IC231 Spring 2022 – Lab 6 – Temperature measurements

Srikanth Sugavanam, Erwin Fuhrer, ssrikanth@iitmandi.ac.in, erwin@iitmandi.ac.in

In this lab you will learn how to calibrate and use a PT100 Resistive Temperature Detector (RTD) for temperature measurements.

Learning outcomes

In this lab, you will learn

- How to calibrate and use a Peltier element as a cooling/heating device.
- How to calibrate and use a PT100 RTD for temperature measurements by employing a Wheatstone bridge configuration.
- (Optional) – How to use an instrumentation amplifier for the differential output from the Wheatstone bridge, for observing a magnified reading of the PT100 sensor.
- In general, how to incorporate the elements of testing, estimation, verification and validation in the experimental process.

Instructions

If you would have seen the Moodle page, there are several instructions. More so, if you would have watched the video link too. But the essence of it is this – ***at the end of this lab, you will be equipped to make temperature measurements using the PT100.***

The PT100 is quite versatile, as it can measure temperatures in a linear fashion over a very large temperature range. Thermistors can also be used over a wide range, however its nonlinear response limits its application.

If you want to use the PT100 for temperature measurements, you will need a device that will be able to measure resistances. Of course, in the lab you can use a multimeter, but in an industry or process control setting, you want to use a transducer. The Wheatstone bridge comes to our rescue, as it can be used to transduce resistance changes to differential voltage changes. Hence, our learnings from our previous labs can be put to task here.

But before you start putting a PT100 into a Wheatstone bridge, you need to know how much the value of the PT100 resistance changes with temperature. This step is important, as it will inform your design going ahead.

Here is where our Peltier element comes in. The video shows you how to connect a Peltier element to a power source. By controlling the amount of current supplied to the Peltier element, you can control the temperature of its surface. So, you can use the Peltier element as a heater/cooler, with which you can calibrate your PT100. But to do that, firstly you will have to calibrate your Peltier itself. Hence the first task of the lab will be to calibrate the Peltier element – such that you have a curve that relates the temperature to the applied current. You will be provided with a digital thermometer that will help you in this task.

Once you have calibrated your Peltier element, you can attach the PT100 sensor on top of the Peltier element. Then, simply by using a multimeter, you can see how the resistance of the PT100 changes over the range of temperatures provided by the Peltier element. Right at this stage, you can also estimate the temperature coefficient of resistance of the PT100, which you can compare with the value that you will obtain using the Wheatstone bridge configuration.

Once you know how much the resistance changes, you can then choose appropriate values of resistances for the Wheatstone bridge. At this stage, you will simulate what will be the output of this Wheatstone bridge over the range of the resistances you expect to observe for the PT100. You can also do this with pen and paper, however I recommend using your codes from your previous labs as it will be faster. ***Further***, I have imposed an additional condition that Vb and Vd should not be greater than +-0.5 V. You can control this either by changing the values of the resistances of the bridge, using a current limiter resistance, or by controlling the voltage of applied to the bridge. The last option is the simplest, so you can opt for this. The reason for this restriction is because then you will be able to use the INA126 instrumentation amplifier at a later stage for amplifying the output of your bridge signal to a desired level.

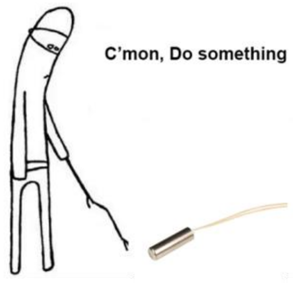
After you have simulated your bridge circuit and verified it with the TA or instructors in class, you can build the Wheatstone bridge and make the necessary connections as shown in the lab demo video. You will then use the oscilloscope to make the necessary measurements. In principle, you can use the multimeter too. However, the multimeter will have lower precision, and also, I want you to learn how to use the oscilloscope efficiently 😊 So you will use the oscilloscope. You will have to make the necessary settings on the oscilloscope so that you can observe the change of the differential voltage level with temperature. In this regard, your simulation results will help you.

The primary result of this lab will be a Vbd vs. temperature curve for the PT100 Wheatstone bridge. You will verify the value of the temperature coefficient of resistance that you obtain from this curve with that you obtained earlier with your multimeter and comment on your observations.

After completing these tasks, you will have the option of using the INA126 amplifier for amplifying the output from your Wheatstone bridge. Should you wish to do this, firstly you will calculate the required amplification, draw the circuit design on pen and paper, and show it to your TA or instructor. Once they say it is ok, you can then proceed to build this physically, and observe the output on the oscilloscope. You may also draw a response curve for this amplified PT100 Wheatstone bridge.

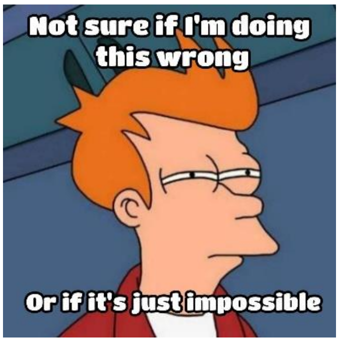
What's the point of all of this?

I am glad you ask. When you are designing a sensor circuit, you just can't willy-nilly buy a sensor off the internet, connect it to a power source, and expect it to work.

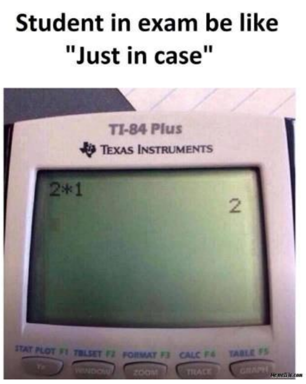


The first step in design is to test. When you are using your multimeter to check how the resistance changes with temperature, you are not only checking whether the sensor is working, but also how sensitive it can be. The datasheets are a good place to start, but the actual device may not always be perfect.

The second step is to estimate signal levels. This is why you use simulation tools, or pen and paper rough calculations. Seasoned engineers do such order of magnitude calculations on the fly in their head. This will ensure you don't burn stuff. And also make you more confident of your build. Then you won't have doubts like this guy -



An intermediate step is verification. To ensure whether you are moving in the right direction, you do multiple checks of arriving at the same result. This is the reason why I am asking you to compare the value that you obtained using the multimeter with the one obtained using the oscilloscope. These are two different techniques – one is a direct resistance measurement, while the other is a transduced voltage measurement. But in the end, both of them should yield the same, or at least similar (order of magnitude-wise) result.



The final step is validation. This is to check whether your measurements are as close to the 'ground truth' as possible. This is why I used not one but two thermometers in my demo. The second thermometer is an independently tested one, which helped me confirm that the digital thermometer is working properly. Validation increases trust in measurement, and hence the reliability of the product you make.

Hence, the idea is that you imbibe this general practice of **testing**, **estimation, verification** and **validation** in your working approach.

Tasks

- **Task 1** – Calibrate your Peltier element temperature as a function of current, over the temperature range of 5 to 50 degrees Celsius. Ensure that you don't cross max limits of the device. Use the digital thermometer provided for the calibration.

- **Task 2** – Estimate the change in resistance over the above temperature range, and hence the temperature coefficient of resistance of the PT100 sensor using a multimeter.

- **Task 3** – Simulate the response of a Wheatstone bridge incorporated with the PT100 sensor, and estimate the differential voltage values. IMPORTANT – the voltages Vb and Vd should not exceed +/- 0.5 V.

- **Task 4** – Construct the Wheatstone bridge circuit with the PT100 sensor, and mount the sensor on the Peltier element. Vary the temperature of the Peltier element, and obtain a Vbd vs. temperature curve for the PT100 sensor. Calculate the value of the temperature coefficient of the PT100 sensor from this response curve, and compare it to the multimeter-estimated value of the coefficient

- **OPTIONAL – Task 5** – Design an amplifier circuit for the Wheatstone bridge based PT100 sensor using the INA126 amplifier. Draw the circuit diagram and show it to the TA/Instructor.

- **OPTIONAL – Task 6** – Build the INA126 based amplified PT100 Wheatstone bridge sensor. Obtain the sensor response curve, and calculate the temperature coefficient.

Task completion criteria

1. You obtain the temperature vs. current curve for the Peltier element over the range of 5 to 50 degrees Celsius.
2. You estimate the range of variation of resistance of the PT100 over the above temperature range.
3. You obtain the calibration curve for the PT100 sensor, and calculate the value of the temperature coefficient for the PT100 based Wheatstone bridge.
4. You compare the value of the coefficient obtained with that estimated using the multimeter readings, and comment on your observations.