

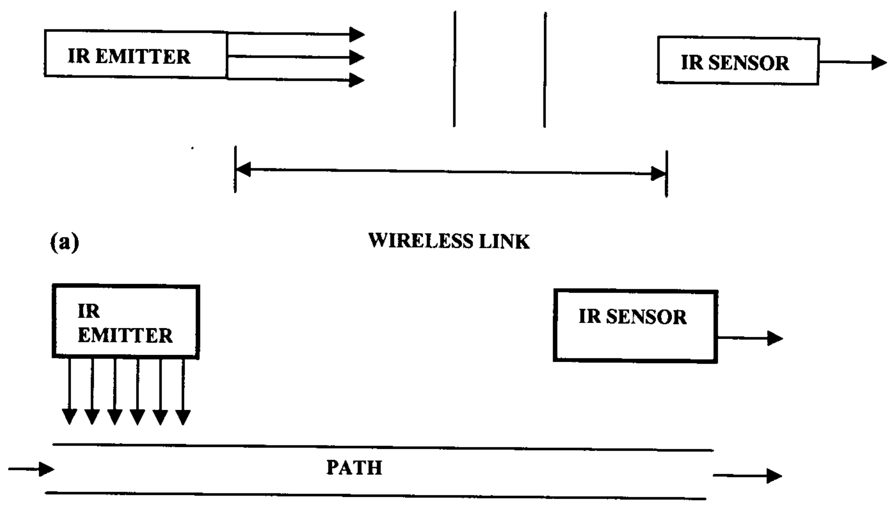

Fig 2.4 infrared beam (a) interruption and (b) reflection

In beam interruption (figure 2.4a) the infrared emitter continuously emit infrared radiation which is directly focused on to the sensor, a solid body passing through the path between the emitter and sensor interrupt the transmission of IR signal to the sensor, this interruption causes a stoppage in the reception of signal by the sensor which triggers which the associated oscillator circuit while in beam reflection, the IR radiation is not focused on the sensor but a solid body passing through the path shown (figure 2.4b) reflects the IR radiation back onto the sensor, this causes the sensor to receive a signal and trigger the associated oscillator[25].

2.3.6 MULTIVIBRATORS

Multivibrators are electronic circuit used to implement a variety of simple two-state system such as oscillations, timers and flip-flops. The most common form is the astable or oscillating type, which generates a square wave. There are three types of multivibrator circuit.

- **Monostable multivibrator**; this is also called a one shot multivibrator in which one of the state is stable, but the other is not. The circuit will flip into the unstable state for a determined period, but will eventually return to the stable state.
- **Astable multivibrator;** this is not stable in either of the two states; it continuously oscillates form one state to the other.
- **Bistable multivibrator;** this circuit is stable in both state and will remain in either state indefinitely; the circuit can be flipped from one state to the other by an external event or trigger.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.0 BLOCK DIAGRAM

In electronic designs, systems are usually represented using block diagrams which are either functional or logical. The block diagram for the system under construction is as shown below (Fig 3.0)

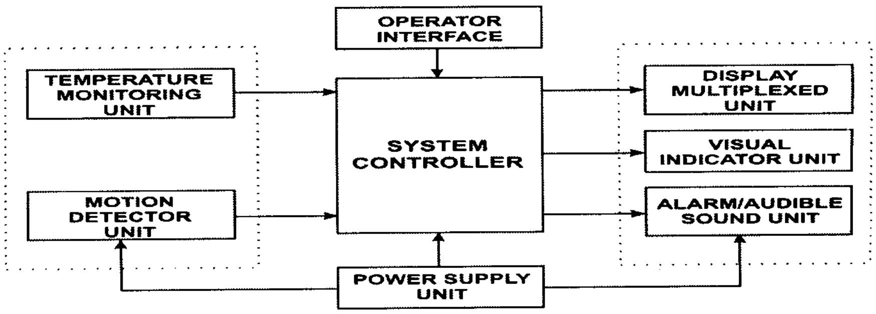

Fig. 3.0 Functional block diagram of Microcontroller Based Electronic Counting system unit temperature monitor.

The design work comprises of the following subsystems:

i. Power supply unit.
ii. Temperature Monitoring unit
iii. Motion detector unit
iv. Operator interface/switches
v. System controller unit
vi. Display Multiplexed unit
vii. Visual indicator unit and
viii. Alarm/audible indicator unit

3.1 POWER SUPPLY UNIT

Most electronic systems require a regulated DC supply for their normal operation. The project under construction is not an exception. Since the most economical and readily available power supply is the 240V, 50Hz AC supply, a number of processes need to be carried out on this supply to transform it to the required regulated DC supply. The following stages are generally involved in the conversion of alternating voltages to DC voltages.

- Stepping down of the 240V supply using a step down transformer
- Rectification of the stepped – down voltage using a rectifier.
- Filtering of the rectified voltage to remove ripples and fluctuations
- Regulation of the filtered voltage to obtain a specified value

The block diagram below gives a summary of how regulated DC voltage is obtained from an AC supply

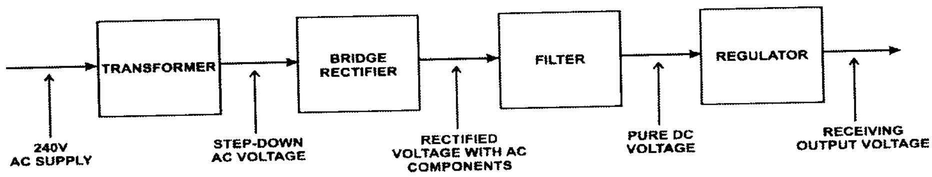

Fig 3.1 Block Diagram of the Power Supply Unit

The power supply unit for this project features a 240V/12V, 0.5A step-down transformer, a full wave bridge rectifier, filter capacitors, a 5-Volt fixed regulator (7805), an adjustable voltage regulator (LM317T) and two 2200μF capacitors wired as shown in the circuit diagram below:

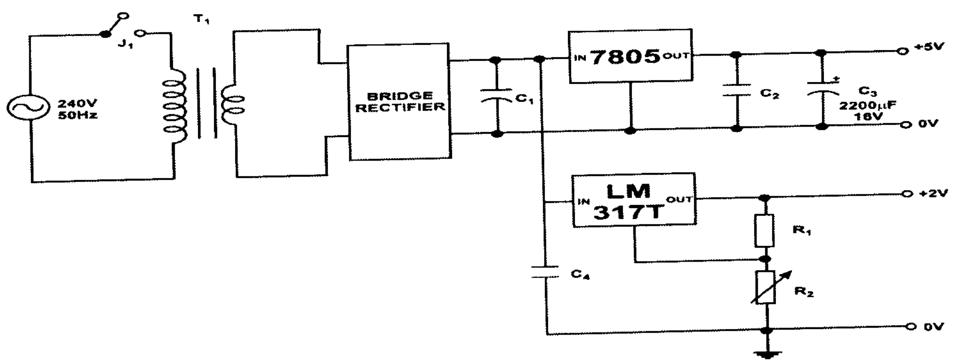

Fig. 3.2 Circuit Diagram of the power supply unit.

3.1.1 THE TRANSFORMER

A transformer is a device which is capable of converting AC voltage at one level to AC voltage at another level (either higher or lower). It transfers electrical energy from one circuit to another through a shared negative field. The secondary included voltage V_p

is scaled from the primary voltage V_P by a factor ideally equal to the ratio of the number of turns in their respective windings.

$$\frac{\text{Voltage in secondary winding}}{\text{Voltage in Primary winding}} = \frac{\text{Turns in secondary}}{\text{Turns in Primary}}$$

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} \tag{3.1}$$

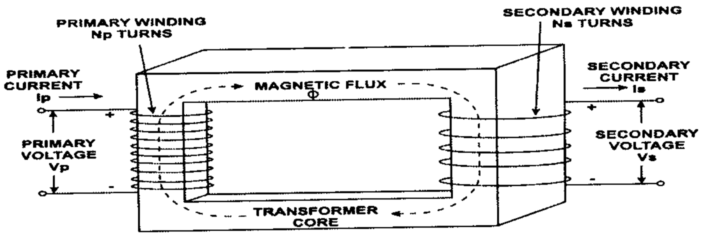

Fig. 3.3 Ideal Step-down transformer.

3.1.1.1 IDEAL POWER EQUATION.

Consider an ideal transformer as a circuit element shown below (fig 3.4). If the secondary coil (winding) is attached to a load that allows current to flow, electrical power is transmitted from the primary circuit to the secondary circuit. The incoming electric power must equal the outgoing power.

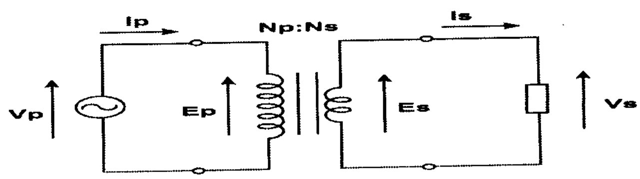

Fig 3.4 The Ideal transformer as a circuit element.

$$P_i = I_P V_P = P_o = I_S V_S \tag{3.2}$$

This gives the ideal transformer equation

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S} \tag{3.3}$$

Where:

V_s = secondary Voltage

V_p = primary Voltage

N_s = Number of turns in secondary winding

N_p = Number of turns in primary winding [27]

3.1.1.2 DESIGN CALCULATIONS

An ideal step – down transformer with rating 240/12V, 0.5A was used in the design to step the 240V AC voltage supply to an approximate root mean square value of 12V.

Therefore; $V_p = 240V$; $V_s = 12V$; $I_s = 0.5A$

By the application of equation 3.3:

$$\frac{V_S}{V_P} = \frac{I_P}{I_S}$$

$$I_P = \frac{12 \times 0.5}{240} = \frac{6}{240}$$

$$I_P = 25mA$$

The current in the primary circuit is thus 25mA.

The peak value of the output voltage is given by the following expression;

$$V_m = \sqrt{2} V_s \tag{3.4}$$

Where:

V_m = peak value of output voltage

V_s = runs value of secondary voltage

$$V_m = \sqrt{2} \times 12V$$

$$V_m = 16.9706V$$

The peak value of step-down output voltage from the transformer with a 240V input is 16.9706V

3.1.2 THE BRIDGE RECTIFIER

A rectifier is a circuit which converts alternating voltage to direct voltage. The non-linear characteristics and the ability of diodes to pass current in only one direction forms the building block for most rectifier circuits. Rectifier circuits are generally grouped into two types based on the nature of waveform produced as outputs viz: Half-wave rectifier which conducts only in one half – cycle of the input waveform and Full-wave rectifier circuit which conducts in both half – cycles of the input waveform [28].

A special type of full-wave rectifiers called full wave bridge rectifier shall be considered here. The bridge rectifier is a package consisting of four P-N junctions diodes arranged such that two of the diodes conduct in each half-cycle of the input waveform.

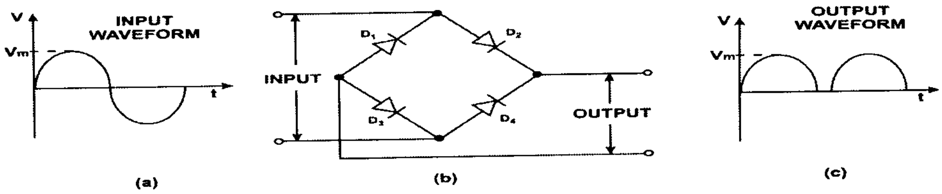

Fig 3.5: Bridge rectifier (a) Input waveform (b) Circuit (c) Output waveform [29]

3.1.2.1 DESIGN CALCULATIONS

The peak DC voltage of the rectifier is given by the expression:

$$V_m = \sqrt{2}V_{rms} - 2V_d \tag{3.5}$$

Where:

V_m = peak DC value of the rectifier voltage

V_{rms} = runs value of input voltage to the rectifier = 12V

V_d = diode voltage drop (typically 0.7V)

$$V_m = \left(\sqrt{2} \times 12 - 2 \times 9\right)V$$

V_m = 15.56V

Thus, the peak amplitude of the unsmoothened DC voltage is 15.56V

3.1.2.2 RIPPLE FACTOR OF THE RECTIFIER

The ripple factor of a voltage is defined by:

$$r = \frac{\text{rms value of ac components of signal}}{\text{Average value of signal}}$$

This can be expressed as:

$$r = \frac{V_{AC(rms)}}{V_{DC}} \tag{3.6}$$

Since the AC voltage components of a signal containing a DC level is:

$$V_{AC} = V_m - V_{DC} \tag{3.7}$$

Where

V_m = peak value of the signal.

The root-mean square (rms) value of the AC components is given as:

$$V_{AC(rms)} = \left[V_{rms}^{\ 2} - V_{DC}^{\ 2}\right]^{\frac{1}{2}} \tag{3.8}$$

Where:

V_{rms} = rms value of the total voltage for a full-wave rectifier signal.

$$V_{rms} = \frac{V_m}{\sqrt{2}} \text{ and } V_{DC} = \frac{2V_m}{\pi}$$

Therefore:

The peak value of the output voltage from the bridge rectifier is:

$$V_{AC(rms)} = 0.308V_m \tag{3.9}$$

$$V_m = 15.56V$$

Thus the rms of AC components is

$$V_{AC(rms)} = 0.308 \times 15.56 = 4.79248V$$

$$V_{AC(rms)} \approx 4.80V$$

3.1.3 THE FILTER

Rectifier circuits usually produce a direct voltage as output. However, there remains a large alternating component. It is desirable to keep the alternating components of this voltage (or current) as small as possible. This can be achieved by the use of smoothing circuits (called filters). The simplest of which consists of a capacitor connected across the output of the rectifier as shown below.

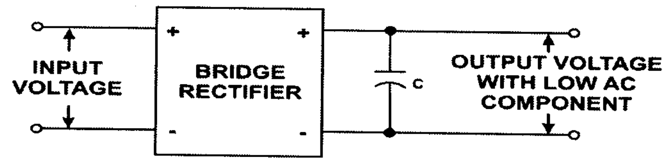

Fig 3.6: Smoothening with a filter capacitor

3.1.3.1 RIPPLE VOLTAGE OF CAPACITOR FILTER

Assuming a triangular ripple as shown below (fig 3.7):

$$V_{DC} = V_m = \frac{V_{r(P-P)}}{2} \qquad (3.10)$$

Where:

$V_{r(p-p)}$ = peak-to-peak value of ripple voltage.

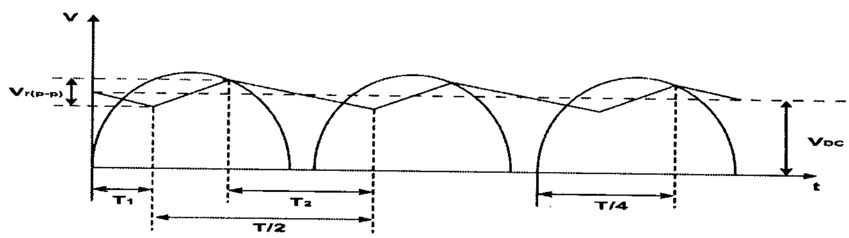

Fig 3.7 Approximate triangular ripple for capacitor filter.

From the triangular ripple waveform (fig 3.7)

$$V_{r(rms)} = \frac{V_{r(P-P)}}{2\sqrt{3}} \qquad (3.11)$$

Similarly,

$$V_{r(P-P)} = \frac{I_{DC}}{2fC} \times \frac{V_{DC}}{V_m} \qquad (3.12)$$

The term $I_{DC}/2fC$ in equation (3.14) gives the ripple voltage for a full-wave rectifier, thus

$$V_r = \frac{I_{DC}}{2fC} \quad [30] \qquad (3.13)$$

3.1.3.2 DESIGN CALCULATIONS

The value of then filter capacitor is determined using equation (3.15). Assuming an allowable ripple of 2V.

$V_s = 2V$, $I \approx 0.5A$, and $f = 50Hz$

$$C = \frac{I_{DC}}{2f \times V_r}$$

$$C = \frac{0.5}{2 \times 50 \times 2} = 2.5 \times 10^{-3} F$$

$$C = 2500 \mu F$$

A value of 2200µF was used in the circuit for filtering.

With the smoothening capacitor connected across the supply, the steady DC voltage is expressed by the relation

$$V_{DC} = \frac{V_m}{1 + \frac{1}{4fCR_L}} \quad [31] \qquad (3.14)$$

Where:

$$V_m = \sqrt{2}V_{rms} - 1.4 = 15.56V$$

f = mains frequency = 50Hz

C = smoothening capacitor = 2200µF

R_L = load resistance

Since a capacitor behaves like an open circuit at DC the load resistance is approximately equal to the resistance presented by the 7805 regulator typically quoted by the manufacturer as greater than 10KΩ

With R_L = 10KΩ = 10000Ω

$$V_{DC} = \frac{15.56}{1 + \frac{1}{4 \times 50 \times 2200 \times 10^{-6} \times 10000}}$$

$$V_{DC} = \frac{15.56}{1+0.00025}$$

$$V_{DC} = 15.556V$$

3.1.4 VOLTAGE REGULATORS

Voltage regulators are devices used to prevent output voltage change with load current and line voltage thereby producing a relatively stable output voltage. The output of the regulator can either be fixed or adjustable depending on the type of regulator. The two voltage regulators used in this project are the 7805 and LM317T and are discussed below.

3.1.4.1 THE 5-VOLT FIXED REGULATOR (7805)

The integrated circuit is a positive voltage regulator with three terminals and is designed to produce a fixed output. It provides an output of +5V from an input which may range from about +7V to about +35V [32].

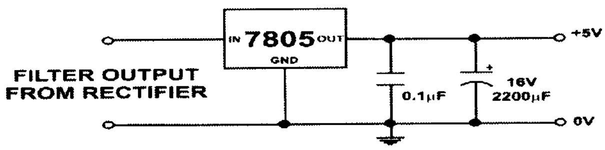

Fig 3.8: Connection diagram for the 7805.

The regulator takes the filtered output from the rectifier as input. The 5V DC output voltage is further stabilized by a 16v 2200μF capacitor and a 0.1μF high frequency noise filtering capacitor connected across the regulator as shown above (fig 3.8).

3.1.4.2 THE LM317T ADJUSTABLE VOLTAGE REGULATOR

The LM317T is an adjustable 3-terminal positive voltage regulator that is capable of supplying in excess of 1.5A over a wide (1.2V to 37V) output range. The regulator has no ground terminal, instead it adjusts volt to maintain a constant voltage (bridge gap) from the output terminal to the adjustment terminal [33].

The regulator is used in the design to provide an adjustable voltage of minimum value of 2V required to control the brightness of the seven segment displays. It is wired as shown below;

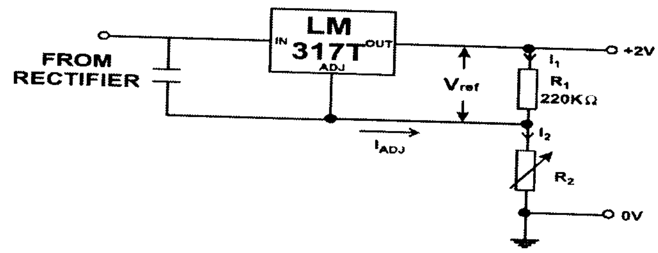

Fig 3.9 The Connection Diagram for LM317T Regulator

3.1.4.3 DESIGN CALCULATION

From the circuit of fig 3.9, voltage across the 220kΩ resistor is the reference voltage (V_{ref}) and a typical value of V_{ref} is 1.25V.

$$V_{out} = V_{REF} + \left(1 + \frac{R_2}{R_1}\right) + I_{ADJ} R_2 \tag{3.15}$$

Where

$I_{ADJ} = 50\mu A = 50\times10^{-6}A$ (Typical value).

$$V_{out} = 1.25 + \left(1 + \frac{R_2}{220}\right) + 50\times10^{-6} R_2$$

For a voltage ($V_{out} = 2V$) as required

$$2 = 1.25 + \left(1 + \frac{R_2}{220}\right) + 50\times10^{-6} R_2$$

Which gives $R_2 = 99.11k\Omega$

A 100kΩ variable resistor was used in design. The external capacitor (C = 2200μF) is used as an input by pass capacitor to eliminate the possibility of variations and improve the ripple rejection of the regulator.

3.2 THE OPERATOR INTERFACE UNIT

This unit comprises of four push-to-make switches. Each switch performs specified function as highlighted below.

- Switch 1: To increment the preset value
- Switch 2: To decrement the preset value
- Switch 3: This is the MODE select switch used to select the parameter – temperature count to be preset.
- Switch 4: To reset the system after every application

Switches 1, 2 and 3 are interfaced to port 3 switch 4 to the RESET pin of the microcontroller as shown below.

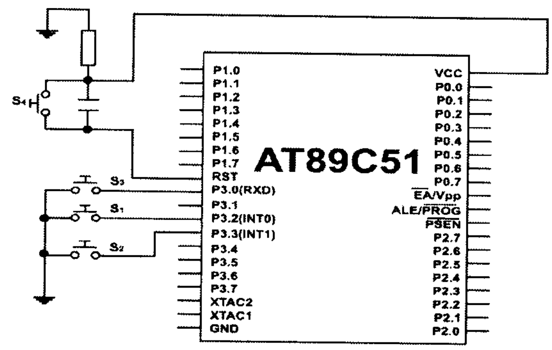

Fig 3.10 push buttons interfaced to port 3 and RST pin

3.3 MOTION DETECTOR UNIT

This unit comprises of two identical modules each consisting of an infrared transmitter and a receiver. The detector unit works on the principle of infrared transmission, reflection and detection. The modules use the infrared region of the electromagnetic spectrum to realize this objective.

An infrared beam generated by a 38kHz oscillator is projected from the module in the same direction as of the receiver. When no solid body moves across the front, the projected IR beam is not reflected back to the sensor but when a solid body passes across the transmitter and receiver, the IR beam is reflected back to the sensor. The sensor then triggers a monostable multivibrator that generates half a second pulse that is counted by the system controller.

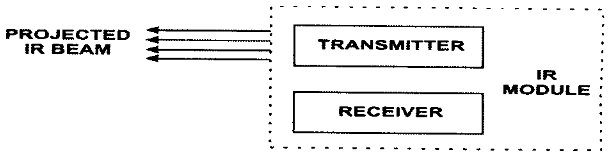

Fig: 3.11: Projected IR beam without reflection

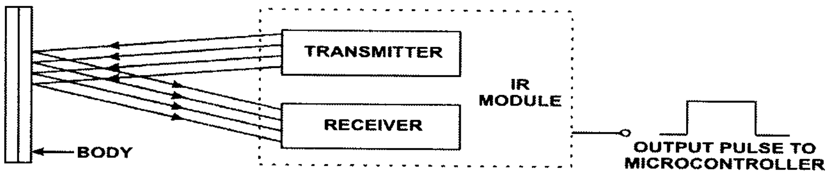

Fig 3.12 IR Beam reflected onto sensor.

3.3.1 THE IR TRANSMITTER

The infrared transmitter comprises of an infrared emitter (LED) wired as an astable oscillator around an NE555 timer integrated circuit. The transmitter in the modules is diagrammed below:

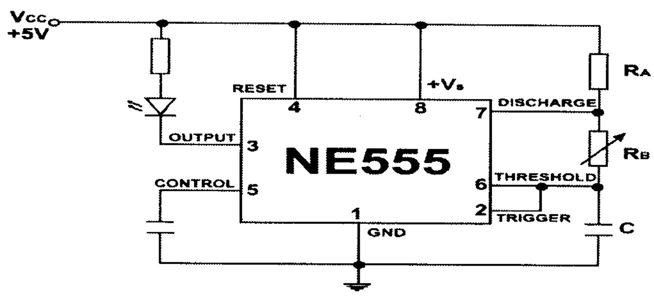

Fig 3.13: IR transmitter wired as an Astable multi vibrator

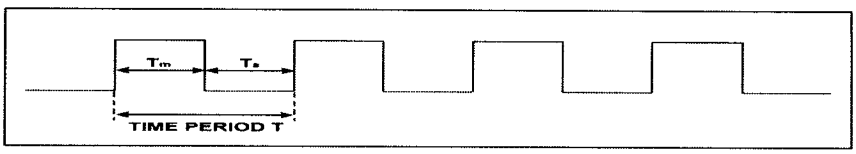

Fig 3.14 555 Astable output

An Astable circuit produces a square wave as shown above (fig 3.14) this is a digital waveform with sharp transitions between low (OV) and high (5V). The duration of the low and high states may be different. The circuit is called an astable because it is not stable in any state; the output continuously changes between low and high.

3.1.3.1 ASTABLE OPERATION.

With the output high (5V), the capacitor is charged by the current flowing through R_A and R_B. The threshold and trigger inputs monitor the capacitor voltage and when it reaches (2/3)V_s (threshold voltage), the output becomes low and the discharge pin now receives 0V.

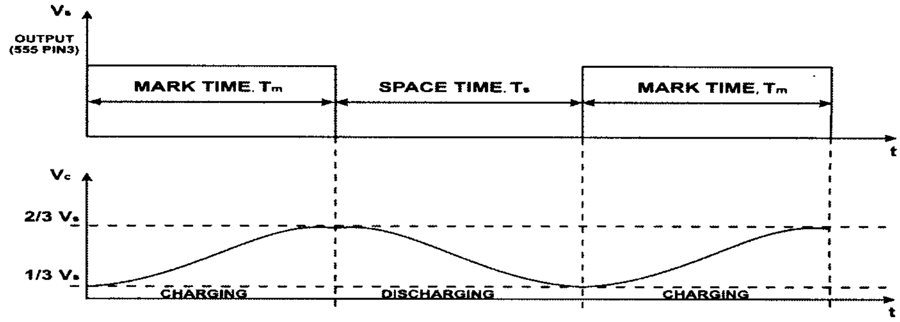

Fig 3.15 Output waveform of Astable 555 timer

The capacitor now discharges with current flowing through R_B into the discharge pin. When the voltage falls to (1/3)Vs (trigger voltage), the output becomes high again and the discharge pin is disconnected; allowing the capacitor to start charging again. This cycle repeats continuously unless the reset input is connected to 0V which forces the output low.

The generated frequency when operated as astable relaxation oscillator is obtained as follows:

The charging of capacitor C through R_A+R_B constitutes the mark time Tm

$$T_m = 0.693(R_A + R_B)C \tag{3.16}$$

The discharge of the capacitor through R_B gives the space time Ts.

$$T_s = 0.693 R_B C \tag{3.17}$$

And the time period T = Tm + Ts

$$T_m = 0.693(R_A + 2R_B)C \quad (3.18)$$

The frequency f = 1/T

$$f = \frac{1.443}{(R_A + 2R_B)C} \quad (3.19)$$

Where:

f = frequency in hertz (Hz)

R_A = resistance between Pin 7 and pin 8 in Ohms Ω

RB = resistance between pin 7 and pin 2 in ohms (Ω)

C = capacitance between pin 2 and pin 1 in farads (F) [34]

To generate a precise infrared frequency (38kHz) output R_B is made adjustable so that measuring with a frequency meter gives the required output.

With f = 38kHz = 38,000Hz, R_A = 1kΩ and C = 0.01μF, the value of R_B is determined using equation (3.21) thus:

$$f = \frac{1.443}{(1000 + 2R_B) \times 0.01 \times 10^{-6}}$$

$$R_B = 1398.68\Omega \approx 1.4k\Omega$$

A 10kΩ variable resistor was used in the design

The 38 kHz output from the Astable oscillator (555 pin3) drives an IR emitter via a 100Ω limiting resistor, producing a peak current of:

$$I = \frac{V}{R} = \frac{5 - 1.2}{100} = \frac{3.8}{100} \approx 0.038A$$

I = 38mA.

3.1.3.2 DUTY CYCLE

The duty cycle of an astable oscillator circuit is the proportion of the complete cycle for which the output is high. It is essentially the ratio of the mark time Tm to the time period T. Therefore,

$$D = \frac{T_m}{T} = \frac{T_m}{T_m + T_s}$$

$$D = \frac{0.693(R_A + R_B)C}{0.693(R_A + 2R_B)C} = \frac{(R_A + R_B)}{(R_A + 2R_B)} \quad (3.20)$$

Where D = duty cycle

For the 38kHz operation of the oscillator;

$R_A = 1000\Omega$, $R_B = 1398.68\Omega$

$$D = \frac{(1000 + 1398.68)}{(1000 + 2(1398.68))}$$

D = 0.6316

D = 63.16%

The duty cycle of the astable output is about 63% which shows that the output is high for about 63% of a cycle.

3.3.2 THE IR DETECTOR (RECIEVER)

The IR detector consists of a three pin commercially produced IR sensor (TS0P1738) connected to the trigger pin of an NE555 timer configured as a monostable multivibrator to generate approximately 0.5s pulses when triggered. The IR detector is diagramed below:

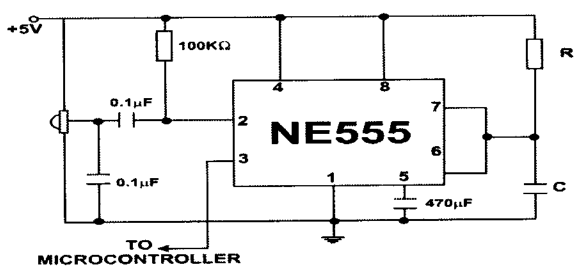

Fig 3.16: Infrared detector Unit.

The monostable generates an output when the voltage at pin 2 falls below 1/3Vs. However, the output remains HIGH indefinitely if pin2 is held low, returning HIGH after the termination of the timing cycle when pin 2 goes HIGH.

The input trigger is coupled into pin 2 of the NE555 via a 0.1μF capacitor. This generates a short voltage dip at pin 2 when the output of the sensor goes LOW.

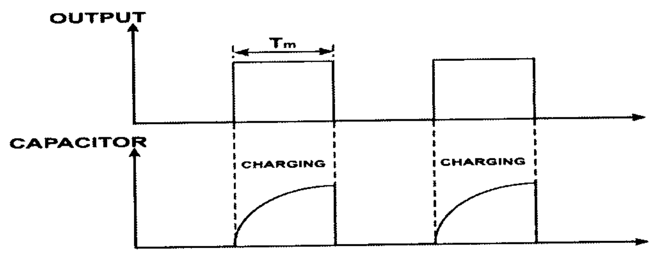

Fig 3.17 output waveform from monostable.

The output pulse width at pin 3 of the monostable multi vibrator is given by the expression:

$$T = 1.1RC \quad (3.21)$$

Where:

T = pulse width in second(s)

R = resistance between V_{cc}(pin 8) and pins (7,6) in ohms(Ω)

C = capacitance between pins (7,6) and ground in Farads (F)

3.3.2.1 DESIGN CALCULATION

For a selected pulse width of T (=0.5s) the value of C is calculated thus: from equation (3.21):

$$C = \frac{T}{1.1R} = \frac{0.5}{1.1 \times 10000} F = 4.54 \times 10^{-5} F$$

$$C = 45.4 \times \mu F$$

A standard capacitance value of 47μF was used in the design.

3.3.3 THE INFRARED (IR) SENSOR

The IR sensor is a 3-pin detector that responds to the 38kHz IR signal generated by the transmitter. The output (pin 1) of the sensor is HIGH in the absence of an IR signal but goes LOW when an IR signal is detected by the sensor. When the output goes low, one end of the 0.1μF capacitor is connected to ground pulling pin 2 (TRIGGER) of the monostable LOW. This triggers the monostable to generate a pulse with 0.5s width at its output pin (pin 3). This pulse is detected at the controller input pins to keep track of the inflow and out flow.

One IR modules (Transceiver) is interfaced with the controllers in a manner as to increment the inflow counts and the other module decrements the inflow counts. The differential count (i.e. Entrance minus Exit) is maintained in RAM by the system controller.

3.4 TEMPERATURE MONITORING UNIT.

The temperature monitoring unit is designed around the popular LM35 integrated circuit temperature sensor which is interfaced to the microcontroller via an analogue to digital converter (ADC0804).

3.4.1 LM35 TEMPERATURE SENSOR.

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output that is proportional to the temperature. It is used in this device for temperature monitoring. The sensor has a temperature-voltage relationship of 1°C-10 mV. It operates with a temperature range of 0-100°C. The device is supplied with a positive 5-voltage DC and the output covers a range of 0-100mV in accordance with the scale factor [34]. The sensor is connected to an analogue to digital convert (ADC0804) for interface with the system controller.

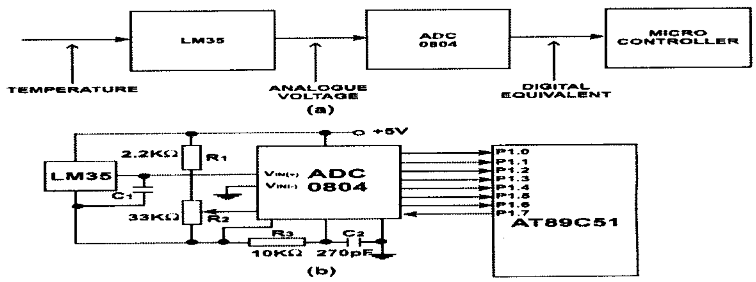

Fig 3.18 LM35 interfaced to port 1 of system controller Via ADC 0804

(a) Block Diagram (b) Circuit Diagram.

The external capacitor (C_1 = 22μF) across the output of the sensor is used to prevent possible fluctuations of the output voltage which may occur due to distance between the sensor and the analogue to digital converter.

3.4.2 THE ANALOGUE-TO-DIGITAL CONVERTER (ADC0804)

The ADC0804 is a CMOS 8 – bit successive approximation analogue to digital converter using a resistive ladder and capacitive array together with an auto–zero comparator. The converter operates with microprocessor controlled buses using a minimum of external circuitry. The tri-state output data lines can be connected directly to the data bus. The differential analog voltage input allows for increased common mode rejection and provides a means to adjust the zero-scale offset. It is a 20-pin device and the pin configuration is shown below.

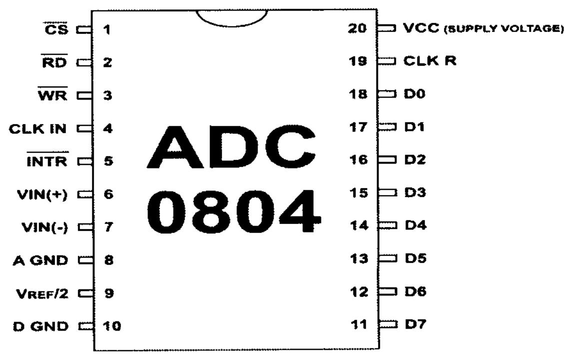

Fig 3.19: Pin configuration of ADC0804

3.4.2.1 FUNCTIONAL DESCRIPTION

This device operates on the successive approximation principle. Analogue switches are closed sequentially by successive approximation logic until the input to the auto-zero capacitor $\lfloor V_{IN(+)} - V_{IN(-)} \rfloor$ matches the voltage from the decoder. After all bits are tested and determined, the 8-bit binary code corresponding to the input voltage is transferred to an output latch. Conversion begins with the arrival of a pulse at the $\overline{WR}$ input if the CS input is LOW. On the HIGH-to-LOW input transition of the signal at the

$\overline{WR}$ or the CS input, the SAR is initialized, the shift register is reset and the $\overline{\text{INTR}}$ output is set HIGH. The device will remain in the reset state as long as the $\overline{CS}$ and $\overline{WR}$ inputs remain LOW. Conversion will start from one to eight clock periods after one or both of these inputs makes a LOW-to-HIGH transition. After the conversion is complete, the $\overline{\text{INTR}}$ pin will make a HIGH-to-LOW transition. This can be used to interrupt a processor [35].

3.4.2.4 DESIGN APPLICATION AND CALCULATIONS

The converter is wired to operate in the ratiometric mode with R_2 (=5kΩ) producing optional full scale adjustment. Resistor R_3 and capacitor C_2 constitute the RC combination that sets the clock frequency (100 kHz to 1.46MHz) of the converter.

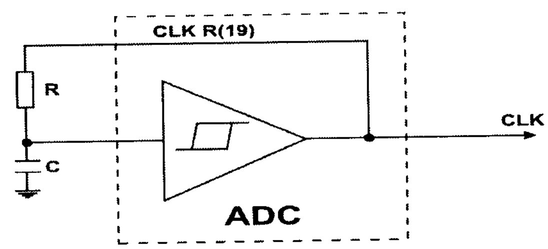

Fig. 3.20 Self clocking of ADC0804

The frequency of conversion is given by the expression:

$$F = \frac{1}{1.1RC} \tag{3.22}$$

Where:

F = clock frequency in Hertz (Hz)

R = resistance in ohms (Ω)

C = capacitance in Farads (F)

With R = 10kΩ and C = 100pF as used in the design.

$$F = \frac{1}{1.1 \times 10000 \times 100 \times 10^{-12}} = 9.09 \times 10^{5}\, kHz$$

F = 909 kHz.

3.5 THE SYSTEM CONTROLLER

The system controller is an Atmel AT89C51 8-bit microcontroller with 4Kbytes of flash programmable and erasable read only memory (PEROM), 128bytes of RAM, 32 input/output lines, two 16-bit timers/counter, a five vector two-level interrupt architecture, a full duplex serial port and an on-chip oscillator and clock circuitry. The device is designed with static logic for operations down to zero frequency and support two software selectable power saving modes. The idle mode stops the CPU while allowing RAM, timers/counters, serial port and interrupt to continue functioning. The power down mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

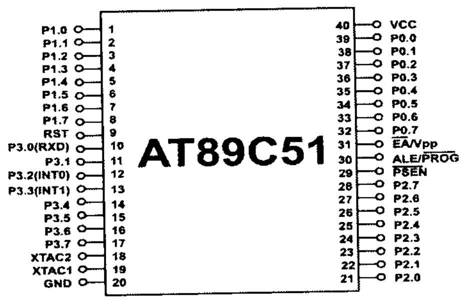

Fig 3.21 Pin Configuration of AT89C51

3.5.1 OSCILLATOR CHARACTERISTICS

XTAL1 and XTAL2 are the input and output of an inventing amplifier which can be configured for use as an on – chip oscillator as show in fig 3.22. Either a quartz crystal or ceramic resonator may be used. Those are no requirements to the duty cycle of the external clock signal. Since the input to the internal clocking circuitry is through a divide-by-two flip-flop.

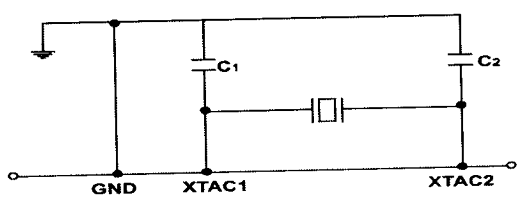

Fig 3.22: Oscillator connection for the AT89C51 Microcontroller.

3.5.2 PROGRAMMING THE AT89C51

The programming interface of the microcontroller accepts either a high – voltage (12-volt) or a low voltage (V_{cc}) program enable signal. The low voltage programming mode produces a convenient way to program the chip inside the user's system, while the high – voltage programming mode is compatible with conventional third party flash or EPROM programmers [36].

3.5.3 CONFIGURATION OF THE CONTROLLER.

The microcontroller is configured in the minimum memory mode. That is, no external memory device is connected to it. It controls the visual display unit, the 8-bit analogue-to-digital converter, the audible and visual indicator and accepts user inputs through the connected push-to-make switches. The controllers execute the program routine directing the functionality of the system.

Basically, the microcontroller at power up initializes the systems RAM variables and input/output ports alongside the special function registers (SFRs) that define the functionality of the entire system.

Two interrupt pins and two timer input pins on the controller provide an external input interface to the system. Two switches (INCREMENT and DECREMENT on P3.2 and P3.3) provide the user, a real–time access to the controller program extension. A third switch; the mode select switch allows the user to preset the inflow value or the maximum temperature expected in the monitored space, the presetting is done using either the INCREMENT (+) OR DECREMENT (-) switches to alter the associated variable.

The two timer inputs on P3.4 and P3.5 enables monitoring of external events via the timer overflow flags that are software configured to generate interrupts when set. The timers: one for exit and the other for entrance detection are loaded with FFFF Hex and their overflow flags cleared. When motion is detected (entrance or exit), the associated timer is incremented, rolling over to 0000 Hex. This sets the overflow flag and interrupts the controller which jumps to the interrupt service routine associated with the particular timer.

In the interrupt service routine (ISR), the variable is tested for maximum or minimum and logical operations are executed. If an entrance in motion is detected the inflow variable is incremented and if it is an exit motion the inflow is decremented, before either the increment or decrement operation, the variable is tested for a zero (0), or FF Hex (256). The differential count is then displayed on the multiplexed visual display unit.

3.5.4 SOFTWARE DEVELOPMENT.

The software for the system is written in assembly language utilizing the input/output ports of the microcontroller for interface with hardware for input and output purposes. The functionality of the system and the necessary conditions to be implemented were first used to develop a pseudo code and flowchart in order to ease the development of the assembly codes.

The flowchart was then transformed into the assembly code (see appendix I) which was burnt into microcontrollers using an EPROM programmer and a prog-studio 6.0 assembler.

3.5.4.1 THE PSEUDOCODE

A pseudo code is a step by step representation of the procedures involved in solving a particular problem. It is an essential tool in the development of a computer program. The pseudo code which was developed for this project is as shown in Appendix III.

3.5.4.2 THE FLOWCHART

The symbolic representation for the program to be developed is subdivided into two viz: the main flowchart and the flowchart for the interrupt service routine (see Appendix II)

3.6 VISUAL DISPLAY UNIT

The visual display unit comprises of four common anode seven-segment light emitting diode (LED) displays wired in multiplexed mode. The display is individually controlled by a anode driver from the controller.

In the multiplex mode all digits to be multiplexed are connected in parallel. Displaying a digit on any desired digit position demands switching off all other digits, writing the seven–segment code for the digit to the common data port turning on the associated digit anode driver, waiting a while for persistence, and then switching off the digit's anode driver. The display is referenced periodically at about 50Hz to prevent display fluctuations.

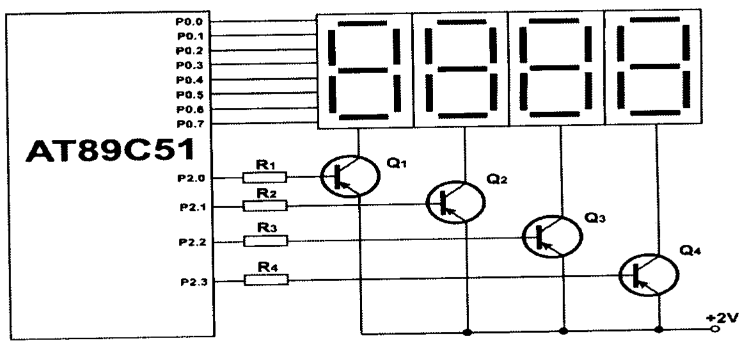

Fig 3.23 Multiplexed display interfaced with the microcontrollers

3.6.1 THE 2SA105GR TRANSISTOR

The 2SA105GR transistor is a PNP silicon planner transistor designed for audio frequency general purpose amplifier applications and drivers state amplifier applications [37]. The transistor is used as an anode driver to switch ON and OFF the approximate

LED display or combination of displays depending on which of the displays (connected to pins 2.0, 2.1, 2.2 and 2.3 of the controllers) is activate in software.

The transistor has a gain (H_{FE}) of 200 to 400 when collector current (I_C) is 2mA and collector – emitter voltage (V_{CE}) is 6V [37].

3.7 OVERFLOW/OVERTEMPERATURE VISUAL INDICATOR UNIT

The visual indicator unit comprises of two coloured light emitting diode (LED) device connected in such a manner that they are switched ON and OFF by the system controller in accordance with the logical output of the comparison between he preset temperature value and inflow value and the values obtained from temperature measurement and differential count respectively. The LED is wired to the controller as shown below.

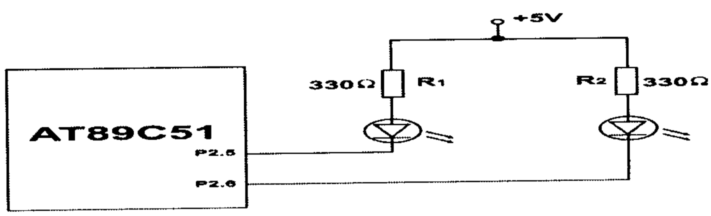

Fig 3.24 Visual indicator interfaced with controllers

3.7.1 DESIGN CALCULATION

From the circuit above (fig 3.20) the supply voltage V_{cc} = 5V

The diode voltage drop V_D = 0.7V

V_{cc} is the voltage biasing the two LEDs

Applying Kirchoff's voltage law (KVL) to fig. (3.24)

$$V_{CC} - IR_A - V_D = 0$$

$$I = \frac{V_{CC} - V_D}{R_A} \tag{3.23}$$

Where:

I = current flowing through either of the two LEDs

$R_A = R_B$ = limiting resistance that limits current flow to the LEDs to safe value.

Since each pin of the AT89C51 microcontroller can sink or source a current in the range of 10-20mA with a typical value of about 15mA.

Using equation (3.23), the value of the limiting resistance is obtained as:

$$I = \frac{V_{CC} - V_D}{R_A}$$

$$15 \times 10^{-3} = \frac{5 - 0.7}{R_A}$$

$$R_A = \frac{5 - 0.7}{15 \times 10^{-3}} = 286.66\Omega$$

$$R_A \approx 287\Omega$$

A standard value of 330Ω was used in the design.

3.7.2 LOGICAL CONDITIONS

The logical condition implemented by the system controller which affects the switching ON/OFF of the visual indicator are:

If temperature value < preset temperature value

Over temperature LED = OFF

Else

Over temperature LED = ON

and

If inflow value < Preset Inflow value

Overfull LED = OFF

Else

Overfull LED = ON.

3.8 ALARM/AUDIBLE INDICATOR UNIT.

The audible indicator unit consists of a piezoelectric buzzer used as an audio sounder. The buzzer is connected to P2.4 and is driven by pulses appearing on the port pin whenever any of the error conditions occur. The sounder is connected directly to the system controller as shown below:

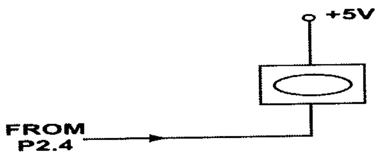

Fig 3.25 Piezoelectric sounder connected to P2.4

The occurrence of any of the error conditions causes the system controller to send out a pulses through P2.4 which activates the piezoelectric sounder and an audible sound is produced which alerts the appropriate operator to carry out a specified action: close the door(s) to prevent further entrance or switch ON cooling systems (e.g. Fans, AC etc) to reduce the temperature of the controlled area.

3.9 THE COMPLETE CIRCUIT DIAGRAM

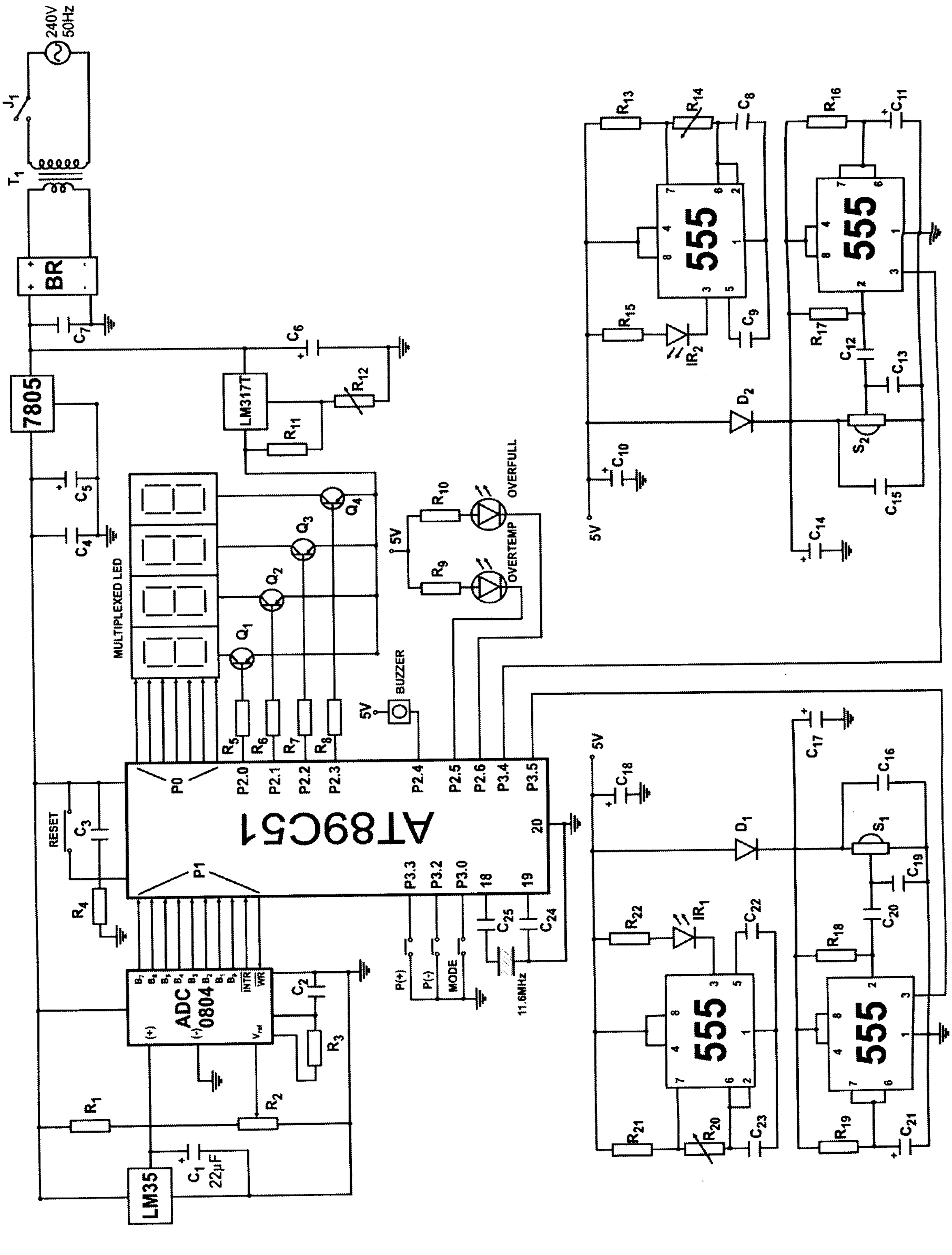

Fig. 3.26 Main circuit diagram

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

This project is constructed in four parts (or sub circuits), the *main* circuit (which comprises of the power supply unit, analogue to digital converter, system controller and multiplexed displayed), the entrance infrared transceiver, the exit transceiver and the temperature sensor. The construction and testing of the four units and entire system was carried out following the same broad principles of electronic circuit construction and troubleshooting.

4.1 CONSTRUCTION OF THE CIRCUIT

At the end of the design stage, simulation of the subsystem was carried out using electronic workbench. The main subsystem comprising of the microcontroller was not simulated because the electronic workbench used has no provision for microcontrollers in its component data base.

A prototype of the four subsystems was constructed on a temporary circuit board (the bread board). This was done to ensure that the designed circuit worked according to the design specifications before final construction of the circuit. This step was taken because it is easier to make modification and adjustments to design where necessary on the temporary circuit board than it is on the permanent circuit board (Vero board)

Before transferring the designed circuit from the breadboard to the Vero board, a sketch of the corresponding Vero board layout was made. This was done to ensure that while transferring component to the Vero board, mistakes would not be made regarding the placement of the circuit components. In transferring the circuits to the Vero boards, a unit by unit construction approach was adopted

The Vero board is electrically continuous horizontally but certain component connections were made vertically. This necessitates the use of connecting wires to ensure vertical continuity and where the wires were used, it was ensured that they were neatly placed and soldered. Integrated circuits (ICs) are heat sensitive devices and as such IC sockets were first soldered onto the Vero board and the ICs and microcontroller plugged into the sockets. This was done to prevent damage of the ICs that might result from overheating if they were directly soldered. Bridging of the conducting lines were avoided during soldering in order to prevent short circuit faults which may damage components

4.2 TOOLS AND INSTRUMENTS

The tools and instruments which were used during the construction of the project work include

(i) Bread board	(ii) Frequency meter	(iii) Lead sucker
(iv) Vero board	(v) Multimeter	(vi) Soldering iron
(vii) Alloy (soldering)	(viii) Circuit component	(ix) connecting wire

4.3 TESTING OF THE CONSTRUCTED CIRCUITS

Since a unit by unit approach was used in the construction, each of the four functional subsystems were tested after construction to ensure that it operate correctly before the succeeding units were constructed and tested.

Upon completion of construction, the subsystems were put together and a functional test was carried out on the system. Where undesirable responses were obtained, troubleshooting was carried out and the faulty components were replaced where necessary until satisfactory performance was obtained.

4.4 RESULTS AND DISCUSSION

The results obtained from the tests on each of the subsystem (or units) are summarized in the table below. The steps taken to detect and rectify faults where the values obtained deviates from expected values are also discussed.

Table 4.1: Results Obtained From Subsystems Tests.

UNIT/SUBSYSTEM	PARAMETER MEASURED	UNIT	VALUE OBTAINED	EXPECTED VALUE	REMARK
POWER SUPPLY UNIT	OUTPUT VOLTAGE	V	4.95	5.00	FUNCTIONAL
ENTRANCE IR DETECTOR	FREQUENCY	kHz	38.80	38.00	FUNCTIONAL
ENTRANCE INFRARED TRANSMITTER	OUTPUT VOLTAGE	V	4.80	5.00	FUNCTIONAL
ENTRANCE IR DETECTOR	PULSE WIDTH	S	0.45	0.50	FUNCTIONAL
EXIT IR DETECTOR	FREQUENCY	kHz	40.00	38.00	FUNCTIONAL
TEMPERATURE SENSOR	OUTPUT VOLTAGE AT ROOM TEMP.	mV	245	250	FUNCTIONAL

4.4.1 OVERALL SYSTEM TEST

After each module have been tested and confirmed functional as shown in table 4.1, the units were coupled together and a functionality test was carried out to see if the system will perform the desired goals. The test was carried out following the sequence highlighted below

- Connect the system to power source and put the power switch ON.
- Preset the maximum count (inflow) and maximum temperature value.
- Move a solid object through the front of each of the motion detector units and observe the displayed count
- Repeat the 3rd step until the maximum preset counts is attained.
- Place a hot object (e.g. a filament bulb that has been ON for a while) close to the LM35 temperature sensor and observe the system behavior.

During the system test, the following malfunctionalities were observed

I. The first digit that is meant to display P (P for preset) has one of the light emitting Diodes (LEDs) burnt and could not displayed the letter correctly.

II. Time delay between instant when a solid body passes the motion detector and the time a change is effected in the display count was longer than the desired and

III. The exit motion detector failed to generate pulses to the system controlled when solid body was passed through it.

4.4.2 TROUBLESHOOTING

The causes of the undesired performance of the electronic counting and temperature monitoring system were traced and the following steps were taken to rectify the faults:

- A solution to the faulty seven segment display with a segment burnt out was to replace the display with a new one but because of the multiplexing replacing the faulty LED display may damage the other displays. An alternative solution which was used was changing the letter to be displayed from P (for preset) to S (for set) which do not require the burnt segment of the display. This was done by changing the data bit to the display from 10001100 to 10010010 in software.
- The time delay was adjusted in software and the response of the system to pulse from the motion detector units improved and
- The circuit for the exit motion detector unit was checked and found complete. The passive infrared sensor was found faulty and subsequently replaced by a new one. The subsystems were then put together and final test was carried out.

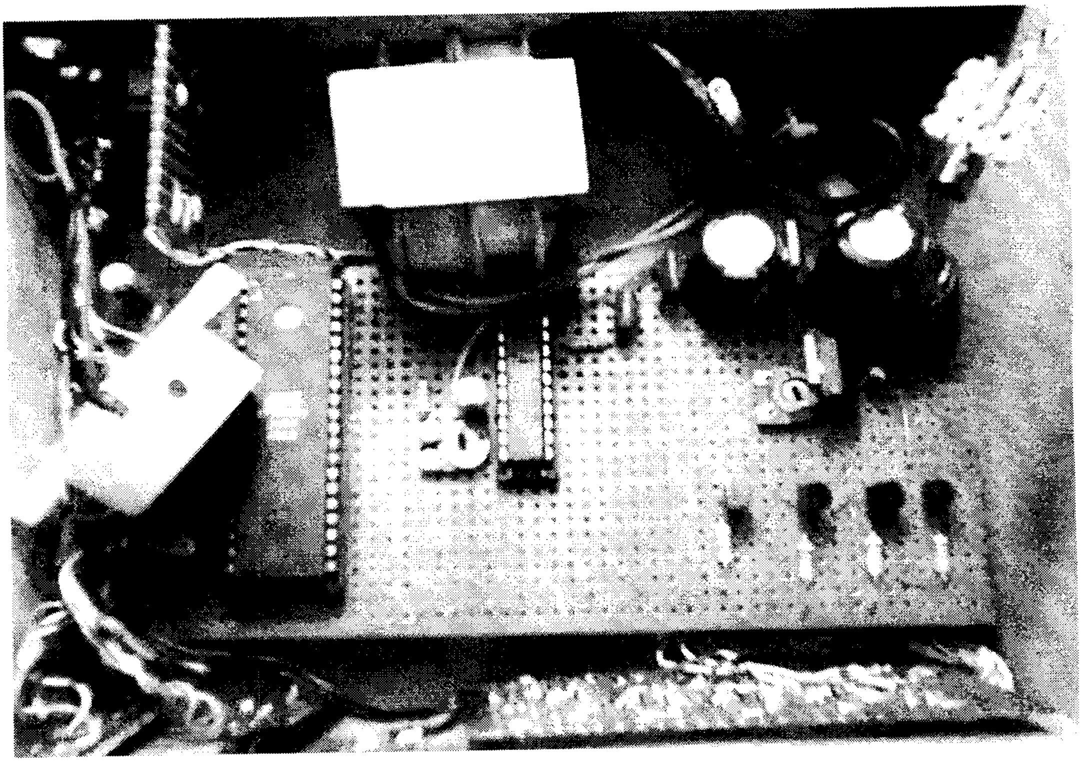

Fig 4.1 Layout of the Main circuit board.

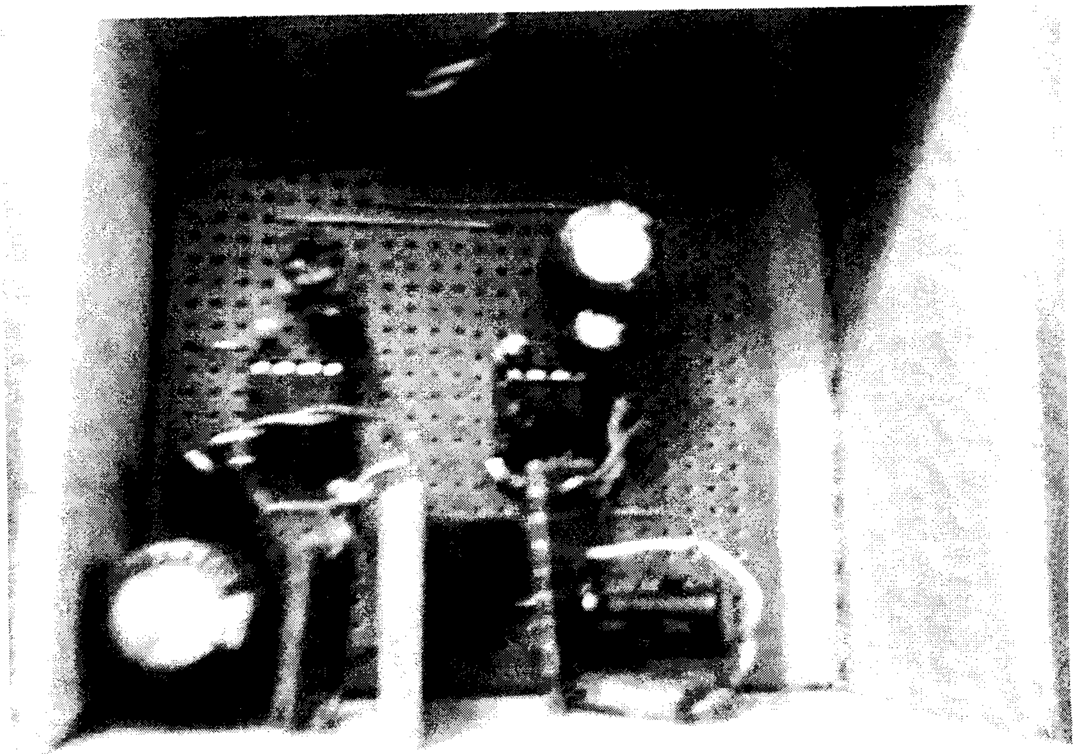

Fig 4.2 Layout of the IR module

CHAPTER FIVE

CONCLUSION

5.1 SUMMARY

The project work is designed and implemented on microcontroller based electronic counting system with temperature monitor for capacity maintenance and temperature monitoring in buildings such as banks, theater, stadium and so on. During testing, it was found that a solid body passing through the motion detector unit reflects the IR signal back to the sensor which either increments or decrements the differential count. The sounder was also trigger when the maximum preset count or temperature was attained.

The results obtained from the tests indicated that the model of the counting system will perform its desired functions with a maximum count of 255 and a maximum temperature of 64^0C.

5.2 PROBLEMS ENCOUNTERED.

While carrying out this project work, several constraints were encountered. Amongst these difficulties encountered are:

- The difficulty encountered sourcing for components especially the integrated circuits and microcontroller,
- Lack of prior knowledge on assembly language programming and the need to develop the software for the application using the language.
- Irregular power supply and
- Wastage of resources, time and energy resulting from damage of some components during soldering.

5.3 RECOMMENDATION

A lot thought and reasoning has been masterly put together to realize this prototype project. I recommend that there should be a stronger link between the theories taught and practical carried out in the department. This is because from my personal experience while carrying out this project work, the design and implementation of a circuit is a complex undertaking that requires an in depth understanding of a wide range of components.

Further improvement can be made in the design by increasing the maximum differential count and prevent possible occurrence of error in counting due to multiple passage. I therefore recommend that the following steps be taken to improve on the design

- A model building be constructed and the microcontroller pin driving the buzzer be connected to a relay to automatically close the doors (entrance and exit) whenever any of the error conditions occur.
- The over temperature condition be used to switch ON/OFF an appropriate cooling system automatically by driving a relay connected to the cooling system using the pin to the over temperature LED indicator.
- The maximum count can be increased by using a register with higher number of bits. The project utilizes an 8 bit register for the count and can handle up to 2^8 (256) counts from 00000000 to 11111111 (255). With a 16 bit register for instance, a total possible differential count of 65535 is possible.
- An appropriate measure be taken to control multiple entry/exit which will results in an incorrect differential count, possible ways of achieving this includes:

i. An order should be given that no two individuals enters or leaves the controlled area at the same time. Strict compliance with this should be ensured.

ii. Doors (Entrance/Exit) leading to the controlled area where the device is to be used be constructed to allow a single passage at a time or

iii. The door should be partitioned and separate motion detectors units be built to monitor passage through each partition.

iv. An alternative power supply using a 9v DC battery be adopted for the design.

5.4 CONCLUSION

Hitting ones target can be gratifying and meeting ones aim and objective can be fulfilling. With this project 'Design and Construction of Electronic Counting and Temperature Monitoring system' which was successfully designed and constructed, counting could be carried out up to a maximum capacity of two hundred and fifty five (255) and the temperature can be maintained at any suitable value between 0 and 64^{o}c. The piezoelectric sounder is used to alert any operator to take an appropriate step whenever any of the error conditions (controlled area overfilled or there is over temperature) occur.

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APPENDIX I

COMPLETE ASSEMBLY CODE FOR THE ELECTRONIC COUNTING SYSTEM WITH TEMPERATURE MONITOR

```
INCLUDE 89c51.mc
adc_port EQU p0
display_port EQU p2
digit_1_dx BIT p1.0
digit_2_dx BIT p1.1
digit_3_dx BIT p1.2
digit_4_dx BIT p1.3
overtemp_led BIT p3.7
overfull_led BIT p3.6
alarm_out BIT p1.4
mode_select BIT p3.0
preset_plus_key BIT p3.3
preset_minus_key BIT p3.2
adc_write BIT p3.1
temp_Value DATA 08h
digit_1 DATA 09h
digit_2 DATA 0ah
digit_3 DATA 0bh
digit_4 DATA 0ch
data_2_convert DATA 0dh
inflow_value DATA 0eh
preset_temp_Value DATA 0fh
preset_inflow_value DATA 10h
update_inflow BIT 20h
overtemp_flag BIT 21h
overfull_flag BIT 22h
p_bit_pattern EQU  13
c_bit_pattern EQU      10
t_bit_pattern EQU  11
blank_digit EQU 12
stack EQU 40h

;p3.2 (INT0) connected to minus input key
;p3.3 (INT1) connected to plus input key
;p3.4 (T0) connected to entrance sensor
;p3.5 (T1) connected to exit sensor

org 0000h
AJMP start_up

org 0003h
AJMP preset_minus

org 000bh
AJMP entrance_cnt

org 0013h
```

```
AJMP preset_plus

org 001bh
AJMP exit_cnt


org 0030h
start_up:       MOV sp, #stack                 ; init stack
                MOV tmod,#01010101b            ; configure time 0, 1 for mode 2
                MOV ip,#0                      ; equal priority level
                MOV tcon,#00000000b            ; interrupt on low edge
                SETB update_inflow  ; force system update
                SETB alarm_out                 ; switch off alarm output
                SETB mode_Select               ;
                MOV adc_port,#0ffh ;
                SETB digit_1_dx                ; turn off all anode drivers
                SETB digit_2_Dx
                SETB digit_3_Dx
                SETB digit_4_Dx
                SETB overtemp_led              ; switch off leds
                SETB overfull_led
                SETB preset_minus_key
                SETB preset_plus_key
                MOV inflow_value,#0            ; initial count of zero
                MOV preset_Temp_Value,#40          ; default preset temperature value
                MOV preset_inflow_value,#100       ; default max inflow value
                MOV th0,#255                   ; set up timers
                MOV tl0,#255
                MOV th1,#255
                MOV tl1,#255
                CLR overfull_flag              ;
                CLR overtemp_flag              ;
                MOV ie, #00001111b ; enable interrupts
                MOV DPTR,#xlate_table          ;
                CLR tf0                        ; clear previous flags on timers
                CLR tf1
                SETB tr0                       ; turn on timers
                SETB tr1
                NOP
                NOP
                NOP
                CLR tf0                        ; clear flags again
                CLR tf1
                SETB ea                        ; enable global interrupt

main:           JNB update_inflow, skip_x   ; skip if no system update
                CLR update_inflow                  ; clear update flag
                MOV data_2_convert, inflow_value  ;convert inflow value to BCD
                ACALL convert_2_bcd
                MOV digit_1,#blank_digit    ; blank first digit
```

```
                ACALL long_delay
                ACALL compare_inflow_preset        ; compare inflow value with preset
value
                JNB overfull_flag, skip_x    ; skip if not equal
                CLR overfull_flag                  ; clear flag
                MOV digit_1,#P_bit_pattern ;show SET digit
                ACALL generate_alarm               ; sound warning
skip_x:ACALL long_Delay
                ACALL convert_temp                 ; get temperature
                ACALL compare_temp_preset          ; compare with preset
                JNB overtemp_flag, main            ; skip if not equal or above
                CLR overtemp_flag            ; clear flag
                MOV data_2_convert, temp_value; convert temperature to BCD
                ACALL convert_2_bcd
                MOV digit_1,#p_bit_pattern
                MOV digit_2,digit_3
                MOV digit_3,digit_4
                MOV digit_4,#c_bit_pattern
                ACALL write_display          ; show temperature value
                ACALL generate_alarm         ; sound warning
                SETB update_inflow           ; set up for system update
                SJMP main              ; loop

generate_alarm:       CLR alarm_out                ; make alarm out low
                      MOV R5,#10
generate_lp:    ACALL write_display                ; refresh display in loop
                      ACALL write_display
                      ACALL write_display
                      ACALL write_display
                      SETB alarm_out               ; amke alarm out high
                      ACALL write_display
                      DJNZ R5, generate_lp               ; repeat for a note
                      RET

compare_inflow_preset:       MOV A, inflow_value         ; load inflow value
                             CJNE A, preset_inflow_value, chk_2; compare with preset
skip_back:                   SETB overfull_flag   ; set flag if equal
                             CLR overfull_led     ; turn on LED indicator
                             RET            ; get back
chk_2:                  JNC skip_Back       ; repeat above if greater than preset
                             CLR overfull_flag    ;
                             SETB overfull_led    ; turn off LED
                             RET            ; get back

compare_temp_preset:         MOV A,temp_value; load t emperature value
                             CJNE A, preset_Temp_value, chk_3 ; compare with preset
temperature value
skip_Back_2:            SETB overtemp_flag  ; set up flag
```

```
                CLR overtemp_led            ; turn on LED
                RET             ; get back
chk_3:          JNC skip_Back_2     ; do same if greater than preset
                SETB overtemp_led   ; turn off LED
                CLR overtemp_flag           ; clear flag
                RET


; 0,1,2,3,4,5,6,7,8,9,C,t,blank, p
; bit patterns corresponding to displayed digits
xlate_Table:    DB
11000000b,11111001b,10100100b,10110000b,10011001b,10010010b,10000010b,11111
000b,10000000b,10010000b,01000110b,10000111b,11111111b,10010010b
; 10001100b

convert_2_bcd:      MOV A, data_2_convert       ; load data to be converted
                    MOV B, #100         ;
                    DIV ab          ; get hundreds
                    MOV digit_2, A          ; store here
                    MOV A, B            ; load remainder
                    MOV B,#10           ;
                    DIV ab          ; get tens
                    MOV digit_3, A          ; store here
                    MOV digit_4, B          ; store units here
                    RET             ; get back

write_display: MOV A, digit_1           ; load BCD for hudreds
                MOVC A, @a+dptr     ; convert to 7-seg code
                MOV display_port,A  ;send to display
                CLR digit_1_dx              ; turn on digit 1 anode driver
                ACALL delay_2_show                      ; delay for persistence
                SETB digit_1_dx         ; turn off anode driver
                MOV A,digit_2           ; repeat for other digits
                MOVC A, @a+dptr
                CLR digit_2_dx
                MOV display_port,A
                ACALL delay_2_show
                SETB digit_2_dx
                MOV A, digit_3
                MOVC A,@a+dptr
                CLR digit_3_dx
                MOV display_port, A
                ACALL delay_2_Show
                SETB digit_3_dx
                MOV A, digit_4
                MOVC A, @a+dptr
                CLR digit_4_dx
                MOV display_port, A
                ACALL delay_2_Show
                SETB digit_4_dx
                RET
```

```
convert_temp: CLR adc_write          ; pulse adc write pin low
              NOP
              NOP
              SETB adc_Write         ; pulse to high
              ACALL write_display           ; refresh display
              MOV temp_Value, adc_port  ; load temperature value
              ACALL write_display                ; refresh display
              RET

preset_plus:   JB preset_plus_key, exit        ; prevent false key
               PUSH 00h       ; save all working registers
               PUSH 01h
               PUSH 02h
               PUSH 03h
               PUSH 04h
               PUSH 05h
               PUSH 06h
               PUSH 07h
               PUSH acc
               PUSH B
               PUSH digit_1
               PUSH digit_2
               PUSH digit_3
               PUSH digit_4
               PUSH psw
               PUSH data_2_convert
               JNB mode_select, preset_temperature_plus   ; skip if mode key

held down

preset_inflow_plus:MOV data_2_convert, preset_inflow_value        ; show present value
of preset inflow value
                 ACALL convert_2_bcd                 ; convert to BCd so we can

display
                 MOV digit_1,#p_bit_pattern ; write the SET digit
                 ACALL long_Delay                    ; slow down before next

increment
                 ACALL long_delay                    ; write display also
                 ACALL long_Delay
                 MOV A,preset_inflow_value           ; check if we reached

maximum 8-bit value
                 XRL A, #255
                 JZ fall_out     ; skip if we have
                 INC preset_inflow_value       ; else increment preset inflow value
                 MOV data_2_convert, preset_inflow_value
                 ACALL convert_2_bcd           ; convert new preset to BCd
                 MOV digit_1, #p_bit_pattern
                 ACALL long_Delay  ; write display
                 ACALL long_Delay
```

```
                  ACALL long_Delay
fall_out:         POP data_2_convert   ; restore all working registers
                  POP psw
                  POP digit_4
                  POP digit_3
                  POP digit_2
                  POP digit_1
                  POP B
                  POP acc
                  POP 07h
                  POP 06h
                  POP 05h
                  POP 04h
                  POP 03h
                  POP 02h
                  POP 01h
                  POP 00h
exit:             RETI   ; exit interrupt routine

preset_temperature_plus:MOV data_2_convert, preset_temp_Value
                        ACALL convert_2_bcd        ;convert preset temp value to
BCd and display
                        MOV digit_1,#p_bit_pattern
                        MOV digit_2, digit_3
                        MOV digit_3, digit_4
                        MOV digit_4, #c_bit_pattern
                        ACALL long_Delay
                        ACALL long_Delay
                        ACALL long_Delay
                        MOV A, preset_Temp_value; load preset temp value
                        XRL A, #64             ; equal to 100?
                        JZ fall_out            ; yes, fall out
                        INC preset_Temp_value       ; else increment preset
temperature value
                        MOV data_2_convert, preset_Temp_Value  ; show new
preset value
                        ACALL convert_2_bcd
                        MOV digit_1, #p_bit_pattern
                        MOV digit_2, digit_3
                        MOV digit_3, digit_4
                        MOV digit_4,#c_bit_pattern
                        ACALL long_Delay
                        ACALL long_delay
                        ACALL long_Delay
                        SJMP fall_out


preset_minus: JB preset_minus_key, exit_2  ; prevent false key input
```

```
                PUSH 00h            ; save all working registers
                PUSH 01h
                PUSH 02h
                PUSH 03h
                PUSH 04h
                PUSH 05h
                PUSH 06h
                PUSH 07h
                PUSH acc
                PUSH B
                PUSH digit_1
                PUSH digit_2
                PUSH digit_3
                PUSH digit_4
                PUSH psw
                PUSH data_2_convert
                JNB mode_select, preset_temperature_minus

preset_inflow_minus:MOV data_2_convert, preset_inflow_value
                ACALL convert_2_bcd
                MOV digit_1,#p_bit_pattern
                ACALL long_Delay
                ACALL long_Delay
                ACALL long_delay
                MOV A,preset_inflow_value
                JZ fall_out_2
                DEC preset_inflow_value
                MOV data_2_convert, preset_inflow_value
                ACALL convert_2_bcd
                MOV digit_1, #p_bit_pattern
                ACALL long_Delay
                ACALL long_Delay
                ACALL long_Delay

fall_out_2:     POP data_2_convert
                POP psw
                POP digit_4
                POP digit_3
                POP digit_2
                POP digit_1
                POP B
                POP acc
                POP 07h
                POP 06h
                POP 05h
                POP 04h
                POP 03h
                POP 02h
                POP 01h
                POP 00h
```

```
exit_2:         RETI

preset_temperature_minus:
                MOV data_2_convert, preset_temp_Value ; load preset
temperature value
                ACALL convert_2_bcd             ; write to display
                MOV digit_1,#p_bit_pattern
                MOV digit_2, digit_3
                MOV digit_3, digit_4
                MOV digit_4, #c_bit_pattern
                ACALL long_Delay
                ACALL long_delay
                ACALL long_Delay
                MOV A, preset_Temp_value; load preset value and test for
zero
                JZ fall_out_2; if zero fall out
                DEC preset_Temp_value     ; else decrement value
                MOV data_2_convert, preset_Temp_Value; show value
                ACALL convert_2_bcd
                MOV digit_1,#p_bit_pattern
                MOV digit_2, digit_3
                MOV digit_3, digit_4
                MOV digit_4, #c_bit_pattern
                ACALL long_Delay
                ACALL long_Delay
                ACALL long_Delay
                SJMP fall_out_2


entrance_cnt:   CLR tr0       ; stop timer 0
                CLR tf0       ; clear timer 0 flag
                PUSH acc      ; save registers
                PUSH psw
                MOV A, inflow_value       ; load inflow value
                XRL A, #0ffh ; compare with 255
                JZ go_1                ; exit if equal
                INC inflow_value       ; esle increment differential count
go_1:           POP psw       ; restore registers
                POP acc
                MOV th0, #255          ; reload registers
                MOV tl0, #255
                SETB tr0      ; enable timer again
                SETB update_inflow  ; set up for system  update
                RETI ;return from routine

exit_cnt:       CLR tr1       ;stop timer 1
                CLR tfl       ; clear overflow flag
                PUSH ACC      ; store registers
                PUSH psw
```

```
                        MOV A, inflow_Value        ; load differential inflow
value                   JZ get_outta_Here      ; if zero exit
                        DEC inflow_value       ; esle reduce by one
get_outta_here:         POP psw        ; restore registers
                        POP acc
                        MOV th1, #255          ; reload timer registers
                        MOV tl1, #255
                        SETB tr1         ; enable timer 1
                        SETB update_inflow  ; set up for system update
                        RETI   ; exit interrupt routine


delay_2_Show:           MOV R6, #00
                        DJNZ R6, $
                        RET


long_Delay:             MOV R7,#5              ; refresh display in this loop
                        ;MOV R7,#10
long_Delay_loop:        ACALL write_display
                        DJNZ R7, long_Delay_loop
                        RET
```

APPENDIX II

THE PSEUDOCODE FOR THE SYSTEM SOFTWARE

Start

Initialize the System

Check the interrupt pin

If the interrupt pin is Active then

Go to ISR

Else

Convert temperature value

Display temperature value

Compare temperature value

If temperature is greater than preset then

Show preset temperature

Generate alarm

Activate over – temp – LED

Else

Check Bit 1 for update

If Bit 1 is updated then

Compare inflow with preset

If inflow greater than preset

Show differential count

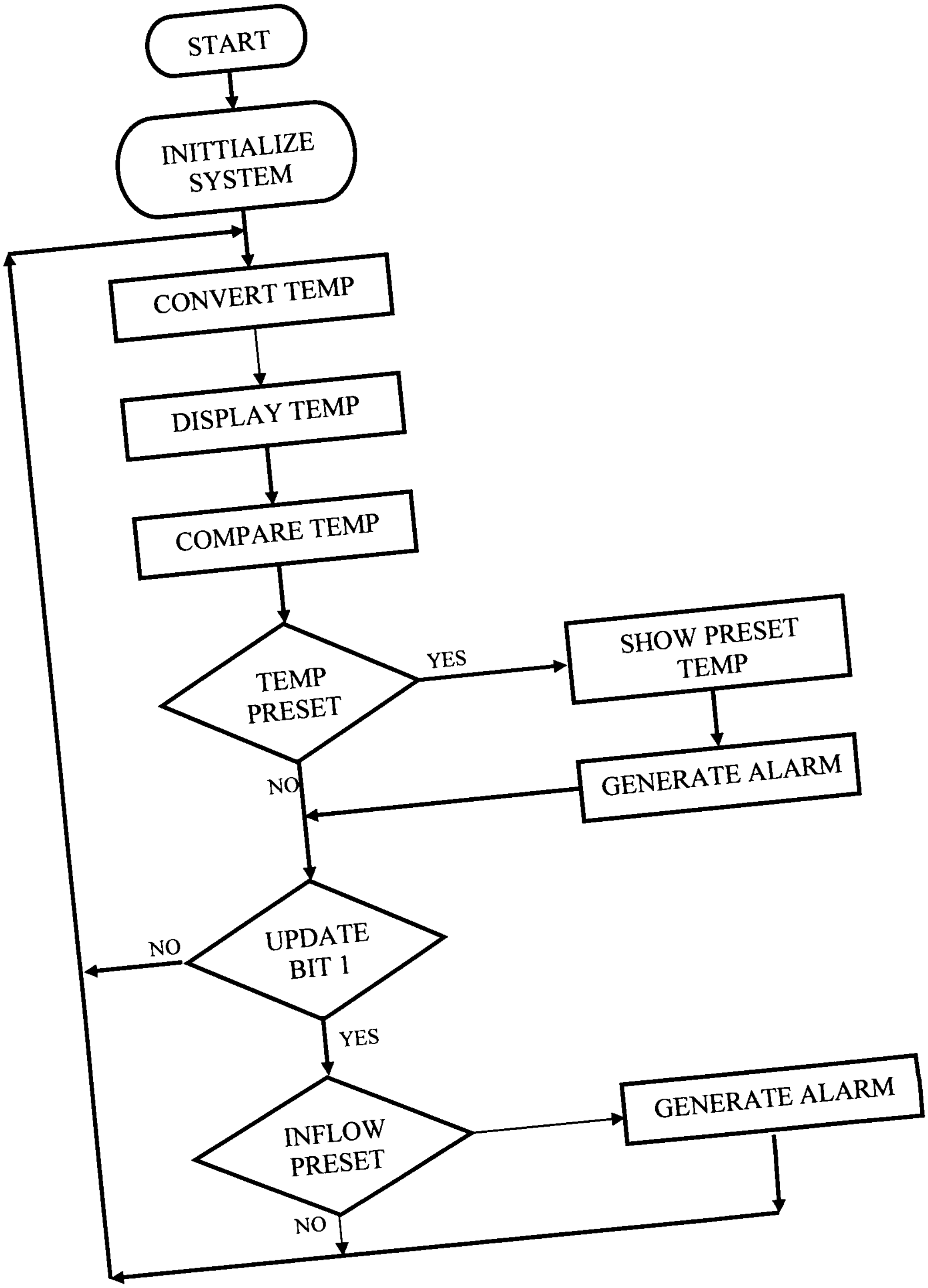
Generate alarm

Activate overflow Led

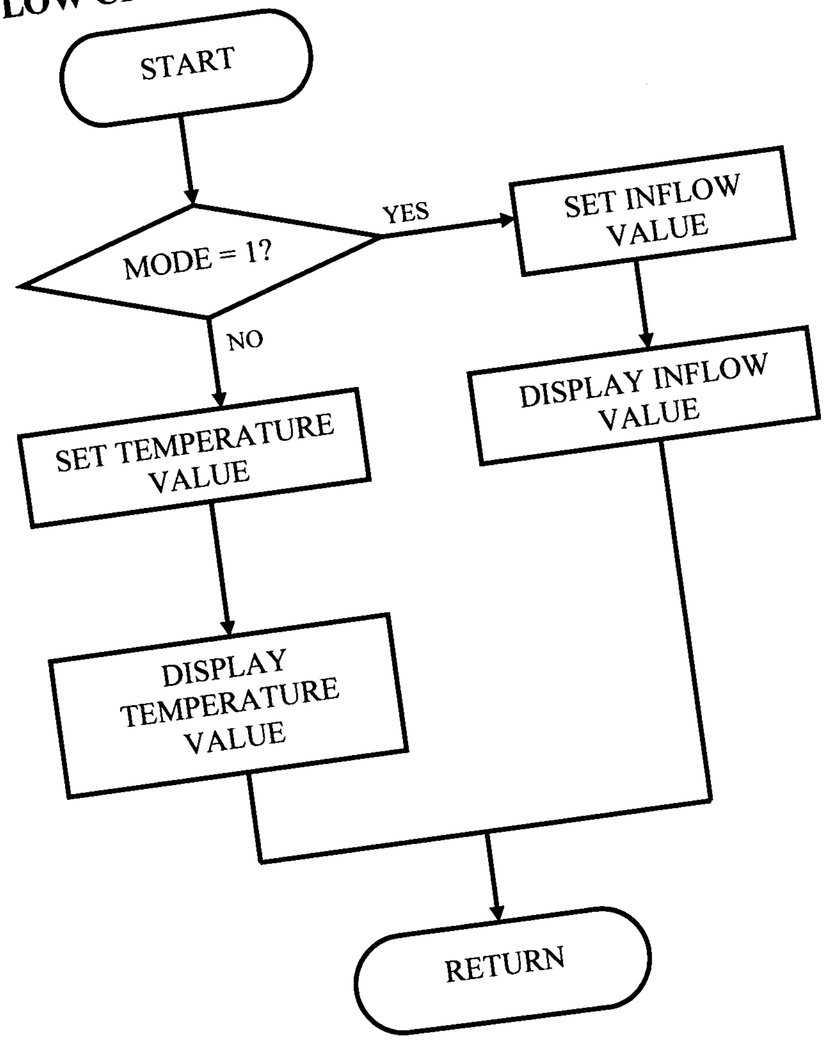
Else

Repeat convert temperature.

APPENDIX III
FLOW CHART
FLOW CHART FOR THE MAIN PROGRAMME



FLOW CHART FOR THE INTERRUPT SERVICE ROUTINE (ISR)



APPENDIX IV

LIST OF COMPONENTS

COMPONENTS	TYPE	RATINGS
R1	FIXED RESISTOR	2.2KΩ
R2	VARIABLE RESISTOR	5.0KΩ
R3	FIXED RESISTOR	10KΩ
R4,R17,R18	FIXED RESISTOR	100KΩ
R5,R6,R7,R8	FIXED RESISTOR	1 KΩ
R9,R10	FIXED RESISTOR	330Ω
R11	FIXED RESISTOR	220Ω
R12,R14,R20	VARIABLE RESISTOR	10KΩ
R15,R22	FIXED RESISTOR	100Ω
R16,R19	FIXED RESISTOR	5KΩ
C1	ELECTROLYTIC CAPACITOR	22μF
C2	CERAMIC CAPACITOR	270μF
C3	CERAMIC CAPACITOR	1μF
C4,C5,C23	CERAMIC CAPACITOR	0.01μF
C5,C7,C10,C18	ELECTROLYTIC CAPACITOR	2200μF16V
C14,C6,C17	ELECTROLYTIC CAPACITOR	220μF25V
C9,C22	CERAMIC CAPACITOR	100μF
C19,C21	ELECTROLYTIC CAPACITOR	100μF
C12,C20,C13,C19	CERAMIC CAPACITOR	0.1μF
C15,C16	CERAMIC CAPACITOR	0.001μF
C24,C25	ELECTROLYTIC CAPACITOR	36pF