

Practical #01

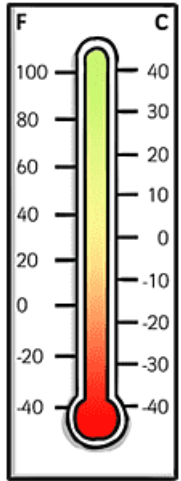
Measuring a biological property

Aims:

- Understanding what is LabVIEW and why we need it.
- Taking measurement of a biological quantity (**Hands-on exercise**).

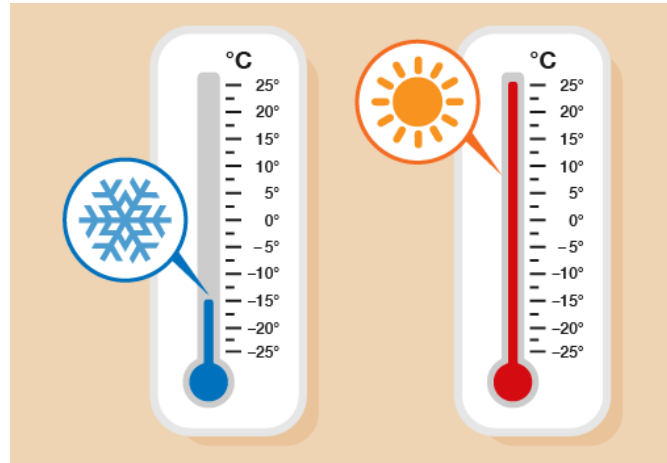
Operations in instrumentation:

Measure



Measure temperature

Analyze



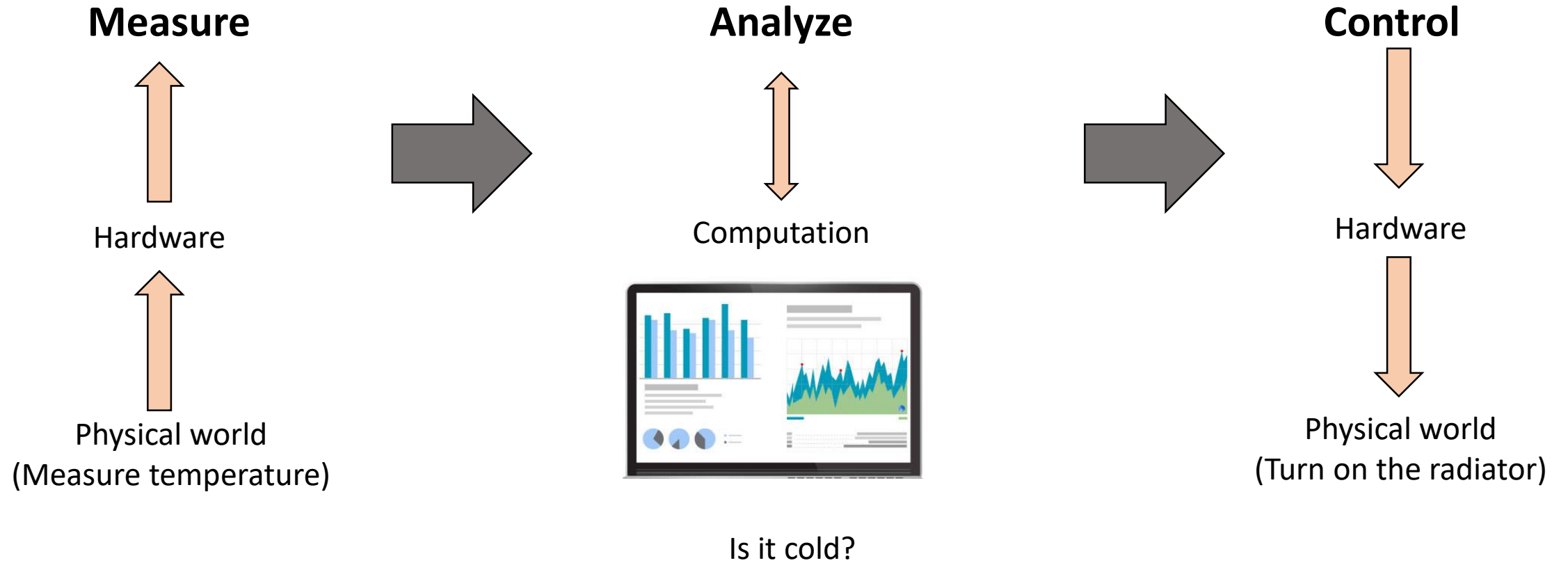
Is it cold?

Control



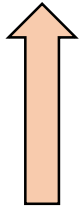
Turn on the radiator

Relation between the three operations

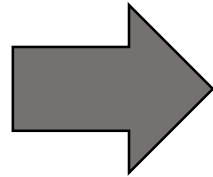


How these three operations are controlled?

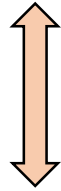
Measure



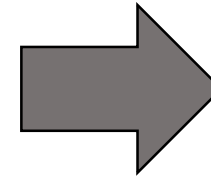
Hardware



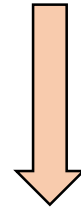
Analyze



Computation



Control



hardware



National Instruments



LabVIEW or Laboratory Virtual Instrumentation Engineering Workbench



An environment to *measure* and *control* physical world objects via *computation*.

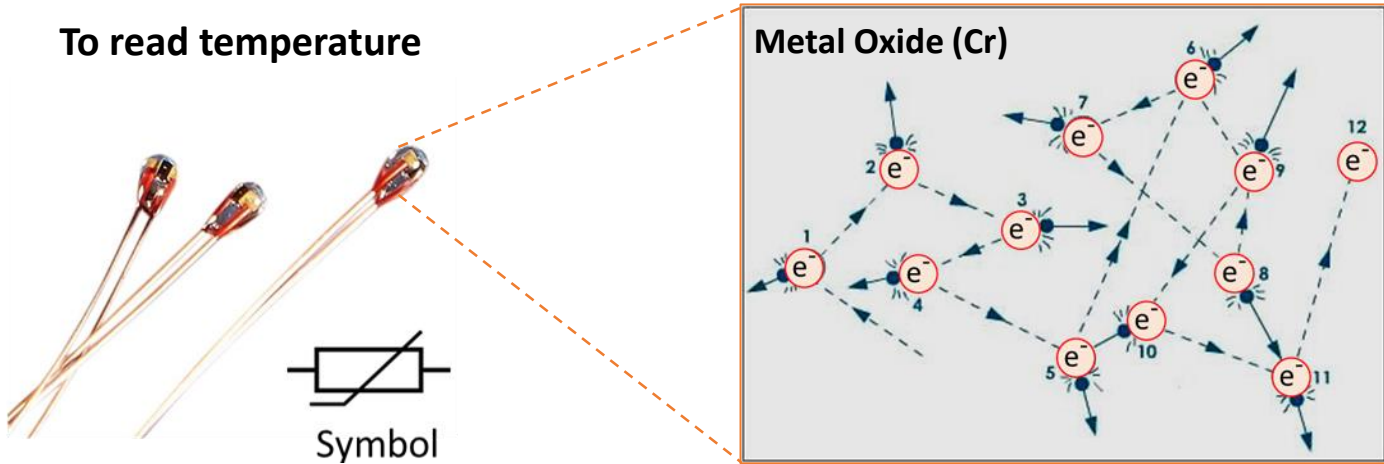
1. Extensive hardware integration
2. Graphical approach to programming (*Lecture 10*)



Example of Hardware integration with LabVIEW

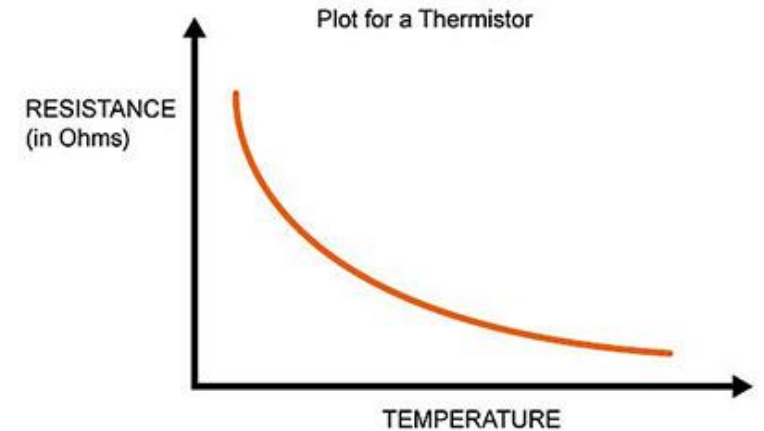
Measuring temperature with a thermistor

To read temperature



Thermistor

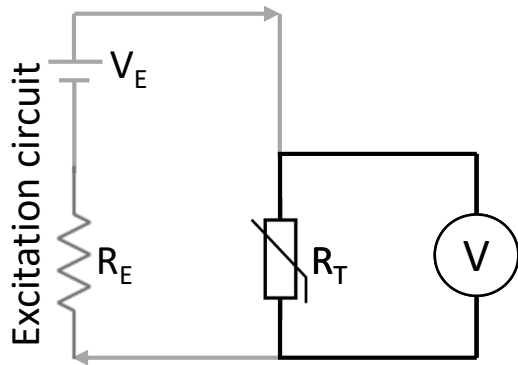
Higher conduction due to thermal agitation



Resistance change with temperature

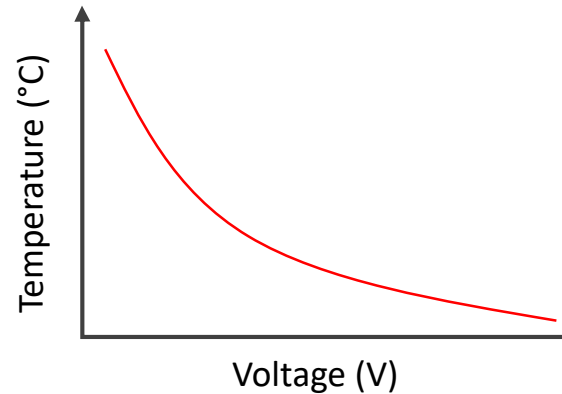
Example of Hardware integration with LabVIEW

Measuring temperature with a thermistor



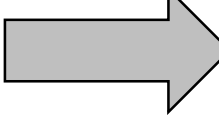
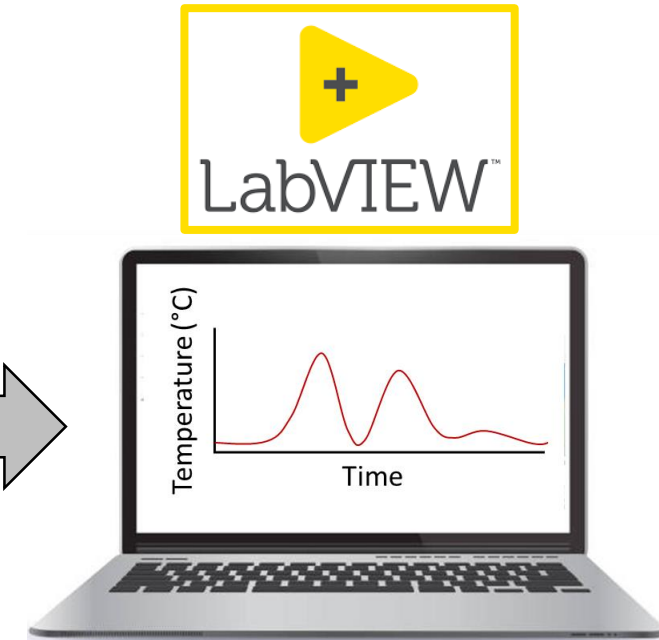
Circuit to read voltage difference (V) across the thermistor

Analog

A large grey arrow pointing from the circuit diagram to the graph, indicating the flow of an analog signal.

Voltage (V) across the thermistor as temperature increases

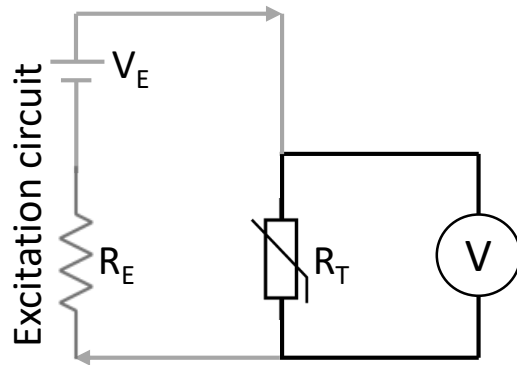
Digital

A large grey arrow pointing from the graph to the laptop, indicating the flow of a digital signal.

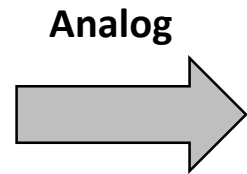
Voltage signals acquired in the computer for analysis

Example of Hardware integration with LabVIEW

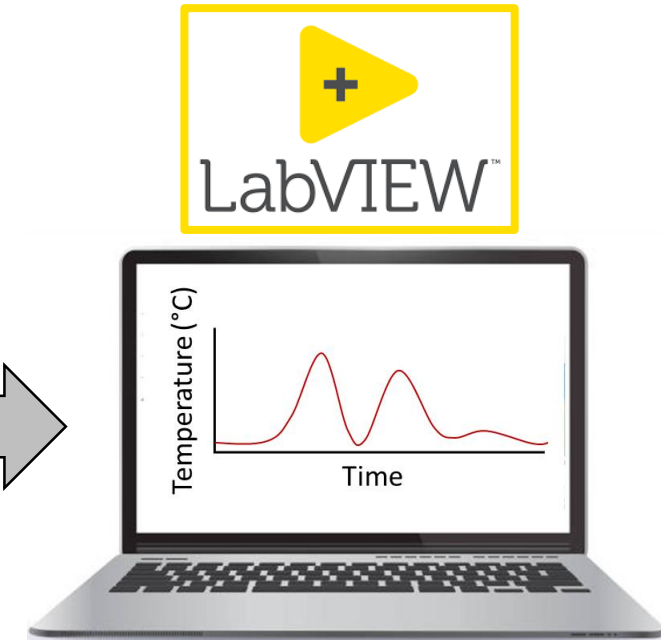
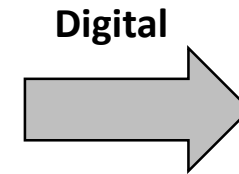
Converting analog signals to digital



Circuit to read voltage difference (V) across the thermistor



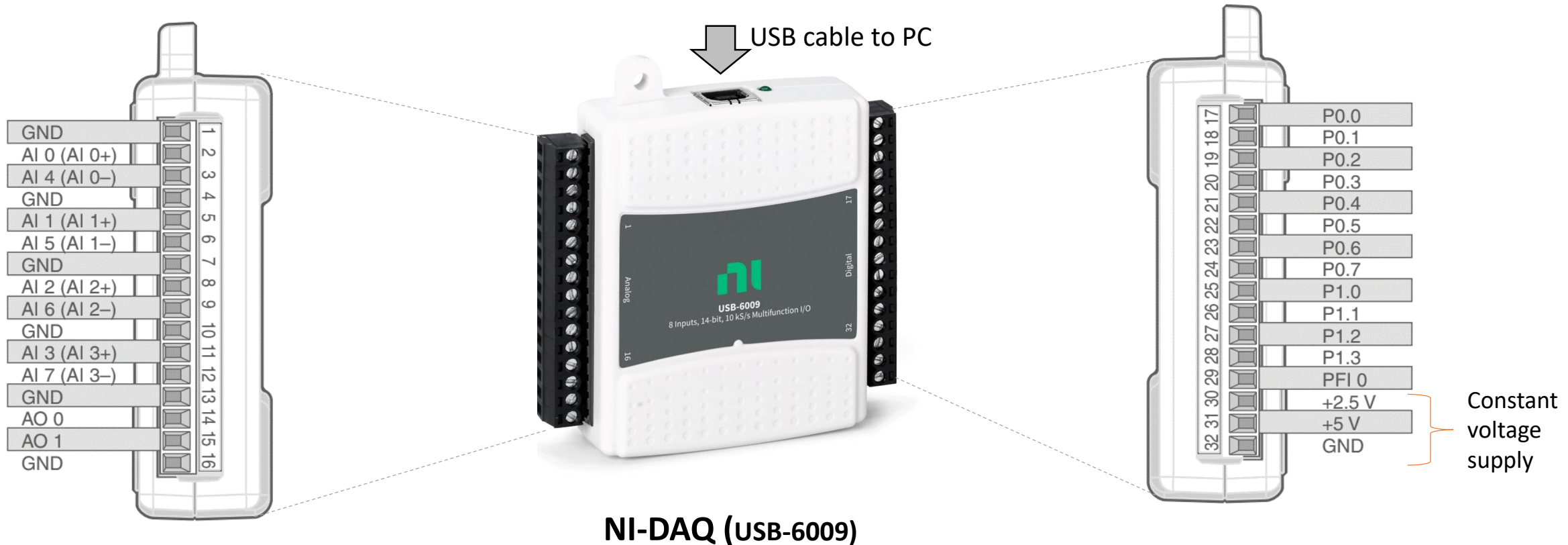
NI-DAQ (USB-6009)



Voltage signals acquired in the computer for analysis

Example of Hardware integration with LabVIEW

NI DAQ (Data Acquisition system)



Analog input (AI) and
output (AO) channels
[GND: Ground]

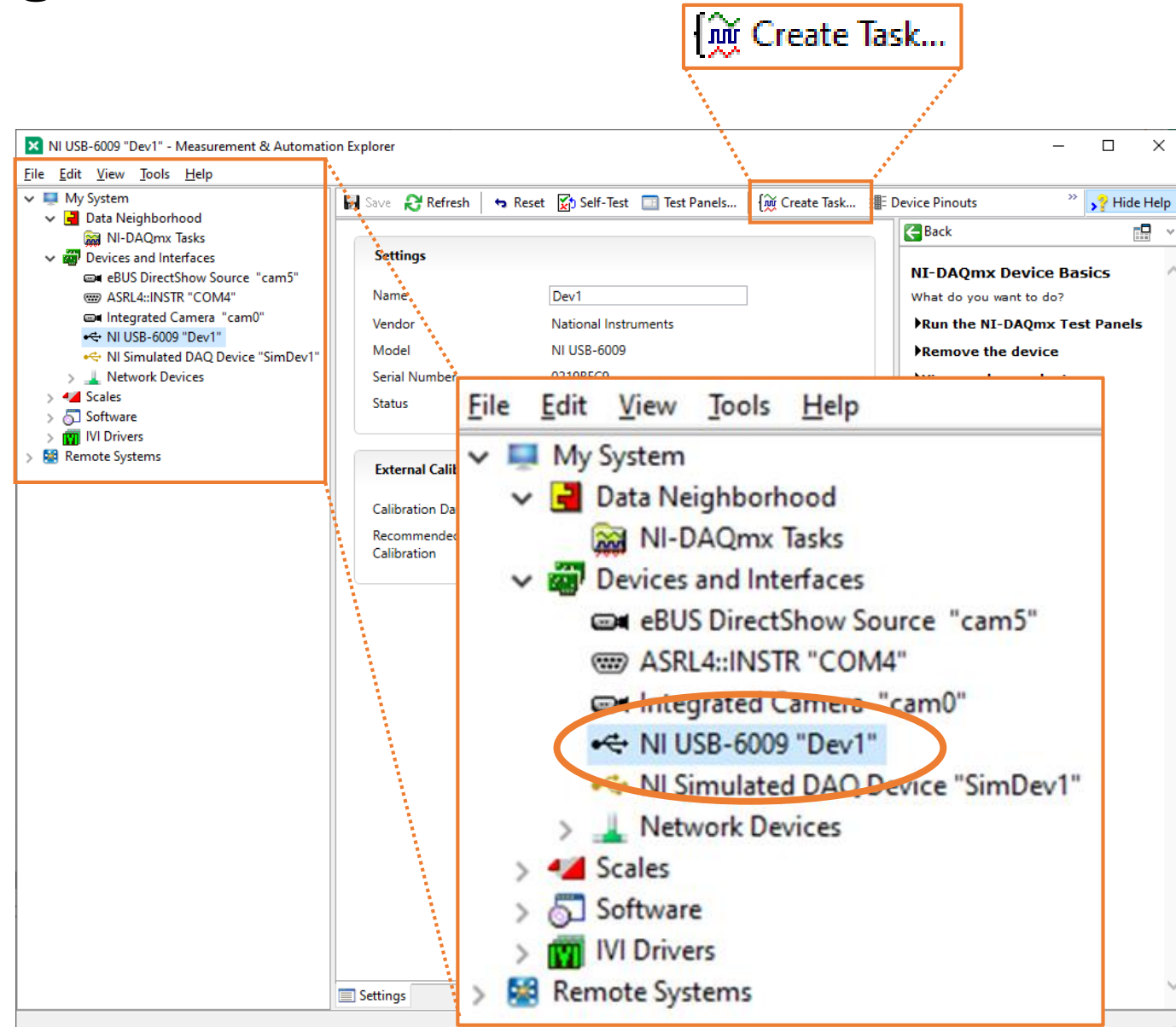
A device to establish communication between physical sensors
(temperature, pressure, force, torque, stress, photons etc.) and
the computer software.

Digital inputs / output
channels

Connecting NI-DAQ to PC



Connect the NI-DAQ to PC via USB cable and open **Measurement & Automation Explorer (NI MAX)**



Configuring NI MAX

Select the measurement type for the task.

A **task** is a collection of one or more virtual channels with timing, triggering, and other properties.

To have **multiple measurement types** within a single task, you must first create the task with one measurement type. After you create the task, click the **Add Channels** button to add a new measurement type to the task.

We choose thermistor that measures temperature by voltage excitation (i.e. temperature is calculated by measuring voltage difference across the thermistor)

Acquire Signals

Analog Input

- ☒ Voltage
- ☒ Temperature
 - ☒ Ix Thermistor
 - ☒ RTD
 - ☒ Thermocouple
 - ☒ Vex Thermistor
- ☒ Strain
- ☒ Current
- ☒ Resistance
- ☒ Frequency
- ☐ Position
- ☒ Sound Pressure
- ☐ Acceleration
- ☒ Velocity (IEPE)
- ☐ Force
- ☐ Pressure
- ☐ Torque
- ☒ Bridge (V/V)
- ☒ Custom Voltage with Excitati...
- ☒ Charge

Select the physical channel(s) to add to the task.

If you have previously configured **global virtual channels** of the same measurement type as the task, click the **Virtual** tab to add or copy global virtual channels to the task. When you copy the global virtual channel to the task, it becomes a local virtual channel. When you add a global virtual channel to the task, the task uses the actual global virtual channel, and any changes to that global virtual channel are reflected in the task.

If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

For hardware that supports **multiple channels** in a task, you can select multiple channels to add to a task at the same time.

Physical

Supported Physical Channels

- Dev1 (USB-6009)
 - ☒ ai0
 - ☐ ai1
 - ☐ ai2
 - ☐ ai3
 - ☐ ai4
 - ☐ ai5
 - ☐ ai6
 - ☐ ai7
- ☒ SimDev1 (NI Simulated DAQ Device)

<Ctrl> or <Shift> click to select multiple channels.

Connecting thermistor to NI-DAQ

Channels in Task

Temperature

Connections List

Point 1	Point 2
Thermistor Ext Vex/CH+	16PinCombicon/2
Thermistor Ext Vex/CH-	16PinCombicon/3

Save to HTML...

NATIONAL INSTRUMENTS

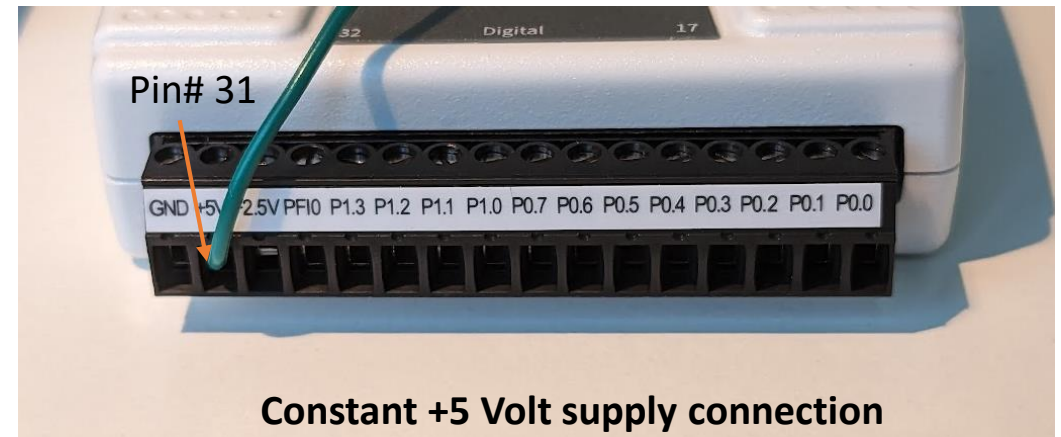
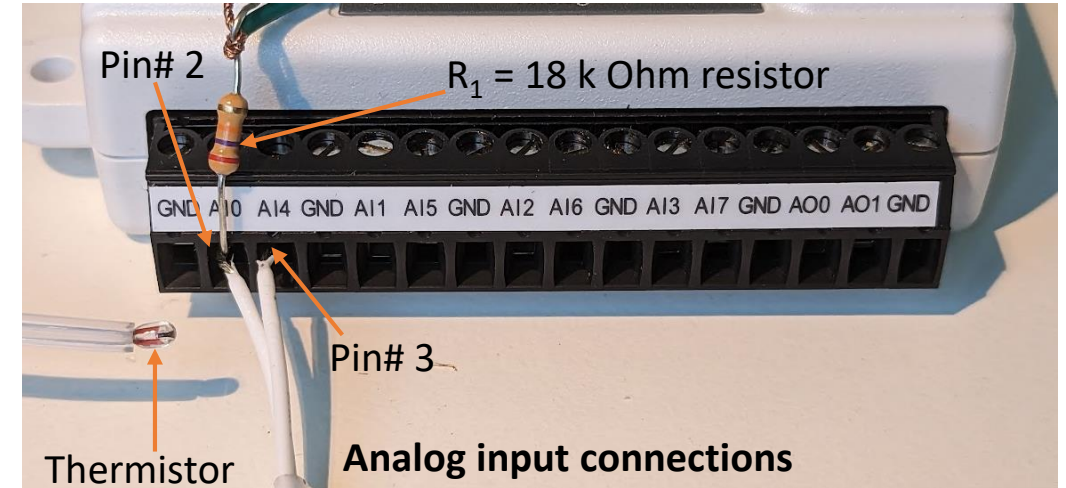
We will use a resistor (18 k Ohms) here

We will provide constant +5 V supply from the DAQ itself

Diagram illustrating the connection of a thermistor to the DAQ. The thermistor is connected to the DAQ input channels (CH+ and CH-) through a resistor (R1). The DAQ provides a constant +5V supply to the circuit.

Physical connection diagram showing the thermistor connected to the DAQ input channels (CH+ and CH-) through a resistor (R1). The DAQ provides a constant +5V supply to the circuit.

NI-DAQmx Task Connection Diagram



Measuring temperature with NI MAX

Thermistor theory

Internally defined parameters by NI DAQ on the basis of thermistor equation

User defined parameters as used in the external circuit

The screenshot displays the NI MAX software interface for configuring a Vex Thermistor. The top panel shows a graph of Amplitude versus Samples, with the Run button circled in orange. The main configuration panel is divided into several sections:

- Channel Settings:** A list of channels with 'Temperature' selected.
- Vex Thermistor Setup:**
 - Signal Input Range:** Max 100, Min 0.
 - Scaled Units:** deg C.
 - Steinhart-Hart Equation Parameters:** A = 1.295361E-3, B = 2.343159E-4, C = 1.018703E-7. These are circled in orange.
 - Vex Source:** External.
 - Vex Value (V):** 5.
 - Configuration:** 3-Wire.
 - R1:** 18k.
- Timing Settings:** Acquisition Mode: 1 Sample (On Demand), Samples to Read: 1k, Rate (Hz): 1k.

Annotations include:

- An orange arrow pointing from 'Thermistor theory' to the Steinhart-Hart equation parameters.
- An orange arrow pointing from 'Internally defined parameters by NI DAQ on the basis of thermistor equation' to the Steinhart-Hart equation parameters.
- An orange arrow pointing from 'User defined parameters as used in the external circuit' to the Vex Source, Vex Value, and Configuration settings.
- The 'Run' button in the top toolbar is circled in orange.
- The 'NI-DAQmx Task' icon in the bottom toolbar is circled in orange.

Measuring Temperature with a Voltage Excitation Thermistor

A **thermistor** is a semiconductor made from metal oxides, pressed into a small bead, disk, or other shape at high temperatures, and coated with epoxy or glass.

As with an **RTD**, by passing a voltage through a thermistor, you can read the voltage across the thermistor and thus determine its temperature. Unlike RTDs, thermistors have a higher resistance (anywhere from 2,000 to 10,000 Ω) and a much higher sensitivity ($\sim 200 \Omega/^{\circ}\text{C}$). However, thermistors are generally used to measure temperature only up to the 300 $^{\circ}\text{C}$ temperature range.

Because thermistors have high resistance, lead-wire resistance does not affect the accuracy of the measurements. Unlike RTDs, **2-wire** measurements are adequate.

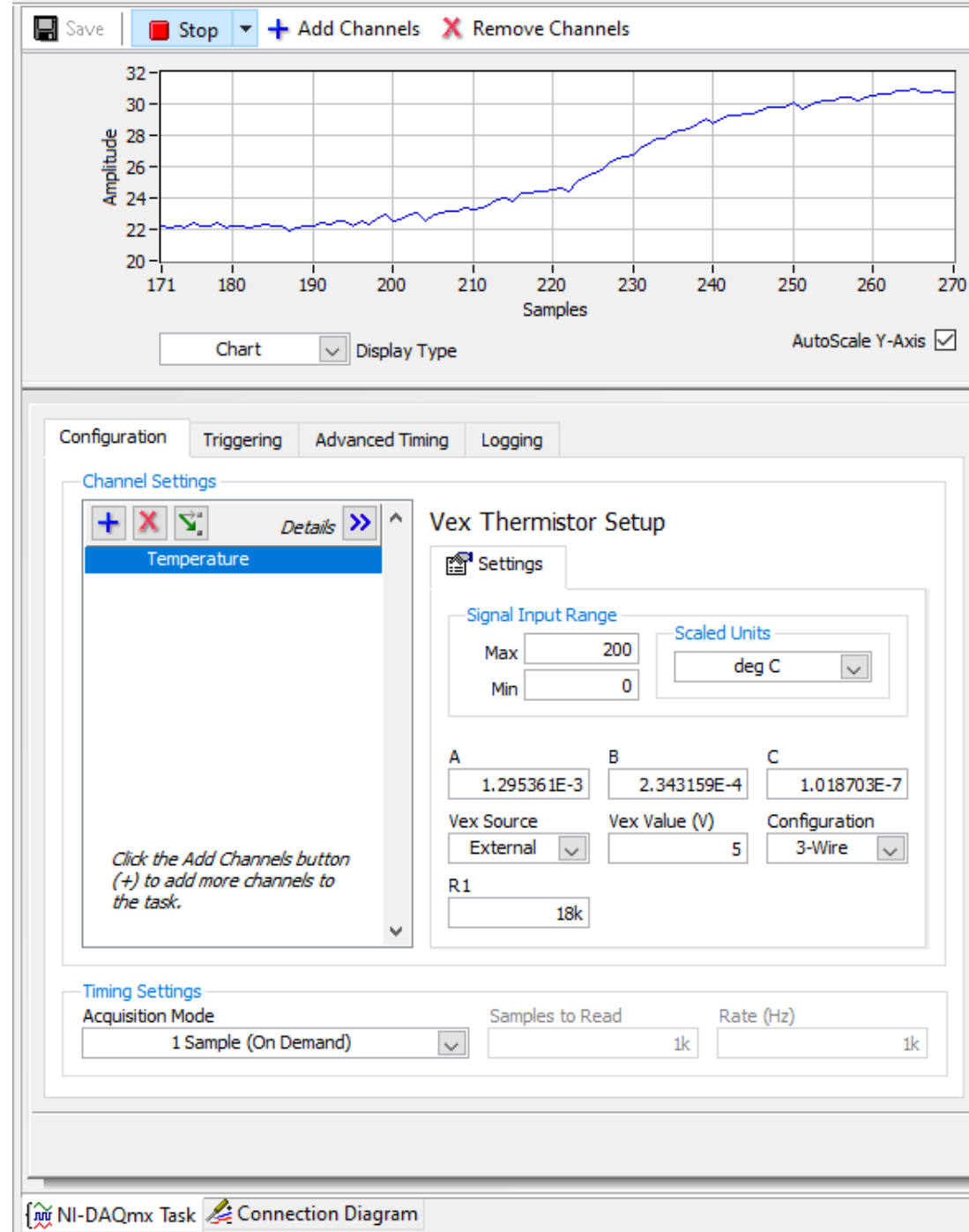
NI-DAQmx scales the resistance of a thermistor to a temperature using the Steinhart-Hart thermistor equation:

$$\frac{1}{T} = A + B(\ln(R)) + C(\ln(R))^3$$

where T is the temperature in Kelvins.

This displays the analog samples acquired or generated by the device.

Measuring temperature with NI MAX



Measuring Temperature with a Voltage Excitation Thermistor

A [thermistor](#) is a semiconductor made from metal oxides, pressed into a small bead, disk, or other shape at high temperatures, and coated with epoxy or glass.

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NI-DAQmx scales the resistance of a thermistor to a temperature using the Steinhart-Hart thermistor equation:

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Video: Measuring temperature with NI MAX

The screenshot displays the NI MAX software interface for a task named "MyTemperatureTask". The interface is divided into several sections:

- Left Panel (System Tree):** Shows the hierarchy of the system, including "My System", "Data Neighborhood", "NI-DAQmx Tasks", "MyTemperatureTask", "Devices and Interfaces", and various hardware components like "eBUS DirectShow Source", "ASRL4::INSTR", "Integrated Camera", "NI USB-6009", and "NI Simulated DAQ Device".
- Top Panel (Plot):** A line graph showing "Amplitude" (Y-axis, ranging from 30.5 to 33) versus "Samples" (X-axis, ranging from 2k to 2k). The plot shows a noisy signal that generally decreases over time. Controls for "Save", "Run", "Add Channels", and "Remove Channels" are visible above the plot.
- Bottom Panel (Configuration):** Contains tabs for "Configuration", "Triggering", "Advanced Timing", and "Logging". The "Configuration" tab is active, showing the "Channel Settings" for a "Temperature" channel. The "Vex Thermistor Setup" is configured with the following parameters:
 - Signal Input Range:** Max = 200, Min = 0.
 - Scaled Units:** deg C.
 - Steinhart-Hart Coefficients:** A = 1.295361E-3, B = 2.343159E-4, C = 1.018703E-7.
 - Vex Source:** External.
 - Vex Value (V):** 5.
 - Configuration:** 3-Wire.
 - R1:** 18k.
- Timing Settings:** Acquisition Mode is set to "1 Sample (On Demand)". Samples to Read is 1k, and Rate (Hz) is 1k.

On the right side of the interface, there is a "Help" panel titled "Measuring Temperature with a Voltage Excitation Thermistor". It provides a detailed explanation of thermistors, their characteristics, and the Steinhart-Hart equation used for temperature calculation:

$$\frac{1}{T} = A + B(\ln(R)) + C(\ln(R))^3$$

where T is the temperature in Kelvins.

*Further signal processing for noise reduction and data analysis can be done by **writing a LabVIEW code** that we will learn in upcoming lectures*

Summary:

Property measured

- Body temperature

Tools used

- Thermistor (An electrical component whose resistance is dependent on temperature)
- NI-DAQ USB 6009 (A hardware device to acquire analog voltage singles from the thermistor and convert them to digital signals)
- NI-MAX (A software to read and show the digital signals from the NI-DAQ in real time)

Alternative approaches

- Similar to acquiring voltage difference across the thermistor to measure the temperature, the *voltage difference across a photosensor can be acquired to measure light intensity*. This instrumentation approach is widely used in biology to quantify various bio-assays, for e.g. qPCR systems, flow cytometers, plate readers, spectrophotometers, high-throughput screening platforms etc.

Hands on Exercise

Measuring temperature with NI-MAX using a thermistor

