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Teaching Thermal Insulation Properties With the myTemp NI miniSystem for NI myDAQ (Pioneer Release)

Overview

This tutorial uses the myTemp NI miniSystem, NI myDAQ, and NI LabVIEW system design software to learn the insulation properties of different materials with a temperature measurement system. You can directly explore fundamental concepts related to measuring temperature. By the end of this tutorial, you will be able to perform the following:

- Connect, configure, and calibrate the myTemp NI miniSystem
- Record and observe temperature changes over time
- Compare the performance of three different insulating materials

Also included are numerous challenge exercises for you to engage in as a means to expand your knowledge of using the myTemp in a wide variety of applications. For example, you can use the myTemp NI miniSystem to measure temperatures along with an additional analog sensor input or to create a temperature control system using the auxiliary output terminals to control a heat source.

To recreate the experiment in your lab or dorm, download the example program and follow the tutorial.

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Background on Thermal Insulation

Many real-world engineering design challenges involve temperature measurement and the study of heat transfer during the research, development, and testing processes. A critical engineering challenge around the world is efficient use of energy resources. The US Department of Energy estimates that more than 950 trillion BTUs (British Thermal Units) are lost every year in homes and businesses due to losses from poor insulation. This amount of energy loss represents the use of approximately 7,500 million gallons of gasoline. A primary source of these losses in commercial buildings is poorly insulated pipes, valves, and other components that are part of industrial steam distribution systems. As a result, many scientists and engineers are currently developing improved materials for thermal insulation that help reduce energy loss in homes, buildings, and other infrastructure.

A breakthrough material that is emerging as a solution to this type of energy loss is silica-based aerogels. Aerogels are ultralow-density flexible materials that are four to five times more thermally efficient than traditional insulation materials. The material has extreme thermal resistance due to its structure of tiny nanoscale pores that are filled with air. In one specific case, the Pentagon incorporated aerogel-based insulation into existing walls with a resulting 23 percent improvement in the insulation performance. They will save 419 million BTUs and reduce their emitted CO_2 by almost 49 thousand pounds per year. Temperature measurement and analysis was used by scientists and engineers extensively as they completed the development and testing of this revolutionary product. The use of aerogels for insulation is an emerging technology with long-term applications. Engineers will continue to work on advancements in thermal materials for many years to come.

About the myTemp

The myTemp by Pitsco Education is a multisensor temperature measurement and control system for NI myDAQ. The system uses one analog input channel to read three thermistor inputs and the other analog input is switch selectable between four additional thermistor inputs or an AUX input terminal. Additionally, the system provides access to two analog outputs, two digital I/O lines, and the 5 V supply from NI myDAQ. The myTemp is shipped with three bead-type NTC thermistors. You can find more information about the thermistors used for teaching applications such as temperature process control, basic sensor measurements, and data acquisition and analysis. You can directly explore important concepts of materials science and green engineering including heat transfer, conduction, convection, and radiation.

You can also directly explore fundamental concepts of temperature measurement and then analyze the heat transfer characteristics in real time to understand the applications similar to an engineer developing innovative aerogel materials.

Understanding the Connections on the myTemp

Analog Input Modes

A switch on the myTemp determines which inputs are connected to the two analog input channels on NI myDAQ.

1. MUX switch position: One reference voltage and seven thermistor inputs are multiplexed into AI0 and AI1
2. AUX switch position: One reference voltage and three thermistor inputs are multiplexed into AI0 and an auxiliary analog input is read from the small terminal block at the inputs labeled AI1+ and AI1-

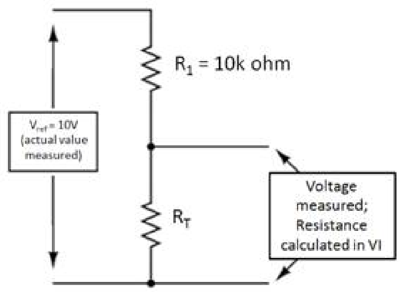
Multiplexer Truth Table

	DIO Line Setting (X = Don't Care)					
AI0 Reading	**DO0**	**DO1**	**DO2**	**DO5**	**DO6**	**DO7**
Reference Voltage	0	0	0	X	X	X

T1	1	0	0	X	X	X
T2	0	1	0	X	X	X
T3	1	1	0	X	X	X
AI1 Reading	**DO0**	**DO1**	**DO2**	**DO5**	**DO6**	**DO7**
T4	X	X	X	0	0	0
T5	X	X	X	1	0	0
T6	X	X	X	0	1	0
T7	X	X	X	1	1	0

Thermistor Connections

Thermistor resistance is measured using the voltage divider configuration shown below. The Voltage Reference (V_{ref}) value is read with each reading and that value is used in the resistance calculation.



Additional I/0 (available on small terminal block)

Analog outputs: AO0 and AO1

DIO lines: DIO3 and DIO4

5 V supply from NI myDAQ

GND

Setting Up the Experiment

In this experiment, observe the differences in the thermal insulation properties of three different containers. This process is similar to the process engineers use to test the performance of materials such as aerogels.

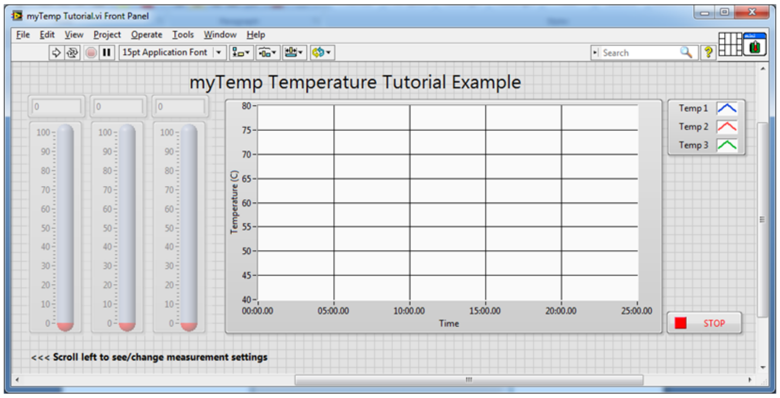
1. Connect the myTemp device to NI myDAQ
2. Connect the three NTC thermistors that were included in the myTemp package to the first three thermistor inputs, T1-T3.
3. Ensure that the NI myDAQ is connected and active with your computer.
4. Select three different types of beverage containers to use in the experiment. This example uses a paper coffee cup, a ceramic coffee cup, and an insulated coffee container with an air core.
5. Heat enough water to fill all three containers.
6. Place the water and containers to the side until you are asked to use them in the instructions below.
7. You are now ready to begin the experiment.

Running the Experiment

1. Download the myTemp Tutorial VI.

2. Open the VI in LabVIEW.

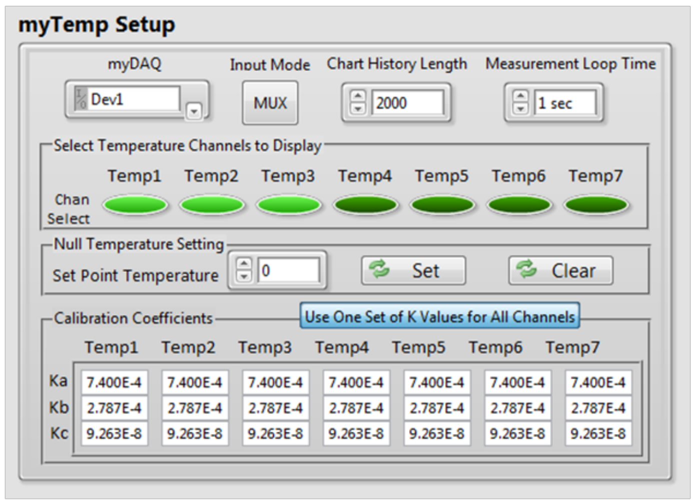
3. The front panel will look like this:



4. Run the VI.

5. The VI is set up to use a standard set of coefficients for all three thermistor temperature calculations. You can run the VI using the default coefficients. To improve the temperature tracking between the three thermistors, you can perform a zero offset measurement to cancel out any offsets. To do this, follow the set of substeps below:

a. Scroll the front panel to the right. You will see the calibration controls.



b. Use a calibrated temperature measurement device to measure the ambient temperature near the thermistors. Enter this value into the *Set Point Temperature* control.

c. Click the *Set* button. The VI will calculate the ideal resistance for that temperature and then store the offset resistance for each thermistor. The offset value will be used in all calculations until the *Clear* button is pressed or you repeat the *Set Point Temperature* procedure.

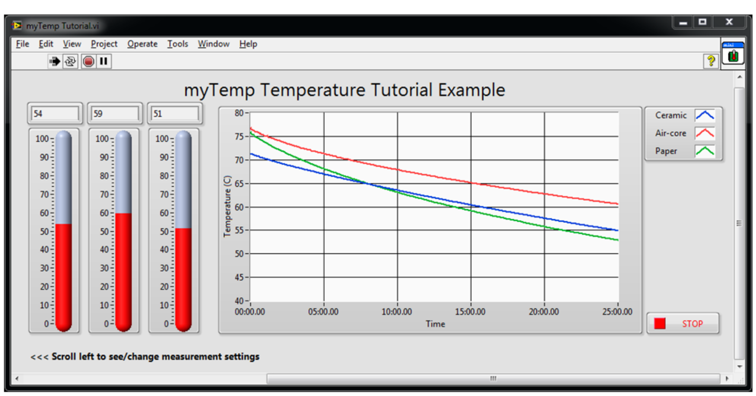
6. Scroll the front panel back to the left so that the thermometer indicators and graph are visible.

7. Place a thermistor in each of the containers and fill each one with hot water.

8. You should begin to see the temperature measurements increase.

9. Let the VI run for 30 minutes or so. Observe the temperature traces as the liquids begin to cool. Which container insulates the best? Which one loses heat the quickest? Does the best or worst stay the best or worst over the entire time?

10. The screenshot below shows the result of this test. The air core insulated container performed the best consistently. Initially, the paper cup outperformed the ceramic mug, but later in the test the ceramic mug maintained the temperature level better than the paper cup.



*Challenge 1: To get even more precise temperature measurements, you can perform a calibration process to calculate specific coefficients for each channel. Try this by following the instructions in the **myTemp Calibrate Example.vi**. Replace the default coefficients in the **myTemp Tutorial.vi** and make some additional temperature measurements with the new coefficients.*

Challenge 2: Conduct a similar experiment to see how well beverage containers keep ice in water from melting. Place containers in direct sunlight. Add water and ice to each container. Measure the temperature in each container along with the amount of sunlight in parallel by connecting a solar cell to the auxiliary analog input channel. **Hint:** Replace the subVI, **Read myTemp Basic – Temp ONLY.vi** with **Read myTemp Basic – Temp and AUX.vi**. Make sure the switch on the board is in the AUX setting and that the MUX/AUX button on the **myTemp Tutorial** VI is set to AUX.

Check back soon for more myTemp tutorials such as the following:

Design a Temperature Control System With myTemp and NI myDAQ

Measure Relative Humidity With myTemp and NI myDAQ

Additional Reading

Saving Energy and Money with Aerogel Insulation

NASA: Aerogels: Thinner, Lighter, Stronger

Aspen Aerogels Case Studies

Thermistor Calibration and the Steinhart-Hart Equation

Resources

Get the myTemp NI miniSystem for NI myDAQ

What Is an NI miniSystem?

What Is NI myDAQ?

Pioneer Release

NI miniSystems in Pioneer Release allow users in higher education (university/college) to purchase units so they can "ramp up" on integrating NI miniSystems into courses as soon as they are available. National Instruments collects active feedback from users of NI miniSystems in Pioneer Release to acquire sufficient feedback for suppliers and partners before the next release. NI miniSystems in Pioneer Release are stable but not feature complete and will most likely require the use of custom programming to fully meet customer application needs. For this reason, it is recommended that customers self-qualify to participate in the Pioneer Release by obtaining basic LabVIEW training (LabVIEW Core 1 and 2). Participants have access to standard training discounts that can be viewed at ni.com/training.

During the Pioneer Release of an NI miniSystem, support is provided via emails to minisystems@ni.com or by posting to a private NI Discussion Forum. To get access to the Forum for yourself or other customers, please contact National Instruments using the above email address.