EGR222 L2, L4 Laboratory Exercise 1 Supplement

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Introduction:

EGR222 Mechatronics for Spring 17 begins with the Lab! That means that you will be coming to the laboratory (SLC125) for your first session in the course, since it is scheduled before the first lecture (when course policies and such are to be presented). So, the purpose of this document is to supplement the normal lab instructions, which assume some familiarity with the course context and temperature measurement in particular. What follows is a brief overview of what mechatronics is about, followed by some basic principles concerning temperature measurement. You should also read the introductory chapter of the textbook and the lab instructions and this document before coming to class, so that you have a good understanding of what you will be doing.

What Mechatronics is:

Mechatronics is a fairly recent term used to define an integrated approach including mechanical, electrical and computer systems to practical problems in engineering products and processes. Electro-mechanical systems have long relied on electrical actuators (motors, solenoids) and sensors (contact switches, electrical temperature sensors and such) along with machines to control systems ranging from manufacturing to propulsion. What is relatively new is the availability and integration of small, inexpensive computers. While computer control in systems has been around for many decades, it began only in relatively large scale process control in applications such as control in the chemical or steel industry, where the large and expensive computers of the day could be justified. But now a computer suitable for control, in the massive quantities typical of consumer electronics, can cost less than a dollar. This provides economic opportunity. Consequently, everything from a coffee maker to a VCR to an automobile has embedded computers that provide control less expensively than alternative methods, and add more functionality.

The automobile is a good example. Into the 70's, automobiles had only simple electrical systems, with mechanical switches to control lights, a cam driven mechanical switch to initiate spark action, and similar simple methods for other controls. Engine timing relationships were fixed by mechanical linkages (the camshaft and valve system). Carburetion was likewise mechanically controlled. Then, electronics were substituted for the mechanical ignition switch. In the late 80’s and 90’s, small and reliable microcomputers became available and were put to work controlling not only engine ignition, but also fuel injection as an alternative to carburation, allowing greater control and efficiency. It was possible to monitor such variables as engine and air temperature and exhaust properties, and calculate the best timing for fuel injection and ignition to give greater performance and / or efficiency. During the 90's and later, the computation power of these computers increased greatly, as have the range of electronics in automobiles, to include object sensors and navigation systems and, coming, automatic driving. Automotive electronics is poised for another significant leap: electronic control of valves, replacing the camshaft with a system that will allow valve action, too, to be optimized beyond what is currently being done with cam based systems. (But, that seems on hold for now.) Hybrid vehicles include electric and electronic control even in transmission of power to the wheels and braking, all yielding efficiency and other benefits.

Similar changes are becoming pervasive. For example, the U.S. Navy is planning to go to all electric propulsion systems in future combatant vessels (and has some in service now), and eventually for weapons (lasers and rail guns). Fixed and autonomous robotic systems will become used in more applications. This is an important part of the Army's concept of the battlefield of the future. Consumer electronics will become more computer driven (cameras are a good example of how this happens). Perhaps you've heard of "The Internet of Things" (IoT). The degree of control in systems will also change. For example, in automotive engine control, it will become possible to model the process in the individual cylinder and optimize timing for that particular unit, rather than rely on generic look-up tables as today's systems do. That is only possible due to the greatly increased computation power available. This same increase in computer power are making possible practical vision systems and many others, limited primarily by the imagination of engineers designing systems.

For that reason, it is important that all engineers have an understanding of the basic elements of mechatronics, including not only elements of your own discipline (mechanical or electrical) but also of the other, and the concept of how control computers operate and can be applied to such systems.

Laboratory 1: Temperature measurement:

A "sensor" is a device that measures some "real world" quantity and gives a signal that presents that information in another form, usually electrically. In the first laboratory exercise, we are interested in sensing temperature. We want sensors to convert the temperature into a Voltage that represents the temperature. We call this an "analog" variable, since a given Voltage represents a particular temperature. Often (but not always) the Voltage is linearly related to temperature, so that we can write $V = kT + b$, a linear equation, that represents what the temperature sensor does. Sometimes the sensor is not linear, but close enough to linearity, that we can still use a linear model (perhaps over a restricted range). The constant "a" in the linear equation is the "sensitivity" of the sensor – it tells us how many Volts per degree the sensor indicates. We can write: k = "Sensitivity" = $(V_1 - V_2)/(T_1 - T_2)$, where V_1 and V_2 are the Voltages measured at temperatures T_1 and T_2 respectively. If a sensor is nonlinear, then "sensitivity" varies depending on the range of temperatures, but there is some other (nonlinear) equation that applies, and the constants for it, once known, can be used to allow Temperature to be accurately measured.

The focus of the laboratory exercise is to "characterize" various sensors and see how they can be used for temperature measurement. We will be looking at four such devices:

1. Thermistor: A nonlinear "negative temperature coefficient (NTC) device characterized by the equation for resistance $R=R_0\ e^{(E/kT)}$. To use this sensor, we need to apply a source of current and measure Voltage (or provide a Voltage and measure current) to get resistance. The lab Ohm meter can be used. By graphing resistance versus Temperature appropriately, we can find the constants R_0 and E. (The constant k is Boltzman's constant.)

2. Resistor: A common resistor can be used as a temperature sensor, and it is reasonably linear. We need to measure Resistance, then plot it versus Temperature to find the constants.

3. Thermocouple: We are using a "type K" thermocouple, which generates a Voltage related to the temperature. A table gives the mapping of temperature to Voltage. But, we need to connect both wires of the thermocouple to copper wires in an "ice bath" to subtract incidental thermocouples (at nonzero temperatures) formed by the thermocouple wire connections. We can use the lab meter to measure the DC Voltage.
4. A diode: Like the NTC thermistor, this device is nonlinear. A source of current can be used (a fixed 10K Ohm resistor) and the Voltage can be measured, and from a plot of Voltage versus Temperature a constant can be found that characterized the diode as a sensor.

In all of these cases, we will use a water bath (in a beaker) that we will heat up with a "hot plate" (lab heater) and cool down with ice to give temperature variations, using a digital thermometer to indicate the temperature.

Note re. thermocouple: We would first dip the thermocouple hot junction into ice-water mixture (0 degree) and measure the voltage, then the sign of this voltage is reversed and added to all the following measurements to compensate for the fact that we do not keep the cold junction in ice-water mixture (we keep it in room temperature) while we collect the data. (Dr. Yong Zhu)

A formal laboratory report for both this exercise and the position sensing lab exercise #2 will be due at the beginning of Lab #3. The Engineering Laboratory Reports Manual(that you should have received in EE283) gives guidance on making formal reports. In short, material must be prepared on the computer, well organized, with properly annotated graphs (use Excel) and appropriately tabulated results. Your conclusions should summarize your results. An abstract (not part of the report proper) should describe the whole report. A joint report is made for each partnership.

Figure 1 shows a photograph of the blackboard that had been used to present the material relevant to this laboratory exercise. This might be useful in understanding what you are to do.

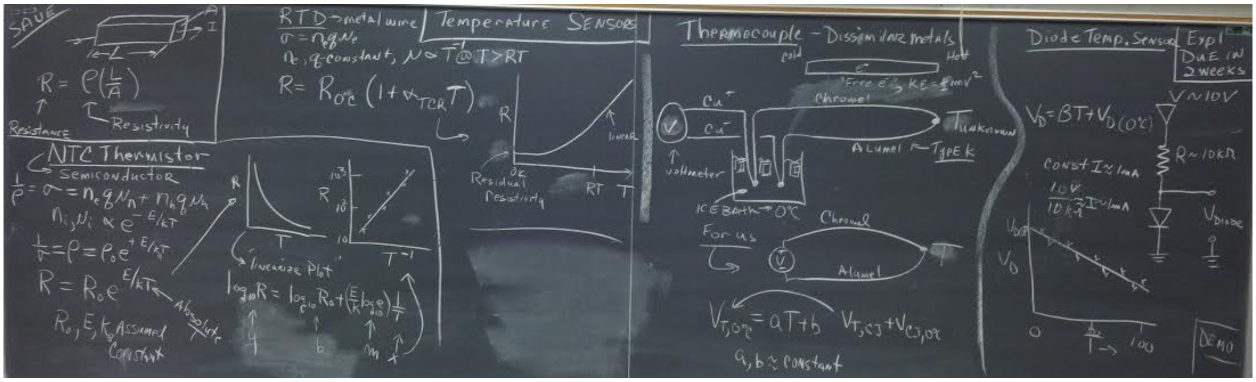

Figure 1 Laboratory Exercise #1 Blackboard

Conclusion:

This lab exercise is a nice introduction to sensors. It's easy to see and understand what is happening. Other sensors you will meet later in the lab measure mechanical position. In real systems, sensors are used to measure pressure, oxygen, luminance, and all sorts of other quantities. I hope you find this lab exercise a good start in what should be an interesting and useful course.