7 **1.** A straight calibration line was fit to temperature sensor data. The slope of the calibration line was found to be 0.04 V/°C. The standard deviation of the sensor output was not affected by the input, and equalled 0.06 V. The input and the mean values of the calibrated sensor output for a series of tests are listed in the table below. Using the given information, determine values for the following performance specifications:
a) repeatability, b) linearity, c) accuracy, d) deadband, and e) hysteresis.

Test number	Temp. Input (°C)	Mean Calibrated Output (°C)	Error mag (°C)
1	0	0	0
2	(5)	0	5
3	10.5	9	1.5
4	15	13.5	1.5
5	30	27	3
6	75	70.5	4.5
7	150	145	5
8	225	219	6
9	300	294	6
10	225	232.5	(7.5)
11	150	157	7
12	75	81	6
13	30	33	3
14	15	16	2
15	10.5	9.5	1
16	5	0	5
17	0	0	0

8 **2.** A force sensor has a sensitivity of 12 mV/N, a range of 50 N to 750 N and an accuracy of ±0.15% of full scale.

a) Assuming other sources of error in the measurement system are insignificant, if the input is 250 N, what is the worst case measurement error?

b) The sensor's output impedance is 1 kΩ. It is connected to an ADC with a 60 kΩ input impedance. Repeat part (a) including the effect of these impedances.

c) The ADC has a 12-bit resolution with 9.7 effective bits. Its input range is ±10 V. Repeat part (b) including this source of error.

6 **3.** A measurement system consisting of an accelerometer and signal conditioner has a range of ± 100 m/s^2, an accuracy of ± 2.5 m/s^2 and a bandwidth of 10 Hz.

a) If the current output is 60 m/s^2 and the true acceleration suddenly changes to a new value, how long should the mechatronic system wait before taking its next reading?

b) If the measured acceleration is a 400 Hz sinusoid with a 80 m/s^2 amplitude, what is the worst case error in the measured amplitude?

Please Note: This number is clearly wrong. The problem was caused by a mistake in equation 2.34 that has since been corrected in chapter 2, problem set 1 and the equation list for test 1.

5 **4.** An encoder is attached directly to the shaft of a motor. The maximum torque produced by the motor is 10 Nm. All other torques are negligible. The moment of inertia of the motor plus load varies from 5×10^{-3} kgm^2 to 4×10^{-2} kgm^2. The encoder produces 1000 pulses per revolution. The controller estimates velocity by backward differencing position measurements taken every 0.005 s. The controller uses quadrature counting. Calculate the worst case velocity error in **rpm**.

9 **5. <u>Based on the material covered in this course</u>**, answer the following questions in the spaces provided:

a) What is the main difference between the outputs of a typical process control system and a typical sequential control system?

b) How did the artificial hand for a small child covered in Chapter 1 save electrical power so its batteries would last longer?

c) Define the sensor specification *resolution*.

d) Why aren't acceleration sensors commonly used with integration to measure velocity?

e) Give one advantage and one disadvantage of a thermistor.

f) What advantage and disadvantage does a retro-reflective proximity sensor have when compared with a thru-beam proximity sensor?

g) Describe a method for making a displacement sensor employing strain gauges less temperature sensitive?