MAE334 - Introduction to Instrumentation and Computers

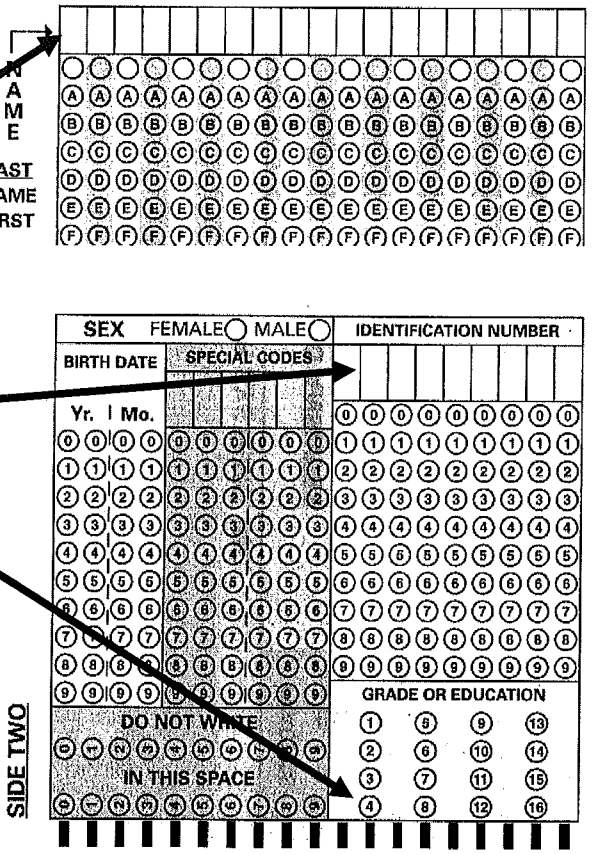
Midterm Examination

October 29, 2008

- **USE A #2 Pencil**
- **Closed Book and Notes**
- **No Calculators**

1. **Fill in your name** on side 2 of the scoring sheet (Last name first!)
2. **Fill in your 8-digit person number** on your scoring sheet.
3. **Fill in circle 4 under GRADE OR EDUCATION** 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 **THE BEST ANSWER** and mark the corresponding answer on the scoring sheet.



The terms ***lab 1***, ***lab 2***, and ***lab 3*** refer to: **Lab 1 Static and Dynamic Calibration of Thermocouples** and **Lab 2 Basics of A to D Conversion** and **Lab 3 Transient Thermal Behavior with Work and Heat Loss.**

All multiple choice questions are worth 2 points.

All short answer questions are worth 5 points.

Total 25x2 + 6x5 = (80 points) midterm + Quizzes (20 points)

1. An instrument's precision is a measure of the random fluctuations in output for repeated applications of the same input.
   (a.) True b. False

2. The settling time in seconds of the second order system response (a) plotted in Figure 1is approximately
   a. 0.70 d. 4.0
   b. 0.25 (e.) 1.5
   c. 1.05

3. Of the two second order system responses plotted in Figure 1 which system has the largest damping ratio, ζ.
   a. response (a)
   (b.) response (b)

4. The damped natural frequency, ω_d, of response (a) is higher than that of response (b) of the second order systems plotted in Figure 1.
   (a.) True b. False

5. The value of the integral of the delta function over the interval from t = -∞ to -1, $A = \int_{-\infty}^{-1} \delta(t)dt$, is
   a. ∞ (c.) 0
   b. 1 d. None of the above

6. The discrete Fourier transform of a signal sampled once every hundredth of a second (δt = 1/100 sec) for 5 seconds would have a maximum frequency of $f_s = \frac{1}{\delta t} = 100$ samples/sec
   a. 100 Hz (d.) 50 Hz
   b. 1/10 Hz e. None of the above
   c. 1/5 Hz $f_N = f_s/2 = 50$ Hz

7. What is the equation relating the confidence interval that a single temperature measurement, T_i, is within 5% of the mean if the data set contains 36 points and has a standard deviation of 1 °C?
   a. $T_i = T' \pm t_{35,95\%} \, 1/\sqrt{36}$ c. $T_i = T' \pm t_{35,5\%} \, 1/\sqrt{36}$ e. None of the above
   b. $T_i = \bar{T} \pm t_{35,95\%} 1$ (d.) $T_i = \bar{T} \pm t_{35,5\%} 1$

8. A discrete Fourier transform of the data plotted in Figure 1 would have a frequency spacing, df, of
   a. 4 Hz d. 2 Hz
   (b.) 0.25 Hz e. None of the above $\Delta f = \frac{1}{T} = \frac{1}{4\text{sec}} = 0.25$ Hz
   c. 1 Hz

9. What sampling rate would be required to accurately represent the wave form shape of the second order system response function plotted in Figure 1? At least 10 times the highest frequency
   a. 1 Hz (d.) 15 Hz
   b. 2 Hz e. None of the above
   c. 4 Hz

10. Heat loss to the laboratory surroundings from the calorimeter used in lab 3 was modeled with the equation, $Q = H(T_{calorimeter} - T_{lab})$
    (a.) True b. False

11. A 4 bit ADC with an input range of 16 volts and an input signal gain of 4 has a quantization step size of
    a. 1 volt
    b. 0.5 volts
    c. 0.25 volts
    d. 0.125 volts
    e. None of the above

$Q = 16/4/24 = 0.25\,V$

12. A very small, very sensitive thermocouple will reach a steady state value sooner for a small step input than a large step input.
    a. True
    b. False

13. The ADC architecture normally associated with the highest precision and slowest conversion rate is
    a. Flash
    b. Pipelined
    c. Successive Approximation
    d. Sigma-Delta

14. Randomization is used to break-up the effects of interference from either continuous or discrete extraneous (i.e. uncontrolled) variables.
    a. True
    b. False

15. The fundamental frequency of the Fourier series $y(t) = \sum_{n=1}^{\infty} \frac{3n}{2}\sin nt + \frac{5n}{3}\cos nt$ is
    a. 1 Hz
    b. 1 rad/sec
    c. 3/2 Hz
    d. 3/2 rad/sec
    e. None of the above

16. When modeling the dynamic response of the thermocouple probe to a step input change in temperature only the initial temperature and the time constant are used.
    a. True
    b. False

Also need a final temp or step size

17. The time constant of the thermocouple plotted in Figure 2 is approximately
    a. 12 seconds.
    b. 5 seconds.
    c. 10 seconds
    d. 2 seconds

18. What portion of the repeated sampling of a static temperature signal are within two standard deviations of the data set's mean value?
    a. 68.3%
    b. 99.7%
    c. 95.5%
    d. 50%
    e. None of the above

19. What is the approximate variance of the data set whose probability density function is plotted in Figure 3?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 6

$3\sigma \approx 6 \;\therefore\; \sigma \approx 2,\; \text{Variance} = \sigma^2 = 2^2 = 4$

20. What is the twos complement binary representation of -11 as an 8 bit number?
    a. 10001011
    b. 00001011
    c. 11110100
    d. 11110111
    e. none of the above

	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
11 →	0	0	0	0	1	0	1	1
1's Comp →	1	1	1	1	0	1	0	0
Add 1								1
2's Comp →	1	1	1	1	0	1	0	1

Short Answer Section Name: _____ Person Number: _____

21. What are the units of the static sensitivity of the thermocouple calibrated in the first lab used to convert the ADC output to temperature? ADC output is in Volts $(Volts)\left(\frac{^oC}{Volts}\right) = ^oC$ ✓
    a. Volts/C° c. C°/microVolts
    b. milliVolts/C° d. C°/Volts e. None of the above

22. The frequency bandwidth of a first order instrument is defined as the frequency below which M(ω)=0.707, or output/input power is -3 dB.
    a. True b. False

23. The smallest quantization step size, as plotted in Figure 4, of the ADC used in the lab is?
    a. 24.4 micro-Volts d. 2.44 x 10^{-4} Volts
    b. 2.44 milli-Volts e. None of the above
    c. 4.88 x 10^{-5} Volts

24. The polynomial equation, $y(x) = a_0 + a_1x + a_2x^2 + a_3x^3$, fit to a data set with 25 points has how many degrees of freedom? 4 unknowns $\therefore \nu = 25-4 = 21$
    a. 21 c. 23
    b. 22 d. 24 e. None of the above

25. It can be determined from the probability density function plotted in Figure 3 that the maximum allowable gain used by the ADC in the lab to collect this data would be?
    a. 1 c. 20
    b. 2 d. 200 ADC range is ±10Volts, data range is ± 6

26. What is the equation used to calculate the damped or ringing frequency, ω_d, of an under damped second order sensor like the one plotted in Figure 1 in terms of natural frequency, ω_n, and the damping ratio, ζ?

$$\omega_d = \omega_n\sqrt{1-\zeta^2}$$

27. What is ADC quantization step size as defined in terms of the input range, E_{FSR}, *Gain* and the number of ADC bits, *M*, for the ADC hardware in the lab with the maximum gain?

$$Q = E_{FSR}/Gain/2^M = 20Volts/20/2^{12}$$

28. What is the equation used to find the standard deviation of a data set?

$$S_x = \left[\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2\right]^{1/2}$$

29. Given a data set with 20 points what is the equation used to find the confidence interval within which 95% of the data is expected to lie?

$$x_i = \bar{x} \pm t_{19,95\%}S_x \text{ or } CI = \pm t_{19,95\%}S_x$$

30. What is the 50% confidence interval of a linear fit $y = a_0 + a_1x \pm CI$ to a 10 point data set?

$$CI = \pm t_{8,50\%}\,S_{yx}/\sqrt{10}$$

31. What is the equation for the error function, Γ(t), used in lab 3 to linearize the cooling data to determine the calorimeter time constant?

$$\ln[\Gamma(t)] = \ln\left[\frac{T_\infty - T(t)}{T_\infty - T_0}\right] = -t/\tau$$

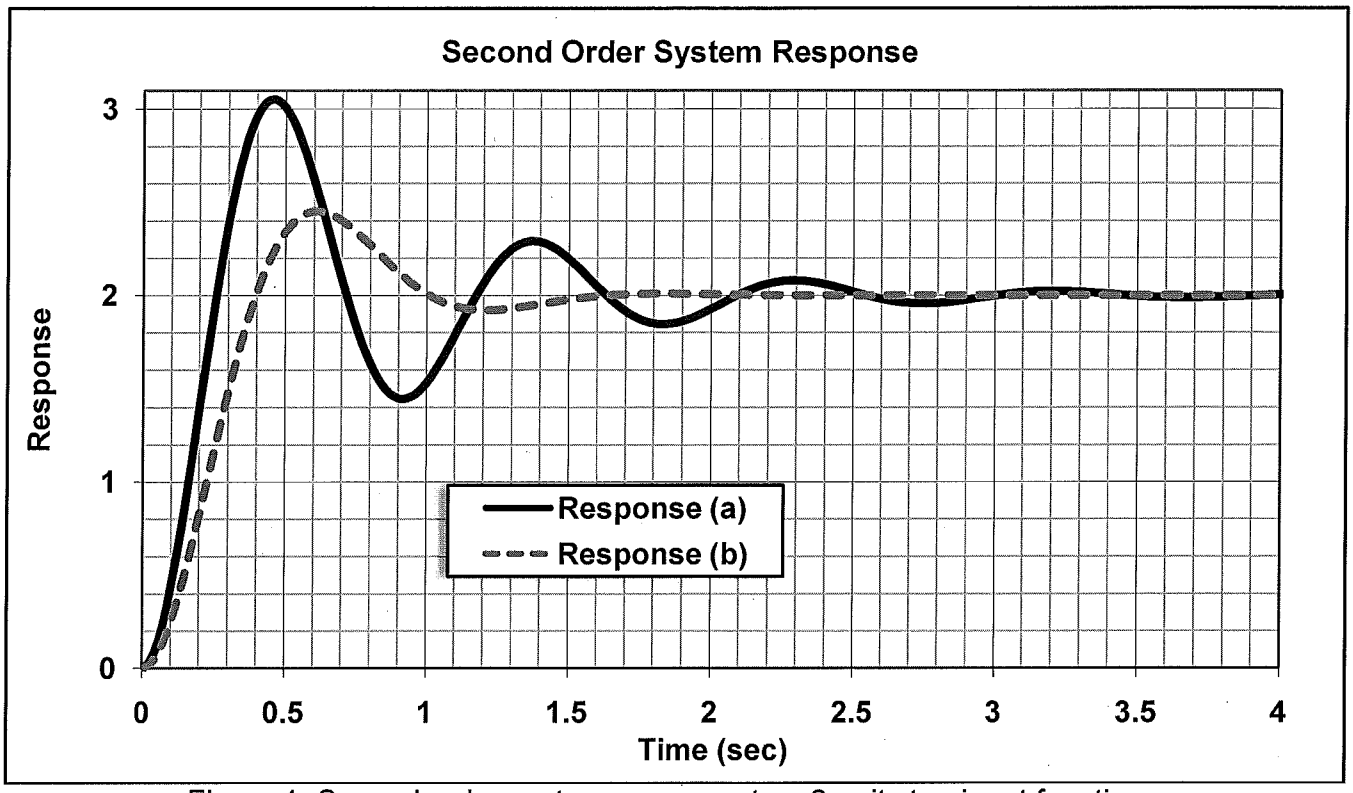


Figure 1. Second order system response to a 2 unit step input function.

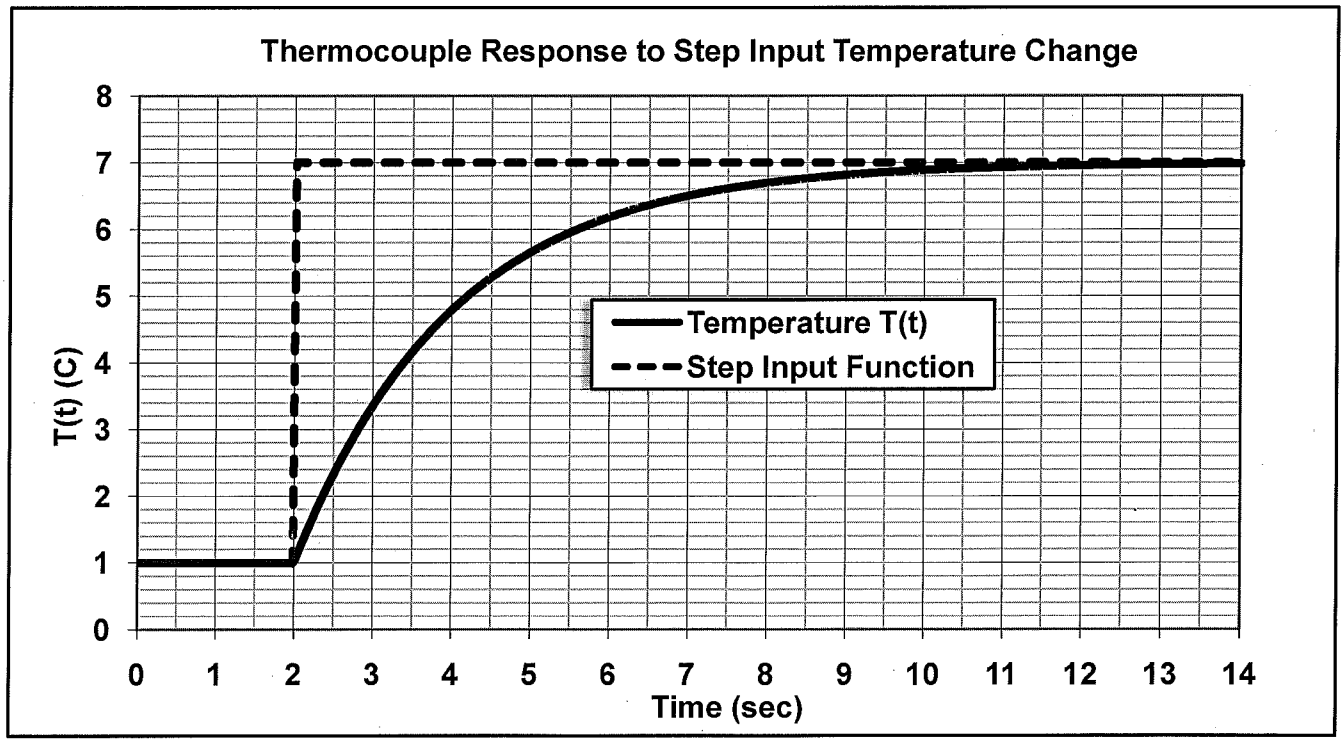


Figure 2. Thermocouple response to a 6 degree C step input temperature change.

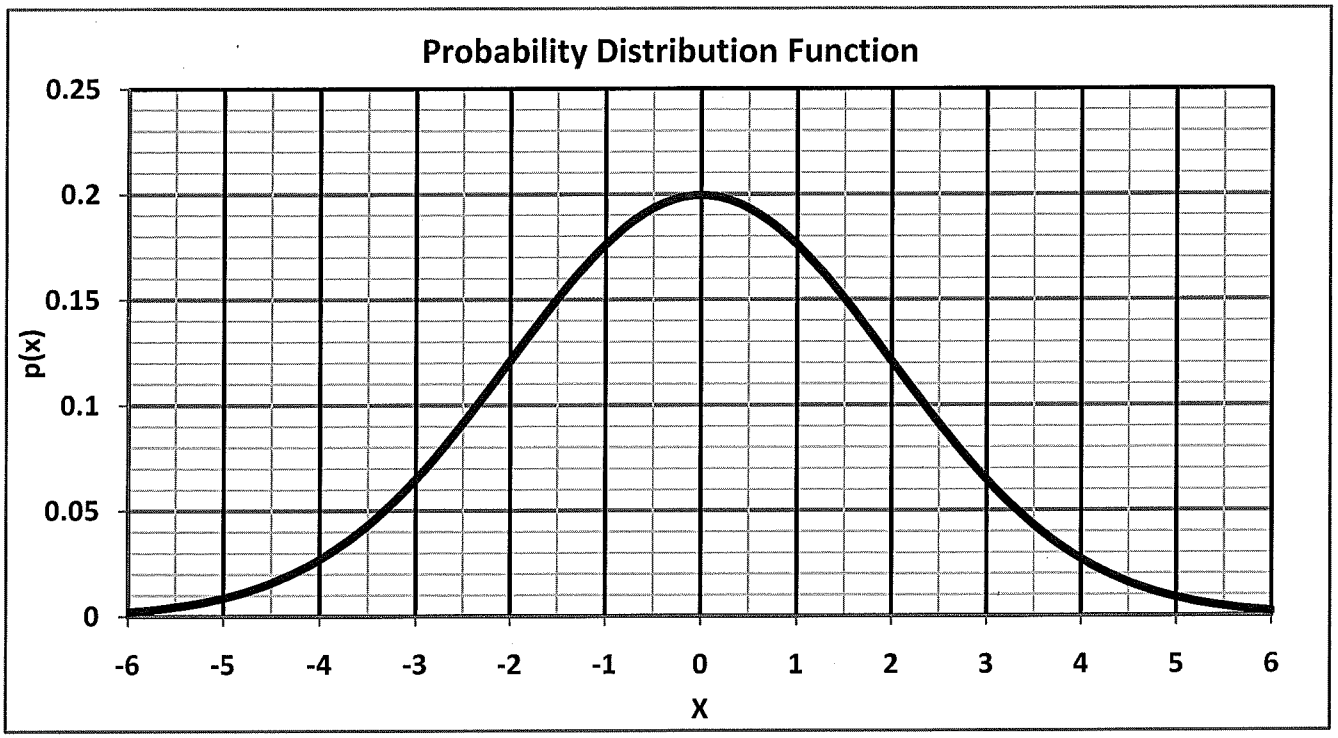


Figure 3. Probability density function of a normally distributed data set.

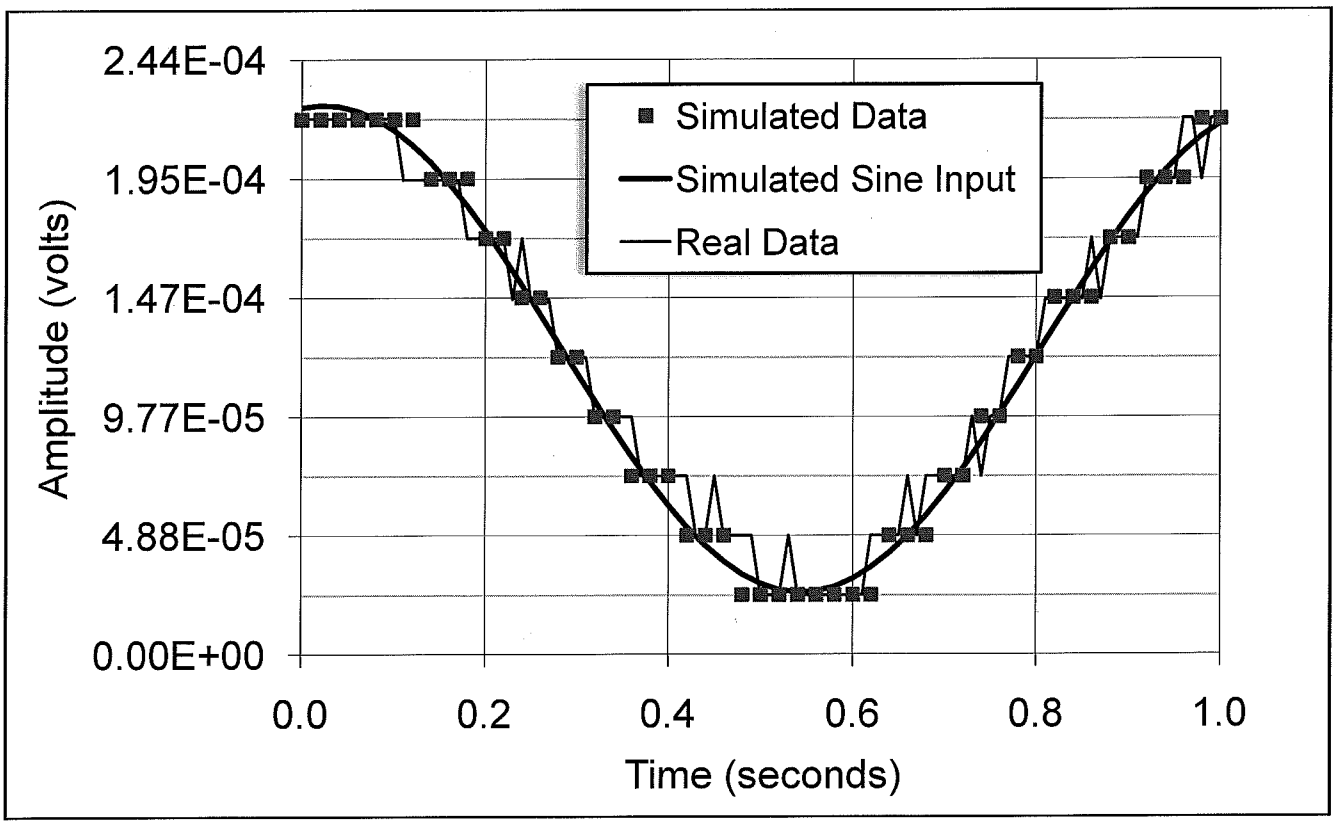


Figure 4. Sample data collected during lab 2 with simulated data superimposed on plot.