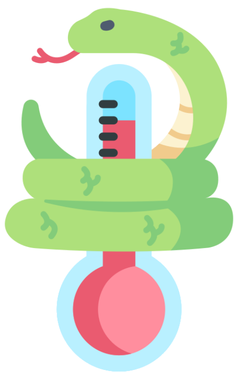
PYRODAQ STUDENT'S GUIDE:



EXPLORING TEMPERATURE SENSING WITH PYTHON AND CONTROLLING NATIONAL INSTRUMENTS DAQ

INTRODUCTION

Welcome to PyroDAQ – your gateway to python driven temperature sensing. This guide is your key to mastering temperature measurement using our application and National Instrument's equipment.

Temperature sensing holds pivotal importance in various fields, from electronics to industry. PyroDAQ is born out of the need to merge Python programming capabilities and accessible, comprehensible code, with National Instrument's precision, enabling you to navigate temperature measurement confidently.

In this guide we'll lead you through installation, circuit setup, and program functionality. Get ready to explore temperature sensing through PyroDAQ – where hardware and software unite for precise measurements. Let's dive in!

ESSENTIAL CONCEPTS IN TEMPERATURE SENSING

In this section, we'll delve into the essential building blocks that underpin accurate temperature measurements and equip you to navigate electronic instrumentation.

Sensitivity:

Sensitivity quantifies a sensor's responsiveness to temperature fluctuations. A highly sensitive sensor detects even subtle temperature changes, enabling accurate and detailed measurements.

Resolution:

Temperature resolution signifies the smallest temperature change a sensor can detect. A higher resolution allows finer distinctions, crucial for precision in temperature-sensitive applications.

The resolution of an ADC refers to the smallest increment of analog input voltage that can be accurately represented as a discrete digital value.

For USB-6001 DAQ:

ADC Resolution: 14 bits
ADC FS voltage: ±10 V

Resolution = (ADC FS voltage) / (2^ADC Resolution)
Resolution = (10 V - (-10 V)) / (2^14) = 1.22 mV

For USB-6002 DAQ:

ADC Resolution: 16 bits
ADC FS voltage: ±10 V

Resolution = (10 V - (-10 V)) / (2^16) = 305 µV

For USB-6211 DAQ:

ADC Resolution: 16 bits
ADC FS voltage: ±10 V, ±5 V, ±1 V, ±0.2 V (with 5% overrange)

Resolution = 320, 160, 32, 6.4 µV

To estimate the resolution in temperature measurement for a data acquisition system using a temperature sensor with a voltage output, it is essential to know the sensitivity of the sensor. The sensitivity of the temperature sensor refers to how much the sensor's output voltage changes in response to a unit change in temperature. The higher the sensor's sensitivity, the higher the temperature measurement resolution you can achieve with the data acquisition system. Resolution is typically calculated as the ratio between the minimum detectable variation in the sensor's output voltage and the sensor's sensitivity. The lower this ratio, the higher the temperature measurement resolution.

For USB-6001 DAQ with LM35 sensor and:

ADC Resolution: 1.22 mV
LM35 sensitivity: 10 mV/°C

Temperature resolution = (ADC Resolution) / (LM35 sensitivity)

Temperature resolution = 1.22 mV/10 mV/°C = 0.122 °C.

For USB-6001 DAQ with a Pt100 TF101k in a Wheatstone bridge with 0.8 mV/°C sensitivity:

ADC Resolution: 1.22 mV
Bridge sensitivity: 0.8 mV/°C

Temperature resolution = (ADC Resolution) / (Bridge sensitivity)

Temperature resolution = 1.22 mV/ 0.8 mV°C =1.5 °C.

Offset:

Offset accounts for inherent sensor errors by adding or subtracting a constant value from the output. Managing offsets fine-tunes accuracy, especially in low-temperature ranges.

Sampling Rate

Sampling rate dictates how often measurements are taken. A suitable sampling rate captures rapid temperature changes without missing vital data.

Calibration

Calibration stands as a critical process that ensures your temperature sensor's readings remain accurate and reliable. It involves adjusting the sensor's output to match a known reference value, thereby correcting any inherent biases or deviations that may arise over time.

Linear Calibration

For sensors with a linear, or relatively so, relationship between their output and the measured quantity (PT100, LM35, limited range Thermocouples, etc.), linear calibration is often employed.

Non-linear Calibration

Not all sensors exhibit linear behavior. Some sensors, especially those with intricate response curves, demand non-linear calibration (thermistor, RTD, thermocouples, etc.). In these cases, more sophisticated equations are employed. Non-linear calibration handles the intricacies of the sensor's behavior and ensures accurate compensation across its entire operating range.

Choosing the Right Calibration Approach

The choice between linear and non-linear calibration hinges on the sensor's characteristics and the desired accuracy. Linear calibration is simple and effective when the sensor's deviation from linearity is minor. Non-linear calibration, while more complex, accommodates sensors with non-linear behaviors and offers better accuracy across a wider range of conditions.

Data Acquisition Device (DAQ)

A component designed to capture, measure, and analyze real-world data from various physical phenomena. It serves as a bridge between the analog world and digital processing, enabling precise data collection for analysis and control.

Wheatstone Bridge

A Wheatstone Bridge is a fundamental circuit used in electronics to measure resistances and detect changes in resistance with high precision. It consists of four resistors arranged in a diamond shape, with a power source connected across one diagonal. When the bridge is balanced, the ratio of resistances is equal on both sides. This setup allows you to measure an unknown resistance by adjusting known resistances until the bridge is balanced.

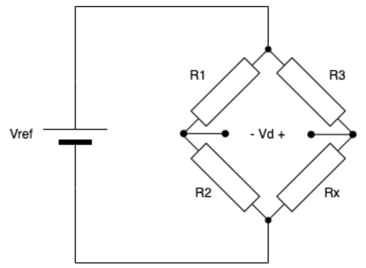


Figure 1. Wheatstone Bridge Diagram

In the following sections, we'll dive deeper into the intricacies of PyroDAQ and its integration with National Instrument's equipment. Get ready to translate theory into practical mastery!

SYSTEM REQUIREMENTS

Before embarking on your temperature sensing journey, let's ensure you have everything you need. Here's a breakdown of the hardware and software necessities:

Hardware Requirements

1. **National Instruments DAQ (USB-6001, 6002, or 6211):** Think of it as the bridge between the real world and your computer. It will also power your circuit (external power source can also be used).

2. **Small flat screwdriver:** necessary for connecting wires to the DAQ.
3. **Circuit Setup:** breadboard, It provides a convenient platform for assembling and connecting the temperature sensor, precision resistors, and wires.
4. **Temperature Sensor:** You can choose a PT100 or LM35 sensor, among others.
5. **Precision Resistors:** These help fine-tune your measurements. They'll be valuable when calibrating.
6. **Wires:** You'll need a few in different colors such as red, black, blue, ...

Software Requirements

1. **Operating System:** Windows will do the job.
2. **PyroDAQ App:** This is your window into the temperature sensing world, it helps you see and understand what's happening with your setup.

Checklist:

- [ ] National Instruments DAQ (USB-6001, 6002, or 6211)
- [ ] Screwdriver
- [ ] Breadboard
- [ ] Temperature Sensor (PT100, LM35, etc.)
- [ ] Precision Resistors (100, 105, 110, 121, 127, 133 and 140 Ω)
- [ ] Wires
- [ ] Computer with Windows Operating System
- [ ] PyroDAQ App (Download and installation process explained next).

With these essentials in place, you're all geared up to explore temperature sensing and dive into the world of electronic instrumentation using PyroDAQ.

INSTALLATION

To get started with PyroDAQ, you'll need to follow a few simple steps to install the application on your computer. Here's a detailed guide:

1. Access the GitHub Repository

First, you'll need to visit the PyroDAQ GitHub repository. You can find the link to the repository here. This is where you'll find all the necessary files to install PyroDAQ.

2. Read the README.md

Once you're on the GitHub page, navigate to the README.md file. This file contains comprehensive instructions on how to install and set up PyroDAQ on your computer. It's your go-to resource for the installation process.

3. Follow the Installation Steps

The README.md file will provide step-by-step instructions for installing PyroDAQ. These steps typically include downloading the necessary files, installing any dependencies, and configuring your environment.

By following these steps and carefully reading the instructions in the README.md file on the GitHub repository, you'll be able to successfully install PyroDAQ on your computer. Happy installation!

GETTING STARTED

Let's kick off your journey by diving into the initial setup process. We will be exploring the Wheatstone bridge circuit setup with a Pt100, but feel free to diverge into other circuit examples.

As you embark on this adventure, it's essential to start with the right foot forward. Ensure you have all the hardware and software requirements in place, as outlined in the "System Requirements" section. This includes your National Instruments DAQ, circuit components, temperature sensor, wires, and your computer with the PyroDAQ app installed.

Wheatstone Bridge Setup with a Pt100

In a Wheatstone bridge setup, calibration is the process of establishing a relationship between the electrical signals produced by the bridge and the actual physical quantity you're trying to measure, such as temperature. Precision resistors play a key role in this calibration process, allowing you to simulate different temperature conditions without changing the actual temperature of the environment.

Here's a step-by-step guide:

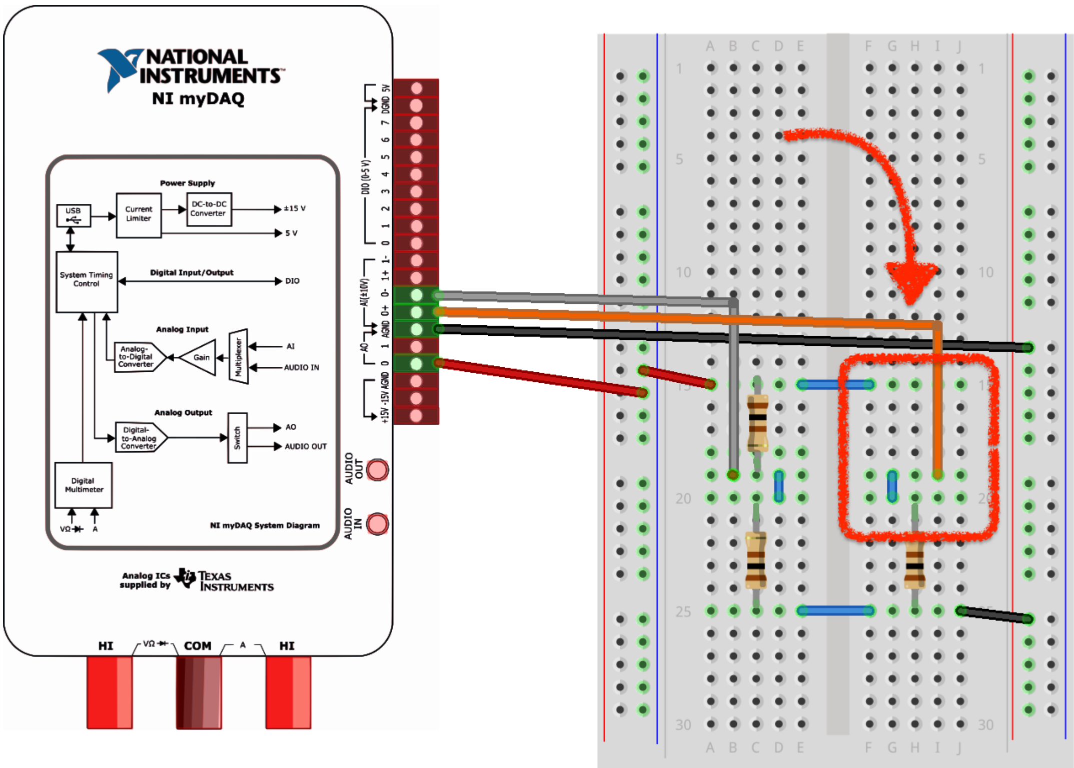


Figure 2. Wheatstone Bridge Circuit Setup

1. Arrange on a breadboard the circuit from Figure 2.

a. The three 100-ohm resistors will form the arms of the bridge. Connect them in such a way that one resistor connects to the positive rail, another to the negative rail, and the third resistor connects to the output pin of the bridge.
b. Connect the first of the precision resistors in the remaining place of the wheatstone bridge (where the red box is). Once calibrated, this will be where we connect the Pt100.
c. Referencing Figure 1, connect the breadboard to the DAQ with wires:

Diagram	DAQ
Vin+, Vin -	AO0*, AOGND
Vout+, Vout -	AI0+, AI0-

**AO0 powers the circuit from the DAQ, if desired this can be replaced by another power supply of 1V. If this is changed, keep in mind that the reading configuration may need to be changed from DIFF to something appropriate like RSE.*

Temperature-Resistance table

To do so, fill in the table, this will correlate the known resistance values of the precision resistors with their corresponding temperatures. This table serves as a reference for simulating different temperature points and we will use it in the calibration step later on.

Rt(Ω)	Theoretical Vd (V)	Temperature (°C)	Measured Vd (V)
100			
105			
110			
121			
127			
133			
140			

Formulated spreadsheet: Student Guide Table.xlsx

Temperature

The relationship between Pt100 and temperature can be represented by:

$R_t = R_o + \alpha(t - t_o)$, with $R_o = 100\,\Omega$, $t_o = 0ºC$ and $\alpha = 0.00385\,ºC^{-1}$

$R_t = 100 + 0.00385(t - 0) \rightarrow t = ((\frac{R_t}{100} - 1)/0.00385) + 0$

Voltage

For a balanced bridge like this one: $V_{OUT} = V_{IN}(\frac{R_t}{R_t+R_3} - \frac{R_1}{R_1+R_2})$

NAVIGATING PYRODAQ STEP BY STEP

Get ready to explore the ins and outs of this powerful tool as we walk you through each step of calibrating and acquiring data from a Wheatstone bridge setup.

LAUNCH

1. The first window you'll encounter will kindly ask you to select the specific model of your DAQ. This information can be found on the underside of your DAQ.

   ❗ Make sure your DAQ is called “Dev1” as the app won’t recognize it if it’s not. This can be checked and changed with the NI MAX software, in devices and interfaces.

CALIBRATION

In this initial stage, we're going to calibrate your temperature sensing setup using precision resistors. Calibration is like teaching your system how to speak the language of temperature changes. Here's how it works:

2. The Calibration Menu appears, ready to log your calibration settings. Once a calibration is set, it can be later used as they’re saved.

   Two options appear: Temperature and Voltage Relation and Input Direct Expression.

For our Wheatstone bridge setup, let's opt for the Temperature and Voltage Relation. This is because we're simulating different temperatures using precision resistors. For known calibrations like for a LM35 circuit setup, the direct input expression would be useful.

3. Click "Calibrate" to proceed.

Temperature and Voltage Relation

4. In this window, you'll first need to select an expression type. We'll go with the linear equation, least squares method for this tour, but feel free to explore other methods.
5. Under input data, toggle "Measure". If you'd instead like to input the calculated voltage toggle for "Type In".
6. Input the corresponding temperature value from your table and either click "Enter" or press the Enter key.
7. Do so for each precision resistor, changing the resistor in the circuit as you go. You can check if your measured values correspond with your previously calculated ones.

   It's normal for the real values to differ a bit from the calculated values.

8. If you make any mistakes, don't worry. You can delete the last input by clicking "delete", or all of them by clicking "Clear".

As you add data points, you'll start to see your calibration plot taking shape.

9. Once all points are added, click "Choose" to finalize the calibration.

Back in the Calibration Menu, you can keep logging calibrations, but for now, let's move forward.

10. Click "Acquire Data" to proceed.

DATA ACQUISITION AND VISUALIZATION

Now, we're ready to use the calibration expression to acquire actual data from the Pt100 sensor:

11. Connect your Pt100 temperature sensor in place of the precision resistors.

12. In the appearing window, you'll see your chosen calibration at the top. If you need to change it, click "recalibrate."
13. Explore control features like temperature alarms. Set minimum and/or maximum alarms by entering desired values and clicking on “Set” (e.g. 25°C, 28°) . Dashed lines will appear in the graph with their corresponding colors.

    To delete the alarms, click on "disable".

Choose your data acquisition type:

14. For on-demand acquisition:
    a. Select the option and click "acquire data."
    b. Adjust the time interval with the slider. For more precision, click on either side of the slider.
    c. Click on “Stop” when you're ready.
15. For finite sampling:
    a. Select the option.
    b. Input the number of samples and time interval (e.g. 10, 2).
    c. Click "Acquire Data."
    d. Once finished, if desired, save the data as a CSV file by clicking on “Save Data”.

       Input a name for the file and open it on your computer to review parameters, alarms, and acquired values.

       This CSV file can easily be opened in other platforms such as excel to further analyze the data.

With this tour, you've unlocked the basics of PyroDAQ. Repeat and experiment as much as you like, delving into different calibrations and sensors. Let your curiosity lead the way as you master the art of temperature sensing!