AMERICAN UNIVERSITY OF BEIRUT

MECH 430 Instrumentation & Measurements

Final Exam – June 11th, 2007

Time Allowed: 2 hours

Closed Book – A non-programmable calculator is allowed.

Test Rules

- Test period = 120 minutes.
- Explain everything in order for me to give you part marks
- **If you are stuck on a part SKIP it and then come back later.**
- Sharing calculators is not allowed.

IMPORTANT: Write your name on this question booklet and hand it in with your script book.

Name: ………………………………………………

Student Number: ………………………………….

Question 1 and 4 are mandatory

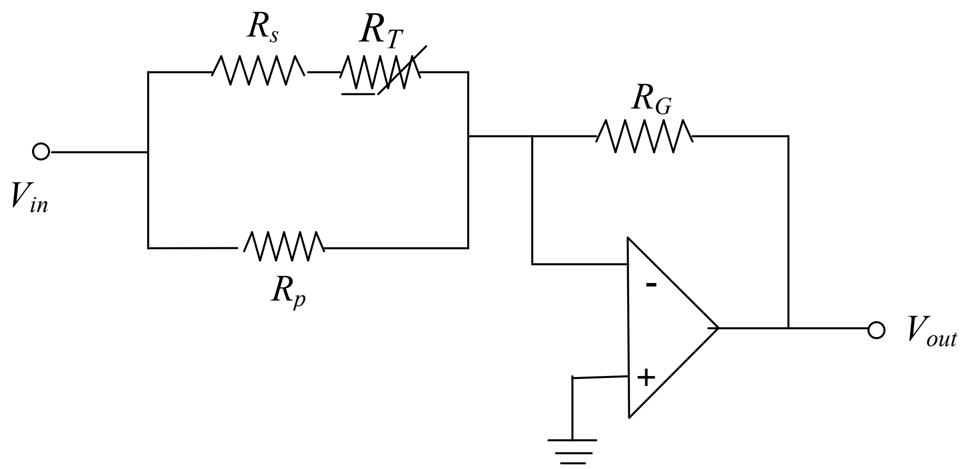
Choose among questions 2 or 3

Problem I (40marks) (comprehensive)

1) What is a hot-wire anemometer and what is it used for? What is a thermal transport mass flowmeter used for and how is it made? What is an ultrasonic flowmeter?
2) Explain the different types of RTD's and what the advantages of each are.
3) How can you use a capacitor as a (1) microphone, as a (2) level sensor, as a (3) proximity sensor?
4) What is an Eddy current displacement sensor? Draw a diagram for such a sensor and explain how it works. What is the typical range and resolution of such a sensor?
5) How would you design a measurement system using an LVDT (from signal to ADC). Explain why we use a phase sensitive demodulator in such a measurement system.
6) What is the main problem that can occur from unsuitable grounding? Explain with means of a graph.
7) The DAQ that you used in your lab includes both an instrumentation amplifier and an A/D converter. Explain what the instrumentation amplifier is and draw its circuit. Why not just used an inverting amplifier? Why not just use a non-inverting amplifier. What are the different issues you want to consider if you want to connect a sensor to this DAQ?
8) Consider the following types of position sensors: inductive, capacitive, eddy current, ultrasonic. For the following conditions, indicate which of these types are not suitable and explain why:
    a. Environment with variable humidity,
    b. Target object made of aluminum,
    c. Target object made of steel,
    d. Target object made of plastic,
    e. Target object several feet away from sensor location
    f. Environment with significant temperature fluctuations

Problem II (20marks)

The DC amplifier below exhibits an increase in gain when there is an increase in temperature. The NTC thermistor has a resistance of 30kΩ at 20°C and B = 4000K for the temperature range of interest. If at temperatures of 15°C, 25°C, and 35°C the gain should be 0.9, 1, and 1.1 what values should the resistors R_s, R_p and R_g have?



Problem III (20 marks)

A given platinum RTD probe has a resistance of 1000Ω and a temperature coefficient α = 0.004Ω/Ω/K at 25°C, and a dissipation constant δ = 5mW/K. Use it to design a thermometer for the range from 0°C to 100°C having the maximum possible sensitivity but without exceeding a 1% relative error of the output voltage. Use a bridge circuit and assume that its output is measured with an ideal voltmeter.

Problem IV (40 marks)

You are working for a robotics company that requires you to construct a sensor to measure the angular rotations of a robotic arm that has a range of rotation of 270 degrees. Given that you have the following equipment available:

- An RTD that is corrupted by noise. Its dissipation constant is 30mW/°C. Its resistance at the nominal temperature of 65° is 150Ω. Its fractional change of R with temperature is 0.004/°C.
- A rotary potentiometer with a diameter of 10cm and a coil diameter of 0.5mm.
- Capacitors, inductors and Resistors of any size.
- An FSR that is corrupted by noise,
- A 2V voltage source,
- A 1 A current source,
- Different types of LED,
- Piezoelectric sensors,
- An 8 bit ADC with (a dynamic range between 0V and +10V)
- An instrumentation amplifier,
- A summer amplifier,
- A buffer amplifier,
- Inverting and non-inverting amplifiers,
- An LVDT,
- An IR sensor.

1) Propose a sensor of the above list that can measure angular rotations of the arm. Given that the diameter of the robot arm is 20cm, what is the smallest arc length the arm can move through?
2) How would you connect this sensor? Explain the non-linearity issue that you might get and you can reduce this effect.
3) It is known that loading is a problem in such a system. How would you design your circuit to reduce the effect of loading?
4) Two types of noise are apparent in such a system: (1) external noise that is common to both the source and reference leads and (2) another high frequency noise (2MHz) that is carried with the signal. How would you eliminate the first source of noise? How would you eliminate the 2nd noise? Design a circuit to attenuate this 2nd source of noise to 1%. What effect does this have on the maximum frequency component of the signal which is 3kHz?
5) Design a circuit to interface the output of (4) to a computer. If you do analog to digital conversion don't forget any amplification and offset that might be necessary for interfacing the circuits. Also define the properties of this analog to digital converter (Offset, span, step size, resolution). Draw a diagram of the entire system including all the components from (2), (3), and (4).
6) What rotation does an output of 11100010 of the ADC correspond to?

$$R_T = R_o e^{B(1/T - 1/T_0)}$$

$$R = R_o(1 + \alpha(T - T_0))$$

$$\frac{v_o}{v_i} = -\frac{R_2}{R_1}$$

$$\frac{v_o}{v_i} = 1 + \frac{R_2}{R_1}$$

$$\frac{V_{OUT}}{V_{ref}} = \frac{x}{x_m}$$

$$V_{OUT} = \frac{R_1}{R_1 + R_2} V_{ref}$$

$$r = \left(\frac{1}{N}\right) \times 100\%$$

$$\frac{V_o}{V_I} = \frac{1}{\sqrt{1 + \left(f / f_c\right)^2}}$$

$$\frac{V_o}{V_I} = \frac{f / f_c}{\sqrt{1 + \left(f / f_c\right)^2}}$$

$$f_c = 1/2\pi RC$$

$$V_X = \left(b_n \times 2^{-1} + b_{n-1} \times 2^{-2} + \cdots + b_1 \times 2^{-n+1} + b_0 \times 2^{-n}\right) \times FS + V_{\min}$$

$$A(w_s) = 10\log\left[1 + \varepsilon^2 \left(w_s / w_p\right)^{2N}\right]$$

$$\varepsilon = \sqrt{10^{A_{\max}/10} - 1}$$

$$f_a = \left|f - nf_s\right|$$

$$V_o = \frac{R_1 R_3 - R_2 R_4}{\left(R_1 + R_4\right)\left(R_2 + R_3\right)} V_R$$

$$v_s = CAx(t)\sin(wt)$$

$$v_p = A\sin(wt)$$

$$v_s \times v_p = CA^2 x(t)\sin^2(wt)$$

$$= 0.5CA^2 x(t)\left[1 - \cos\left(2wt\right)\right]$$