EE 4770 Homework 1 Due: 2 February *1994*

Problem 1: An integrated temperature sensor converts temperature to current such that

$$i = \frac{T}{10\,\mathrm{K}}\,\mathrm{mA},$$

where T is the temperature, K is the unit of temperature[1], Kelvin, and i is the current flowing through the sensor. Using this sensor design a circuit that will convert temperature in the range $-20\,^\circ\mathrm{C}$ to $40\,^\circ\mathrm{C}$ linearly to 0 to 10 V. Show the following:

- The process variable to electrical quantity transfer function, H.
- The transfer function needed from the conditioning circuit, C.
- A schematic of the conditioning circuit, showing the sensor and the value of all resistors and voltage sources.

Hint: Use the summing amplifier with one resistor replaced by the temperature sensor.

EE 4770 Homework 2 Due: 4 March *1994*

Problem 1: Two options for measuring temperature using an RTD are being considered. In both options, the resistance of the RTD will be converted into a number which will be read by a computer[2]. This number can be further processed in cyberspace to obtain the measured temperature. Let T denote the temperature to be measured and let D denote the contents of an area of the computer memory. Then

$$D = H(T) = T/\,^\circ\mathrm{C},$$

that is, the memory contains a pure number (do not be concerned about the format for this assignment), the temperature in degrees Celsius.

In option 1 the linear RTD model presented in class will be used, that is,

$$S_1(T) = R_0(1 + \alpha_1 T),$$

where $R_0 = 100\,\Omega$ is the resistance of the RTD at $0\,^\circ\mathrm{C}$, $\alpha_1 = 0.00392\frac{1}{^\circ\mathrm{C}}$, and T is the temperature to be measured. In option 2 a more precise model will be used:

$$S_2(T) = R_0(1 + AT + BT^2),$$

where $R_0 = 100\,\Omega$, $A = 0.003977\frac{1}{^\circ\mathrm{C}}$, and $B = -5.966 \times 10^{-7}\frac{1}{^\circ\mathrm{C}^2}$. An analog to digital converter (ADC) is available that will convert voltages from 0 to 10 V into a floating point number from 0.0 to 10.0. The output of the ADC is fully interfaced to the computer.

Design the systems (one for each model) for temperature measurement, *following the instructions below.*

- Design the circuit(s) which converts the RTD resistance to a voltage for the ADC. Use a 3 wire RTD. Show all component and voltage source values.

[1] The symbol k is an abbreviation for 1000. The symbol K is sometimes used for 2^{10}, but it won't be used that way in class.

[2] Relax, you do not have to design this part.

- Explain what the software should do to convert the voltage into the proper number. This should be written for a programmer, who would then write the code. (For example, "Let x be the value read from the ADC. Write $x - e^{\pi i} + 1$ in the result area of memory.") The programmer knows how to read the ADC and write the memory location, but does not know about temperature measurement. Remember that answers should be given for both models.

Suppose at temperature 181 °C the resistance of the RTD is 170.0 Ω. Compute the model error for both models. Express it has a percent error.

Problem 2: Design a threshold detector which monitors the voltage at its input and produces a current between its two outputs. When the threshold detector is *on* a 100 mA current should flow from one of its output to the other (through whatever external device is connected). When the threshold detector is *off* there should be zero current. The threshold detector should switch to the on state when the input voltage exceeds 7 volts. The threshold detector should switch to the off state when the input voltage falls below 6.5 volts.

EE 4770 Homework 3 Due: 8 April 1994 *1994*

Problem 1: A large displacement force sensor is to convert force in the range of 0 to 20 mN to a voltage so that $v_o = 1000F\,\frac{\mathrm{V}}{\mathrm{N}}$. The sensor uses a spring with spring constant $K = 1.5\,\frac{\mathrm{mm}}{\mathrm{mN}}$. To measure the displacement of the spring an optical sensor will be used. The spring, as it moves, uncovers a shutter. On one side of the shutter is a light source of fixed intensity, on the other is a photodiode. The photodiode has sensitivity $K_s = 3\,\frac{\mu\mathrm{A\,cm}^2}{\mathrm{mW}}$.

- Draw a diagram of this system, labeling all components.
- Show the intensity of the light source, and other component values to realize the desired output.
- The circuit above should be solved assuming $x = KF$. Suppose now that the force/displacement relationship for the spring were $x = K_1F + K_2F^2$, where K_1 and K_2 are non-zero constants. Show how the linear output, $v_o = 1000F\,\frac{\mathrm{V}}{\mathrm{N}}$, could be attained by modifiying the shutter.

Problem 2: Design a force sensor based on a piston. The sensor should measure forces from 0 to 1000 Newtons. The output should be $v_o = \frac{F}{100}\,\frac{\mathrm{V}}{\mathrm{N}}$. The force is applied to a piston which compresses air in a cylinder. Assume that in the cylinder the equation $PV = k$, where k is a constant, P is the pressure, and V is the volume, holds over the range of interest.

The force can be determined in two ways: by measuring the displacement of the piston or by measuring the pressure in the cylinder. Solve the problem both ways.

- Choose a sensor to measure displacement and pressure. Choose any reasonable responses for the sensors.
- Show the design for each circuit, include all component and supply values.
- Discuss any advantages one circuit has over the other.
- Explain how the precision of the output changes with force.