Bansilal Ramnath Agarwal Charitable Trust’s

Vishwakarma Institute of Information Technology

(Department of Electronics & Telecommunication Engineering)

Hardware implementation entitled

"Measuring Temperature from PT100 Using Instrumentation Amplifier"

Roll No.	GR Number	Name of Student	E-mail	Contact Number
213032	17U352	Prabhat Kumar	prabhat.17u352@viit.ac.in	+91 8051062409
213027	17U433	Sainathan Iyer	sainathan.17u433@viit.ac.in	+91 8446055531
213029	17U304	Shriyash Khorate	shriyash.17u304@viit.ac.in	+91 8600255677

For the course

(Electronic Workshop Practice– II)

Project Based Learning (PBL)

Domain:

___Integrated Circuits/Semiconductor Devices___

S.Y. B. Tech

SEM-IV

Course Teacher

Mr. Vishal Ambhore

Year 2018 – 2019

Course Objectives:

- To learn the steps in electronic circuit through simulation and hardware implementation
- To imbibe good soldering design practices for robust design of electronic systems.
- To understand the importance of documentation by compiling Project Report

PBL Objectives:

The main objective of the PBL, as a methodology to improving the learning of our students:

- Integrate knowledge and skills from various areas through more complex and multidisciplinary projects
- Autonomous learning and work:
    1. Unstructured problems that need research.
    2. Autonomy will lead to research and the search for information and in that context is essential to develop their ability to discern which information is reliable and which is not.
- Self-evaluation and self-criticism, against self-complacency, trying to see beyond their own ideas and knowledge.
- Development of team skills:
    1. Actively contributing to the group problem-solving process.
    2. Learning from and accepting help from others in the group.
    3. Teaching and helping others in the group as appropriate in the learning process.
    4. Accepting constructive criticism from others in the group.
    5. Providing constructive criticism to others.
    6. Taking responsibility for tasks required in the group's ongoing work.

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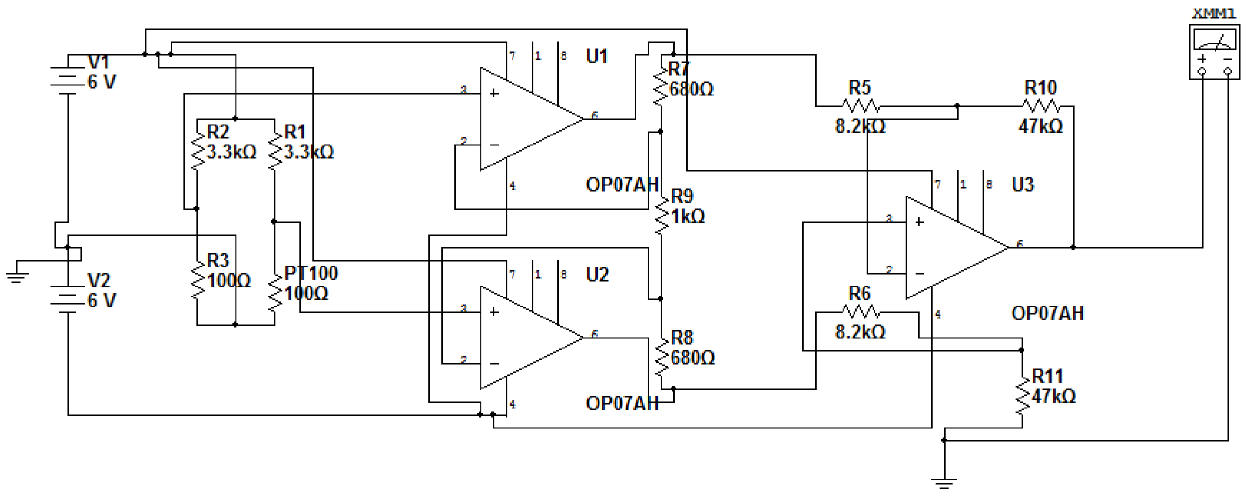
1. Objective of Project:

The PT100 is a resistance temperature detector (RTD) which changes its resistance depending on its surrounding temperature, it's used widely for industrial processes with slow dynamics and relatively wide temperature ranges. It's used for slow dynamic processes because RTDs have slow response times but are accurate and have low drift over time. The main objective of this project is to make this sensor work for a temperature range of **0 to 600 degrees Celsius**. To achieve that we have calculated the specific resistances to get the desired gain.

1.1. Circuit diagram of application and working:

A. Circuit Diagram:



B. Working:

Formula for calculating the temperature from resistance of PT100 is:

$$R_x = R_0(1 + \alpha * T)$$

Where Rx is the PT100 resistance, R0 is the PT100 resistance at 0 degrees C, α is the temperature resistance coefficient and T is the temperature.

We need a range of 0 to 600 degrees Celsius.

$$R_x = 100(1 + 0.00385 * T)$$

R0 is 100ohms as this is a PT100, if it was a PT1000, R0 would be 1000ohms. α is 0.00385 ohms/degrees C taken from the datasheet.

Formula to calculate temperature for a given resistance:

$$T = \frac{\frac{R_x}{R_0} - 1}{\alpha}$$

We want to measure something which would have a temperature range of 0 to 600 degrees C.

For T=0 degree Celsius, put **T = 0** in the above equation we get **Rx = Ro** and **Rx = 100 ohms.** (Since Ro = 100 ohms).

Similarly for **T = 600** degree Celsius we get **Rx = 331 ohms**.

Formula to calculate voltage range using voltage divider:

$$V = V_{in} * \frac{R_x}{R1 + R_x}$$

Here **Vin = 6V,** for 100 ohms we get **V1 = 0.1765V**, and for 331 ohms we get **V2 = 0.55V**.

Finally we have a range of resistance values taken from PT100 for operation in (0 to 600 degree C). This gives us a range of **0.3735V** and a DC offset of **0.142V**. To get rid of the DC offset and to increase the sensitivity we use Wheatstone bridge. **3.3k ohms** for **R1 and R2** to limit current and increase linearity. **100 ohms** resistor is called **R offset**. RTD **(PT100)** passing too much current gives incorrect readings due to self heating. Output of the 2nd Voltage divider (Vb-) will be subtracted from the 1st Voltage divider (Vb+).

For that we used **differential amplifier**:

$$(V_{b+} - V_{b-}) = V_{in}\left(\frac{Rx}{R1 + Rx} - \frac{R_{off}}{R3 + R_{off}}\right)$$

For PT100 at **100 ohms** we have **(Vb+ - Vb-) = 0V**.

For PT100 at **331 ohms** we have **(Vb+ - Vb-) = 0.3735V**.

Now we have the output range of two voltage dividers i.e. **0V to 0.3735V**.

We need a differential amplifier with **Gain = 1**.

Feed **Vb+ in Inverting** terminal and **Vb- in Non-inverting** terminal.

$$V_{out} = \left(V_{b_+} - V_{b_-}\right) * A_d$$

Formula to calculate gain of differential amplifier:

$$A_d = \frac{R_b}{R_a} = \frac{47k}{8.2k} = 5.732$$

Formula to calculate gain of instrumentation amplifier:

$$A_i = 1 + \frac{2R_c}{R_{gain}}$$

Formula to calculate gain of total circuit:

$$A_T = \left(\frac{R_b}{R_a}\right)\left(1 + 2 * \frac{R_c}{R_{gain}}\right)$$

We need a total gain of **At = 5V/0.3735V = 13.38**

So now we need **Rc** and **Rgain** values.

Using Equation: **At = Ai * Ad**

13.38 = Ai * 5.732

Ai = 2.334

We get **Rc/Rgain = 0.67**

Hence we now have

Rc = 680 ohms.
Rgain = 1000 ohms.
R10 = R11 = 47k ohms.
R5 = R6 = 8.2k ohms.

1.2. Power Supply Requirement: Two batteries of 6V are enough to power the Circuit.

1.3. Electronic Component list and specifications:

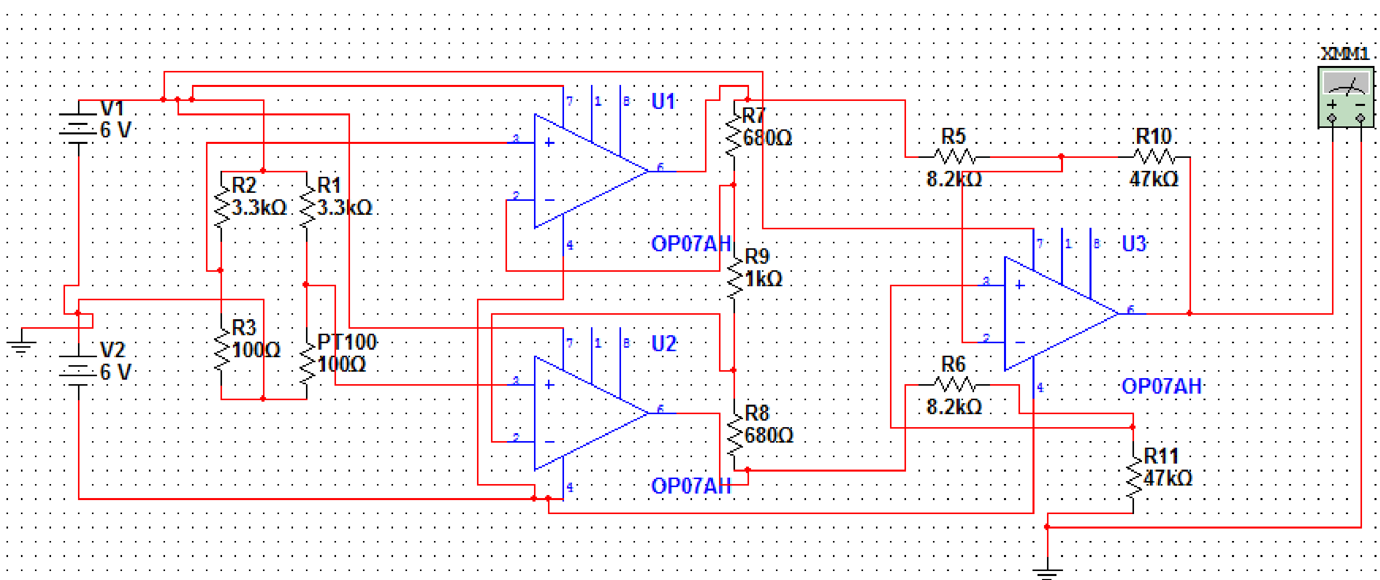
Sr. No.	Name of components	Quantity	Specifications/Value	Cost
1.	PT100	1	High Precision Platinum Two Wire	370/-
2.	Resistors: **3.3k ohm**	2	Wire Wound	5/-
3.	Resistors: **100 ohm**	2	Wire Wound	5/-
4.	Resistors: **680 ohm**	2	Wire Wound	5/-
5.	Resistors: **8.2k ohm**	2	Wire Wound	5/-
6.	Resistors: **47k ohm**	2	Wire Wound	5/-
7.	Resistor: **1k ohm**	1	Wire Wound	2/-
8.	Op-Amp	3	OP07AH	60/-

Total = 457 Rupees Only

2. EDA tool used for schematic and PCB design:

Altium Designer 16.0 and NI Multisim 11.0 were used.

3. Circuit diagram implementation using EDA tool:

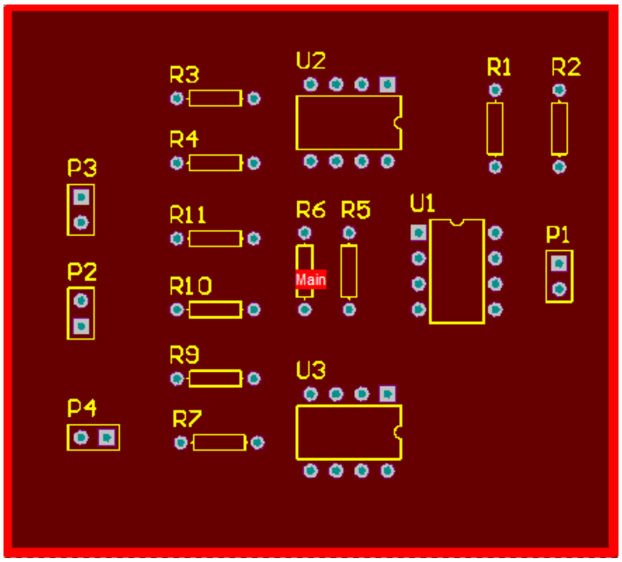


4. Implementation of PCB using EDA tool:

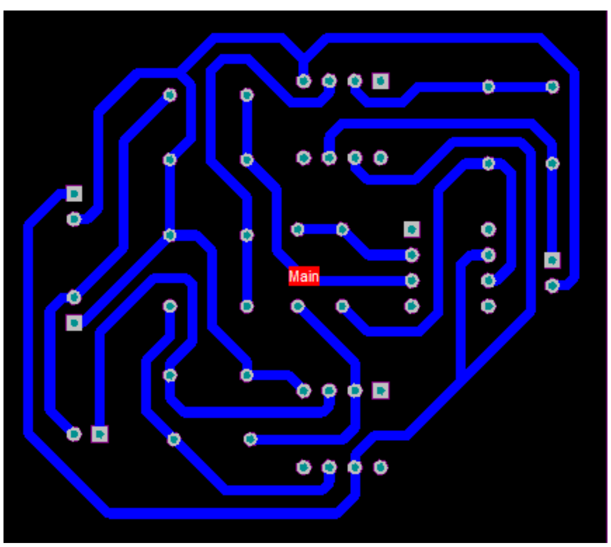
4.1. Rules specified for PCB design:

Track Width = 39.9mils with appropriate Track Clearance.

4.2. Top layer (Image of Component Layer):



4.3. Bottom layer (Image of Copper Layer):



4.4. PCB information:

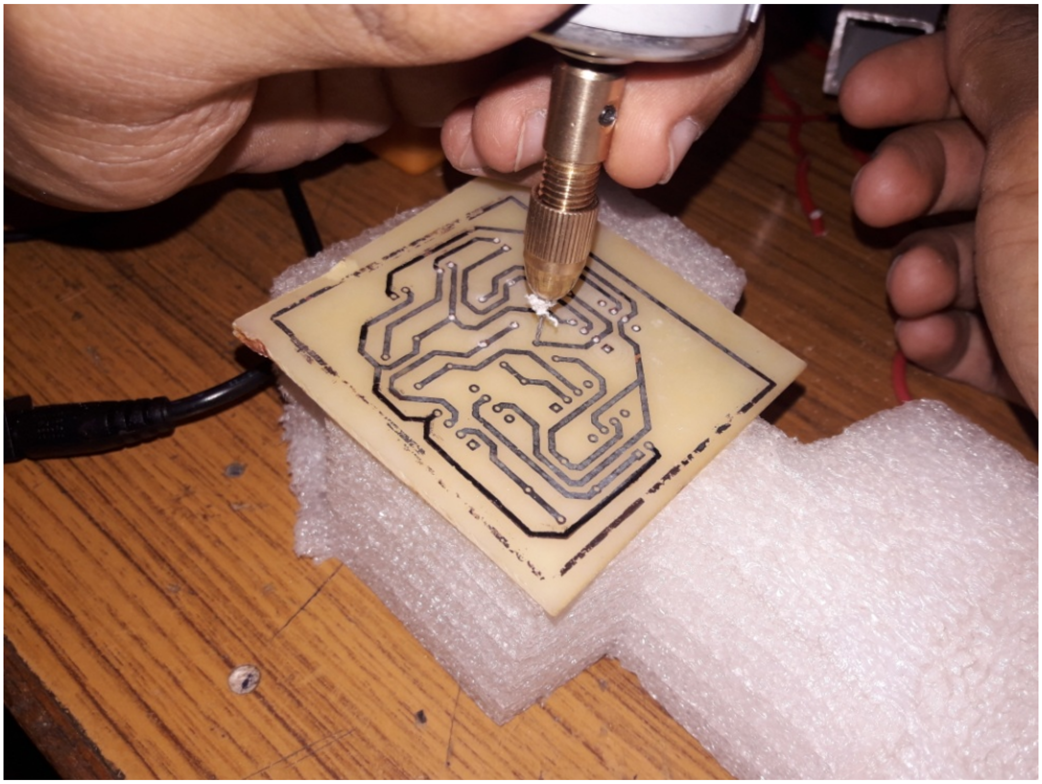
1) It is a Single Layered PCB.
2) Dimensions = 6X6cm.
3) No of Components Placed = 14.

5. PCB Development Process:

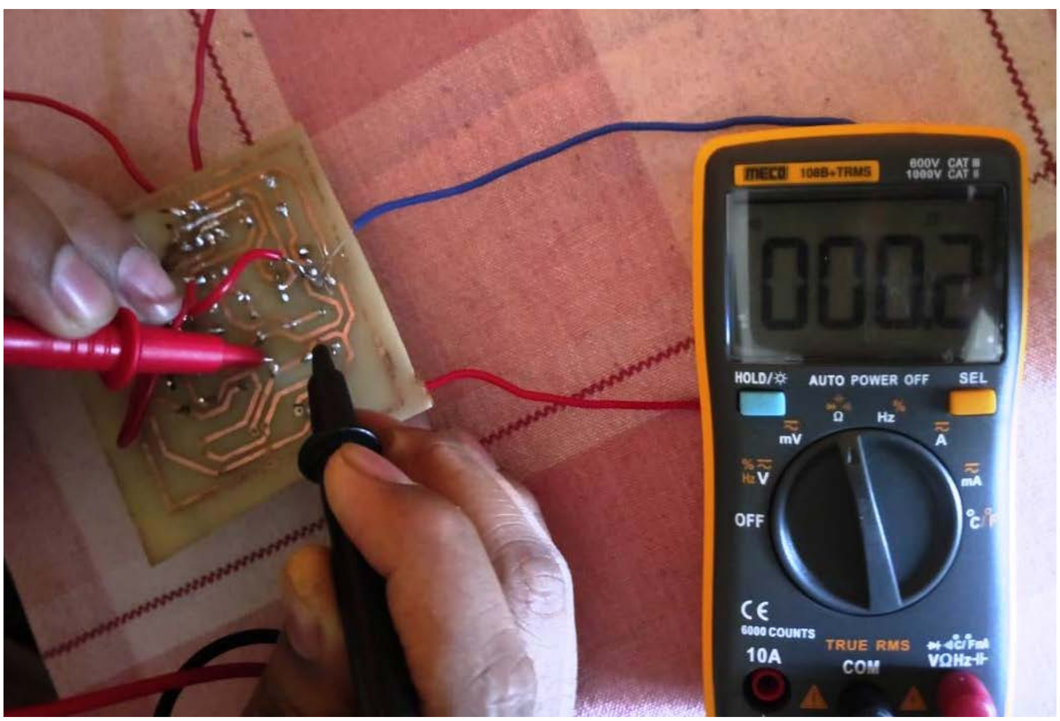
5.1. PCB Etching:

5.2. PCB Cleaning:

5.3. PCB Drilling:



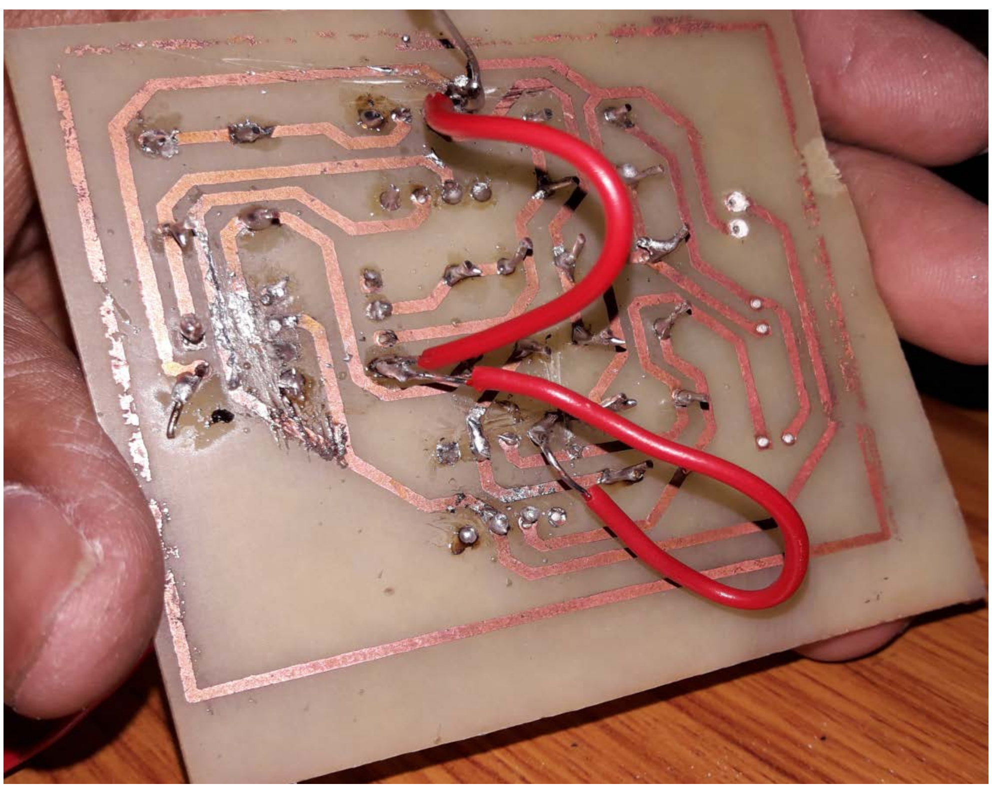
6. Verification of PCB (Track Continuity Checking):



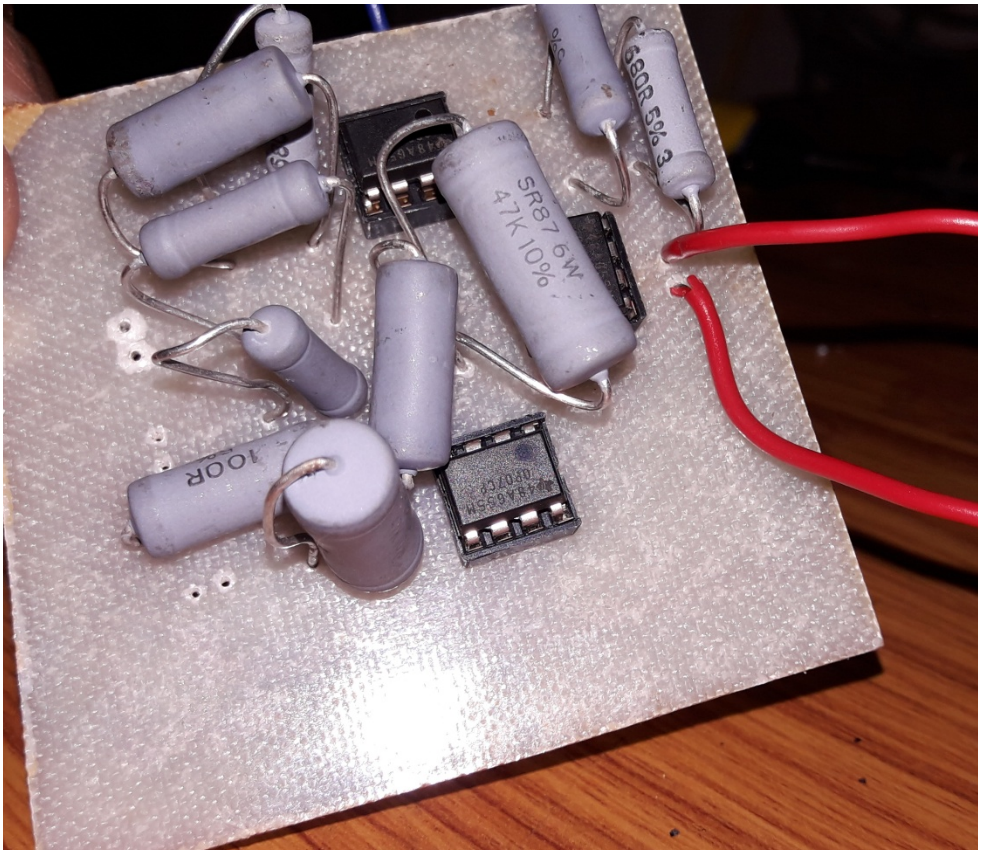
7. Soldering techniques/Processes:

8. Actual Hardware Images:

8.1. Solder side (Copper layer Side):



8.2. Component side:



9. Conclusion:

The key to successful PCB is making sure that the ink transfers successfully on the photo paper so that all the tracks and pads remain intact. It is always advised to use a better iron for transferring the layout successfully on the PCB. Etching process can be very easy if the above steps are completed successfully. However etching process can be a bit lengthy depends on the Etching Solution and its dilution. The drilling and soldering is probably the phase that requires real skills and efforts. This project was successful in completing the Course and PBL outcomes outlined in the Introduction. We would like to thank the respective course teacher and course coordinator for assigning this project due to which we got hands on experience of PCB Designing and Manufacturing Process.

References:

1) https://www.instructables.com/id/Reading-Temperature-From-PT100-Using-Arduino/
2) https://datasheetspdf.com/pdf-file/1271954/AnalogDevices/OP07/1
3) **Electronic Principles** (Special Indian Edition) 7th Edition by **Albert Malvino** and **David Bates**
4) Franco's **Design with Operational Amplifiers and Analog Integrated Circuits**, 3e