Experiment title – Temperature Measurements

Week no. – 6

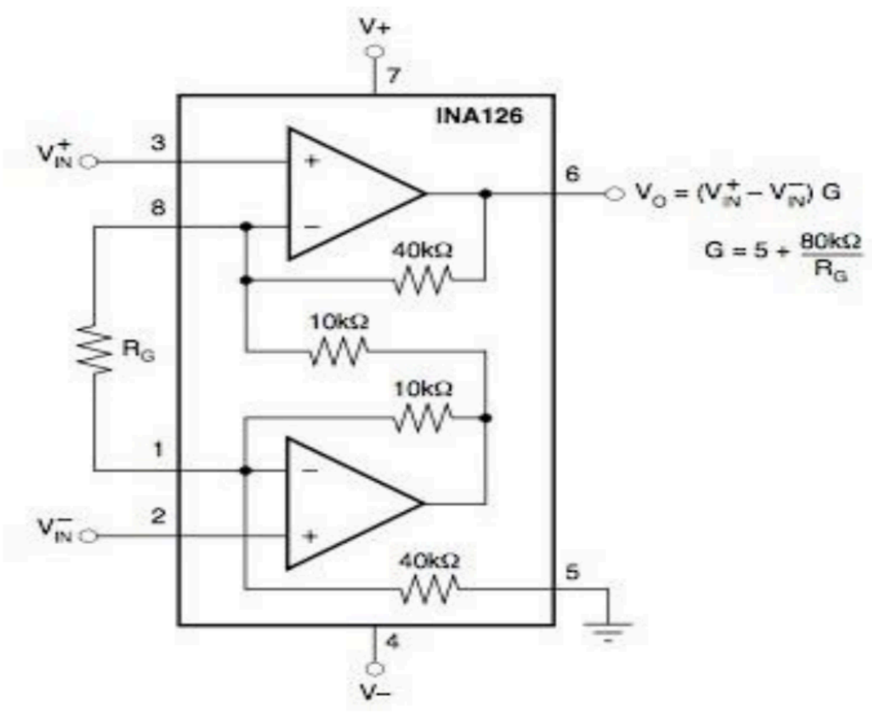
Date of experiment – 10/10/2023

Group name – T6

Group members – Jasnoor Tiwana (B21194), Saransh Duharia (B21021), Adarsh Santoria (B21176), Rawal Ram(B21219), Binduthraya Matta (B21203).

1. Experiment layout

An instrumentation amplifier is a differential op-amp circuit providing high input impedance, and with the ease of gain adjustment through the variation of a single resistor. It is used to provide a large amount of gain for very low-level signals, often in the presence of high noise levels. The major properties of Instrumentation Amplifiers are high gain, large common-mode rejection ratio (CMRR), and very high input impedance. Instrumentation Amplifiers can be made using a 2 op-amp configuration or a 3 op-amp configuration with each configuration having different CMRR and input impedance. INA126 is one such instrumentation amplifier which uses 2 op-amp configuration.

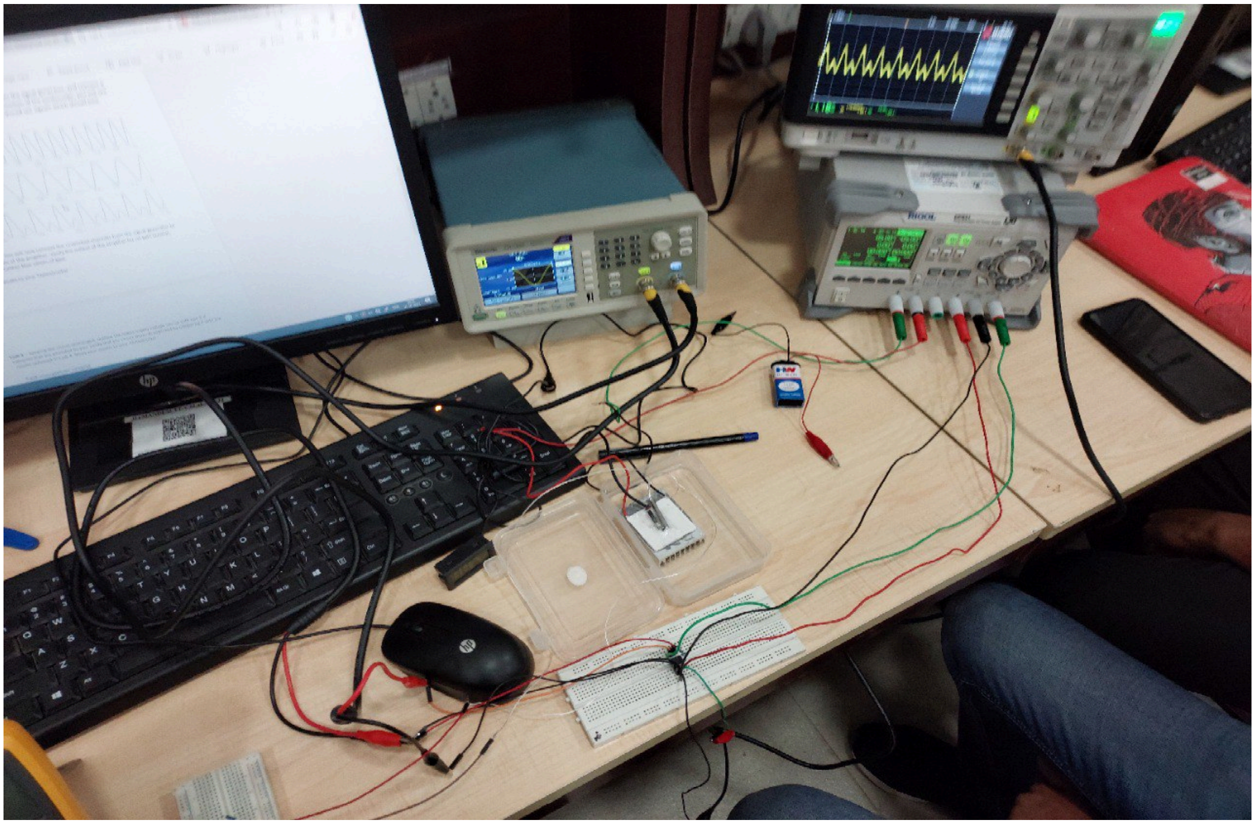


Above figure shows the internal circuit of INA 126, which consists of 2OP-AMPs and an output terminal whose gain can be changed by changing the external resistance connected to it. The V+ and V- are the voltage supply to the OP-AMPs which play a crucial role in limiting the gain of the circuit. The difference of both the Vin gets amplified.

2. Results

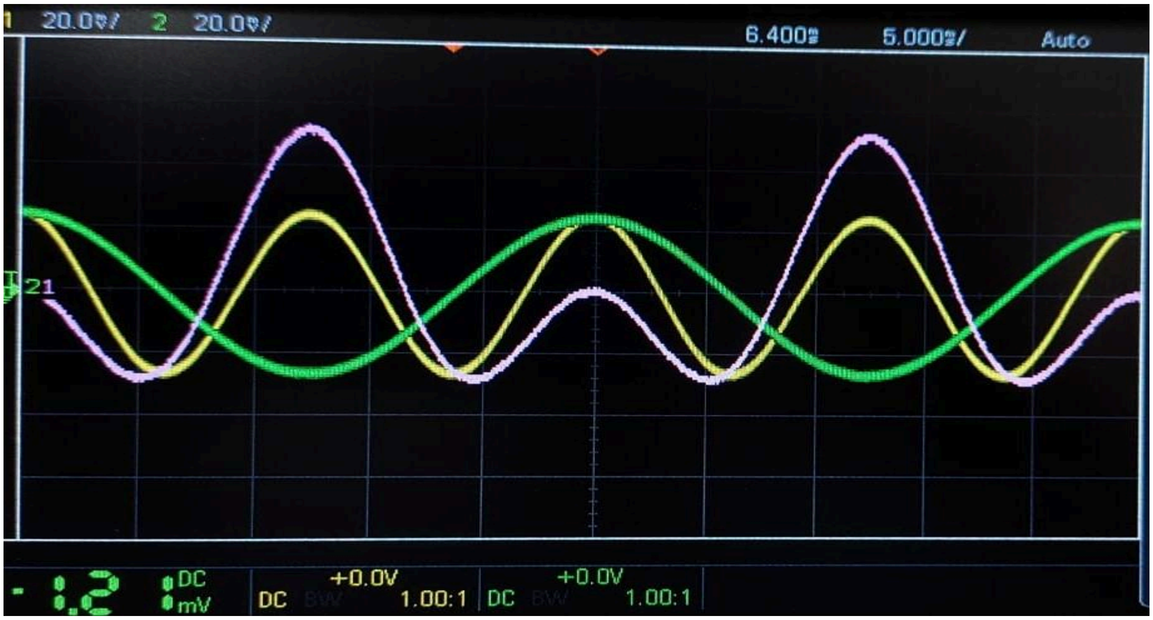
Task 1.1 – Build the complete circuit diagram of the amplifier circuit on the breadboard and get it verified by your Instructor/TA. You don't need to add the gain resistor at this stage.

In this experiment, We established a fundamental instrumentation amplifier circuit using the INA126. At first, we supplied power through two 9-Volt batteries, connected distinct input signals to the positive inputs, and grounded the negative inputs. The resulting amplified output was observed on an oscilloscope, confirming the circuit's capability to amplify the difference between the input signals.



Task 1.2 – You will provide a differential input to the amplifier using two channels of the signal generator. For the non-inverting input of the amplifier you will provide a 80 Hz, 50 mVpp signal, and a 40 Hz, 50 mVpp signal for the inverting amplifier input. You will perform this task in two stages.

In Task 2, We provided a differential input to the amplifier using two channels (80Hz, 50 mVpp and 40Hz, 50 mVpp) of the signal generator in two stages.



During the first stage, We connected the output signals directly from the signal generator to the oscilloscope. Utilizing the oscilloscope's math function, we calculated and recorded the expected difference signal, observing that it accurately represented the variance between the 80 Hz and 40 Hz input signals. In the above figure, the pink waveform (frequency=40Hz) represents the output signal.

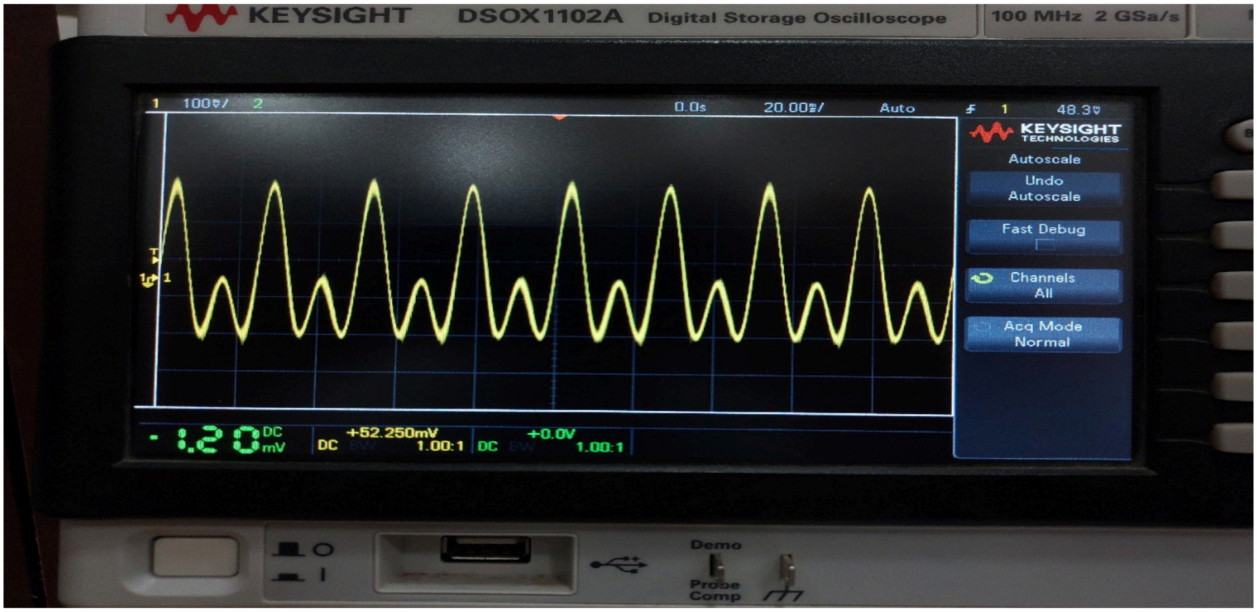
In the second stage, We connected the respective channels from the signal generator to the inputs of the amplifier. Firstly, without a gain resistor, we observed that the output signal is the same as previous but amplification or gain changes to 5. This exactly matches with the theoretical gain with infinite gain resistance (resistance of air) using the formula (5 + 80k/Rg). Subsequently, we adjusted the gain resistor to four different values, meticulously recording the output voltages for each setting. These observations provided valuable insights into the amplifier's behavior at various gain configurations.

These observations not only validated the functionality of the amplifier but also provided essential data for further analysis and experimentation.

Task 1.3 – Keeping the circuit unchanged, replace the mains supply voltage source with two 9-V batteries that are provided to you. Verify that the circuit works as expected by comparing it with the results obtained in Task 2. Show your results to your TA/Instructor.

Here, we kept the circuit configuration unchanged and replaced the mains supply voltage source with two 9-V batteries as instructed. We meticulously verified the circuit's operation, ensuring accuracy by comparing the newly obtained results with those acquired in Task 1.2, which utilized the mains supply voltage. This comparison allowed us to confirm the circuit's consistency and functionality under different power sources. This demonstration provided clear evidence of the circuit's stability and reliability, validating its operation under varying power sources according to the experimental requirements.

Following is the output of the amplifier for the same input signals as in the earlier task, the gain here is 5 as no gain resistance is connected.



Task 2.1 – Construct a Wheatstone bridge for a PT100 sensor, such that

a. **You are using the same battery that is being used for the INA as the voltage source for the bridge. The supply voltage should be 1.5 V.**
b. **The Wheatstone bridge is operating in (approximately) its maximum sensitivity configuration.**

Here, we constructed a Wheatstone bridge for a PT100 sensor using a 1.5 V supply voltage from the same battery that powers the INA. To achieve maximum sensitivity, the bridge was set up in a balanced state where the voltage across the bridge is minimized when no external stimulus is applied. We connected the PT100 sensor in one arm of the bridge (R1) and three resistors in the other three arms.

I (A)	T (°c)	R (ohm)	Vbd (V)
0.66	12	105.1	0.0159
0.6	13.2	105.5	0.0157
0.55	14.5	105.8	0.0150
0.5	15.2	106.0	0.0122
0.4	17.2	106.6	0.0106
0.3	18.9	107.7	0.0074
0.2	20.6	107.8	0.0075
0.1	22.4	108.1	0.0059

0	24.5	108.8	0.004
-0.1	27.0	110.0	0
-0.2	29.2	110.6	-0.002
-0.3	31.8	111.3	-0.0045
-0.4	34.6	112.2	-0.0074
-0.5	37.8	113.4	-0.0107
-0.6	41.4	114.5	-0.0153
-0.66	43.8	115.5	-0.0163

We adjusted the resistances of R1 until the bridge was balanced, ensuring there was no voltage across the bridge in the balanced state. For this, at first, we calibrated the resistance of PT100 at different temperatures and found the range of values and took the other three resistances (150 ohm, 220k ohm, 300k ohm) accordingly such that the wheatstone bridge balanced at 110 ohm . The 1.5 V supply from the battery powered the bridge, allowing us to measure and analyze the PT100 sensor's response accurately. This configuration at balanced point provided the maximum sensitivity for detecting small changes in the PT100 sensor's resistance.

Task 2.2 – Connect the PT100 sensor to the Peltier configuration like the last class. You will have to redo both the calibration of the Peltier and the PT100, as the experimental configuration will no longer be the same as the previous class.

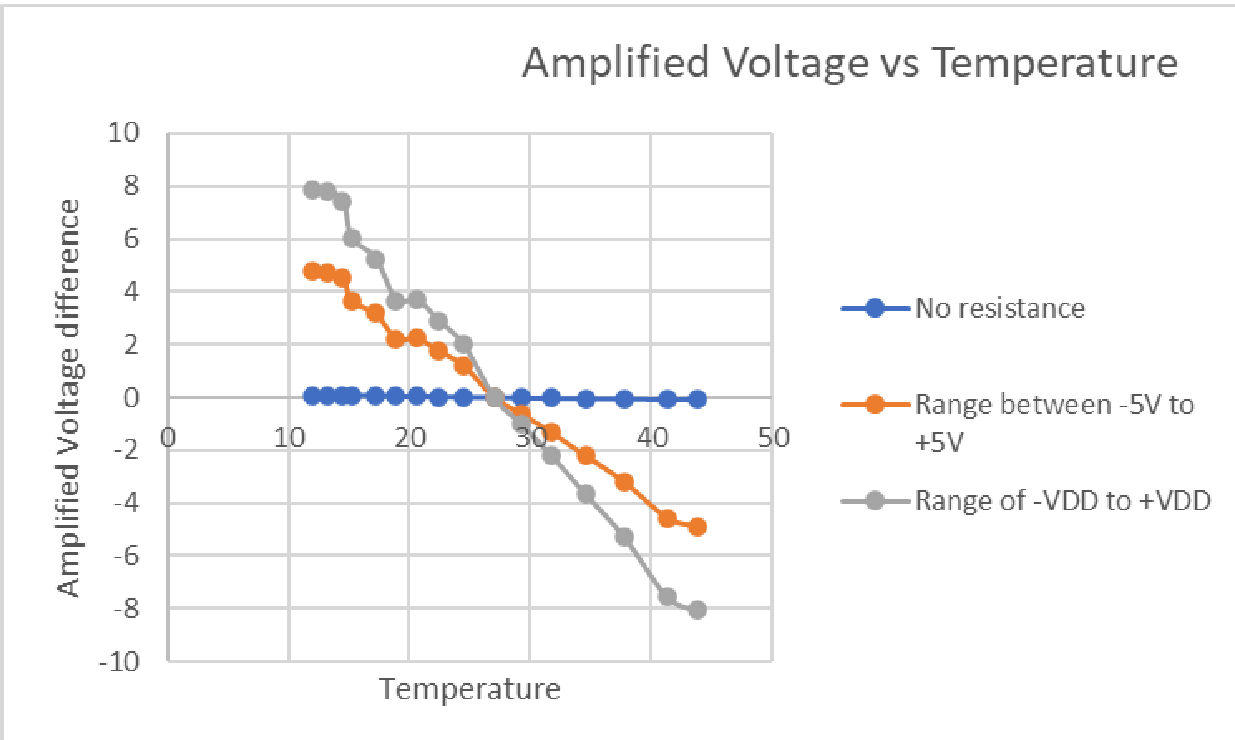
In Task 2.2, we had to redo both the calibration of the Peltier device and the PT100 sensor. This step was necessary to ensure accurate measurements and reliable data collection, considering the altered setup and experimental conditions. By recalibrating both the Peltier device and the PT100 sensor, we ensured that our measurements were precise and aligned with the new experimental configuration, allowing for meaningful analysis and interpretation of the results. Tasks 2.1 and 2.2 were done simultaneously and the results were combined in the table shown under task 2.1.

Task 2.3 – Connect Vb and Vd of the Wheatstone bridge to the inputs of the instrumentation amplifier. Obtain the transfer characteristics of the Wheatstone bridge-instrumentation amplifier, as you vary the temperature of the Peltier, for three values of amplifier gain – a. Without any gain resistor. b. Gain such that the output covers the operational range of your temperature span corresponds to an amplifier output voltage range of +/- 5V. c. Maximum gain that will cover the operational range of your temperature span. You will show the three transfer characteristics on a single plot, where the x-axis is temperature, and y-axis is the output voltage of the instrumentation amplifier.

In Task 2.3, we connected Vb and Vd of the Wheatstone bridge to the inputs of the instrumentation amplifier. We obtained the transfer characteristics of the Wheatstone bridge-instrumentation amplifier by varying the temperature of the Peltier device. We performed this task for three values of amplifier gain:

a. **Without Any Gain Resistor:** We measured the output voltage of the instrumentation amplifier without adding any gain resistor, providing the baseline response.
b. **Gain to Cover Operational Range:** We adjusted the gain resistor to a value that ensured the output covered the operational range of our temperature span, corresponding to an amplifier output voltage range of +/- 5V.
c. **Maximum Gain for Operational Range:** We set the gain resistor to its minimum allowed value according to the applied voltage to our difference amplifier.

We plotted these three transfer characteristics on a single graph, where the x-axis represented the temperature, and the y-axis represented the output voltage of the instrumentation amplifier. This comprehensive plot allowed us to visualize and analyze the amplifier's response to varying temperatures under different gain configurations, providing valuable insights into the system's behavior.



Here the VDD applied to the differential amplifier was 9V, so the magnitude of output voltage can never be higher than 9V. We chose the resistor to adjust the gain accordingly.

3. Conclusion

1. **What in your opinion is the most important thing you learnt from the experiment?**

We learnt how to use an instrumentation amplifier with Wheatstone Bridge-based differential inputs. We also learnt that the gain of our device is restricted/limited by the voltage we have applied to it, and that the output voltage after being amplified can never be never be more than source voltage applied to the amplifier.

2. **What was interesting about the experiment?**

It was interesting to see that we were able to modify the amplifications of the difference output according to our needs, and to a amplification that was in the range of 5 to whatever the values were limited by our source voltages (V+ and V-). It was also interesting to see our device amplifying the AC signals and not just DC values.

3. **What was challenging about the experiment?**

The experiment was pretty straightforward this time, the only tricky part was the setting up the PT100 sensor as we had to take care of some small but crucial details in order to avoid errors in our measurements. Our group had got the pre-set up PT100 in the last lab, which wasn't the case for this lab and we had to assemble it on our own.

4. **Were there any drawbacks of the way the experiment was done? How would you do it better?**

There were no noticeable drawbacks in how we did our experiment.

5. **Contribution statement -** Adarsh assembled the PT100 sensor, tabulated and plotted the readings. Jasnoor and Saransh worked on assembling the wheatstone bridge, taking care of the gain of the amplifier and using the DSO to verify that the amplifier was giving the correct output for certain inputs. Adarsh helped both of them in assembling the rest of the circuit. Binduthraya and Rawal relied outputs to adarsh and verified the circuits. As for the lab report, everyone contributed to its making.