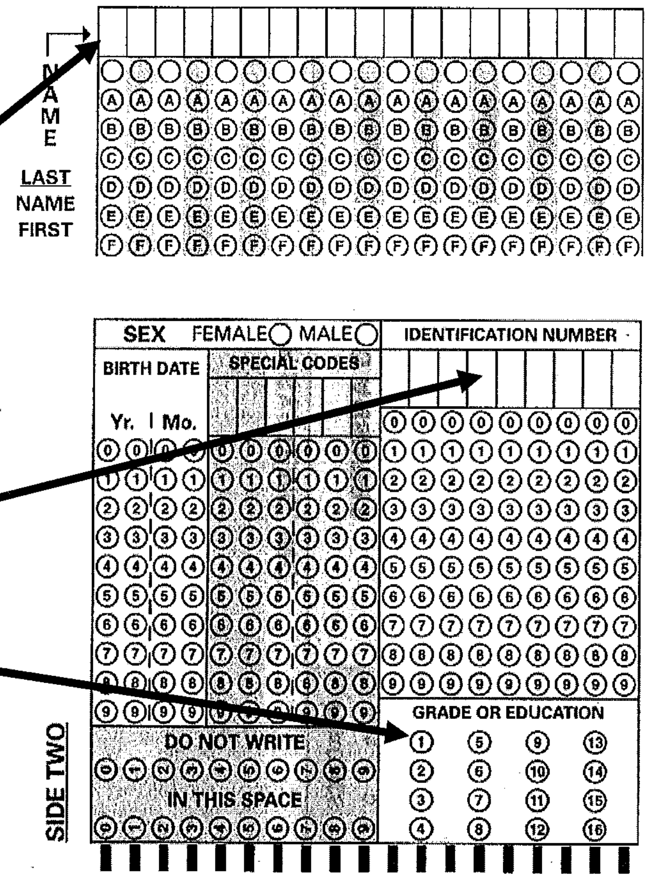
MAE334 - Introduction to Instrumentation and Computers

Midterm Examination

October 25, 2006



- **Closed Book and Notes**
- **No Calculators**

1. **<u>Fill in your name</u>** on side 2 of the scoring sheet (Last name first!)

2. **<u>Fill in your 8-digit person number</u>** on your scoring sheet.

3. **<u>Fill in circle 1 under GRADE OR EDUCATION</u>** on your scoring sheet. This is your test number! You will receive a ZERO if you do not indicate your test number.

- For each question, choose **<u>THE BEST ANSWER</u>** and mark the corresponding answer on the scoring sheet.

The terms ***lab 1*** and ***lab 2*** refer to: **Lab 1 Basics of A to D Conversion** and **Lab 2 Thermocouple, Static and Dynamic Calibration**

The last page of the exam has the "Student-t Distribution Table" and the "Probability Values for Normal Error Function $z_1 = \frac{x_1 - x'}{\sigma}$"

1. The static sensitivity of a thermistor is constant over all temperatures.
   a. True
   b. False

2. In lab 2 the thermocouple response was linearized by taking the natural log of the function, $\left[\frac{(T_\infty - T(t))}{(T_\infty - T_0)}\right]$, where *t* is time and *T*, is temperature.
   a. True
   b. False

3. Repeated measurements of a static temperature reading will
   a. Have a normal distribution
   b. Show the bias error
   c. Can be used to determine the measurement system precision
   d. All of the above
   e. None of the above

4. An 8 bit ADC with an ±12.8 volt input signal range subjected to a 4.1 volt signal will output a value.
   a. 4
   b. 41
   c. 82
   d. 8
   e. None of the above

$\pm 12.8 \Rightarrow 25.6V$ RANGE

$\frac{25.6V}{2^8} = \frac{25.6}{256}V = 0.1V = Q$

$\frac{4.1}{Q} = 41$

A temperature sensor is to be selected to measure the fluctuating temperature within a cylinder of an internal combustion engine. It is suspected that the temperature will behave as a periodic waveform with a frequency around 180 radians/second. (Rotating at 1800 rpm). Several size sensors are available, each with a known time constant.

5. What percent reduction in output/input signal magnitude would you expect at the 1800 cycle/minute frequency from a thermocouple with a 1/9 of a second time constant? (assume π = 3 and static sensitivity, K=1)
   a. 5%
   b. 30%
   c. 70%
   d. 95%
   e. None of the above

$M(\omega) = \frac{1}{\sqrt{1-(\tau\omega)^2}} = \frac{1}{[1+(\frac{1}{9}180)^2]^{1/2}} = \frac{1}{[1+20^2]^{1/2}} \cong \frac{1}{20} = 5\%$

THEREFORE 95% REDUCTION

6. If you were required to maintain a dynamic error of less than 29.3% ($M(\omega) \geq 70.7\% = 1/\sqrt{2}$) for the internal combustion engine temperature measurement described above what would be an acceptable thermocouple time constant?
   a. 1/180 seconds
   b. 1/90 seconds
   c. 1/60 seconds
   d. 1/30 seconds
   e. None of the above

$M(\omega) = \frac{1}{\sqrt{2}} \therefore \sqrt{2} = \sqrt{1+(\tau\omega)^2}$

$2 = 1 + (\tau\omega)^2$

$1 = (\tau\omega)^2$

$1 = \tau\omega$

$\tau = \frac{1}{\omega} = \frac{1}{180}$ SECONDS

7. Thermistors are normally not as sensitive as RTDs, but are much less expensive to manufacture.
   a. True
   (b.) False

   thermistor are more sensitive and less expensive

8. An inclined manometer with an indicating leg at 30° containing colored water (specific weight, $\gamma = 1.0$) is used to measure pressure. What is the static sensitivity of the manometer in (Pressure in Inches of Water/Inches of Deflection)?
   (a.) 0.5
   b. 1.0
   c. 1.5
   d. 2.0
   e. None of the above

   $P_{\text{IN } H_2O} = K L_{\text{INCHES}} = \sin 30 \, L_{\text{INCHES}} = 0.5 L_{\text{INCHES}}$

9. A strain-gauge equipped diaphragm pressure transducer is a null device with a dynamic behavior described as a second-order system.
   a. True
   (b.) False

   diaphragm pressure are deflection devices they are 2nd order sensors.

10. An under damped second order system will *always* oscillate with a greater amplitude than the forcing when the input forcing is at the natural frequency.
   a. True
   (b.) False

   ζ, damping ratio must be less than ~0.707 to get an increase in magnitude

11. The precision error associated with the ADC used in our lab can not be less than
   a. $10/200/2^{12}$ Volts
   (b.) $20/200/2^{12}$ Volts
   c. $20/2^{12}$ Volts
   d. None of the above

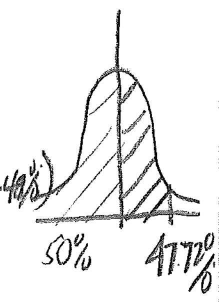
   $\frac{E_{FSR}/\text{GAIN}}{2^{12}} = \frac{20/200}{2^{12}}$

12. It is known that the statistics of a normally distributed temperature signal are x' = 20 °C and $\sigma^2 = 4$ °C^2. What is the probability that a measurement will yield a value greater than 24 °C?
   (a.) 5%
   b. 32%
   c. 34%
   d. 48%
   e. 52%

   $\sigma^2 = 4°C \qquad Z_1 = \frac{24-20}{2} = \frac{x_1 - x'}{\sigma} = 2$

   $\sigma = 2°C \qquad$ Probability value = .4772

   BEST ANSWER IS 5% ACTUAL ANSWER IS 100% − (50% + 48%)



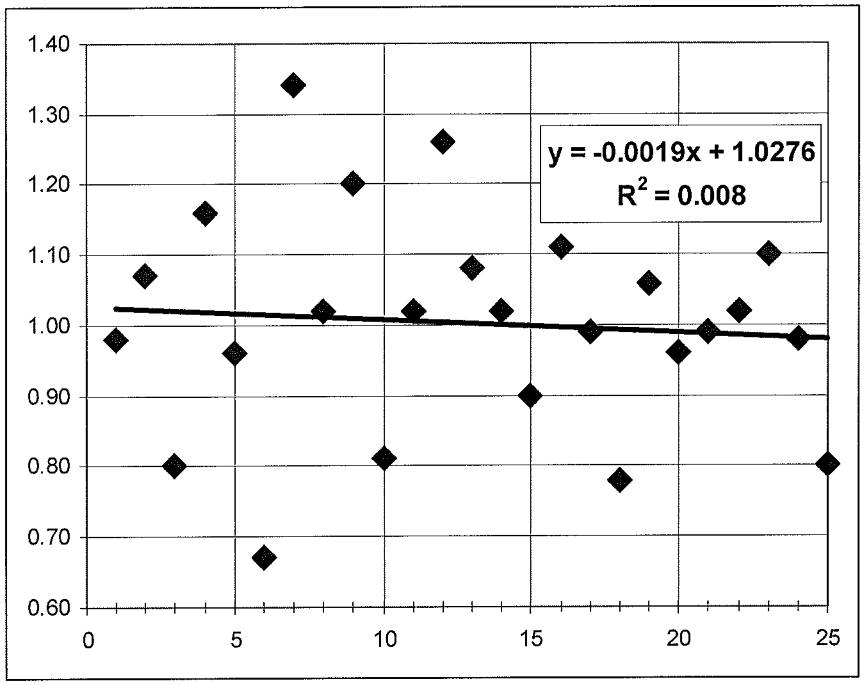
13. The input impedance of a deflection device such as a Bourdon Tube pressure gauge is inversely proportional to the static sensitivity.
   (a.) True
   b. False

14. An extraneous variable in an experiment usually refers to *all possible* unaccounted for or uncontrollable variables that can affect the value of the measured variable.
   a. True
   (b.) False

   all plausible

Table 1. Sample data set with a normal distribution, a mean value of 1.0 and a standard deviation of 0.15 and a plot of the data set with a linear curve fit added.

i	x_i	i	x_i
1	0.98	14	1.02
2	1.07	15	0.94
3	0.86	16	1.11
4	1.16	17	0.99
5	0.96	18	0.78
6	0.68	19	1.06
7	1.34	20	0.96
8	1.04	21	0.99
9	1.21	22	1.02
10	0.86	23	1.10
11	1.02	24	0.98
12	1.26	25	0.97
13	1.08		



15. Given the data set in Table 1, what is the probability of recording a value within the range of 1.0 ± 0.30
    a. 50%
    b. 90%
    c. 95%
    d. 99%
    e. None of the above

$S_x = 0.15$ $\quad t_{24,?} S_x = 0.30$

$t_{24,?} = \frac{0.30}{0.15} = 2.0 = t_{24,95\%}$

16. Given the data set in Table 1, give an estimate of the true mean value of the measurand at 99% probability
    a. $x' = \bar{x} \pm (2.787 \times 0.03)$
    b. $x' = \bar{x} \pm (2.797 \times 0.03)$
    c. $x' = \bar{x} \pm (2.787 \times 0.15)$
    d. $x' = \bar{x} \pm (2.797 \times 0.15)$
    e. None of the above

$x' = \bar{x} \pm t_{24,99} \frac{S_x}{N^{1/2}}$

$\bar{x} \pm 2.797 \frac{0.15}{5}$

17. The line fit to the data set in Table 1 has how many degrees of freedom?
    a. 25
    b. 24
    c. 23
    d. None of the above

18. The correlation coefficient, R^2 value of 0.008, indicates a high quality fit to the data in Table 1.
    a. True
    b. False

$R^2 = 1.0$ is high quality

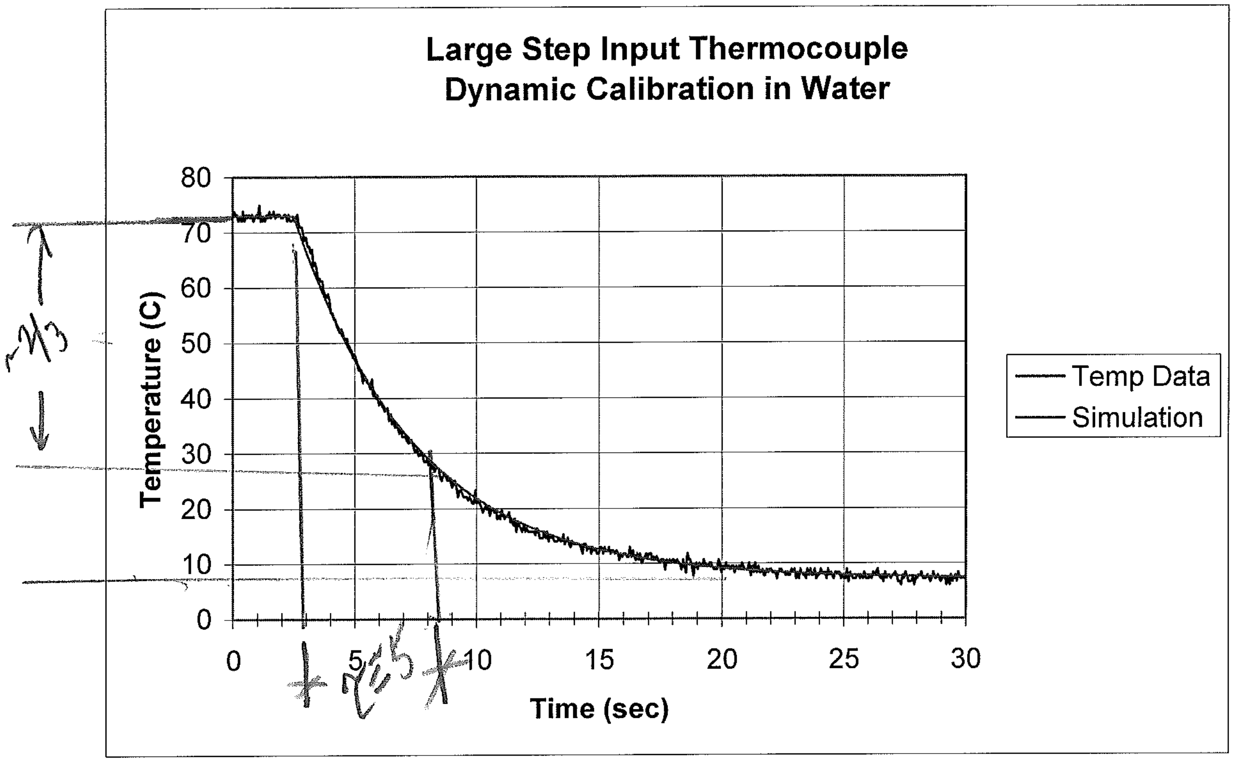


Figure 1. Data set from Lab 2 dynamic calibration.

19. The approximate time constant, τ, of the thermocouple response plotted in Figure 1 is:
   a. 2 seconds
   b. 5 seconds
   c. 7 seconds
   d. 10 seconds
   e. 23 seconds

20. If a thermocouple is more sensitive (the static sensitivity is larger) the dynamic response would be faster (the time constant would be smaller).
   a. True
   b. False

21. The ADC used in the lab would output what binary value corresponding to -4?
   a. 111111111100
   b. 100000000100
   c. 000000000100
   d. 111111111011
   e. None of the above

22. The ADC used in our lab has what type of architecture?
   a. Flash
   b. Pipelined
   c. Successive approximation
   d. Sigma-delta

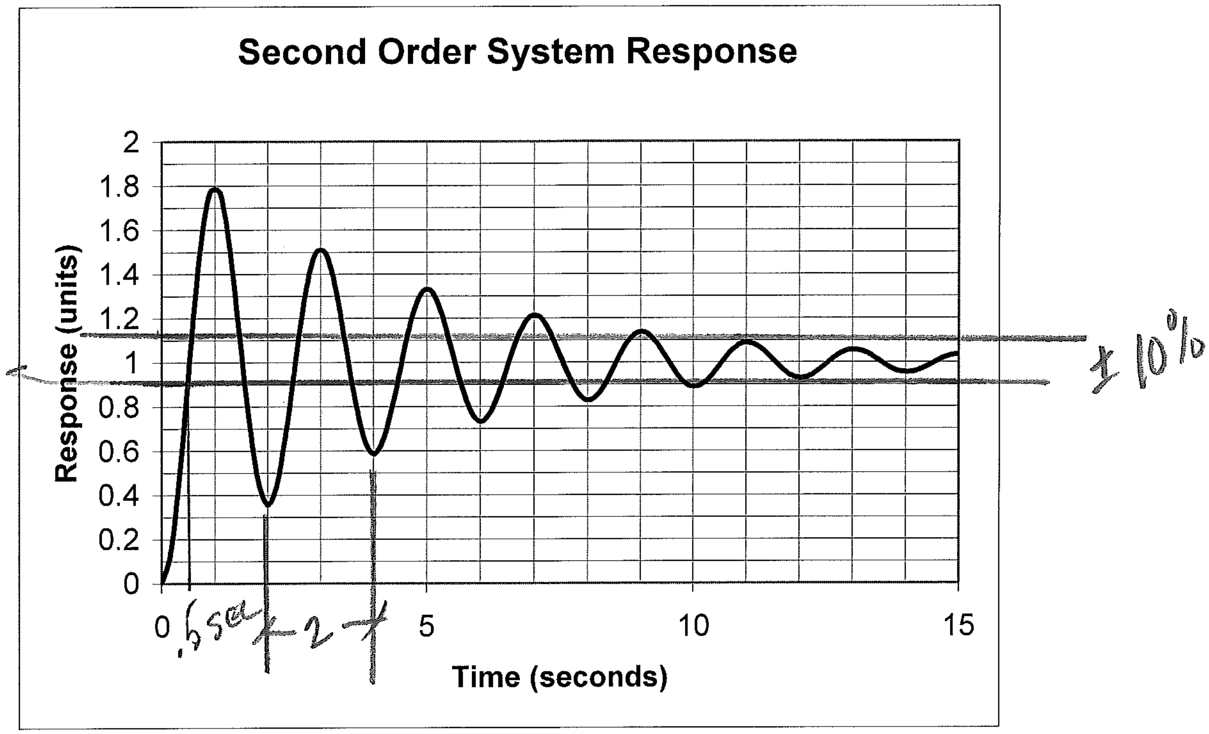


Figure 2. Pressure transducer time response to a step input function.

23. The rise time in seconds of the pressure transducer plotted in Figure 2 is approximately
    a. 0.5
    b. 1.0
    c. 10.
    d. None of the above

24. The natural frequency of the pressure transducer plotted in Figure 2 is very close to
    a. 0.5 Hz
    b. 1.0 Hz
    c. 10 Hz
    d. None of the above

$\frac{1}{2} = 0.5$ Hz

25. The ADC architecture normally associated with the best resolution is
    a. Flash
    b. Pipelined
    c. Successive approximation
    d. Sigma-delta

see notes

26. A 55 Hz sine wave sampled at 100 Hz will result in a sampled data set with what frequency
    a. 45 Hz
    b. 55 Hz
    c. 5 Hz
    d. none of the above

see fig 7.3

Table 2. Student-t Distribution

ν	t_{50}	t_{90}	t_{95}	t_{99}
15	0.691	1.753	2.063	2.947
16	0.690	1.746	2.052	2.921
17	0.689	1.740	2.043	2.898
18	0.688	1.734	2.035	2.878
19	0.688	1.729	2.027	2.861
20	0.687	1.725	2.021	2.845
21	0.686	1.721	2.015	2.831
22	0.686	1.717	2.010	2.819
23	0.685	1.714	2.005	2.807
24	0.685	1.711	2.000	2.797
25	0.684	1.708	1.996	2.787

Table 3. Probability Values for Normal Error Function $z_1 = \frac{x_1 - x'}{\sigma}$

	0	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990