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Design and implementation of microcontroller based temperature monitoring system

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Usman Bashir Tayab [1,2,*], Chan Weng Yuen [3]

[1] University of Sunderland, United Kingdom
[2] University Malaysia Perlis, Malaysia
[3] Taylor's College Subang Jaya, Malaysia

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ABSTRACT

Temperature monitoring system plays a very important role in modern liquid industrial process especially where temperature monitoring is impossible through traditional methods. In this paper a design and implementation of temperature monitoring system using ATmega328 microcontroller has been proposed. The proposed system consists of two different parts. The first part is temperature monitoring system and the other is GUI interfacing between temperature monitoring system and computer as temperature data storage. The monitoring part is composed of an ATmega328 microcontroller, temperature sensor LM35, alarm buzzer, a LED and a LCD. The microcontroller is programmed in embed C language using Arduino Uno software to read data from temperature sensor LM 35, convert and display in digital form on LCD. Moreover, this part also indicates whether the temperature is low, high or safe by LED light and alarm buzzer. The second part is GUI interfacing between temperature monitoring system and computer which is performed through visual basic programming using Microsoft visual basic software. The function of this part is to store and display the temperature values and their waveform along with time and date on computer.

1. Introduction

Temperature monitoring and control are vital in many industrial processes. Accurate control of temperature is essential nearly in all chemical processes. In some applications, an accuracy of around 5-10ºC may be acceptable. There are also some industrial applications which require better than ±1ºC accuracy. Temperature is measured using temperature sensors. These sensors come in many different forms and a number of techniques have evolved for the measurement of temperature.

* *Corresponding author.*
E-mail address: usman.tayab@yahoo.com (Usman Bashir Tayab)

There are new forms of sensors those require no contacts with the medium to sense its temperature. The majority of sensors still require touching the solid, liquid, or the gas to measure their temperature. Four technologies are currently in use: thermocouples (TCs) [1], thermistors [2,3], resistance temperature detectors (RTDs) [4,5], and integrated circuit (IC) sensors [6]. Most temperature sensors produce an analog output voltage which is proportional to the temperature. In some sensors like TCs this voltage is in the microvolt range and special techniques are employed to measure this voltage and hence the temperature cannot be measured correctly. Analog sensors require analog-to-digital (A/D) converters so that the output voltage can be converted into digital form. This enables us to make an interface of this part directly to a digital computer. Some temperature sensors (e.g. some IC sensors) produce digital outputs and these sensors can directly be connected to microprocessors or microcontrollers without the requirement of A/D converters.

The authors of [5] have discussed about the design of automatic temperature and light monitoring. In this paper, temperature and light monitoring is performed with the help of two sensors and displayed on an LCD screen and the desired values of temperature and light are set with the help of keypad provided with the device. PIC microcontroller and an ADC 0809 have been used for analog to digital conversion for their system. The desired set-point in our system is given through a potentiometer.

In [6] an embedded system for monitoring the temperature is proposed. In this system, microcontroller AT 89S52 is used which is a 40 pin IC. The temperature measurement from the channels of ADC 0809 is taken for display. The performances of channels are distinguished on the basis of its accuracy. The accuracy indicates how accurately the sensor can measure the actual and the real world parameter. The authors of [7] have development a system for rugged environmental monitoring units for temperature and humidity. This system has additional complexity of construction and calibration for certain applications those involve harsh environment. The system also does not have any hardware control unit to meet specific conditions.

The proposed system in [5-11], can measure the temperature value and user have to sit near to system for monitoring due to the failure of store the temperature value for longer period of time. Motivating from these points we are going to design a microcontroller based temperature monitoring system with GUI interfacing for storing the temperature value for long period. The reminder of this paper is organized as follows: Section 2 discuss the methodology for experiment. Section 3 provides the experimental results and discussion. Finally, the conclusion is drawn in Section 4.

2. Methodology

A simple flow chart diagram is presented in Fig. 1 to explain the working principle of microcontroller based temperature monitoring system. The overall process includes: temperature monitoring, tabulation of data, finally display the final results of the test subjects in digital form through an A/D converter. The end users of the microcontroller based temperature monitoring system can monitor and control by entering the Voltage (V) obtained from the display program into the GUI designed.

The Arduino microcontroller ATmega328 is the heart of this whole system. The Arduino microcontroller ATmega328 must be powered either by external supply or with regulated supply through the connection of the Universal Serial Bus (USB) cable to the computer for our developed system prototype in order to function properly. Fig. 1 shows the simple flow chart diagram of this research work.

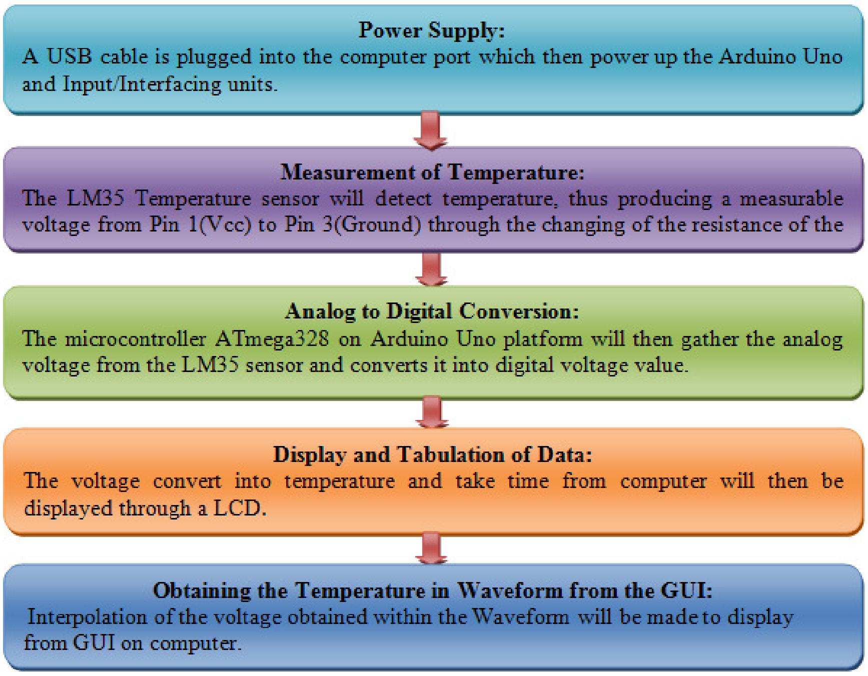

Fig. 1. Flow chart of the working principle of temperature monitoring system

The experimental setup is composed of a ATmega328 microcontroller, a temperature sensor LM35, an LCD, an LED and a Buzzer. ATmega328 microcontroller is used for controlling, LM35 for temperature monitoring, LCD for temperature display with time, LED and Buzzer for alarm. Therefore, the design for each component will be discussed accordingly. The circuit was designed and drawn using software, EAGLE 6.0 which will be explained briefly in next section (Etching process). The schematic of the temperature monitor system prototype is shown in Fig. 2.

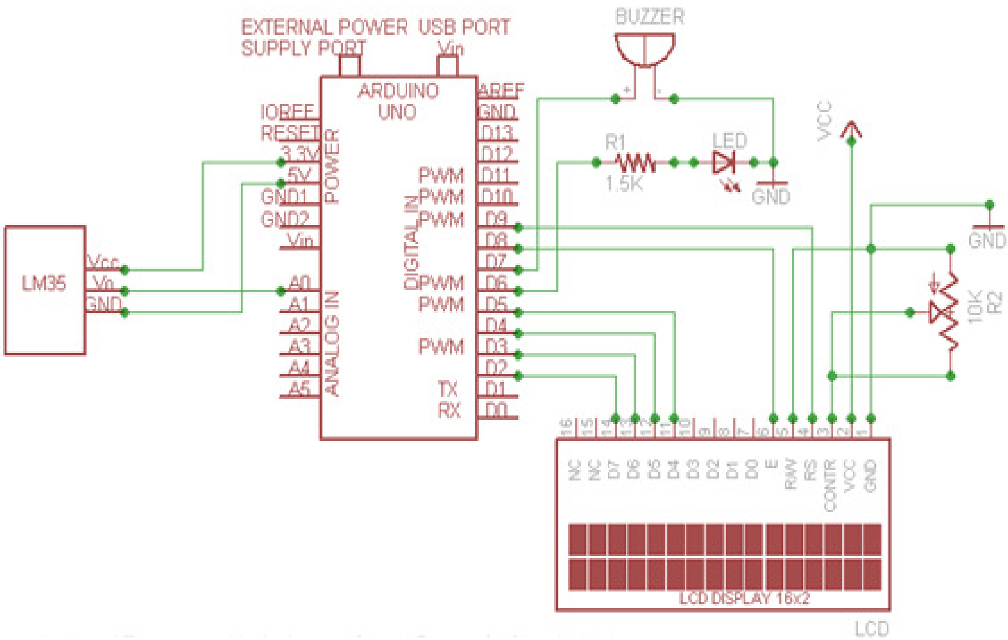

Fig. 2. Schematic diagram of temperature monitoring system

2.1. Etching process

In this section, the etching process of PCB board is discussed. The design of temperature monitoring system was construct using Easily Applicable Graphical Layout Editor (EAGLE 6.0) and shown in Fig. 2. After completing the design in EAGLE 6.0, the board button is clicked to acquire the PCB circuit layout. In order to get the best fit of components and reduce the size of PCB, the components were rearranged using auto-route function in EAGLE 6.0. After obtaining the best circuit layout, the circuit was printed on a transparency paper using a laser jet printer and placed on PCB board. A chemical solution of Ferric Chloride was prepared and circuit board with transparency paper was submerged into the solution for half an hour. By this process, the copper from unprotected area of circuit board dissolved and covered area by transparency paper was cleaned by using sand paper. Thus, the remaining copper on PCB board forms the required circuit. To ensure that the circuit was continuous and has no gaps the testing process was done. Finally, the components were soldered on according to the design and were tested again for connection errors.

2.2. Programming process

This section is divided into two subsections. First subsection will deal with the description of the ATmega328 microcontroller programming to operate without computer, which is programmed in embed C language using Arduino 1.0.4 software. Second subsection will focus on interface between temperature monitoring system and computer for storing the results which is done in visual basic language using Microsoft Visual Basic 6 (VB6) software.

2.2.1. Arduino 1.0.4

To enable the ATmega328 microcontroller, the Arduino 1.0.4 software was used. The Arduino 1.0.4 programming consists of five main parts i.e., pin assignment, declaration of variables and configure pins, declaration of sub routines and sub routines instructions, main function and main body.

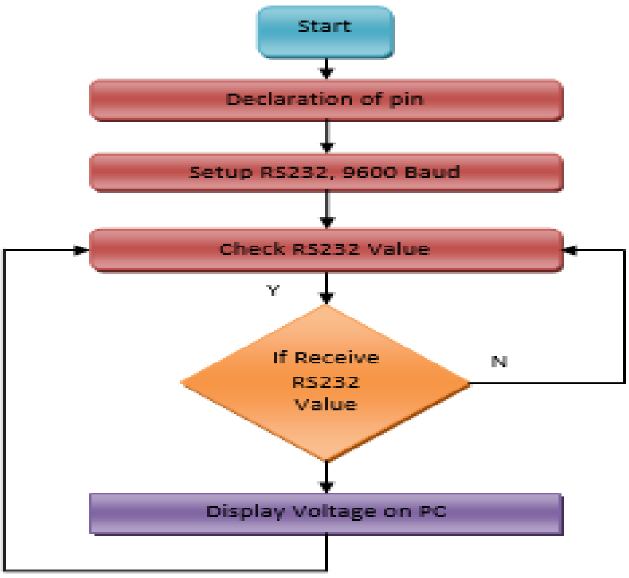

Fig. 3(a). Flow chart for display result on PC

The ATmega328 microcontroller is programed to perform three major tasks– to read values, convert and display the results. When the temperature sensor detects the presence of temperature, the ATmega328 microcontroller will read a series of 10bits analog values from the LM35 Analog pin (2) ranging from 0~1023 on the Analog Pin 0 of Arduino Uno, these analog values are then converted and displayed in a series form of digital values ranging from 0V~5V through the programmed commands. Fig. 3(a) and (b) shows flow chart of programming process of microcontroller.

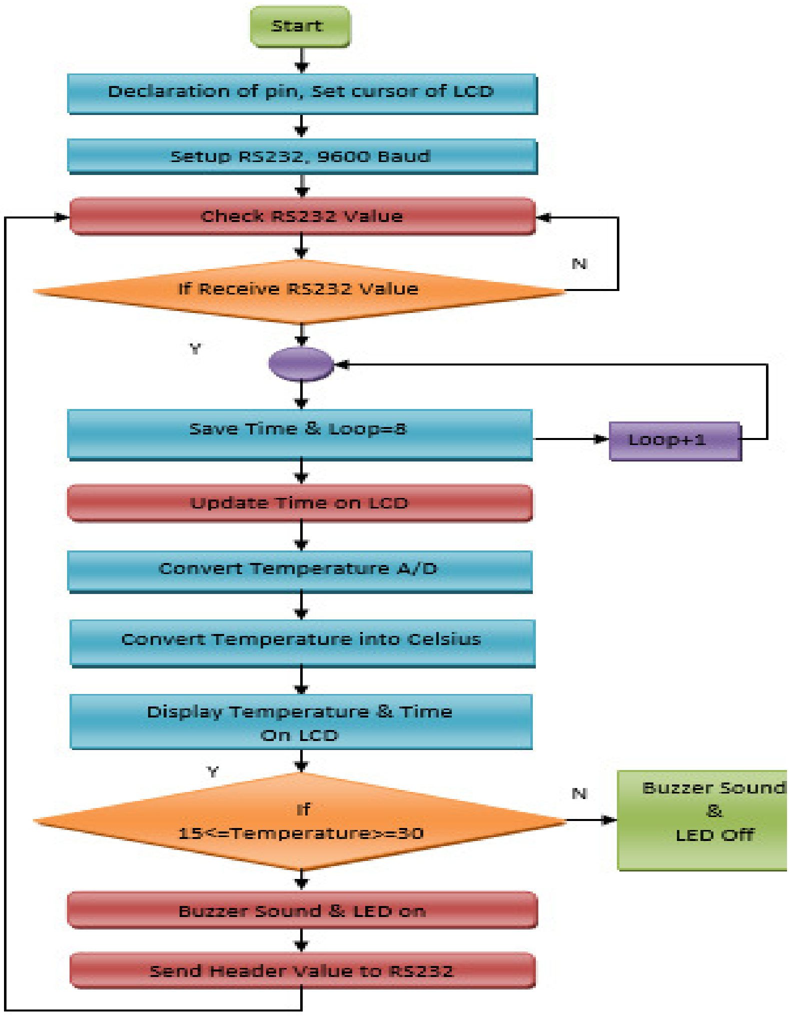

Fig. 3(b). Flow chart for programming code through Arduino Uno

2.2.2. Visual basic

To perform the interfacing between the ATMega328 microcontroller and computer, VB programming is used. The main function of this programming is to display information from the microcontroller, calculations and also to prompt user for actions. Fig. 4 shows the visual basic graphical user interface for the microcontroller based temperature monitoring system. The flow chart of visual basic program is demonstrated in Fig. 5.

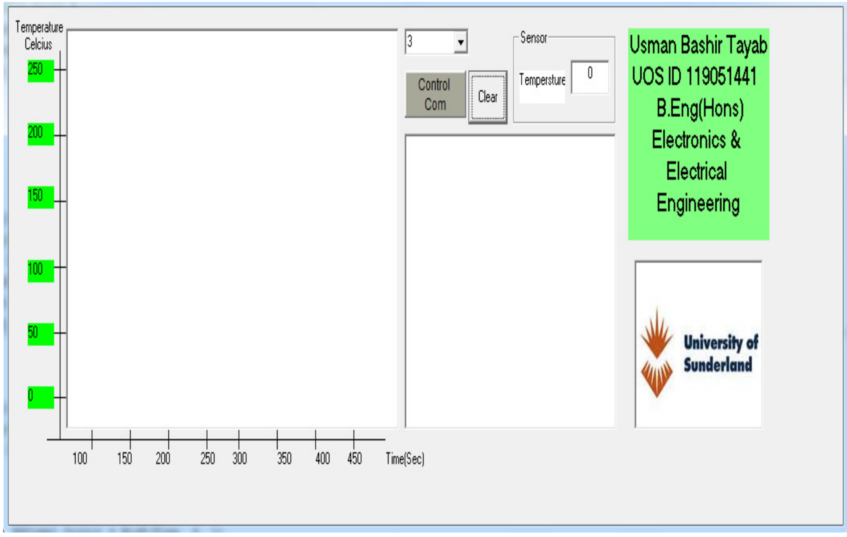

Fig. 4. VB graphical user interface

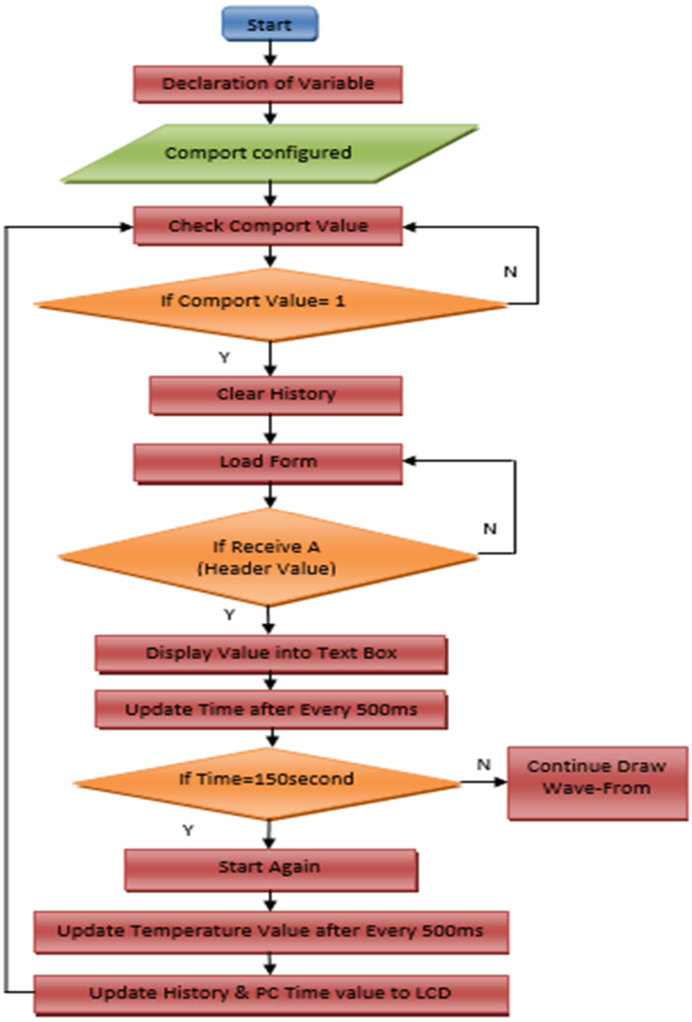

Fig. 5. Flow chart of VB programming

3. Results and discussion

This section discussed results of microcontroller based temperature monitoring system with and without graphical user interface under different temperature conditions.

3.1. Microcontroller based temperature monitoring system graphical user interface

The results obtained using the VB programming in the microcontroller based temperature monitoring system graphical user interface is shown in Fig. 6. It essentially records the temperature values of sensor along with time and date. It also displays the waveform of temperature values.

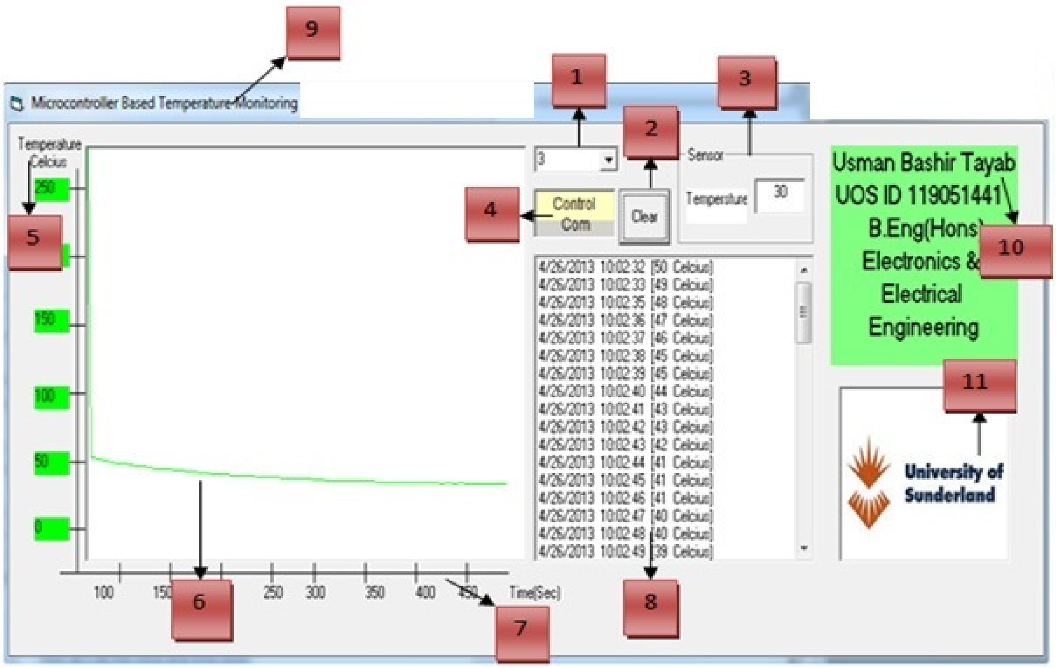

Fig. 6. Result through visual basic

Table 1
Function of different parts of GUI

No.	Function
1	Set the communication port
2	Clear history
3	Display the sensor temperature
4	Control the communication port
5	Display temperature on Y-axis
6	Display sensor temperature in waveform within every second
7	Display time on X-axis
8	Save temperature with time and date by every second
9	Title of project
10	Designer detail
11	University name

3.2. Microcontroller based temperature monitoring system without interfacing

Microcontroller based temperature monitoring system have three parts to perform the desired functions. Each part of the system managed to provide a good and desired result. Therefore, it can be concluded that the microcontroller based temperature monitoring system was able to meet all the expected objectives. The structure of microcontroller based temperature monitoring system prototype is shown in Fig. 7 and results of temperature measurement under different conditions are shown in Fig. 8, 9 and 10, respectively.

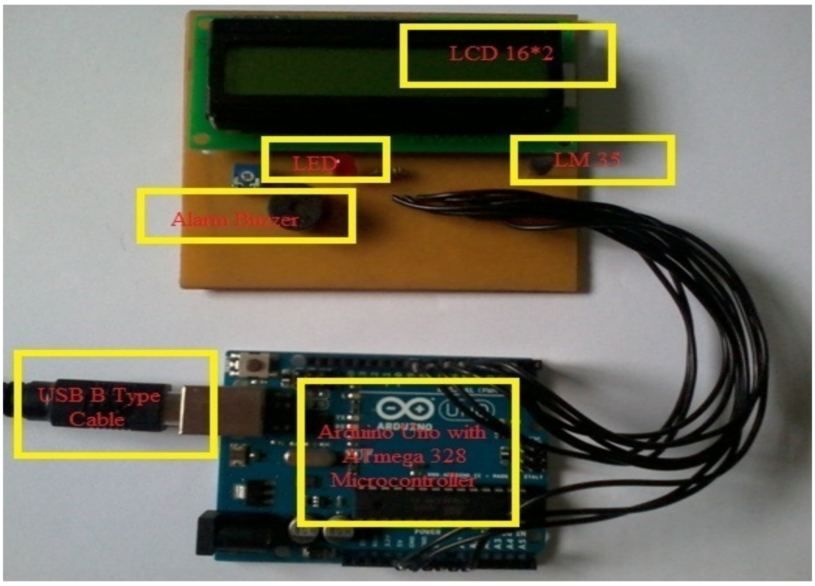

Fig. 7. Temperature monitoring system using Atmega 328 microcontroller

Fig. 8. System result during safe temperature

The performance of the temperature monitoring and control system is distinguished on the basis of accuracy. The LM35 temperature sensor provides higher accuracy. The accuracy indicates how intimately the temperature sensor can measure the actual or real values of the parameters. The more accuracy of temperature measurement shows the better performance of a sensor.

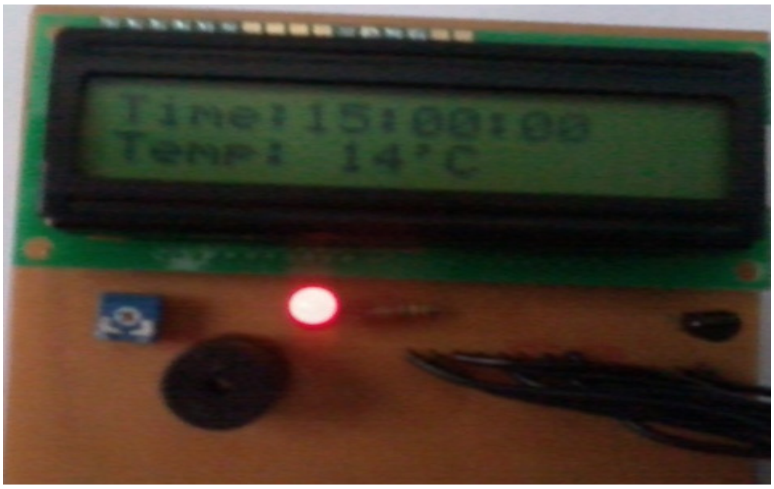

Fig. 9. System result during low temperature

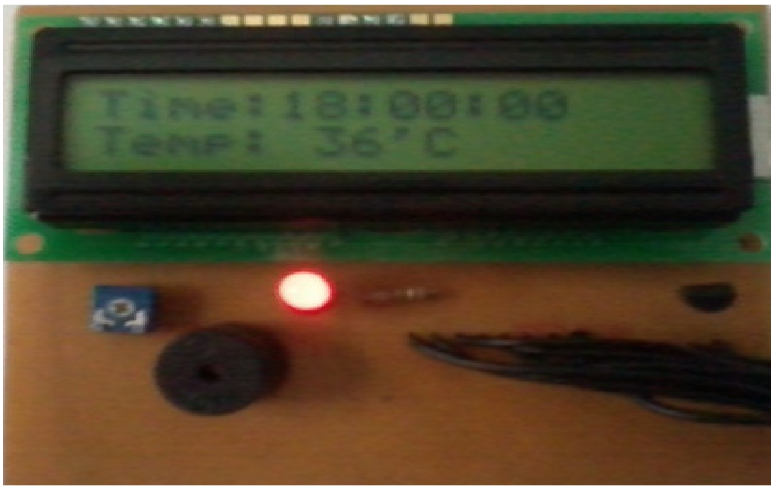

Fig. 10. System result during high temperature

The readings from the temperature monitoring and control system are taken under different conditions for specific time interval. Comparing the readings obtained from the sensor under the different conditions with thermometer temperature and safe temperature limit, the most accurate time period among them is determined.

The safe temperature limit is considered between 15-30 degree centigrade. The results of temperature measurement through design system under different temperatures are provided in Table 2-4. The deviation between the system and thermometer is calculated by Eq. 1.

$$\text{Deviation} = (\text{System Temperature} / \text{Thermometer Temperature}) * 100 \quad (1)$$

Table 2 shows the readings of sensor temperature at safe temperature limit of industry after time intervals of 01 hours, deviation and the function of alarm buzzer and LED. The readings of the sensor temperature are compared with the readings of temperatures obtained from thermometer.

Table 3 presents the readings of the temperature monitoring system at low temperatures from the require temperature after intervals time of 01 hours, deviation and the function of alarm buzzer and LED. The experimental results were obtained by placing ice cold water with help of cotton ball over the sensor. This procedure helped in getting a near-real environmental condition in the industry.

The readings of the sensor are compared with the readings of temperatures obtained from the thermometer temperature.

Table 4 shows the readings of the sensor temperature at high temperatures from the required temperature maintaining time intervals of 01 hours, deviation and function of alarm buzzer and LED. To achieve high temperature condition, a room was heated to increase the air temperature by using heater. This actually represented the high temperature in industry due to a lot of processes. Finally, the sensor was successfully applied to sense the temperature accurately. The readings of the system are compared with the readings of temperatures obtained from the standard temperature indications obtained from the thermometer.

Table 2
Results during safe temperature limit condition

Time	Thermometer Temperature (°C)	Sensor Temperature (°C)	Alarm Buzzer And LED	Deviation (%)
10:00:00	27	27	OFF	0
11:00:00	25	25	OFF	0
12:00:00	21	21	OFF	0
13:00:00	24	24	OFF	0
14:00:00	28	28	OFF	0

Table 3
Results during low temperature condition

Time	Thermometer Temperature (°C)	Sensor Temperature (°C)	Alarm Buzzer And LED	Deviation (%)
12:00:00	11	11	ON	0
13:00:00	13	13	ON	0
14:00:00	12	12	ON	0
15:00:00	14	14	ON	0
16:00:00	09	09	ON	0

Table 4
Results during high temperature condition

Time	Thermometer Temperature (°C)	Sensor Temperature (°C)	Alarm Buzzer And LED	Deviation (%)
14:00:00	32	32	ON	0
15:00:00	35	35	ON	0
16:00:00	34	33	ON	3.1
17:00:00	38	38	ON	0
18:00:00	36	36	ON	0

Accuracy is the degree of conformity which is measured by comparing the results obtained from system with thermometer temperature. Note: It is assuming that thermometer temperature is actual temperature.

The results shown is Table 2 and 3, clearly indicate that system temperature is accurate because of less deviation among the values and close to that of the thermometer. However, during the normal or safe temperature condition and low temperature condition, the error found is 0%. The LED and alarm buzzer is switch off during the measurement taken under safe limit or normal condition but the LED and alarm buzzer is switched on during the low temperature conditions. On the other hand,

Table 4 shows that the system temperature is less close to actual temperature and the error is found about 20%. The LED and alarm buzzer is most of time switched on and indicate the temperature is higher compare to safe limit temperature under high temperature condition.

4. Conclusion

This paper presents an effective design and development of microcontroller based temperature monitoring system. The system detects the temperature value through temperature sensor LM35 and display on LCD by every second continuously. Moreover, the temperature sensor is interfaced with computer through VB coding which stores and displays the waveform on computer. Based on experimental results, it also can be concluded that, among the three conditions, the system gives highly accurate performance at normal and low temperature conditions. The microcontroller based temperature monitoring system is a stepping stone for extended research to be done in order to ensure further improvement or modification of the system so that it can be implemented in various industries to solve the existing everyday problems.

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