System Level Laboratory

Thermocouple based Temperature Measurement System

Objective

The objective of this experiment is to study the characteristics of thermocouples for temperature measurement. VI will be built in LabVIEW to collect data and display the time response of the thermocouple when the temperature changes suddenly. You will analyze the data to determine the sensor time constant.

1. Introduction

The thermocouple (TC) is a temperature sensor that produces a voltage as a function of the difference between two temperatures. Figure 1 shows that the TC sensor consists of two different metals, A and B, which are connected together at one end and connect to a third type of metal wire, C (usually copper), at the other end. A voltage will be produced across the copper wire common connections. The voltage is nearly linearly relates to the temperature difference between the junction of the TC wires and the common wire. It is very small ($\cong$ 60 □V/^{o}C) so a high gain differential amplifier is often used to increase it to practical levels. Since the TC voltages are so low great care must be taken to keep noise to a minimum.

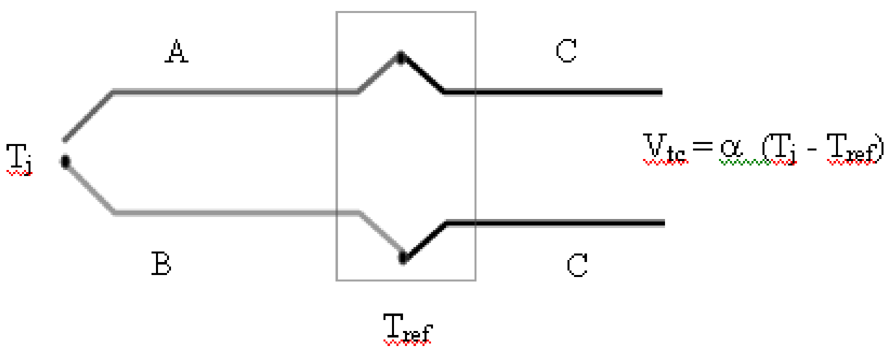
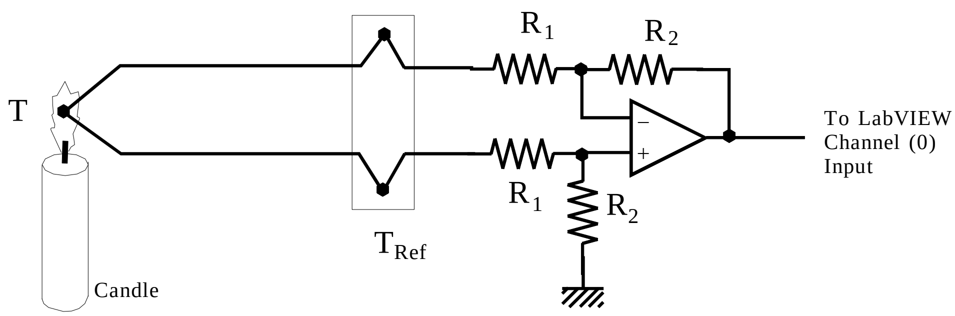


Figure 1 Thermocouple principle

Certain standard types of thermocouples are identified by the types of metals used and given special names. A Type J TC uses iron and an alloy called constantan wire; a Type K TC uses Chromel and Alumel wire; a Type S uses Platinum and alloy of Platinum and Rhodium wire, and so on. For these types of thermocouple, tables of voltage versus temperature for a particular reference are widely published. TCs typically exhibit first order time response.

2. Thermocouple and the signal conditioning circuit

In this experiment, you will use a thermocouple to measure the temperature characteristics of a candle flame and determine the time constant of the TC. The reference junction is formed where the TC wires are inserted into the breadboard sockets at room temperature. We expect the flame temperature to be between 600 and 750 ^{o}C (1000 to 1400 ^{o}F). The candle flame will flicker so baffles should be constructed, using books for example, to keep drafts away. The basic structure of the experiment is shown in Figure 2.



NOTES: (1) match the resistor pairs as close as possible
(2) keep leads short to minimize noise
(3) plug the TC directly into the breadboard, this becomes the reference temperature point

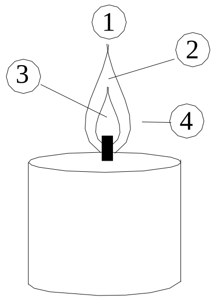
Figure 2

(1) Based on expected flame temperature range: 600 ~ 750^{o}C (1000 ~ 1400^{o}F), what types of thermocouple can we use? Use room temperature (23^{o}C) as reference, find the reference temperature voltage correction factor from the corresponding TC tables. Determine the reference corrected, expected TC voltage output for a temperature of 745^{o}C.

(2) Design and simulate a differential amplifier that can be used to amplify TC's output voltage to 0-5V. Use 1kΩ resistors as one pair of resistors in the differential amplifier, select another pair that will give the gain needed to amplify TC's output voltage.

(3) Calculate the peak-to-peak amplifier output resulted from a temperature of 745^{o}C when using Type J thermocouple.

In this experiment, you will use LabVIEW to build data acquisition system that takes in temperature values measured by thermocouple, record its voltage value when temperature changes, study its first order dynamic behavior, and determine its time constant.



Candle flame has layers and you will see it by examine the color of the candle flames changes from yellow to red to blue from inside towards outside. You will measure the flame temperature at the marked points shown in the left figure by engulfing the junction of TC there.

3. Why use 4-20mA transmission standard?

Read the 4-20mA.pdf in Blackboard course and summarize why 4-20mA is a popular transmission standard in 100~150 words.