MASSACHUSETTS INSTITUTE OF TECHNOLOGY
22.071/6.071 Introduction to Electronics, Signals and Measurement
Spring 2006

Measuring the Temperature Coefficient of Resistors.

For this laboratory we will design an experiment, run it and collect and analyze data in order to measure the temperature coefficient of a resistor.
We will devote the entire 2 hours period on Friday February 24 for this experiment.

In preparation for the experiment you will develop the data collection methodology that you are going to follow and the mathematical model for the system.

In general any resistor, even the so called "fixed value resistor", has a temperature dependence associated with it. We may say that the change in resistance ΔR is a function of the change in temperature ΔT.

$$\Delta R = \mathcal{F}(\Delta T) \tag{1.1}$$

For certain devices like the thermistor, the temperature dependence is pronounced and it is exploited in order to extract useful physical measurements like temperature.

The material composition of the resistor and the manufacturing process, determine the resistivity of the material and thus the resistance of a component constructed from the material. Generally, the temperature coefficient of metals such as aluminum, copper, iron, lead, platinum etc., and metal alloys like nichrome and brass increases with increasing temperature. Semiconductor and metal oxide materials may exhibit both positive and negative temperature coefficients. The thermistor that we have tested before and the one we are going to use in this experiment in order to measure the temperature of our test resistor has a negative temperature coefficient (NTC).

The resistor for our experiment will be the standard 5% 10kΩ resistor used in the class laboratory. We will call this test resistor, Rt.

You will be investigating the resistance characteristics of this device as a function of temperature. In general we may say that the change in resistance, ΔRt is a function of the temperature coefficient of resistance, α, and temperature change, ΔT. By extending Eq.(1.1) we may write this general relationship as

$$\Delta Rt = \mathcal{F}\left(\alpha, \Delta T\right) \tag{1.2}$$

The exact function dependence will be determined from the data analysis.

The suggested experimental setup is shown on the following figure.
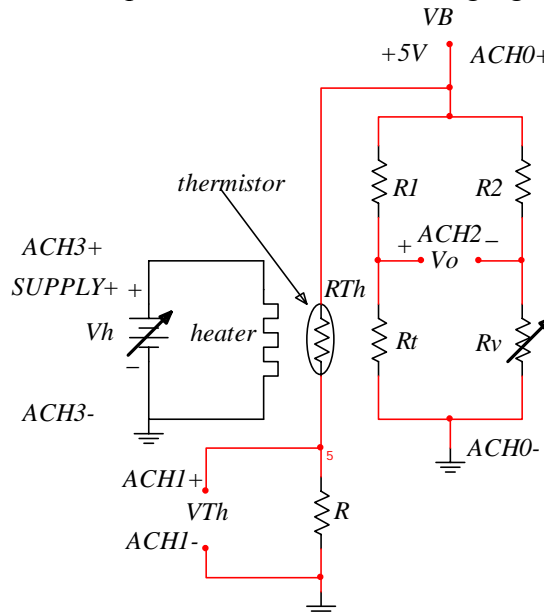
The system is composed of the following sub-systems:

- A Wheatstone bridge circuit for measuring the small changes that result from the resistance change.
- A heater for raising the temperature of the test resistor.
- A thermistor for measuring temperature

The heater, thermistor and test resistor are assembled in a single physical unit and you have constructed this in a previous experiment. In its cartoon representation this sub-system looks like:


And its circuit equivalent is
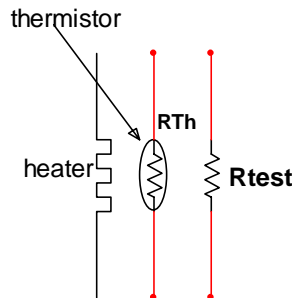
We have used a variable resistor in one leg of the Wheatstone bridge in order to offset the system.

For our experiment we need a means of setting the temperature of the test resistor to the desired value. This is actually a very interesting controls problem and we will take this opportunity to play a game before we proceed with taking the data for our experiment.

Later in the semester we will learn how to construct electronic circuits that perform various feedback control operations including temperature control
For now we have created a temperature controller with the following interface:
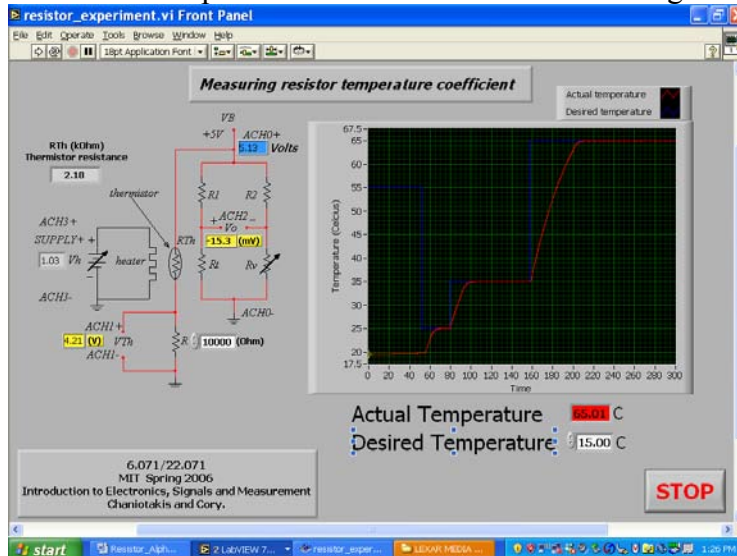
Courtesy of National Instruments. Used with permission.

This instrument automatically adjusts the voltage of the variable power supply, *Vh* , in order to achieve the desired temperature.

Before we use this automatic instrument we will try to do the control manually!!!
For this we will adjust the voltage of the variable power supply by hand to achieve the desired temperature. This manual instrument is driven by the program called **manual_resistor_experiment** and it may be downloaded from your class web site. Select the manual option for your variable power supply and make certain that the knob is turned all the way counterclockwise.

Run the instrument and watch the temperature trace. Select the desired temperature, for example 40 degrees Celsius. Adjust the voltage of your power supply and observe the behavior of the temperature.

IF YOU SEE THE TEMPERATURE GETTING ABOVE 70 DEGREES SHUT THE SYSTEM DOWN SO THAT YOU WILL NOT MELT YOUR HEATER ASSEMBLY AND THE PROTOBOARD (and your fingers of course!)

How close to the 40 degrees can you get?
Do you find that the temperature oscillates about 40 degrees?
As you play more can you make the amplitude of these oscillations smaller?
What about the period of the oscillations?
Is there a limit as to how small you can make the period of these oscillations?
Compare the rate of change of temperature increase to the rate of temperature decrease. Are they different? Why?

Now let's proceed with the experiment at hand.

Download the program called **resistor_experiment** from the class web site. The interface of this instrument is the same as the manual version that you just used. This one however automatically controls the heater in order to accurately obtain the desired temperature.

You are now ready to collect the data for your experiment. The experimental process is as follows:

- With the apparatus running at room temperature we offset the system by trimming the potentiometer Rv such that $Vo = 0$ Volts.

- Increase the temperature by an amount ΔT and measure the resulting Vo. Record the temperature differences ΔT and the corresponding bridge voltages Vo.

- From the measured Vo calculate the corresponding change ΔRt in the test resistor.

- Now we have a set of data ΔRt versus ΔT.

- From this data we will be able to determine the temperature coefficient of our test resistor.

Your lab report should include the following sections:
- Introduction
- Theory
- Experimental design
- Data collection
- Data analysis

And should in the minimum address the following:

1. Describe the experimental setup.
2. Estimate the voltage Vo as a function of the bridge circuit parameters.
3. Calculate the value for Rv such that $Vo = 0$ Volts.
4. Express the voltage VTh as a function of the thermistor resistance and the fixed resistor R.
5. Express the resistance Rt as a function of the bridge voltage Vo and the other parameters of the bridge circuit.
6. Estimate the error in your measurement of the temperature coefficient α.