Test 1 2021 questions

Mechatronics (McMaster University)

4H03 Test 1, 2021

1) A straight calibration line was fit to the mean outputs of an inexpensive force sensor. The slope of the calibration line was found to be 0.05 V/N and its offset was 0.68 V. The standard deviation of the sensor output was not affected by the input, and equaled 0.29 V. The sensor's worst performance occurred when the actual force was 100 N. When that force was applied, the mean value of the sensor's output equaled 6.52 V. Using the given information, determine values for the following performance specifications:
a) sensitivity, b) repeatability, c) linearity, and d) accuracy.

2) A temperature sensor has a bandwidth of 3.0 Hz, a range of -20 °C to 80 °C, and an accuracy of ±0.3 °C.
a) If its current output is 27 °C, and the actual temperature suddenly changes, how long should the mechatronic system wait before taking its next reading?
b) Let's call the time duration you found in part (a), t_{wait}. If the measurement is taken $\frac{1}{2}t_{wait}$ after the actual temperature changes, what is the worst case measurement error?

3) A pressure sensor has a sensitivity of 0.5 V/MPa, a range of 0.5 MPa to 5 MPa and an accuracy of ±0.7% of full scale.
a) Assuming other sources of error in the measurement system are insignificant, if the input is 3 MPa, what is the worst case measurement error in MPa?
b) The sensor's output impedance is 0.1 kOhm. It is connected to an ADC with a 10 kOhm input impedance. Repeat part (a) including the effect of these impedances.
c) The ADC has a 8-bit resolution with 7.3 effective bits. Its input range is 0.25 V to 3.25 V. Repeat part (b) including this source of error.

4) A position sensor with an analog output is attached directly to the shaft of a motor. The controller estimates velocity by backward differencing the position measurements. When the sampling period equals 0.017 s, the worst case velocity error is 47 rpm. The worst case velocity error changes to 72 rpm when the sampling period is changed to 0.027 s. Determine:

a) The optimal sampling period.

b) The standard deviation of the position sensor noise.

5. Based on the material covered in this course, answer the following qualitative questions:

Qualitative question: A) Which temperature sensor is the best choice for measuring a rapidly changing low temperature? Explain why.

Qualitative question: B) What is the best method for sensing the level of a corrosive liquid in a tank? Explain why.

Qualitative question: C) Explain why strain gauges are normally used in pairs.

Qualitative question D) You are re-designing an accelerometer. You cannot change its stiffness. What should you do to double its bandwidth? How much will the sensitivity of your new design differ from the original design?