# DESIGN AND CONSTRUCTION OF A MICROCONTROLLER BASED DIGITAL THERMOMETER WITH CELSIUS AND FAHRENHEIT DISPLAY

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2003/15385EE

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A THESIS SUBMITTED TO THE DEPARTMENT OF
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MINNA, NIGER STATE

NOVEMBER, 2008

# DEDICATION

I dedicate this project report to Almighty God Who has given me the health, strength and financial wherewithal for the successful completion of the project.

# DECLARATION

I, Isah Omeiza Rabiu 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 copy right to the Federal University of Technology, Minna.

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# ABSTRACT

This project involves the design and construction of a digital thermometer using a microcontroller. The thermometer displayed output is digital, thus help to avoid the limitation due to parallax error in analogue thermometer. The whole system incorporates a microcontroller which is interfaced to other components. These components include a temperature sensor, an analogue-to-digital converter (ADC) and eight-digit-seven-segment display. The temperature sensor used is an integrated circuit (LM 35). This IC senses temperature and generates at its output an analogue voltage that is proportional to the temperature it senses. The microcontroller through the program code written to it then convert the binary values to its equivalent temperature in degree centigrade (°C) and degree Fahrenheit (°F) and displays the values on the eight-digit-seven-segment display simultaneously.

## TABLE OF CONTENT

CHAPTER ONE

CHAPTER TWO: Literature review

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER ONE

## 1.1 INTRODUCTION

Temperature measurement plays an important role in almost all spheres of life ranging from industrial, domestic to scientific activities. Systems such as physical, chemical, mechanical, electrical, biological are widely affected by temperature.

Temperature is measured by means of a thermometer. This instrument of which a number of different types are available such as clinical thermometer, liquid – in – glass thermometer, maximum and minimum thermometer are associated with analogue devices such as that due to parallax, bended pointer, scale calibration, pointer vibration etc [10].

This project is an electronic digital thermometer that provides a means of measuring temperature and displaying the result digitally. The device employs a solid state temperature sensor, an analogue – to – digital converter, the microcontroller and seven – segment display unit. It displays the measured temperature in both Celsius and Fahrenheit degree read out simultaneously [14].

## 1.2 AIMS AND OBJECTIVES

This project is aimed at the design and construction of a simple digital thermometer that measures temperature from 0°C to $100^0$C and its equivalent in Fahrenheit i.e. From 32°F to 212°F and display it in both units simultaneously.

Popular types of thermometer such as liquid-in-glass thermometer, clinical thermometer, maximum and minimum thermometer, resistance thermometer and the thermoelectric thermometer are analogue and as such liable to errors associated with analogue devices such as that due to parallax, bended pointer, scale calibration, pointer vibrations etc. However this project is a continuation of earlier projects, but aimed at overcoming some deficiencies such as difficulties encountered in converting from degree Celsius to degree Fahrenheit, inability to interpret the exact temperature value, ambiguous size of the instrument and the cost of the system components.

## 1.3 METHODOLOGY

The digital temperature system comprises 5V system power supply, LM 35 temperature sensor, eight–bit analog to digital converter, eight–bit microcontroller and eight digital seven –segment display.

In the system power unit, a 240V/12V transformer was interposed between the bridge rectifier and the 240V A.c utility supply. The rectified D.c voltage was smoothened by 2200µf capacitance. This voltage and the 9-volt D.c battery incorporated in the system via OR gate are regulated by a 5-volt voltage regulator (LM 7805) which serve the main circuits and its sub-circuits.

The LM 35 sensor sensed the ambient temperature and convert it to analogue output voltage. To achieve a steady output, a RC circuit of 47kΩ resistance and 22µf capacitance was placed across the sensors output.

Analog-digital-converter (ADC 0804) convert the output voltage of the sensor to its digital equivalent by pulsing WR low, then high.

The microcontroller, through the program codes written to it convert the digital output of the D.c to degree Celsius and degree Fahrenheit. The microcontroller has 12MHz crystal which is internally divided by a factor of 12. This makes it to count up to 1,000,000 times per second. The seven-segment displays now display the outputs of the microcontroller for visual observations.

## 1.4 SCOPES AND LIMITATION

The project design temperature range lies within 0 degree Celsius to 100 degree Celsius. It would not be useful for temperature higher than 100 degree Celsius or lower than 0 degree Celsius applications. It employs 240V a.c main supply which is stepped-down by a 12V 0.5A step-down transformer and incorporates with it a 9V D.c battery using OR gate. The battery needs replacement when it runs down.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 REVIEW OF THE THERMOMETER

Thermometers measure temperature by using material that change in some way when they are heated or cooled. In a mercury or alcohol thermometer, the liquid expands as it is heated and contracts when it cools. So, the length of the liquid column is longer, or shorter depending on the temperature. Modern thermometers are calibrated in standard temperature units such as Fahrenheit or Celsius.

### 2.1.1 EARLY HISTORY

The first thermometers were called thermoscopes and while several inventors invented a version of the thermoscope at the same time, Italians inventor Santorio Santorio was the first inventor to put a numerical scale on the instrument thermoscope which was later called an air thermometer [14]. Galileo Galileo invented a rudimentary water thermometer in 1593 which, for the first time allowed temperature variation to be measured. In 1714, Gabriel Fahrenheit invented the first mercury thermometer – the modern thermometer.

### 2.1.2 EVOLUTION OF THERMOMETER

At the start of the seventeenth century there was no way to quantify heat .Santorio antorio invented several instrument, a wind gauge, a current meter and a thermoscope n the year 1612, a precursor to the thermometer. Santorio was the first to apply a umerical scale to his thermoscope, which later evolved into the thermometer.

Daniel Gabriel Fahrenheit (1686-1736) was a German physicist who invented the lcohol thermometer in 1709 and the mercury thermometer in 1714. In 1724, he introduced the temperature scales that bear his name – Fahrenheit scale and the thermometer was called mercury thermometer [14].

The Celsius temperature scale is also referred to as the "centigrade scale" Centigrade means "consisting of or divided into 100 degrees". The Celsius scale, invented by a Swedish astronomer Andre Celsius, (1701-1744), has 100 degrees between the freezing point (0 degree Celsius) and boiling point (100 degrees Celsius) of pure water at sea level air pressure. The term "Celsius" was adopted in 1948 by an International Conference on Weight and Measures in Britain [14] Andre Celsius devised the centigrade scale or "Celsius scale" of temperature in 1742. Celsius was not only an inventor and astronomer but also a physicist. He and an assistant discovered that the Aurora Borealis had an influence on compass needles. However, what made him famous was his temperature scale, which based on the boiling and melting point of water. This scale, an invented forms of Celsius' original design, was adopted as the standard and is used in almost all scientific work.

Lord Williams Kelvin took the whole process one step further with his invention of the Kelvin scale in 1848. The Kelvin scale measures the ultimate extreme of hot and cold. Kelvin developed the ideas of absolute temperature, what is called the "second law of thermodynamics", and developed the dynamic theory of heat in the year 1850 [1].

The early thermometers were non-electric in nature because they use thermal expansion of matter i.e. solids and liquids. They had the disadvantage of possessing a limited temperature range and were also subjected to reading errors.

In "The design and construction of a digital temperature measuring instrument vere using a thermistor" by Ajaguna Bamisaye James, the Author was engaged in the design and construction of a digital thermometer using a thermistor as the sensor. He employs thermal resistors (thermistors) as his temperature sensor and his recommendations – proposed the use of integrated circuit sensors for better linearity and accuracy [15].

Thereafter, in "The design and construction of a digital thermometer" by Peter O. Adeiza, the Author made use of this recommendation and also constructed a digital thermometer using a fixed temperature sensor (LM35) and the microcontroller that allows the output signal to be displayed on the seven – segments display unit (LED) in degree Celsius [17].

This project work has made advancement to this earlier works by putting the added feature of displaying in degree Celsius and degree Fahrenheit simultaneously.

## 2.2 THEORETICAL BACKGROUND

An electronic thermometer is a device, which contains the temperature sensor in conjunction with other units. The project consist of temperature sensing unit, an analogue–to– digital converter, microcontroller, seven segment display (LED) and finally the power supply unit.

### 2.2.1 TEMPERATURE SENSING TECHNIQUES

A temperature sensor/transducer is a device that senses temperature variation in n environment to give useful electrical signals. Their properties change with change in emperature. Various temperature sensors, which are in use, include; thermocouple, esistance temperature detector (RTD), thermistor and sensor integrated circuits.

A thermocouple consists of two different conductors coupled together at their nds. As it senses temperature, the thermoelectric voltage developed between the junctions is proportional to the temperature difference between the junctions. Thus with one end fixed at a known temperature, the device is used to measure the temperature of the either junction. It is also used to convert a radiant energy to fixed energy. A thermistor is a device whose resistance value change with temperature. It offers greater accuracy and stability than thermocouples, but its non-uniform resistance temperature characteristics can be disadvantageous in some applications where it is required to obtain a more linear variation. Applications like thermometer, analogue thermometer [8].

The integrated circuit temperature sensor(LM35) is a precision semi-conductor giving an output of 10mV per degree centigrade. Unlike devices with outputs proportional to the absolute temperature (in degree Kelvin), there is no large offset voltage, which in most applications will have to be removed. It does not require any external calibration.

### 2.2.2 ANALOGUE TO DIGITAL CONVERTER

An analogue to digital (ADC) is an electronic circuit that converts an input analogue voltage to a digital number. It converts continuous signals to discrete digital number. All ADCs suffer from non-linearity error caused by their physical imperfections causing their output to deviate from a linear function. The ADC used here is the ADC 0804 that employs successive approximation as its conversion method. It is used because f its availability and relative cheapness.

### .2.3 MICROCONTROLLER

The microprocessor comprises of central processing unit(CPU), instruction ecoder, arithmetic logic unit, register all integrated into a single chip.

The central processing units (CPU) bundle with supporting component such as memory and i/o peripherals and this gives right to microcomputer. Integrating all the elements of microcomputer onto a single chip is called microcontroller.

In this project, the AT89C51 is being used. This is a low-power, high performance CMOS 8-bit microcontroller with 4k bytes of flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel high density nonvolatile memory technology and is compatible with the industry standard MCS-51tm instruction set and pivot. The on-chip flash allows the programme memory to be reprogrammed in-system or by a conventional nonvolatile memory programme combining a versatile 8-bit CPU with flash on a monolithic chip, the Atmel AT89c51 is a powerful microcontroller which provides a highly flexible and cost effective solution to many embedded control application.

The AT89C51 provides the following standard features: 4k bytes of flash, 128 bytes of RAM, 32 ½ lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, a chip oscillator and clock circuitry . In addition, the AT89C51 is designed with static logic for operation down to zero frequency and support two software selectable power saving modes. The idle mode stops the CPU while allowing the RAM, timer/counter, serial port aid interrupt system to continue functioning. The power down mode saves the RAM content but freeze the oscillator disabling all other chip functioning until the next hardware reset.

### 2.2.4 THE SEVEN SEGMENT DISPLAY

The electronic display unit is concerned with using presentation of small numeric and alpha numeric output information.

In this project, the display unit consists of eight-seven-segment display chip connected to the microcontroller.

A seven segment display is an assembly of light emitting diodes (LED). The LED is an electroluminescent system that emits light when a voltage is impressed on it. A voltage of 5v is mostly used [9].

Other electroluminescent systems are the liquid crystal display (LCD) and the light emitting film (LEF). Each light emitting diode of the seven segment display is powered individually and connected via a resistor.

The LED chips are connected in the common anode mode.

### 2.2.5 THE POWER SUPPLY

This project employs 220v a.c main supply which is stepped-down by a 12v:0.5A step-down transformer and incorporated with a 9v D.c main supply and 9v D.c battery are being regulated by a voltage regulator (7805 I.c.). This gives a stable output voltage required for the devices components. The battery needs replacement when it runs down.

# CHAPTER THREE

# SYSTEM DESIGN AND ANALYSIS

## 3.1 DESIGN AND CONSTRUCTION

This section will give a thorough description of the system that was designed and constructed. The system consists of four basic units, which include the control unit, the display unit, the output unit and the power supply unit. The block diagram for the system is given in figure 3.1

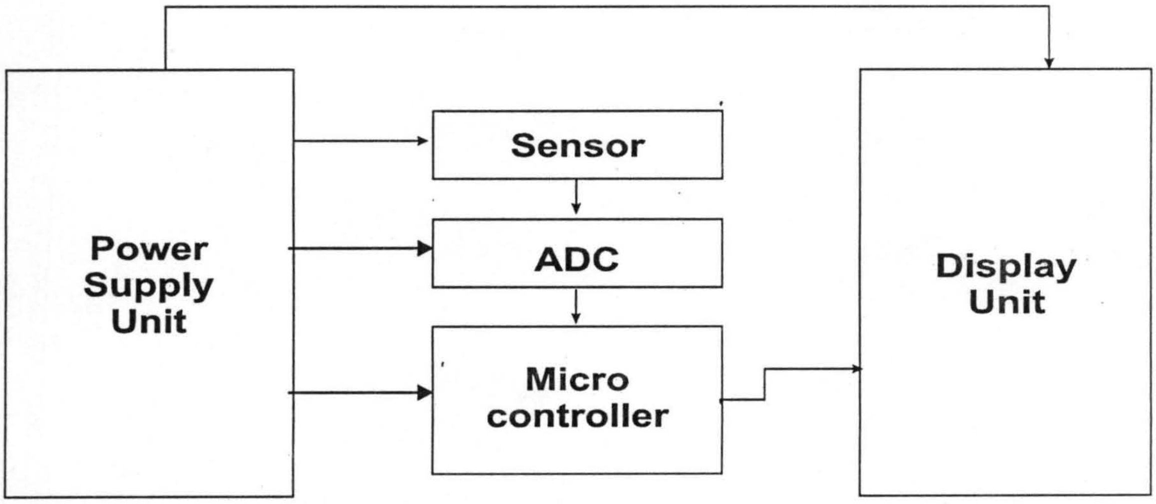

Fig 3.1: Block diagram of the design

### 3.1.1 POWER SUPPLY UNIT

The power supply was derived from two sources

i. Ac supply

ii. Optional dry cell battery (9V)

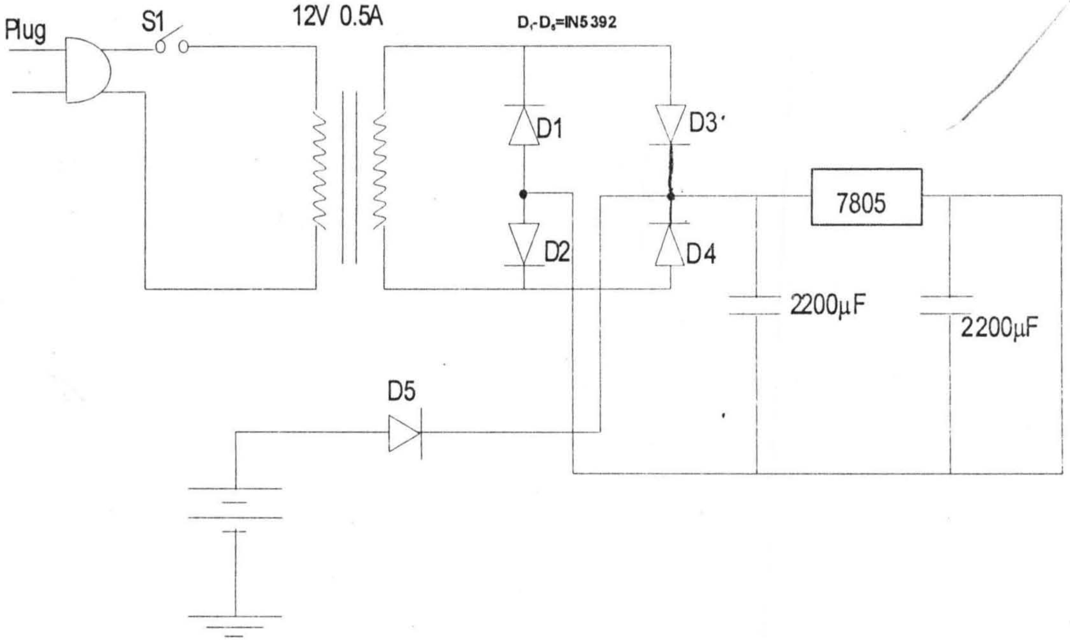

Fig 3.2: Power supply unit

A 240/12v step-down transformer was interposed between the bridge rectifier and the 240v A.c utility supply.

The 12v A.c voltage was converted into a DC voltage by a 4-diode bridge rectifier as shown in fig 3.1.

The DC output voltage has peak value of $Vdc = (Vr.m.s\sqrt{2}) - 1.4v$

$Vdc = 12\sqrt{2} - 1.4 = 15.5v$

This voltage was smoothened by a capacitance deduced from the expression

$Q=CV=It$

C=smoothening capacitor

V=maximum a.c ripple voltage

I=maximum load current

t=1/2F; F=A.C mains voltage frequency

The system was designed to function with an AC input voltage as low as 140v with a 20:1 step-down transformer, the AC output voltage was calculated from the relationship. $V_1/V_2 = N_1/N_2$. Therefore,the a.c output voltage was calculated to be 7v.The rectified output voltage was to be $7\sqrt{2}-1.4=8.5$v

A +5v operation voltage was required since the controller and ADC required such. A 7805 3-terminal fixed voltage regulator was used to generate the regulated 5v DC. For a 5 volt output, the minimum input voltage into the regulator is 7v(taken from manufacturer's data sheet) [10].

At 140V, the maximum allowable ripple voltage is $(7\sqrt{2} - 1.4) \approx 1.4$V

The operating current was calculated as below;

i. Microcontroller 15mA

ii. ADC 2mA

iii. 8 digit display

Peak current = (8 x 5mA segment current x 8)

= 0.320Amps

Total system current = 0.015mA + 0.002 + 0.320

= 0.337

$\approx 0.34\text{Amp}$

Therefore, total system current = 340mA

Inserting into the relation $Q = CV = It$

$C = It/V$

$= (0.34 \times 1/2 \times 50)/1.4$

$\approx 2200\mu f$

This value of capacitance gives the minimum usable on a 140V supply.

### 3.1.2 CONTROL UNIT

This unit is responsible for controlling the system through programme written in assembly language. The unit consists of a temperature sensor, an analogue- to- digital converter (ADC) and a microcontroller (MCU).

#### 3.1.2.1 TEMPERATURE SENSOR

The temperature sensor used in this project is an LM35DZ sensor. The sensor is a precision semiconductor temperature sensor giving an output of 10mV per degree centigrade. The device has a sensitivity range of 0°C-100°C with a typical accuracy of about ±2°C. over this range the device has the specifications stated below:

### SPECIFICATIONS

- Output calibrated directly in degree Celsius (centigrade).
- Linear +10.0m V/°C scale factor
- Operates from 4v to 30v
- Less than 60μA current drain

- Low self heating around 0.08°C
- Low impendence output, 0.1Ω for a 1mA load.

The device was connected to the converter as shown in fig 3.2.

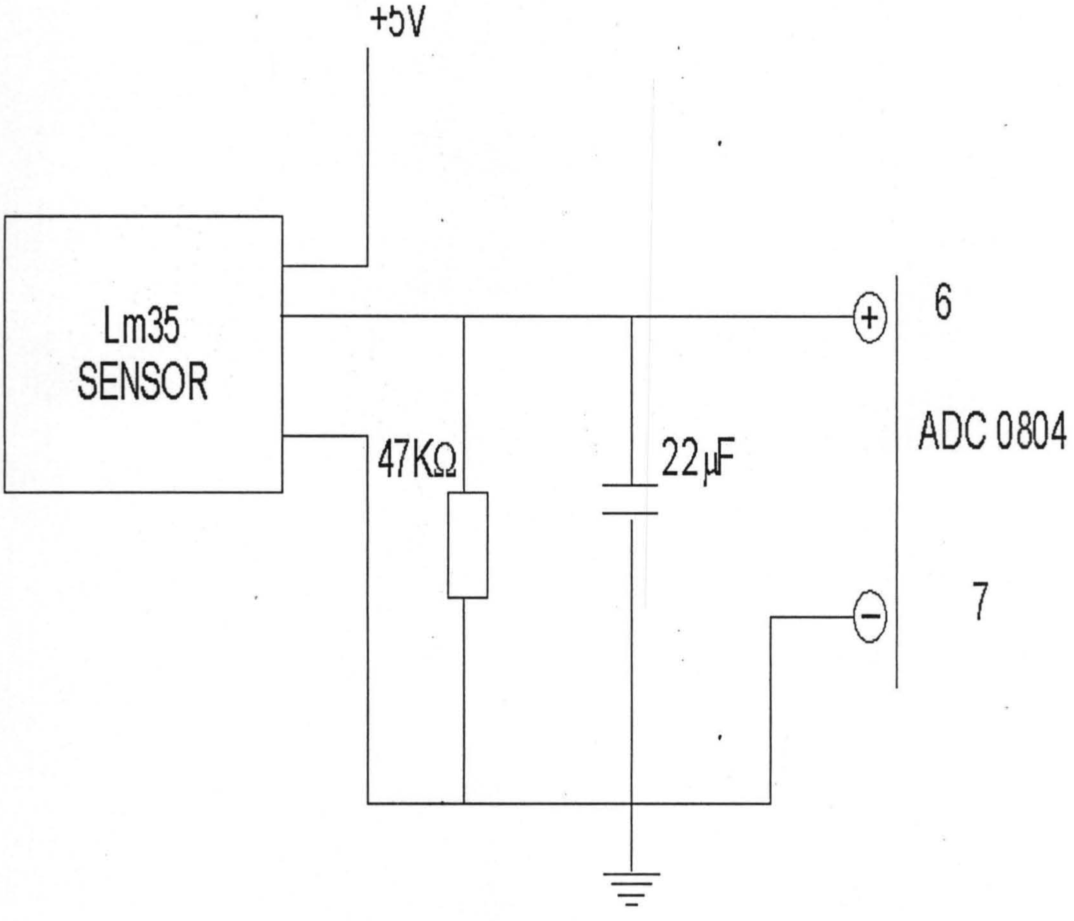

Fig 3.3 Lm 35-ADC interface

A parallel RC circuit of 47kΩ resistance and 22μF capacitance was placed across the sensor output. The time constant was chosen such that the D.c output of the sensor was maintained steadily as rapidly changing output would produce a hard-to-read visual information. The discharge time constant was calculated as follows:

$T = RC = 4.7 \times 10^{4} \times 2.2 \times 10^{-5}$

= 1.034Sec ≈ 1.0Sec.

This time constant was low enough to track the sensor output as it reduces, to prevent an incorrect reflection of the sensed temperature. The sensor is supplied with 5v from a 5v regulator. The output voltage could be in a range of -1.0v to 6v. Based on the indicated relationship, the output terminals could produce voltage from 0-1000mV.

In a situation where the sensor is subjected to a temperature of about 30°C, the output voltage from the sensor would be 300mV. This relationship applies to the entire temperature range with little or no accuracy of about ±2°C. The simple linear temperature sensor circuit is shown in fig 3.4 below.

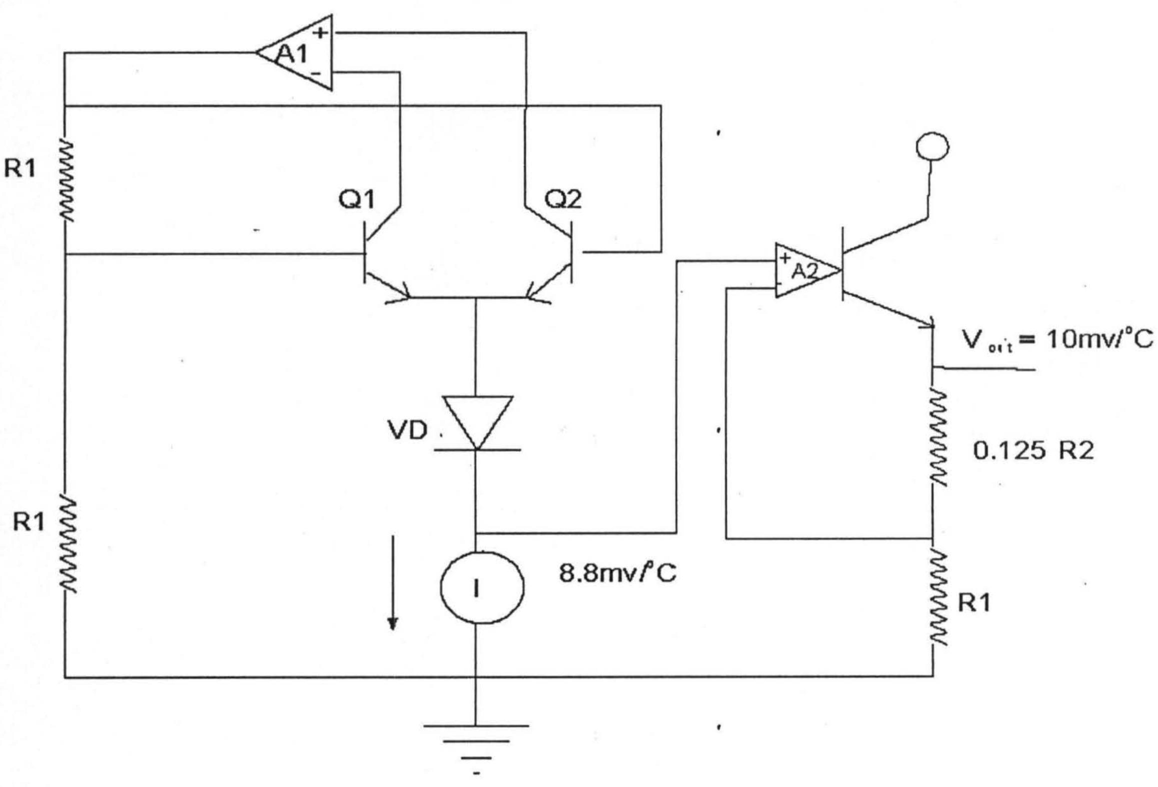

Fig 3.4; Simple Linear temperature sensor circuit

## 1.2.2 ADC( ANALOGUE-TO-DIGITAL CONVERTER)

The usual method of converting analogue signals into digital ones is to use an ıalogue to digital converter (ADC). This design incorporates such an ADC. The esence of ADC 0804 is to change an analogue voltage level to an 8-bit signal that can understood by a microcontroller. An ADC 0804 is an 8-bit successive approximation gister analogue to digital converter. It has typical conversion time of 100ms and a 0KHZ clock.

The device was interfaced with the microcontroller via port 1, with two control nes, WR and INTR connected to P3.0 and P3.1 respectively.

Conversion is effected by pulsing WR low then high. WTR goes low after 100μs signal the end of conversion. The digital value of the digitized voltage can then be read ver port1 (P1). The device was run on a high frequency clock source determined by the C timing components connected to pin 19 as shown in fig 3.6

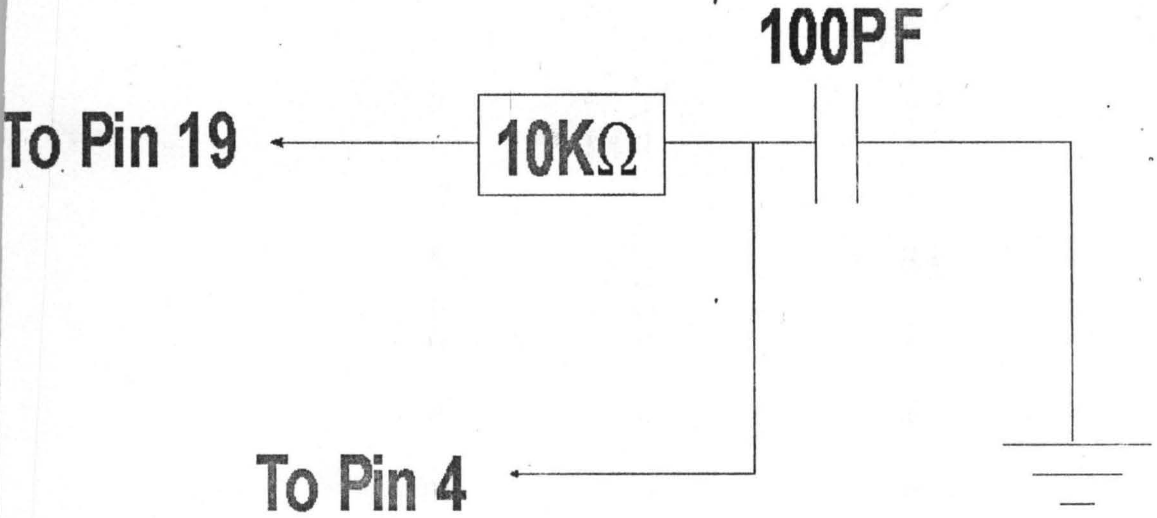

Fig 3.5: ADC clock Generator

The frequency of the RC clock circuit was specified as $F_{ADC} = 1/1.1RC$ where R is typically 10KΩ and C was made 100PF from the manufacturer's data sheet [13].

Therefore,

$F_{ADC} = 1/1.1 \times 10^4 \times 10^2 \times 10^{-12}$

$= 909090.9HZ$

$F_{ADC} = 910KHZ$

ADC control was effected using P3.0 and P3.1 as shown in the diagram below

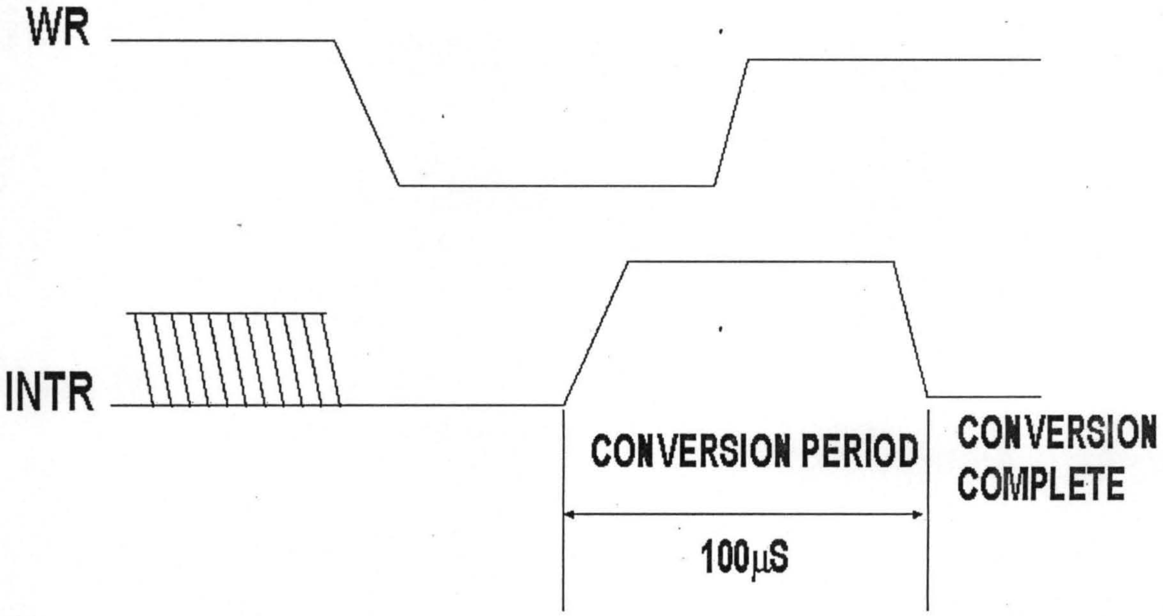

Fig 3.6; Conversion wave form diagram

The ADC was set up to have a one-on-one correspondence between the voltage appearing in pin 6 and DB0-DB7. Since it is an 8-bit converter, it was easy to fix the maximum input voltage at 2.56v (from data sheet) as this produces a single bit LSB change at the output for a 10mV change in the applied input voltage.

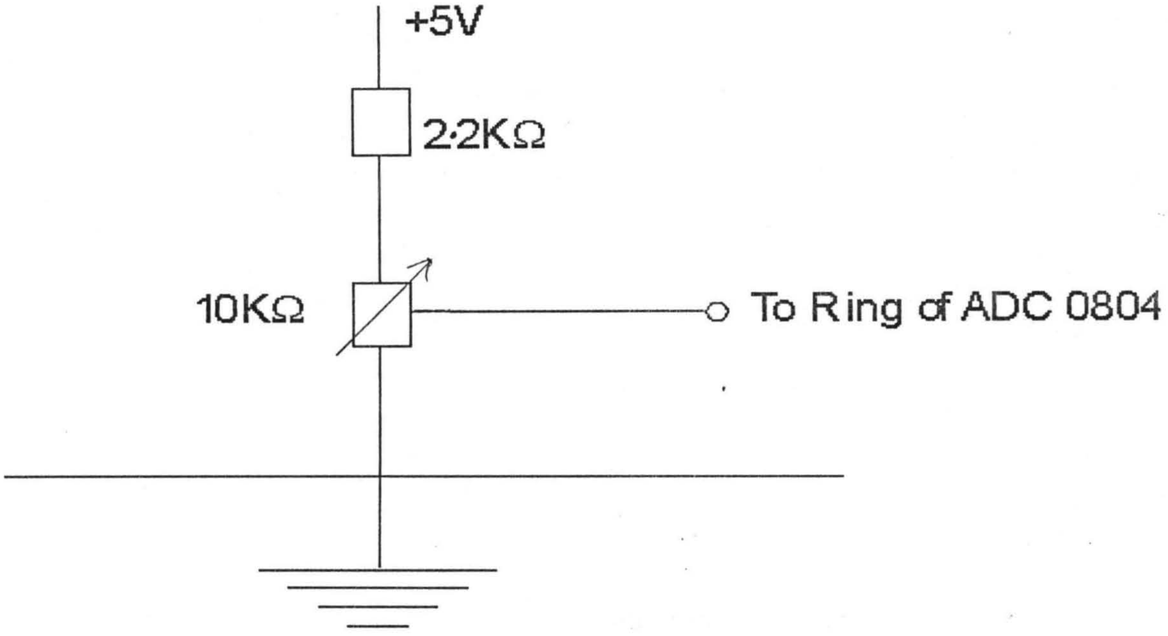

Fig 3.7: $V_{ref}$ Generator

The 10kΩ resistance was adjusted to provide 1.28V on pin 9 as this voltage is internally multiplied by two to give 2.56V.

### 3.1.2.3 MICRO CONTROLLER

No modern electrical system will be complete without a microcontroller or microprocessor. In the scope of this project, a microcontroller is used to capture, save and display digital data.

An AT89C51 8-bit microcontroller was incorperated in the design for intelligence. It was selected as it provides easy manipulation of the hardware resources, possesses enough RAM memory and 32 input and output pins, housed in a 40 pins dual in-pin (DIP) package.

The AT89C51 provides the following standard features: 4 K bytes of flash, 128 byte of RAM, 32 input-output lines, two 16-bit timer/ counter, a six vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and circuitry. In addition, the AT89C51 is design with static logic for operation down to zero frequency and supports two software selectable power saving modes. The idle mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The power down mode saves the RAM contents but freezes the oscillator, disabling all other chip function until the next hardware reset.

The AT89C51 is a low power-high performance CMOS 8-bit microcontroller with the following features:

- Compatible with MSC-51$^{TM}$ products
- 4k bytes of in-system Reprogrammable Flash memory.
- Endurance: 1,000 write/erase cycles.
- Fully static operation: 0HZ to 24 MHZ
- Three-level program memory lock.
- 128 x 8-bit internal RAM
- 32 programmable 1/0 lines
- Two 16-bit timer/counter
- Six interrupt source
- Programmable serial channel
- Low power idle and power down modes
- 4v to 5.5v operating range.

The AT89C51 was interfaced with the ADC over port 1, the seven-segment display over port 0 (PO), and the digit driver over port 2(P2). The control software was coded in assembly language for maximum flexibility.

## CONTROL SOFTWARE

The firmware was broken down into the following:

1. **Initialization routine**:

This block of code is executed at system start up. It configures the system Parameters and associated variables. This routine, amongst other things:

i) Configures port1 (P1) as an 8-bit input port.

ii) Blanks the display

iii) Turns off all digit drivers

iv) Hands over control to the mainline code.

2. **The mainline code**: this code is a looped routine and encompasses:

i) Digitizing of the sensor output to its digital equivalent.

ii) Conversion of the binary value to degree centigrade and Fahrenheit

iii) Conversion of BCD results obtained in (ii) above to their 7-segment codes.

iv) Refreshing of display by writing the 7-segment codes to the 8-digit visual display.

## 3.2 DISPLAY UNIT

This unit basically consists of eight-control transistor and eight 7-segment displays. The eight digit seven-segment display unit was interfaced with the microcontroller as shown below:

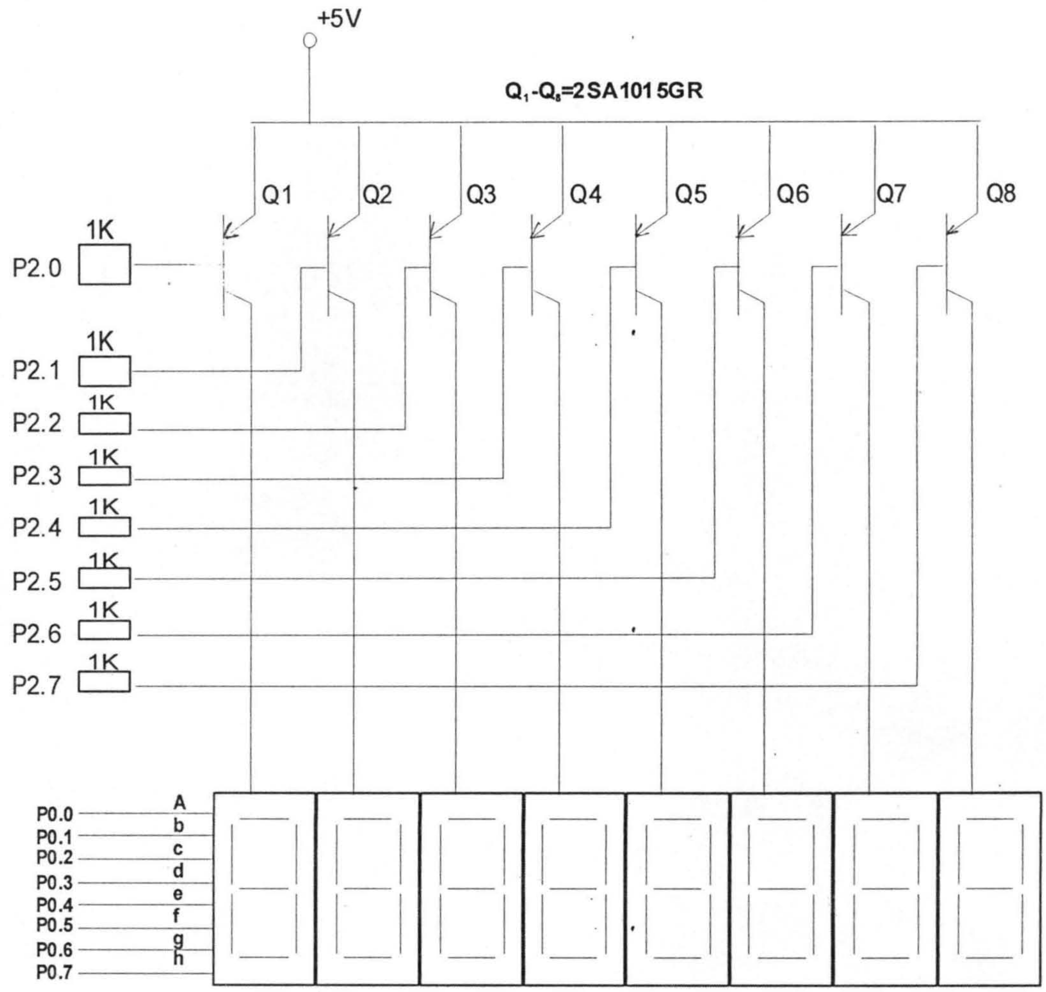

Fig 3.8: 7-Segment display interface

Eight PNP transistors were used for controlling the eight display positions. A multiplexed display system was used as fewer number of wires are needed. Writing data to a multiplexed display involves:

i) Turning off all display digit drivers.

ii) Placing the binary mask of the data to display on the common data port.

iii) Turning on the digit drivers (Q1-Q8) associated with the desired digit position.

iv) Delaying a little bit for persistence.

v) Turning off the digit driver switched in step iii.

The above refresh loop is executed at a frequency greater than 50HZ to prevent screen flicker.

The digit drivers were connected to P 2 clearing the port pin associated with each base resistance forward-biases the appropriate transistor which then source current through the segments. P0.0 – P0.7 provides a return path for the current through the illuminated segment(s)

## DESIGN CALCULATION

For an n-digit display, the current that must flow through each segment is $I_F$ x number of digits. i.e. the current through each segment is 8I where $I_F$ is the LED forward-current (basically 5mA to 20mA). A segment current of 10mA was chosen thus, the peak current through each segment is 10mA x 8 = 80mA.

For an 8-segment display (a, b, c, d, e, f, g, h), the peak current the digit driver will handle is 80 x 8 = 640mA.

This corresponds to the collector current Ic.25A1015GR PNP transistors were used for digit control. The transistor has a gain of about 200. for an I.C of 640mA

$I_B = I_C / \beta$

$= 0.64 / 200$

$= 3.2\text{mA}$

$R_B = (V_{cc} - V_{BE})/I_B$

$= (5 - 0.7)/0.0032$

= 1.3KΩ

The nearest preferred value of 1k was used.

## TABLE 3.1: TABLE BELOW SHOWS THE VARIOUS

## Components Used and their Functions

| | Names Of Components Used | Functions |
|---|---|---|
| 1 | LM 35DZ sensor | Temperature sensor |
| 2 | Capacitor 2200µf | Filtering and smoothening |
| 3 | Resistor 10KΩ | Current limiting |
| 4 | ADC 0804 | Analog-to-digital converter |
| 5 | Microcontroller (AT89C51) | Decoding, converting, controlling and timing |
| 6 | Transistors (25A1015GR) | Output controlling |
| 7 | Seven-segment display | Display output |
| 8 | 12MHZ crystal | for clocking |

### 3.3 BASIC OPERATION OF THE CIRCUIT DESIGN

The combination of all the sub-circuits yields the desired design of the digital thermometer. Temperature sensor (LM35) senses temperature and convert it to analogue voltage. This analogue output voltage measured is proportional to the temperature it sensed (i.e. for every 1 degree Celsius is 10mv). This output voltage was fed to ADC 0804 which converts the analogue voltage to binary equivalent in an 8-bit resolution. The output of the ADC is then fed to the microcontroller, which decodes the binary digit and allows it to be displayed digitally on a seven-segment digit display unit. The entire circuit is connected to power supply that powers the circuit. The main circuit diagram is as shown below

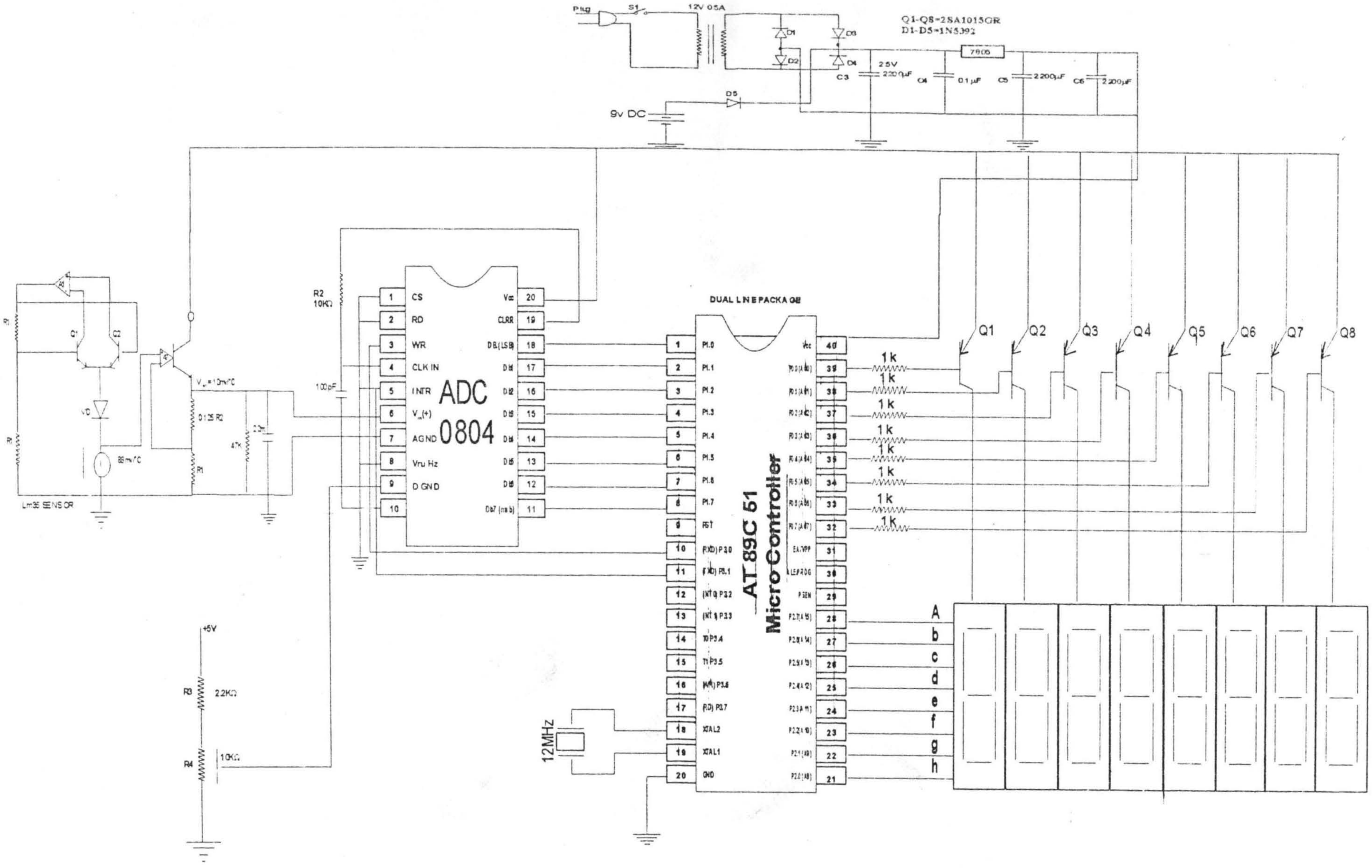

Fig 3.9: Circuit Diagram of the design

# CHAPTER FOUR

# CONSTRUCTION, TESTING AND RESULT

## 4.1 PROJECT CONSTRUCTION

The circuit construction of the digital thermometer measuring temperature ranging from 0°C to 100°C and 32°F to 212°F was carried out in sections.

On inspection of the required components, the components were first tested and subsequently mounted on the bread board following systematically the circuit diagram. The circuit was tested and transferred to the Vero board after thorough cleaning of the surface of the Vero board. Modular approach was adopted and each module was separately and independently soldered on a sectioned Vero board.

Certain component like the temperature sensor integrated circuit and the switch were soldered on a Vero board pieces and connected to the main board through adequate wires. The modular approach allowed each sub circuit to be soldered and tested appropriately before connected. Thereafter, the entire circuit was powered and tested accordingly

## 4.2 TESTING

The circuit was designed and soldered on a Vero board in which a temporary test was performed. Components were tested individually and subsequently modules of the circuit were tested. Component like base resistor of the PNP transistor (for switching the digit displays) were first calculated to be 1.3kΩ. But during testing, I found out that 1kΩ was more suitable because it provides brighter output of the digital display. This is because it offers less resistance to the flow of current than 1.3kΩ.

Moreover, after the whole soldering, wire link and connections, the circuit continuity was carefully tested. This test was carried out to confirm and check that the soldering was along the specified design, so that any deviation noticed were carefully amended. Later the circuit was powered to see the outcome of the initial process.

At first the operation of the circuit was out of the specified design. The errors involve in circuit were carefully corrected such include circuit bridge and unwanted soldering gaps. After the corrections, the circuit was working in accordance with the design.

Finally, the digital displays displayed the intended ambient environmental temperature.

## 4.3 DISCUSSIONS AND RESULT

The output displays indicate a rise in temperature when a heat source such as soldering iron was brought near the temperature sensor. There was a drop or decrease in the indicated temperature in absence of heat source. Also in the power supply test, temperature decrease as voltage level decrease and vice-versa.

The tables below show the results obtained from the test carried out on the constructed digital thermometer and the corresponding standard thermometer.

Table 4.1 **Temperature Readings Of The Thermometer**

| Voltage Level (V) | Constructed digital thermometer | | Standard thermometer | | Average constructed thermometer | | Average standard thermometer | |
|---|---|---|---|---|---|---|---|---|
| | °C | °F | °C | °F | °C | °F | °C | °F |
| 9 | 25.00 | 77.00 | 24.50 | 76.10 | 36.00 | 97.00 | 36.33 | 97.40 |
| 9 | 36.00 | 97.00 | 38.00 | 100.40 | | | | |
| 9 | 47.00 | 117.00 | 46.50 | 115.70 | | | | |
| 8 | 26.00 | 79.00 | 28.00 | 82.40 | 36.33 | 97.67 | 37.33 | 99.20 |
| 8 | 36.00 | 97.00 | 36.50 | 97.70 | | | | |
| 8 | 47.00 | 117.00 | 47.50 | 117.50 | | | | |
| 7 | 27.00 | 81.00 | 27.50 | 81.50 | 37.33 | 99.33 | 37.83 | 100.1 |
| 7 | 37.00 | 99.00 | 38.00 | 100.40 | | | | |
| 7 | 48.00 | 118.00 | 48.00 | 118.40 | | | | |

Table 4.2 The table below also shows the test conducted on the power supply.

| Input voltage ($V_{in}$) | Constructed thermometer (volt) | Theoretical value (V) | Percentage errors (%) |
|---|---|---|---|
| 9 | 5.00 | 5.35 | 6.54 |
| 8 | 4.98 | 5.35 | 6.92 |
| 7 | 4.90 | 5.35 | 8.41 |

## THE ACCURACY OF THE THERMOMETER

Accuracy of any device is the ability of that device to give measurement that is equivalent to the true value of the quantity measured. The accuracy of the realized digital thermometer can be related to the percentage error measurement, which is given as:

% = [C - S] / C x 100 %

Where C is the average constructed thermometer temperature reading and S is the average standard temperature reading.

% Accuracy = 100 - % error.

At 9v, % error for Celsius display

$$\% \text{ error} = \frac{36.33 - 36.00}{36.33} \times 100$$

= 0.91%

Therefore % accuracy = 100 - % error = 100 – 0.91

= 99.09%

% error for Fahrenheit display

$$\% \text{ error} = \frac{97.40 - 97.00}{97.40} \text{ x } 100$$

= 0.41%

Therefore % accuracy = 100 – 0.41

= 99.59%

At 8V,

% error for Celsius display

$$\% \text{ error} = \frac{37.33 - 36.33}{37.33} \text{ x } 100$$

Therefore % accuracy = 100 – 2.68

= 97.325

% error for Fahrenheit display

$$\% \text{ error} = \frac{99.20 - 97.67}{99.20} \text{ x } 100$$

= 1.545

Therefore, % accuracy = 100 – 1.54 = 98.46%

At 7v

% error for Celsius display

$$\% \text{ error} = \frac{37.83 - 37.33}{37.83} \text{ x } 100$$

Therefore % accuracy = 100 – 1.32

= 1.32%

Therefore percentage accuracy = 100 – 1.32

= 98.68%

% error for Fahrenheit display

$$\% \text{ error} = \frac{100.1 - 99.33}{100.1} \times 100$$

Therefore, % accuracy = 100 – 0.77

= 99.23%

The reasons for the inaccuracy observed are:

1) The sensor not responding to temperature changes as quickly as the standard thermometer.
2) Component malfunction due to environmental conditions such as dust, humidity, heat etc.

## 4.4 CASING

This was constructed by modifying two pieces of plastic tiles. They were fitted together using adhesive gum,.

The plastic tiles were shaped into a rectangular box and outlets were made on the tiles by drilling some parts to provide adequate ventilation for the components.

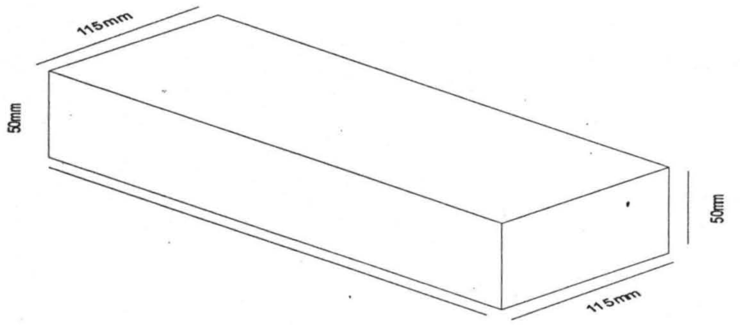

**Fig. 4.1: Casing Construction**

## 4.5 PROBLEMS ENCOUNTERED

The following problems and difficulties were encountered the design and construction.

1) Problem of short circuit on the board due to the bridging of wires
2) Damages of some certain components due to excessive heat while soldering.
3) Problems of soldering the seven segment displays the problem arises due to bridging of the jumper wires used to link the segment together.

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 CONCLUSION

This project is a prototype of a digital thermometer that can measure environmental temperature; indicate it on a digital display. The project is working according to the specified design and the digital display system used in this project has solved the parallax-error problems encountered in reading analogue thermometers.

While the system is suitable for both domestic and industrial applications, it may not be suitable for measurement at higher temperature.

## 5.2 RECOMMENDATION

For more sensitive and efficient system the following recommendations are made;

1. The LED display could also be replaced with LCD for less power consumption.
2. The system could be designed to display in degree centigrade, degree Fahrenheit and Kelvin simultaneously using LCD.
3. The circuit could also be designed for use below zero degree centigrade (0°C) temperature.

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# Appendix

```
adc_port EQU p1
adc_write BIT p3.0
adc_intr BIT p3.1
digit_0 DATA 08h
digit_1 DATA 09h
digit_2 DATA 0ah
digit_3 DATA 0bh
digit_4 DATA 0ch
digit_5 DATA 0dh
digit_6 DATA 0eh
digit_7 DATA 0fh
digit_8 DATA 10h
digit_9 DATA 11h
digit_10 DATA 12h
digit_11 DATA 13h
result_0 DATA 14h
result_1 DATA 15h
result_2 DATA 16h
result_3 DATA 17h
data_0 DATA 18h
data_1 DATA 19h
data_2 DATA 1ah
data_3 DATA 1bh
data_4 DATA 1ch
data_5 DATA 1dh
data_6 DATA 1eh
data_7 DATA 1fh
stack EQU 60
adc_Value DATA 20h
dx_Ctrl DATA 21h
max_loc DATA 22h
tempx DATA 23h
div_hi DATA 24h
div_lo DATA 25h
temp1 DATA 26h
mask data 27h
dx_port EQU p2
c_mask EQU 01000110b
f_mask EQU 00001110b
```

```
data_port EQU p0

org 0000h
start_up:         CLR ea
                  MOV sp,#stack
                  acall sys_init
mainloop:         ACALL convert_temp
                  ACALL process_Temp
                  acall show_long
                  sjmp mainloop

show_long:                mov r1,#130
loop_repeat:              ACALL show_temp
                  djnz r1, loop_repeat
                  ret

sys_init:         ACALL dly_1_sec
                  clr rs0
                  clr rs1
                  MOV dx_port,#0ffh
                  MOV data_port,#0ffh
                  mov adc_port,#0ffh
                  acall show_id
                  mov adc_Value,#0
                  MOV data_3,#c_mask
                  MOV data_7,#f_mask
                  MOV digit_3,#0
                  MOV digit_8,#0
                  MOV digit_9,#3
                  MOV digit_10,#2
                  MOV digit_11, #0
                  ACALL process_temp
                  RET
;*****************************************************

convert_temp:     CLR adc_write
                  NOP
                  NOP
                  NOP
                  nop
                  nop
                  SETB adc_Write
                  acall show_long
```

```
                mov adc_value, adc_port
                RET
;*********************************************************
look_up:        MOV DPTR,#xlate_Table
again:                MOV A,@R0
                MOVC A, @a+dptr
                MOV @R0,A
                INC R0
                MOV A, R0
                CJNE a, max_loc, again
                RET


xlate_Table:    DB
11000000b,11111001b,10100100b,10110000b,10011001b,10010010b,100000
10b,11111000b,10000000b,10010000b

;*********************************************************

convert_7_seg:        MOV R0,#data_0
                MOV max_loc,#data_0+3
                ACALL look_up
                MOV R0,#data_4
                MOV max_loc, #data_4+3
                ACALL look_up
                RET
;*********************************************************
dly_1_sec:      MOV R6,#10
reload:               MOV R5,#200
loop_show:            ACALL dly_2_Show
                DJNZ R5, loop_Show
                DJNZ R6, reload
                rET
;**************************************************
show_temp:            MOV dx_Ctrl,#11111110b
                MOV R0,#data_0
loop:                 ;MOV dx_port,#0ffh
                MOV data_port,@R0
                MOV dx_port,dx_ctrl
                MOV A, dx_ctrl
                SETB C
                RLC A
                MOV dx_Ctrl,A
```

```
                ACALL dly_2_Show
                mov dx_port,#0ffh
                mov data_port,#0ffh
                INC R0
                CJNE R0,#data_0+8, loop
                RET
;*******************************************************
***************
show_id:        ACALL blank_display
                ACALL write_ready
                ret

blank_display:          mov r0,#data_0
                mov a, #0ffh
blank_loop:             mov @r0,a
                inc r0
                cjne r0,#data_0+8, blank_loop
                ACALL write_display
                RET

write_display:          acall show_long
                ret
id_string:  db
11111001b,10010010b,10001000b,10001001b,11111111b,11001110b,100010
00b,10000011b,11111001b,11000001b,11111111b,10100100b,11000000b,11
000000b,  10110000b,11111111b
id_string2: db
11111001b,10010010b,10110000b,10000000b,10010010b,10000110b,100001
10b

write_ready:            MOV DPTR,#id_string
                mov r2,#1
re_do:                  CLR A
                MOV R5,#23
main_loop:              PUSH acc
                MOVC A,@a+dptr
                MOV mask, A
                ACALL write_now
                POP acc
                INC A
                DJNZ R5, main_loop
                MOV mask,#0ffh
                ACALL write_now
```

```
                MOV mask,#0ffh
                ACALL write_now
                MOV mask,#0ffh
                ACALL write_now
                MOV mask,#0ffh
                ACALL write_now
                MOV mask,#0ffh
                ACALL write_now
                MOV mask,#0ffh
                ACALL write_now
                MOV mask,#0ffh
                ACALL write_now
                MOV mask,#0ffh
                ACALL write_now
                ;ACALL blank_display
                djnz r2, re_do
                ret

write_now:              MOV data_0, data_1
                MOV data_1, data_2
                MOV data_2, data_3
                MOV data_3, data_4
                mov data_4, data_5
                mov data_5, data_6
                mov data_6, data_7
                mov data_7, mask
                ACALL write_display
                RET

;;**********************************************************
*********
process_temp:   ACALL convert_2_bcd
                ACALL convert_2_Farenheit
                MOV data_4, result_0
                MOV data_5, result_1
                MOV data_6, result_2
                ACALL convert_7_seg
                RET
;***************************************************8888
convert_2_bcd:  MOV A, adc_Value
                MOV B,#100
                DIV ab
                MOV data_0, A
```

```
                MOV A, B
                MOV B,#10
                DIV ab
                MOV data_1, A
                MOV data_2, B
                RET
;************************************************************8
88
convert_2_farenheit:
                MOV digit_0, data_0
                MOV digit_1, data_1
                MOV digit_2, data_2
                MOV A, adc_value
                MOV B,#10
                DIV ab
                MOV div_hi, A
                MOV div_lo, B
                MOV B,#8
                MUL ab
                MOV temp1, A
                MOV A, div_lo
                MOV B,#8
                MUL ab
                MOV B,#10
                DIV ab
                ADD A, temp1
                MOV temp1, A
                MOV digit_7, B
                MOV B,#100
                DIV ab
                MOV digit_4, A
                MOV A,B
                MOV B,#10
                DIV ab
                MOV digit_5,A
                MOV digit_6,B
                MOV A, digit_3
                ADD A, digit_7
                ADD A, digit_11
                MOV B,#10
                DIV ab
                MOV result_3, B
                ADD A, digit_2
```

```
                ADD A, digit_6
                ADD A, digit_10
                MOV B,#10
                DIV ab
                MOV result_2,B
                ADD A, digit_1
                ADD A, digit_5
                ADD A, digit_9
                MOV B,#10
                DIV ab
                MOV result_1, B
                ADD A, digit_0
                ADD A, digit_4
                ADD A, digit_8
                MOV result_0, A
                MOV A, result_3
                CJNE A,#5, go_a
                MOV A, result_2
go_back:        INC A
                CJNE A, #10, go_b
                MOV result_2,#0
go_back1:       MOV A, result_1
                INC A
                CJNE A, #10, go_c
                MOV result_1,#0
go_back2:       MOV A, result_0
                INC A
                MOV result_0, A
                RET
go_a:                   JNC go_back
                RET

go_b:                   JNC go_back1
                RET

go_c:                   JNC go_back
                RET
;*******************************************
dly_2_Show:
delay_1:   mov r3,#0
           djnz r3, $
           ret
      end
```