EE 4770 — Homework 1 — Due: 8 February *1995*

Problem 1: Offset can be adjusted in an inverting amplifier by applying an appropriate voltage to v_+. Show how to choose components for such an amplifier so that there is an output of x given an input of $v_\mathrm{A} = a + xb$, where a is a voltage and b is a dimensionless negative number. (Note that offset and gain cannot be independently adjusted.)

Problem 2: Design a system to convert temperature, x, to a floating-point number $H(x) = \frac{x}{{}^\circ\mathrm{C}}$, the temperature in degrees Celsius. Temperature is to be measured using a transducer with response $H_\mathrm{t}(x) = R_0(1 + ax + bx^2)$, where $R_0 = 100\,\Omega$, $a = \frac{0.064}{\mathrm{K}}$, and $b = \frac{0.00107}{\mathrm{K}^2}$. Temperature will vary in the range $[-10\,{}^\circ\mathrm{C}, 50\,{}^\circ\mathrm{C}]$. A 16-bit, $5\,\mathrm{V}$ ADC, $H_{\mathrm{ADC}(5\,\mathrm{V},16)}(y)$ is to be used. The temperature is to be written into a variable named `tee`.

Use the gain/offset circuit for conditioning. Be sure to make appropriate use of the ADC input range. (The ADC input should not vary, for example, from 4 to 4.1 volts.) Show all component and supply values. Show pseudocode to convert the ADC output to a floating point number, the temperature in degrees Celsius.

Hint: Remember that the conditioning circuit must be designed so the ADC input is between 0 and $5\,\mathrm{V}$*. Since the ADC output will be computer-processed the conditioning circuit does not have to convert the process-variable value to* $H(x)$*.*

EE 4770 — Homework 2 — Due: 20 February *1995*

Problem 1: A single copper RTD is to be used to measure temperature in the range $x \in [-50\,{}^\circ\mathrm{C}, 100\,{}^\circ\mathrm{C}]$. The system is to convert the RTD output to a voltage using a Wheatstone bridge and instrumentation amplifier, convert the amplifier output to a digital quantity using an $H_{\mathrm{ADC}(5\,\mathrm{V},16)}$ ADC, and write $H(x) = x/{}^\circ\mathrm{C}$ to a variable, `tee`. Use the bridge circuit presented in class. Design the circuit so that the ADC input is $\approx 0.5\,\mathrm{V}$ at $-50\,{}^\circ\mathrm{C}$ and $\approx 4.5\,\mathrm{V}$ at $100\,{}^\circ\mathrm{C}$. (Do this only by appropriate choice of arm resistors, bridge voltage, and amplifier gain.) The interface routine should correct for the non-linear response of the bridge. The model of the RTD to use is

$$H_{\mathrm{t}2}(x) = R_0(1 + \alpha x),$$

where $\alpha = 0.0041/{}^\circ\mathrm{C}$ and $R_0 = 50\,\Omega$. *Hint: Here is an idea that will almost work. Suppose we want the bridge output to be* $0\,\mathrm{V}$ *at* $-50\,{}^\circ\mathrm{C}$*. Put the process variable in the form* $x = x' + T_\mathrm{min}$*, where* $T_\mathrm{min} = -50\,{}^\circ\mathrm{C}$*. Transform the RTD model into the form:* $H'_{\mathrm{t}2}(x') = R'_0(1 + \alpha' x')$*. The problem is we need the bridge output to be* $0.5\,\mathrm{V}$ *at* $-50\,{}^\circ\mathrm{C}$*. End of hint.*

EE 4770 — Homework 3 — Due: 6 March *1995*

Problem 1: Find a linear model of a Type J thermocouple based upon the following polynomial model:

$$T = (a_0 + a_1 v + a_2 v^2 + a_3 v^3 + a_4 v^4 + a_5 v^5)\,{}^\circ\mathrm{C},$$

where v is the thermocouple voltage measured at an isothermal block at $0\,{}^\circ\mathrm{C}$, T is the temperature of the thermocouple (IPTS-68), $a_0 = -0.048868252$, $a_1 = 19873.14503/\,\mathrm{V}$, $a_2 = -218614.5353/\,\mathrm{V}^2$, $a_3 = 11569199.78/\,\mathrm{V}^3$, $a_4 = -264917531.4/\,\mathrm{V}^4$, and $a_5 = 2018441314/\,\mathrm{V}^5$. The center of the temperature range to be measured is $T_\mathrm{M} = 550\,{}^\circ\mathrm{C}$; the thermocouple output will be $30.21\,\mathrm{mV}$ with $T_R = 0\,{}^\circ\mathrm{C}$. *Hint: do not even think about solving for* v *in the equation above. Instead find a linear model for temperature in terms of voltage. Then, solve for* v*.*

Problem 2: Design a circuit, using a Type J thermocouple, for measuring temperature, $x \in [500\,^\circ\mathrm{C}, 600\,^\circ\mathrm{C}]$. The output should be $H(x) = \frac{x/\,^\circ\mathrm{C} - 500}{10}\,\mathrm{V}$. The circuit should be designed using the linear model of thermocouple response found above. Assuming the fifth-order equation above is perfect, find the model error for the thermocouple at $500\,^\circ\mathrm{C}$ and $600\,^\circ\mathrm{C}$.

EE 4770 — Homework 4 — Due: 12 April *1995*

Problem 1: A widely available large-displacement pressure transducer consists of a flattened tube of paper rolled into a coil. A pressure port is located at one end of the tube. Pressure at the port will cause the tube to unroll. When the tube completely unrolls an audible pressure alarm will sound. (The sound is generated by a small opening which is exposed when the tube fully unrolls.) The model function for this device gives the length of the unrolled portion, $H_{t1}(x) = x\frac{\mathrm{m}}{100\,\mathrm{kPa}}$. The transducer must be allowed to unroll freely, force on the unrolling portion will reduce its accuracy.

Design a circuit using this transducer to convert process variable $x \in [0, 50\,\mathrm{kPa}]$ (gauge pressure) to a voltage, $H(x) = x\frac{\mathrm{V}}{10\,\mathrm{kPa}}$. Choose whatever additional transducers are needed for the circuit. Draw a diagram showing how the displacement of the tube is measured. Optical methods are recommended.

(FYI: The pressure port is usually kept sterile [although not to clinical standards] before use; after use the transducer is discarded.)

Problem 2: Design a system to measure water flow in a pipe using an orifice-plate obstruction flow meter. Convert the flow $x \in [0\frac{\mathrm{l}}{\mathrm{min}}, 500\frac{\mathrm{l}}{\mathrm{min}}]$ to a floating-point number $H(x)$ to be written into variable `vfl`, where $H(x) = x\frac{s}{\mathrm{ml}}$. The pipe has a diameter of 50 mm and the orifice has a diameter of 10 mm. Use a similar type of differential pressure sensor used in class, the only difference is p_{max}, which should be chosen as part of the solution. Design the circuit so that the value written has a precision of $\pm 1\frac{\mathrm{ml}}{\mathrm{s}}$. Use the minimum number of bits in the ADC needed to attain the precision goal, *taking into account the non-linear response of the flow meter.*