Developing and Testing a Thermal Sensor for Biomedical Application

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***Abstract*—In this report, an Arduino-based Temperature Sensor using LM35 and thermistor is presented. LM35 series are precision integrated-circuit temperature sensors whose output voltage is linearly proportional to the temperature in Celcius. We use this to check the temperature of the body as accurately as possible. Integrated with it is an LED bulb which indicates if the temperature is above 40°C, a potentiometer as a control to inputs such as sensor and LCD, and finally an LCD screen to display the output. We obtain temperature readings with an error of ± 5-6% (± 0.75°C). Additionally, a thermistor is also used to compare with the values obtained from LM35. It was observed that LM35 produced more consistent readings with a greater margin of error, while that of the thermistor was more accurate but produced significant variations in reading. We explore these observations under different conditions and provide a conclusion about their working and accuracy.**

***Index Terms*—LM35 Thermal Sensor, Thermistor, Arduino, Potentiometer**

I. Introduction

Nowadays, Temperature monitoring and maintenance is important for many control applications. A temperature sensor is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record, monitor, or signal temperature changes. One such sensor that we will discuss in detail is LM35. LM35 is a temperature sensor that outputs an analog signal which is proportional to the instantaneous temperature. The sensor has three pins: V_s (connected to 5V input of Arduino), V_{out} (connected to analog input pin A0), and GND (connected to the ground of Arduino). The output voltage can easily be interpreted to obtain a temperature reading in Celsius. LM35 can measure from -55°C to 150°C. The accuracy level is very high if operated at optimal temperature and humidity levels. The conversion of the output voltage to centigrade is also easy and straightforward. The input voltage to LM35 can be from +4V to +20V. The advantage of LM35 over thermistors is it does not require any external calibration. The coating also protects it from self-heating.

LM35 has a linear scale factor of +10 mV per degree centigrade. It means that with an increase in output of 10 mV by the sensor V_{out} pin, the temperature value increases by one. The formula to convert the voltage to centigrade temperature for LM35 is:

$$Temperature\,in\,Celcius = (Voltage\,Read\,by\,ADC)/10mV \tag{1}$$

In this project, we test the ability of the sensor to give temperature readings under 3 different conditions:
1. Room Temperature
2. Body Temperature
3. Rate of increase when exposed to flame for a few seconds

A red LED bulb is connected to the circuit setup to indicate if the temperature has crossed 40°C (indicative of a high fever). To test the working of this, a flame is shown to the sensor for a few seconds. The potentiometer is a three-terminal variable resistor. Out of its three terminals, two of them are fixed, and one is a varying rotary terminal. It is connected to regulate current flow and ensure excessive current does not enter the LM35 (which will result in wrong readings).

A thermistor is a resistance thermometer or a resistor whose resistance is dependent on temperature. We have with us an NTC (Negative Temperature Coefficient) thermistor, where the temperature and resistance are inversely proportional. A thermistor has two pins, one of which is connected to ground of Arduino and the other to input 5V through a 10kΩ resistor.

We have used a 16X2 LCD to display the output of the two sensors. 16×2 here means that the LCD has 2 lines and can display 16 characters per line. Therefore, a 16×2 LCD screen can display up to 32 characters at once. In the code, we have used the LiquidCrystal library that comes pre-installed with the Arduino IDE.

During our experiment, we observe that LM35 gives more consistent readings in all three cases (Room temperature, Body Temperature, and Flame Temperature), while that of the thermistor is more accurate (closer to desired values) by a small margin. However, the readings fluctuate a lot for the thermistor. The integration of potentiometer with LM35 could be the reason for consistent readings, while the thermistor has a 10kΩ resistor connected to it. Using the push button, we can switch between the readings of LM35 thermal sensor and thermistor. By the end of the project, we can conclude that both the sensors are suitable for testing temperatures (with a small margin of error), each having its benefits and drawbacks.

II. The Experiment

A. Objective

To develop and test a sensor for a biomedical application and to integrate an appropriate circuit for the same. There will be a computational analysis of the sensor also. We interface a thermistor and LM35 with Arduino, connect a switch to select the sensor i.e. thermistor or LM35, calibrate and restrict the sensor for human body temperature measurement, display the data in Arduino terminal and an LCD.

B. Materials and Methods

Arduino UNO (1) , Jumper wires, Wires, Breadboard (1), LED bulb - Red (1), 10 kΩ Resistors (3), 10 kΩ Potentiometer (1), 16X2 LCD screen, NTC Thermistor (1), LM35 thermal sensor (1), Push-button (1)

The temperature of thermistor is calculated using the Steinhart and Hart equation, which is an empirical expression that has been determined to be the best mathematical expression for the resistance - temperature relationship of a negative temperature coefficient thermistor. The equation is as follows:

$$Temperature\ in\ Kelvin = \frac{1}{(A + B[ln(R)] + C[ln(R)]^3)} \quad (2)$$

where A = 0.001125308852122, B = 0.000234711863267 and, C = 0.000000085663516.

Arduino analog pins can measure up to +5 volts and the Arduino analog pin resolution is 0-1023. On acquiring a +5 volt input it counts to 1023. LM35 max voltage output is 1500mV (at 150°C). 1500mV is equal to 1.5V. So LM35 at max output is 1.5V. We get the voltage reading from temperature sensor as follows: (5/1023)*1000 = 4.8828mV. Since LM35 has a linear scale factor of +10 mV per degree centigrade, Factor = 0.48828. So the temperature is updated as temperature(new) = temperature (current) X 0.48828.

C. Circuit Diagram

The circuit connections are made as follows:

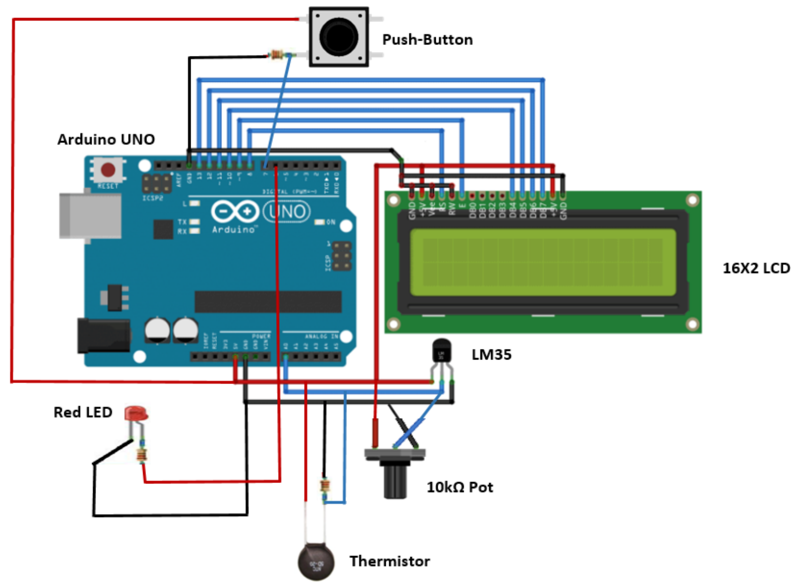

Fig. 1. Circuit Connection

D. Procedure

1. The connections are made as shown in the circuit diagram.
2. A thermistor is used to compare with the readings of LM35 temperature sensor.
3. The ground of LM35 thermal sensor is connected to ground of Arduino. The V_s is connected to +5V of Arduino, V_{out} is connected to A0 using jumper wires/wires, and GND of LM35 is connected to ground of Arduino. A 10k ohm potentiometer is connected to this accordingly.
4. One leg of the thermistor is connected to 5V input and the other to a 10k ohm resistor. One leg of the resistor is connected to ground and the other one (thermistor and resistor common) is connected to A1 of Arduino board.
5. The Analog to Digital Converter (ADC) converts analog values into a digital approximation based on the formula:

$$ADC\ Value = \frac{sample * 1024}{reference\ voltage\ (+5v)} \quad (3)$$

6. The code (attached separately) was written and uploaded to the Arduino board and results were observed for thermistor and LM35.

E. Images

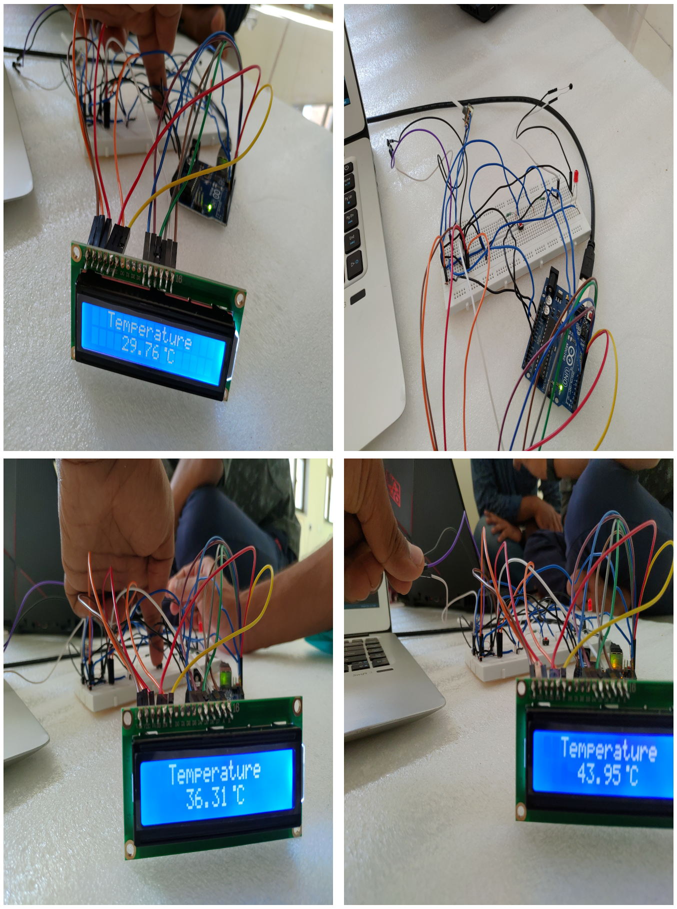

Fig. 2. The Setup

F. Results and Discussion

The following observations were made and results obtained from the project:

1. The reading is close to that of the surrounding temperature which varied between 31-35°C in both the sensors.

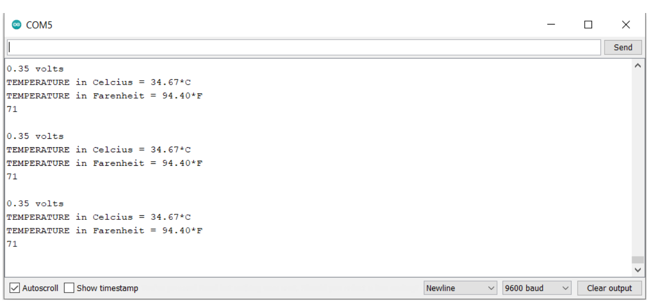

Fig. 3. LM35 Room Temperature

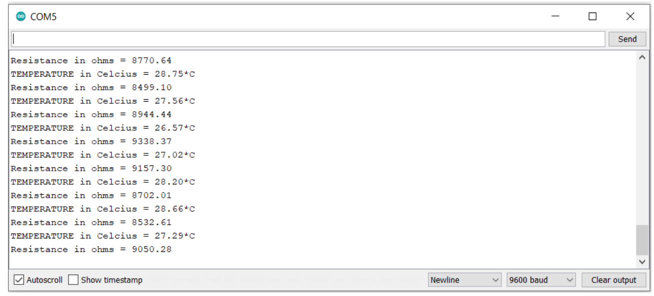

Fig. 4. Thermistor Room Temperature

2.The reading is close to that of the body temperature which varied between 37-39°C in both the sensors.

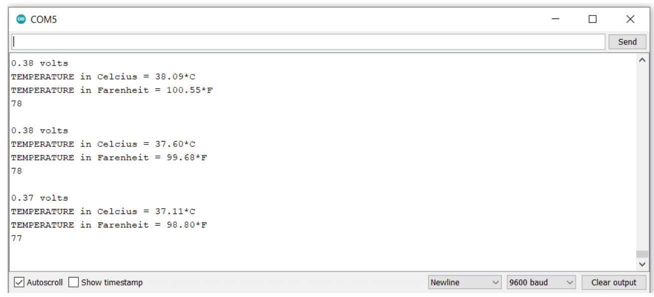

Fig. 5. LM35 Body Temperature

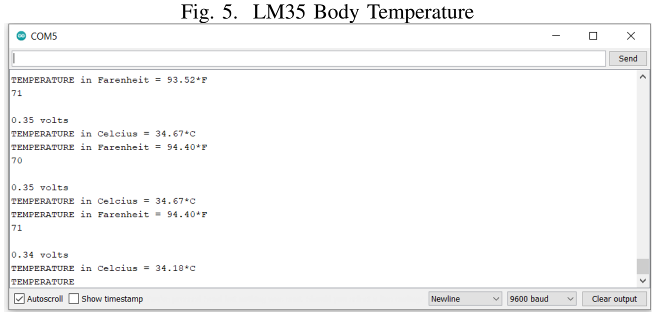

Fig. 6. Thermistor Body Temperature

3. Similar, but not same, readings were obtained from the two different sensors under the same condition.
4. The temperature obtained from LM35 sensor was more consistent than that of the thermistor, while that of thermistor was slightly more accurate.
5. The potentiometer helped maintain stability in voltage for the LM35 thermal sensor which ensured accurate readings, a similar role is played by the 10k ohm resistor for thermistor.
6. Exposing the sensors to a flame for a few seconds successfully lit the red LED bulb, which is kept to indicate temperatures above 40°C, or situations where a person may have fever.

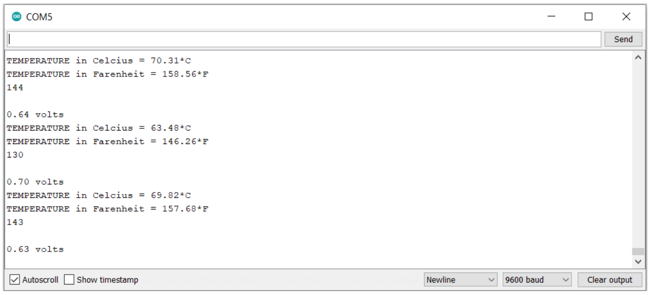

Fig. 7. LM35 Flame Temperature

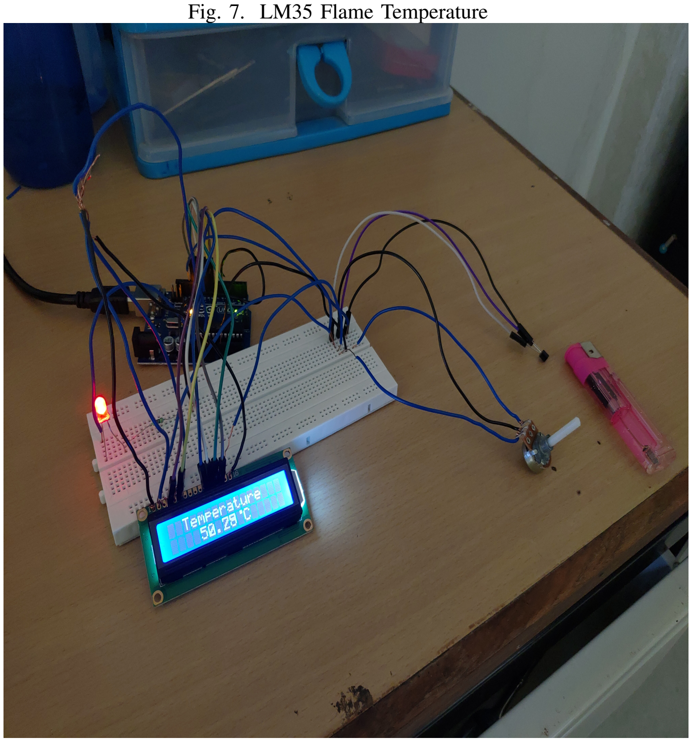

Fig. 8. Glowing of red LED in temperature above 40°C

7. The push-button successfully changes the readings shown in the output terminal and LCD. While being OFF the program displays the output of LM35 and when the button is pushed ON, we see the output of the thermistor.

G. Conclusion

- Both the sensors, LM35 and Thermistor, can be used to check body temperature with a marginal error (4-6%).
- Integrating a potentiometer with the LM35 sensor helps in its safekeeping by controlling the current entering the sensor. It also helps maintain voltage at a constant level providing consistent readings throughout.
- The thermistor with its simple setup is able to give accurate readings although not quite stable.
- The equation used to convert temperature to voltage and show output is linear in the case of LM35, while it is non-linear in the case of thermistor, requiring us to use the Steinhart-Hart-Equation.
- Both the sensors have a large operating temperature range, i.e, -55°C to +150°C, and low self-heating.

References

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