Equatorial Journal of Computational and Theoretical Science, 2 (1): 6-15
Journal Homepage: www.erjournals.com
ISSN: 0184-7937

LM35 Based Digital Room Temperature Meter: A Simple Demonstration

B. O. Oyebola[1]; V. T. Odueso [2]
[1]Department of Computer Engineering Technology, Gateway (ICT) Polytechnic Saapade, Nigeria
[2]Department of Electrical/Electronic Engineering, University of Ibadan, Nigeria.
Corresponding email: E-mail: blessedolalekan@gmail.com

ABSTRACT
Temperature measurement in today's industrial environment encompasses a wide variety of needs and applications. To meet this wide array of needs the process controls industry has developed a large number of sensors and devices to handle this demand. Temperature is a very critical and widely measured variable for most mechanical engineers. To medical practitioner's temperature is a fundamental quantity that must be measured in order to attain healthy life in the world of medicine but to the world of engineering temperature is either conserved for the purpose of effective work or release not to damage the job. The need to measure and quantify the temperature of something started around 150 A.D. when Galen determined the 'complexion' of someone based on four observable quantities. The actual science of 'thermometry' did not evolve until the growth of the sciences in the 1500's the first actual thermometer was an air-thermo scope described in Natural Magic (1558, 1589), which all lead to the development of thermometer. The first calibrated thermometer was the liquid in glass thermometer which was later divided in mercury in glass thermometer and alcohol in glass thermometer. During the invention of this thermometer some facts were not in place which lead to their disadvantages and with the aid of technology advancement digital thermometer came into existence. Digital thermometer brings together the likes of microcontroller to be interfaced with Lm35 temperature sensor all together working with an embedded C programming language. In advancement in technology, digital thermometer can be added to home automation utilizes, IOT service for medical records, industrial jobs and many more.

Keywords: Temperature*;* Room; Thermometer; Monitoring; Measurement.

Citation: Oyebola B. O. and Odueso V. T. (2017), LM35 Based Digital Room Temperature Meter: A Simple Demonstration. *Equatorial Journal of Computational and Theoretical Science*, 2 (1): 6-15

1.0 Introduction

Microcontroller based temperature measurement in today's environment encompasses a wide variety of needs and applications. To meet this wide array of needs the process controls industry has developed a large number of sensors and devices to handle this demand. In this project you will have an opportunity to understand the concepts and use of the LM35 sensor, and actually run an experiment using a selection of this device (Colins, 2008). Temperature is a very critical and widely measured variable for most conditions or a particular covering. Temperature measurement varies in different location judging by the temperature needs to be met at that location. Many processes must have either a monitored or controlled temperature. More difficult measurements such as the temperature of smoke stack gas from a power generating station or blast furnace or the exhaust gas of a rocket may be need to be monitored. Much more common are the temperatures of fluids in processes or process support applications, or the temperature of solid objects such as metal plates, bearings and shafts in a piece of machinery (Mike, 2015; Omosule, Olusegun, Abiodun and Feyisetan, 2017; Oyebola and Odueso 2017; Olalekan and Toluwani, 2017).

1.1 Statement of the Problem

The microcontroller based system developed will automatically detect the temperature of a particular atmosphere or a room. Noticing or taking into consideration the results of an operation being carried out due to the temperature of the room or atmosphere. For instance, in a laboratory where experiments are being carried out on different items, a certain temperature is required and needs to be maintained in order to achieve a good result on the experiment being carried out.

1.2 Aims and Objectives

Digital room temperature is very important since it is needed to keep in check a certain temperature of a room or an atmosphere digitally. That means it overrides the stress of using an analog temperature reader which might involve more calculations to get the current temperature of the environment. This system enables the user to obtain more precise representation of the temperature in the room using LM35 temperature sensor.

2.0 Literature Review

Microcontroller can be regarded as a single-chip special-purpose computer dedicated to execute a specific application. As in general-purpose computer, microcontroller consists of memory (RAM, ROM, and Flash), I/O peripherals, and processor core. However, in a microcontroller, the processor core is not as fast as in general purpose-computer, the memory size is also smaller. Microcontroller has been widely used in embedded systems such as, home appliances, vehicles, and toys. There are several microcontroller products available in the market, for example, Intel's MCS-51 (8051 family), Microchip PIC, and Atmel's Advanced RISC Architecture (AVR). We discuss Atmel ATmega8535 and LM35 temperature sensor in this section (Theophilus and Setiawan, 2012).

2.1 LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling (Donald, 1998). The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾ °Cover a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package (Texas, 2016).

2.2 History of Temperature Measurement

Heat is a measure of the energy in a body or material — the more energy, the hotter it is. But unlike physical properties of mass and length, it's been difficult to measure. Most methods have been indirect, observing the effect that heat has on something and deducing temperature from this. Creating a scale of measurement has been a challenge, too. In 1664, Robert Hooke proposed the freezing point of water be used as a zero point, with temperatures being measured from this. Around the same time, Ole Roemer saw the need for two fixed points, allowing interpolation between them. The points he chose were Hooke's freezing point and also the boiling point of water. This, of course, leaves open the question of how hot or cold things can get.

That was answered by Gay-Lussac and other scientists working on the gas laws. During the 19th century, while investigating the effect of temperature on gas at a constant pressure, they observed that volume rises by the fraction of 1/267 per degree Celsius, (later revised to 1/273.15). This led to the concept of absolute zero at minus 273.15°C. Galileo is reported to have built a device that showed changes in temperature sometime around 1592. This appears to have used the contraction of air in a vessel to draw up a column of water, the height of the column indicating the extent of cooling. However, this was strongly influenced by air pressure and was little more than a novelty. The thermometer as we know it was invented in 1612 in what is now Italy by Santorio Santorii. He sealed liquid inside a glass tube, observing how it moved up the tube as it expanded. A scale on the tube made it easier to see changes, but the system lacked precise units.

Working with Roemer was Daniel Gabriel Fahrenheit. He began manufacturing thermometers, using both alcohol and mercury as the liquid. Mercury is ideal, as it has a very linear response to temperature change over a large range, but concerns over toxicity have led to reduced use. Other liquids have now been developed to replace it. Liquid thermometers are still widely used, although it is important to control the depth at which the bulb is immersed. Using a thermo well helps ensure good heat transfer.

The bimetallic temperature sensor was invented late in the 19th century. This takes advantage of the differential expansion of two metal strips bonded together. Temperature changes create bending that can be used to activate a thermostat or a gauge similar to those used in gas grills. Accuracy is low — perhaps plus or minus 2 degrees — but these sensors are inexpensive, so they have many applications.

When Fahrenheit was making thermometers, he realized he needed a temperature scale. He set the freezing point of salt water at 30 degrees and its boiling point 180 degrees higher. Subsequently, it was decided to use pure water, which freezes at a slightly higher temperature, giving us freezing at 32°F and boiling at 212°F.

A quarter century later, Anders Celsius proposed the 0 to 100 scale, which today bears his name. Later, seeing the benefit in a fixed point at one end of the scale, William Thomson, later Lord Kelvin, proposed using absolute zero as the starting point of the Celsius system. That led to the Kelvin scale, used today in the scientific field (Omega, 2015).

3.0 METHODOLOGY

This chapter provides the detailed explanation on how the system was designed and constructed. The system is composed of two major parts the software development and the hardware development/ the software part discuss the virtual part of the systems, the circuit diagram, simulation of the circuits and the designing the PCB layout. The hardware development focuses on that physical aspect

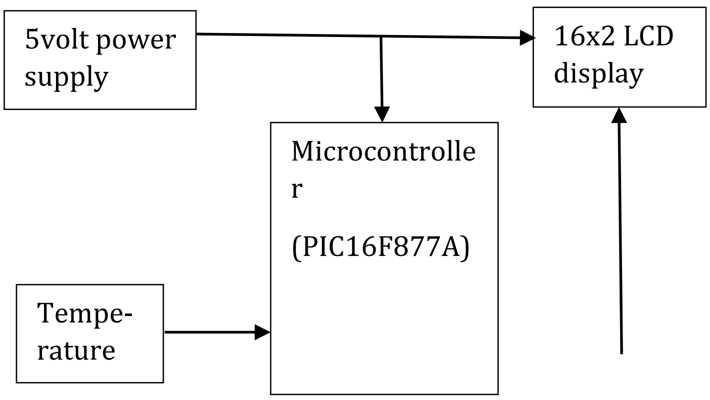


Figure 1: Block Diagram of Digital Temperature Meter (Srireddy, 2009)

The block diagram of temperature monitoring system consists of temperature sensor, ADC, microcontroller and LCD. LM35 is used as temperature sensor it senses the temperature. The output of Temperature sensor is in the form of analog signal. ADC0804 is used to convert this analog signal to digital. The output of ADC is given to the Microcontroller. The output of controller will be displayed on the LCD.

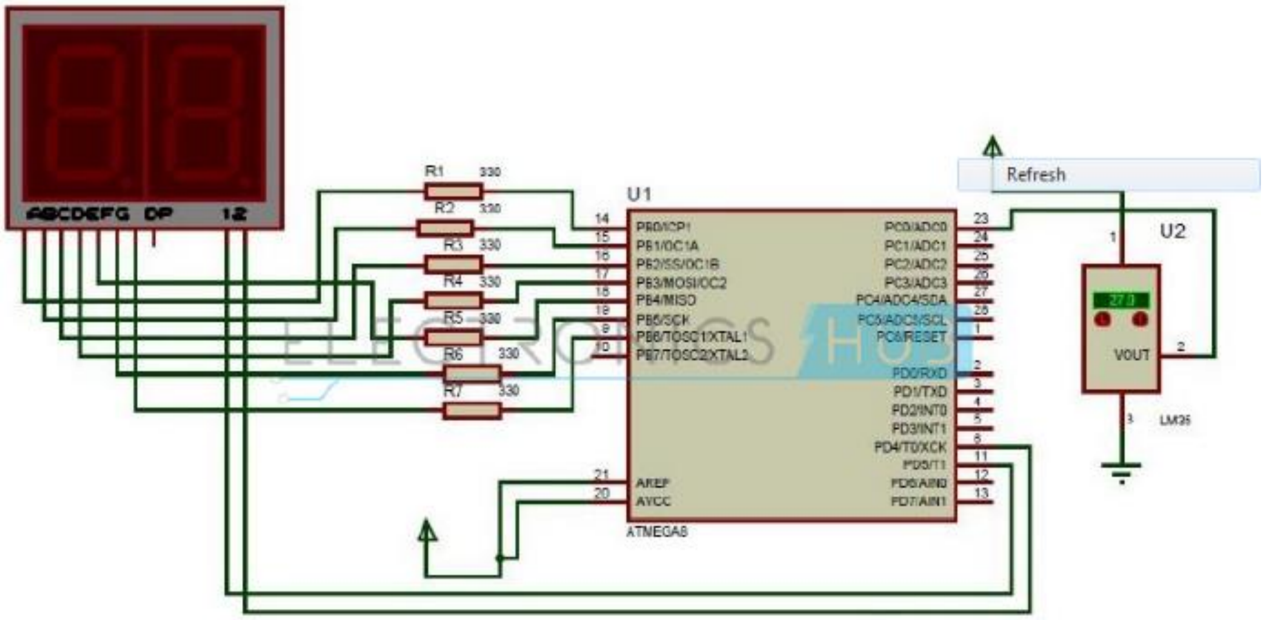


Figure 2: Circuit Diagram of Digital Temperature Reader (Mike, 2015)

3.1 Major Hardware Description

3.1.1 LM35

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature (Omega, 2015).

Figure 3: LM35 Temperature Sensor (Geek, 2014)

if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature (Texas, 2016). On the other hand, a small thermal mass may be added to the sensor, to give the steadies treading despite small deviations in the air temperature (Texas, 2016).

3.1.2 Microcontroller

This is the heart of the thermometer as this is where all the arithmetic conversion takes place and also it controls what to display on the LCD screen. It is a microcomputer that has 40pins for connection, as shown in figure 4

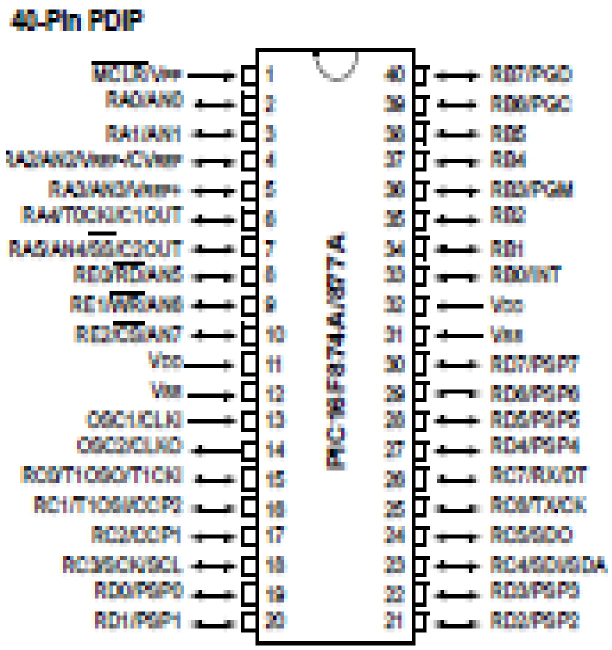


Figure 4: A 40 pin microcontroller (Microchip, 2003)

3.1.3 LCD DISPLAY

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on (Kushagra, 2012). Figure 5 shows the pictorial diagram of LCD Display

.

Figure 5: 16x2 LCD display (Orient, 2017)

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines as shown in figure 5 above. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD (Kushagra, 2012). The pin arrangement for LCD Display is shown in table 1 below.

Table 1: LCD pin lay out (Kushagra, 2012)

Pin number	Function	Name
1	Ground(0V)	VDD/Ground
2	Supply voltage(5V)	VCC
3	Contrast adjustment; through a variable resistor	VEE
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pin 1	D0
8	8-bit data pin 2	D1
9	8-bit data pin 3	D2
10	8-bit data pin 4	D3
11	8-bit data pin 5	D4
12	8-bit data pin 6	D5
13	8-bit data pin 7	D6
14	8-bit data pin 8	D7
15	Backlight VCC (5V)	Led+/A
16	Backlight Ground (0V)	Led-/K

3.1.4 TEMPERATURE SENSOR (LM35)

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°Cover a full −55°C to 150°C temperature range.

3.2 Software Description

3.2.1. Assembly Language

Software used are;

- MicroC Programming Software
- Microsoft Viso
- Proteus Simulator

The system was designed such that it automatically detects the temperature of the room or atmosphere. It only needs to be placed in an open place.

MicroC Programming Software

MicroC is the powerful C compiler integrated in Super-Flash which produces programs which can be run not only by Super-Flash applications, but others as well.

The programs compiled with MicroC operate under the strict control of the runtime engine. This means only correct instructions Are carried out, keeping the high level of reliability peculiar to Super-Flash. Since it does not produce a machine code, the programs do not have to be recompiled to be used on other platforms.

Below are some of the possibilities offered by MicroC

- Execution of calculations in floating point
- Execution of calculations which involve trigonometric functions
- Development of communication protocols
- Runtime modification of the characteristics of the Variables
- Deferred recording of Trends
- Deferred recording of Alarms
- Importation, processing, exportation of the data generated by the applications (Trend, Alarms, Recipes, etc.)
- Carrying out management of fully customized files
- Carrying out completely free control functions
- Implementation of control functions for the input data
- Implementation of general control functions of data coherence
- Reduction in the Super-Flash Variables needed for an application
- Possibility of protecting your know-how
- Making processing drivers seen by the system as a normal peripheral
- Interaction with the Event Management
- Interaction with Smart DB.

3.3. Digital Thermometer Controlling Codes

```
sbit LCD_RS at RB2_bit;
sbit LCD_EN at RB3_bit;
sbit LCD_D4 at RB4_bit;
sbit LCD_D5 at RB5_bit;
sbit LCD_D6 at RB6_bit;
sbit LCD_D7 at RB7_bit;

sbitLCD_RS_Direction at TRISB2_bit;
sbitLCD_EN_Direction at TRISB3_bit;
sbit LCD_D4_Direction at TRISB4_bit;
sbit LCD_D5_Direction at TRISB5_bit;
sbit LCD_D6_Direction at TRISB6_bit;
sbit LCD_D7_Direction at TRISB7_bit;
floattmp;
chartmpStr[10];
void main() {
trisd0_bit=1;
trisd1_bit=1;
trisa=0xff;
adcon1=0x00;
lcd_init();
lcd_cmd(_lcd_clear);
lcd_cmd(_lcd_cursor_off);
lcd_out(1,1,"Temp Meter( C)");
lcd_chr(1,12,223);
while(1){
tmp=adc_read(0);
tmp=tmp*100/204.5;
floattostr(tmp,tmpStr);
lcd_out(2,1,tmpStr);
delay_ms(500);
}
}
```

3.4 Flow Chart

The program starts once the circuit is powered; the temperature sensor reads the temperature and forwards it to the microcontroller to be displayed by the LCD.

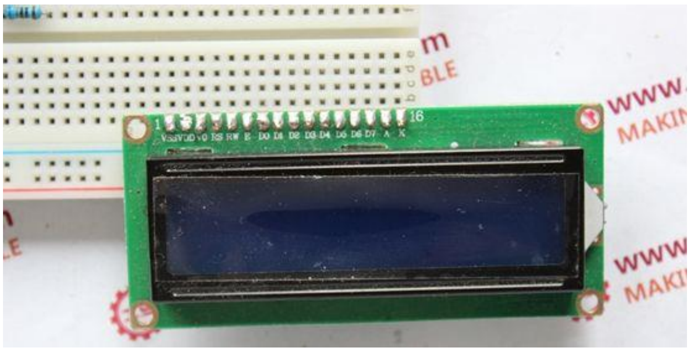
4.1 Discussion

In the temperature monitoring system we have used four blocks those are temperature sensor,ADC0804,AT89s52microcontroller,LCD.In this system the first block temperature sensor senses the temperature in the atmosphere in analogue form and then sends this analogue signal to ADC to convert into digital signal. This digital signal is fed to microcontroller through data lines. By using the microcontroller process the data and send it to LCD in the form of ASCII code. Finally LCD displays the external temperature in the atmosphere

4.2 Procedure

4.2.1 Identifying the Lm35 Pin

One side of the sensor will be rounded, and the other will be flat. With the flat side facing towards you, and the pins facing down, the pins from left to right are: 1, 2 and 3, as can be seen in the illustration below.



4.2.2 Connection of the LM35 and the Microcontroller

Plug the LM35 into your breadboard and place jumper cables from pin 1 to 5v on the Arduino, pin 2 to an analogue pin on your Arduino (for this example we'll use analogue pin 5) and pin 3 to the GND pin on the Arduino.

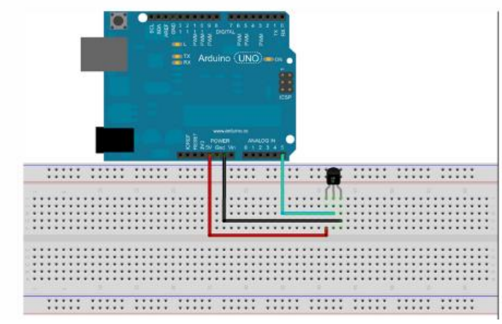
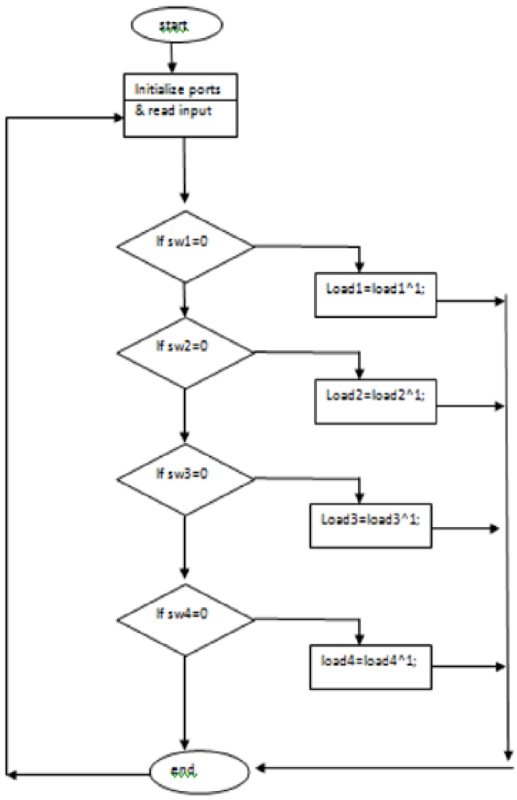


Figure 6: Connection of the microcontroller to the Bread Board (Donald, 1998)

4.2.3 Connecting the LCD to the Breadboard

There are 11 bus lines: D0 through D7 (8 data lines) and RS, EN, and RW. D0-D7 are the pins that have the raw data we send to the display. The RS pin lets the microcontroller tell the LCD whether it wants to display that data (as in, an ASCII character) or whether it is a command byte (like, change position of the cursor). The EN pin is the 'enable' line we use this to tell the LCD when data is ready for reading. The RW pin is used to set the direction - whether we want to write to the display (common) or read from it (less common)

4.2.4 FLOW CHART



A es
t

- Temperature – this is where we will store the temperature in centigrade (if you want to use Fahrenheit just alter the calculation accordingly)
- Reading – this is where we will store the raw reading from the analogue pin prior to any calculations

- Lm35Pin - this is where we will store the pin number that we are reading from

In the setup method we make a call to the analog Reference method. This allows us to set the reference voltage of the Arduino (i.e. the value used as the top of the input range). The reason we are using this is because the LM35 only produces voltages from 0 to +1V, and setting the reference voltage to INTERNAL will set it to 1.1 volts, as a result significantly improving the precision. The second line of the setup method is simply to allow us to read the data we are gathering via the Serial Monitor window (found under the Tools menu).

Inside the loop method, we begin by reading the value from the analogue input, and then divide that reading by 9.31. The reason we divide by 9.31 is because the range of our reading is 1024 and as we have set our reference voltage to be 1.1 volts we calculate each "step" in the analog reading as being approximately equal to 0.001074 volts, or 1.0742 millivolts. As the LM35 reports 1 degree Celsius per 10 millivolts, this means that for every (10 / 1.0742), we detect a one degree change i.e. every 9.31; so by dividing the reading by 9.31 we get our temperature reading in Celsius.

The following lines of code simply write the temperature to the Serial Monitor and then delay execution by a second.
This section discusses the testing, result and findings in the construction of digital thermometer using PIC microcontroller and LM35 temperature sensor.

4.3 Working Principle of the Device

Digital thermometer is a less hazardous instrument use for taking/recording temperature from a specific body. It works just like a liquid in glass thermometer but in a different way because of its accuracy in reading, the temperature of the given body is taken by the temperature sensor (LM35) and feed into the microcontroller (PIC16F877A) where the conversion takes place. The ADC port of the microcontroller(PIC16F877A) is interfaced with the temperature sensor which allows it to have direct access to the temperature reading from the sensor, the reading taken from the temperature sensor is been processed by the microcontroller to be given as an output on the LCD display screen. The LCD displays the processed data given to it by the microcontroller while the potentiometer is used as contrast level changer for the LCD (increase and decrease level of brightness for the LCD screen). The oscillatory circuit works at 8 MHz rate and it serves as clock counter for the microcontroller allowing the microcontroller to read between logic 1 and 0 synchronously.

4.4 Design and Implementation of Digital Thermometer

Figure 7 and 8 are pictorial diagram of digital thermometer design and construction.

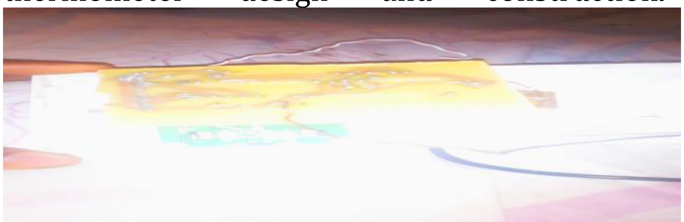


Figure 7: PCB design of digital thermometer

Figure 8: Digital thermometer taking reading from the environment

4.5 Advantages and Economic Importance of Digital Thermometer

1. Digital thermometer can accurately take, decide and measure temperature with the aid of temperature sensor and digital display.
2. Digital thermometer is easier to read compare to glass thermometer
3. Digital thermometer is fast, accurate and convenient for use.
4. Digital thermometer can measure the body temperature and can ensure accuracy

5. Digital thermometer has wide range of application, it is usually applied to measure gas, liquid and solid temperature. In numerous fields, it can be applied in several areas such as the Hospital, restaurant and schools.

5.0 Conclusion

The main aim of this work was to design and construct a microcontroller based digital thermometer with .This has been achieved. The device has been tested and is working. This project illustrates the use of embedded systems particularly in instrumentation design and generally in the design of electronic devices. Embedded system design should be encouraged to simplify and provide flexibility for electronic circuits / electronic designs. Those seeking guidance on embedded system design that employ ADC interfacing, specialized LCD interfacing, digital filtering, etc. should avail themselves with this work.

With the aid of advancing technology in the past few years, whereby technology has been aiding the work of man daily. Digital thermometer is an innovation to end the error due to parallax reading in liquid in glass thermometer and also comfort the easy access and accurate reading of temperature. Digital thermometer can further more be advanced into home automations, use in cold rooms, food temperature reserve and so on.

5.1 Recommendation:

In temperature monitoring system it can interface alarm to 8051 microcontroller. By using this interface we can integrate an alarm system to sound when temperature increases to certain level.

References

Berlin, A. (2009). Microcontroller Operating Modes. *Scientific research*.

Bharath, V. K., & Anndurai, D. (n.d.). Retrieved January 2nd, 2017, from https://www.scribd.com/document/38876507/Biochips-Using-tics

Donald, T. (1998). Priciples and Methods of Temperature Measurement. *International Journal of Science and Technology*.

Gabrael. (2017). Digital Room Temperature Meter. *Internernational Scientific Research*.

Geek. (2014). LM35. *Geek Studio.ICT Implants in the human body : A Review - Molar.* (n.d.). Retrieved from molar.crb.ucp.pt/

Machenzie, S. (1998). The 8051 Microcontroller. In *Theraja Electrical Technology, Alternating Current Circuits.*

Mazidi, M. A. (2004). The 8051 Microcontroller and Embedded Systems.

Mike. (2015). *Digital Temperature Circuit.* Electronics Hub.

Nsanze, F. (2004, December 21). Retrieved January 4, 2017, from ICT implants in the human body : a review: molar.crb.ucp.pt/

Olalekan, O. B. and Toluwani, O. V. (2017). Remote Control of Electrical Loads Using GSM Module. Journal of Industrial Technology, 2 (2): 38- 50.

Omega. (2015). History of Temperature Measurement. *Omega Engineering*.

Orient. (2017, september 3). *orient LCD*. Retrieved septemeber 3, 2017, from orientlcd.com: https://www.google.com/search?q=16x2+lcd+display.

Oyebola B. O. and Odueso V. T. (2017), Design and Development of Microcontroller Based Temperature and Humidity Controller for Infant Incubator. Journal of Industrial Technology, 2 (4): 78 –87

Omosule, N. I., Olusegun, A. S., Abiodun, R. O. and Feyisetan, F. O. (2017). Evaluation on the Challenges of Modern Car Maintenance in Nigeria. Journal of Industrial Technology, 2(3): 51- 61.

PaulBrokaw. (1974). A Simple Three-Terminal IC Bandgap Voltage Reference. *IEEE Journal of Solid State Circuits,*.

Rammon, P. A., & G, J. (1991). Sensors and Signal Conditioning. *Webster*.

Shiengold, D. (2015). Non linear Circuits, Analog Devices. *Inc*.

Slutz, S., & Hess, K. L. (n.d.). Retrieved February 15, 2017, from Science Buddiies: http://www.sciencebuddies.org/science-fair-projects/top_research-project_signal-to-noise-ratio.shtml

Srireddy. (2009). *Temperature Monitoring System.* Scribd.

Surampalem, E. G., & District, A. (2009). THE-BIO-CHIPS. *BIO INFORMATICS, PRAGATI ENGINEERING COLLEGE.* www.PPTSworld.com.

Theophilus, W., & Setiawan, B. (2012). A Microcontroller- based Room Temperature Monitoring System. *International Journal of Computer Applications*.

Venka, T., & Rao, N. (2012). Biochip Technology –A Gigantic Innovation. *International Journal of Emerging Technology and Advanced Engineering*, 129-135.

Ventola, C. L. (2014, July). Social Media and Health Care Professionals: Benefits, Risks, and Best Practices. *Pharmacy and Therapeutics (P&T)*, 491-499. Retrieved February 15, 2017, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4103576/

Vishnoi, A., Saxena, A., & Bhatia, A. (2014). BIOCHIP - A REVIEW ON CUTTING-EDGE BIOCHIP TECHNOLOGY. *International Journal of Scientific Research and Management Studies (IJSRMS)*, 405-411. Retrieved from

Wells, W. (n.d.). Retrieved from The Chips Are Coming: http://www.biotext.com/biochip.html

Widdis, G. (1998). Electrical Measurements and Measuring Instruments.

Williams, J. (1993). Analog Devices. *Linear Technology Corporation*.

Wong, J. (1984). Temperature Measurement Handbook. *Inc*.