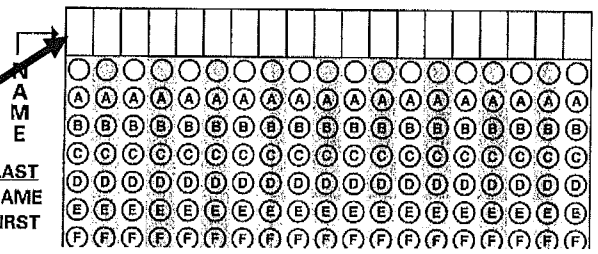
MAE334 - Introduction to Instrumentation and Computers

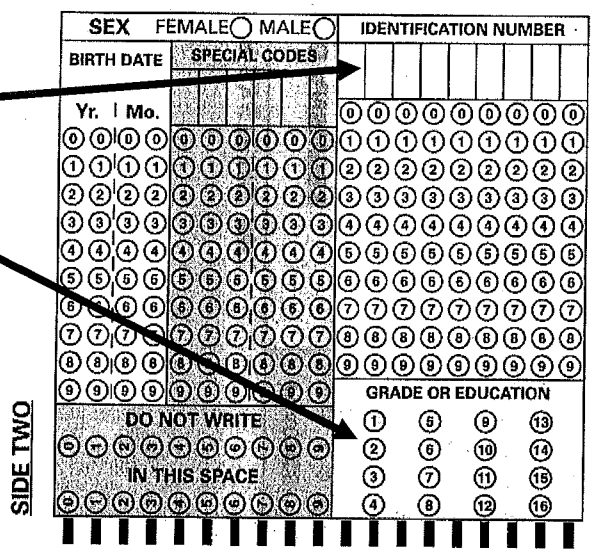
Midterm Examination

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 2 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. 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

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

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

4. 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)

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

6. The ADC architecture normally associated with the lowest precision and fastest conversion rate is
   (a.) Flash c. Successive Approximation
   b. Pipelined d. Sigma-Delta

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

8. A discrete Fourier transform of the data plotted in Figure 1 would have a frequency spacing, df, of
   a. 4 Hz (d.) 0.25 Hz
   b. 2 Hz e. None of the above $\Delta f = \frac{1}{T} = \frac{1}{4\,sec} = 0.25\,Hz$
   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?
   a. 1 Hz (d.) 15 Hz Approximately 10 times faster than
   b. 2 Hz e. None of the above the highest frequency.
   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. 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 d. 3/2 rad/sec
    (b.) 1 rad/sec e. None of the above
    c. 3/2 Hz

12. What is the twos complement binary representation of -10 as an 8 bit number?
    a. 00001011
    (b.) 11110110
    c. 11110111
    d. 10001010
    e. none of the above

	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
10 →	0	0	0	0	1	0	1	0
1's Comp	1	1	1	1	0	1	0	1
add 1							+	1
2's Comp →	1	1	1	1	0	1	1	0

13. What are the units of the static sensitivity of the thermocouple calibrated in the first lab used to convert the ADC output to temperature?
    a. Volts/C°
    b. milliVolts/C°
    c. C°/microVolts
    (d.) C°/Volts
    e. none of the above

ADC output is in Volts

$(Volts)\left(\frac{C°}{Volts}\right) = °C$ ✓

14. 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

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

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

17. 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

$3\sigma = 6 \therefore \sigma = 2$, Variance $= \sigma^2 = 2^2 = 4$

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

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

20. 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?
    (a.) 21
    b. 22
    c. 23
    d. 24
    e. None of the above

4 unknowns $\therefore \nu = 25 - 4 = 21$

21. 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
    b. 2
    c. 20
    d. 200

Person Number:

Short Answer Section Name:

22. 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.) 0 c. ∞
b. 1 e. None of the above

23. 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

a. 100 Hz d. 1/10 Hz
(b) 50 Hz e. None of the above
c. 1/5 Hz

$f_s = \frac{1}{\delta t} = 100$ samples/sec
$f_n = f_s/2 = 50$ Hz

24. 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.) $T_i = \bar{T} \pm t_{35,5\%} 1$ 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. $T_i = T' \pm t_{35,95\%} 1/\sqrt{36}$

25. 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 c. 0.25 volts e. None of the above
b. 0.5 volts d. 0.125 volts

$16/4/2^4 = 0.25$ ✓

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 the equation used to find the standard deviation of a data set?

$S_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$

28. 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?

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

29. What is the 95% confidence interval of a linear fit $y = a_0 + a_1 x \pm CI$ to a 30 point data set?

$CI = \pm t_{28,95\%} \cdot S_{yx}/\sqrt{30}$

30. 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?

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

31. 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?

$Q = E_{FSR}/GAIN/2^M = 20$ volts$/200\ GAIN/2^{12}$

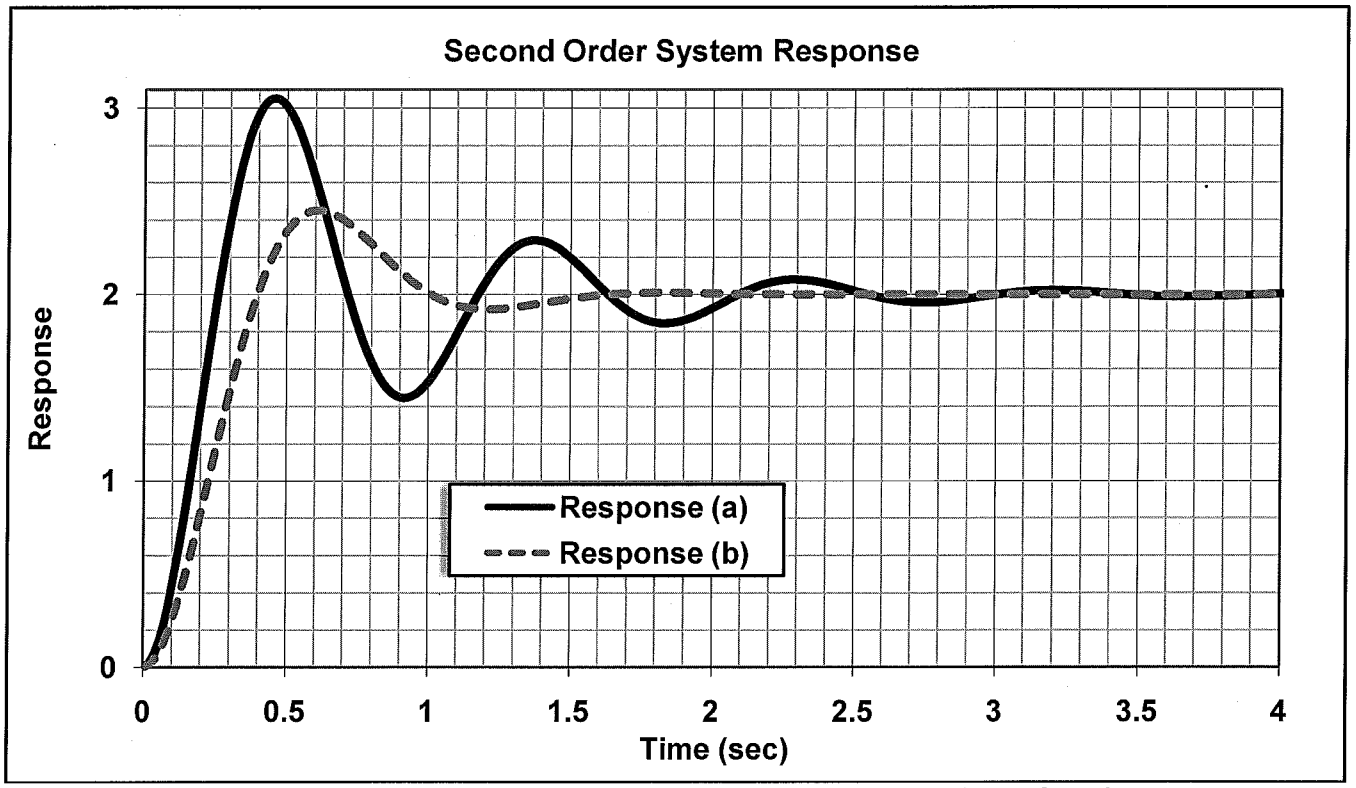


Figure 1. Second order system response to a 2 unit step input function.

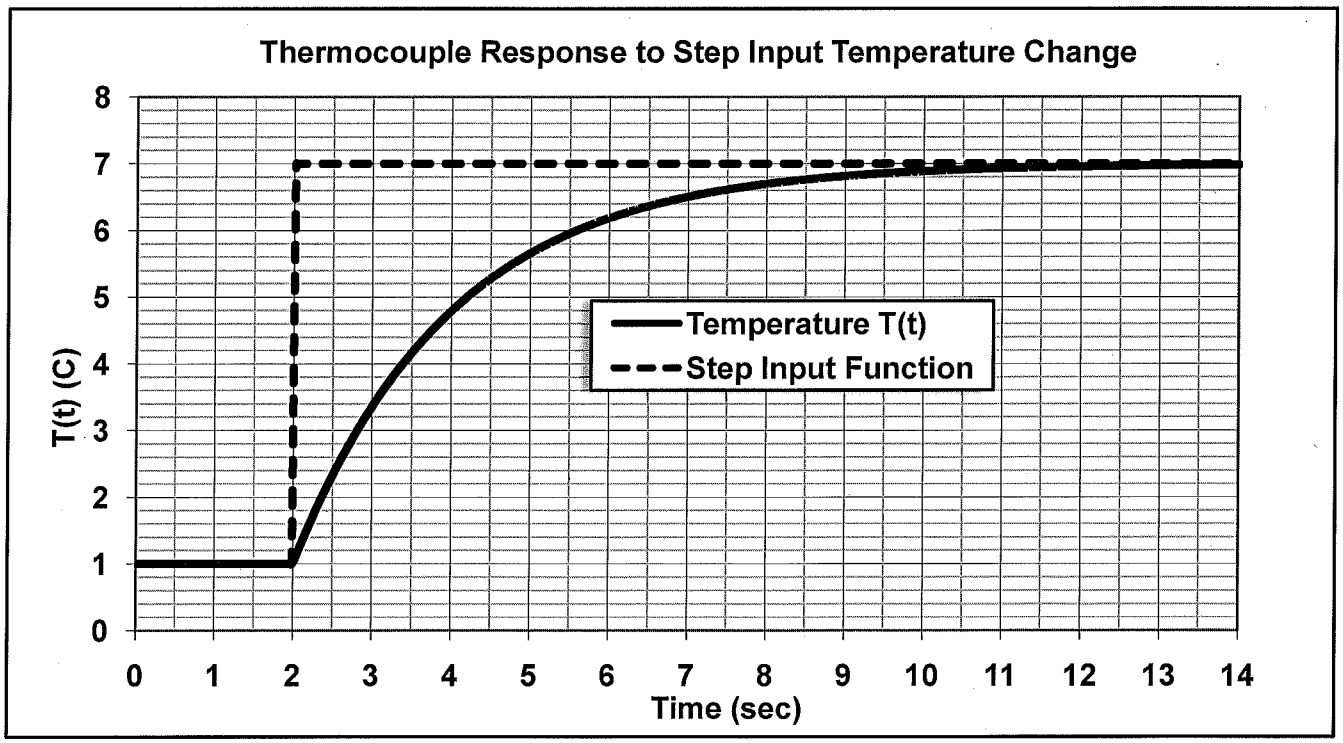


Figure 2. Thermocouple response to a 6 degree C step input temperature change.

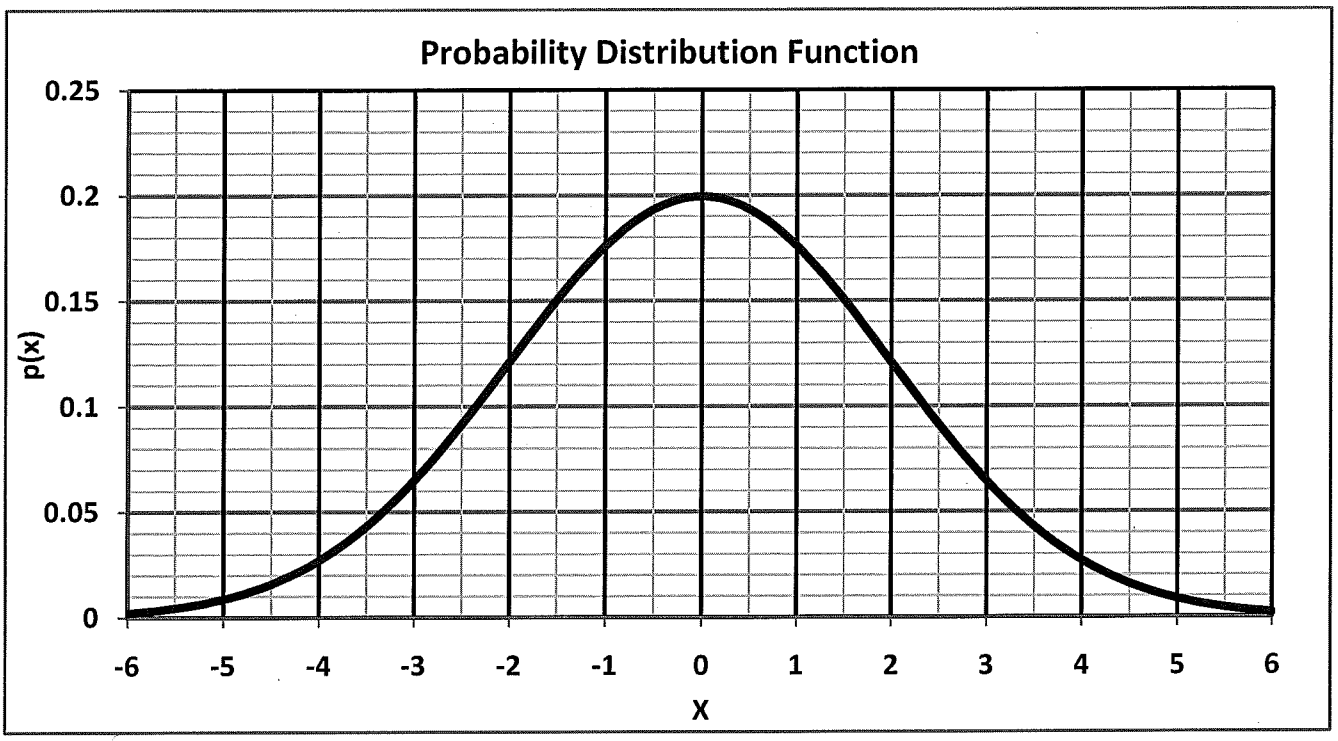


Figure 3. Probability density function of a normally distributed data set.

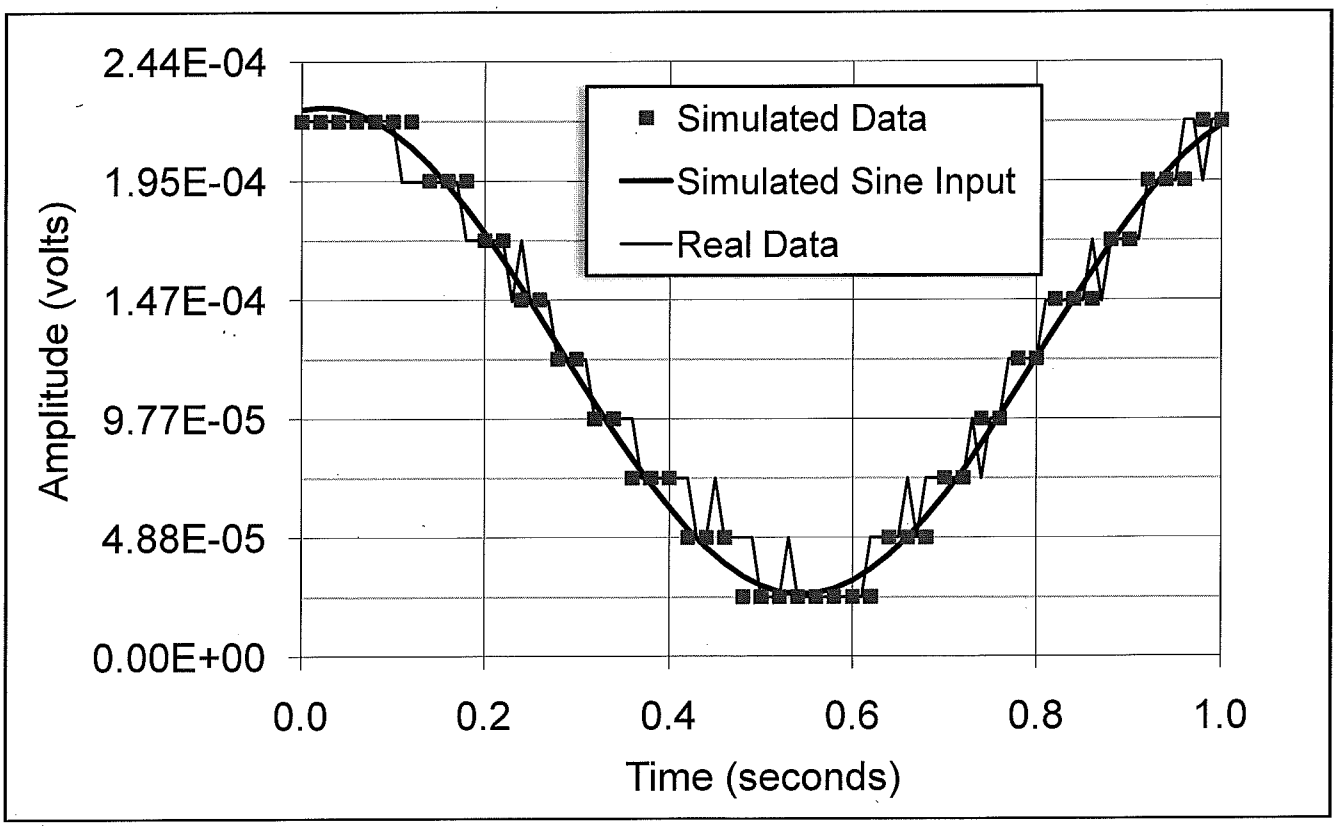


Figure 4. Sample data collected during lab 2 with simulated data superimposed on plot.