# Lab 1 Instrumentation

Sensors/Transducers/Transmitters and Data Acquisition

**Aims**

- To calibrate transducers and transmitters
- Determine characteristics of transducers and transmitters
- To determine coefficients of transducers and transmitters
- To operate PC-based measurement systems
- To use data acquisition boards and software (MATLAB/Simulink, Data Acquisition Toolbox) to log data

**Learning Outcomes**

- Describe methods to measure temperature
- Explain procedures to calibrate temperature measuring systems
- List variables in the temperature measuring systems
- Use NI PCI-6036E board and MATLAB/Simulink, Data Acquisition Toolbox

**Prerequisites**

- Simulink Tutorial 1 Temperature Measurement
- Knowledge of temperature measuring systems

Lab 1 consists of three experiments/hands-on exercises below:

1.1 Thermocouple Temperature Transmitter: Calibration a thermocouple temperature transmitter and determination of its time constant
1.2 RTD Transducer: Determination of characteristics of an RTD transducer
1.3 RTD Temperature Transmitter: Determination of coefficient/s of an RTD

**Experiment 1 Calibration a thermocouple temperature transmitter and determination of its time constant**

**Learning Objectives**

- To determine the characteristic of a thermocouple (J-type)
- To calibrate a temperature transmitter
- To determine time constant and sensitivity of the thermocouple temperature transmitter

**Prerequisites**

- Basic operation of MATLAB and Simulink
- Knowledge of main physical laws
- Operating principles of the thermocouple
- Data acquisition system and signal conditioning

**Methodology**

- Guided experience

**List of Equipment**

- J-type thermocouple (0-100$^{o}$C)
- Digital multimeter or mAmeter
- Set of leads

- PC with PCI-6036E, MATLAB/Simulink, Data Acquisition Toolbox
- Ice beaker ($0^oC$) with ice, boiling water beaker ($100^oC$) with a heater

**Introduction**

This exercise looks at how to calibrate a temperature measuring system and determine its time constant. The temperature is measured by a thermocouple (J-type) associated with Acromag transmitter which converts the measured temperature first into a small voltage and then the voltage into a current range of 4 to 20mA (corresponding to 0oC -100oC). The temperature measuring system has dynamics of a first-order system expressed by a first-order differential equation below:

$$\tau\dot{y} + y = Ku$$

where y is the output current [mA] and u is input temperature [$^oC$], K is sensitivity [mA/$^oC$] and $\tau$ is time constant [sec]. After doing experiments it is possible to estimate time constant of the temperature measuring system.

Computer-based instrumentation systems require data acquisition or I/O interface boards and logging, analysis and visualization software. The exercise also looks at how to acquire data using a computer, I/O interface board and software.

**Procedure**

**1. Connection, Test and Preparation**

- Connect the thermocouple, Acromag transmitter, mAmeter (or digital multimeter), volt-to-current converter, terminal board, cable (see Appendix 1) and PC as in **Fig. 1**.

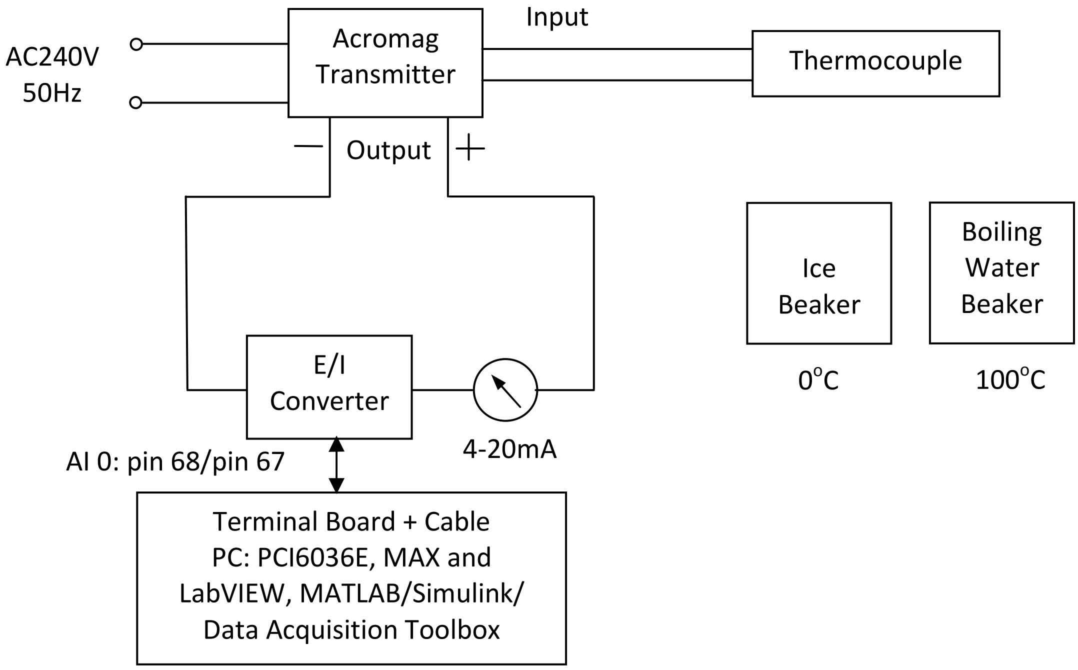


**Figure 1** Connection diagram

- Put ice and water in the ice beaker
- Pour water in the boiling water beaker, put the heater in it and turn on the power
- Turn 240 volt supply onto the transmitter
- Turn on the computer and log on with your name and password (if necessary)

**Notes:** You may need to run NI Measurement and Automation Explorer (MAX) to reset the NI PCI-6036E board if there is an error when running a Simulink model with Data Acquisition Toolbox Blocks.

### 2. Programming and Testing Functionality

- See the sample program for Experiment 1.1

### 3. Calibration

1. Run the Simulink model
2. Place the probe (thermocouple) in ice beaker ($0^oC$)
3. Adjust ZERO pot (of the Acromag transmitter) for 4mA output (*if necessary*)
4. Place the probe (thermocouple) in boiling water ($100^oC$)
5. Adjust SPAN pot (of the Acromag transmitter) for 20mA output (*if necessary*)
6. Repeat step 2 to 5 about five times or until readings converge
7. The transmitter is now calibrated.

### 4. Collect Data

1. Put the thermocouple in melting ice beaker
2. Start the Simulink model
3. Move the thermocouple into the boiling water
4. Observe the Scope when the current is just about constant
5. Move the thermocouple into melting ice. [DO NOT stir]
6. Observe the Scope when the current is just about constant
7. Repeat steps 3 to 6 but this time stir the ice water vigorously
8. Stop the Simulink model
9. Save data into MAT-formatted file in the prompt of MATLAB Command Window
10. Copy the data file/s from the PC to your USB memory stick

### 5. Calculation and Report

Using the obtained data procedures in Appendix 2 (you can also download from the lecturer's website) determine the time constant and sensitivity of the thermocouple temperature transmitter. Plot the output current versus time (you may use MATLAB or Excel).

Using the obtained data try to derive a differential equation relating *the input temperature* ($^oC$) and *the output current* (mA) or *voltage* (V) for the temperature transmitter.

Using the obtained time constant and sensitivity simulate the thermocouple temperature transmitter and compare simulated results with the experimental results.