Department of Mechanical and Aerospace Engineering
MAE334 - Introduction to Instrumentation and Computers

Midterm Examination

October 14, 2003

- **Closed Book and Notes**
- **Fill in your name** on your scoring sheet
- **Fill in your 8-digit person number** on your scoring sheet.
- **Fill in circle 1 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*** and ***lab 2*** will be used throughout the exam.
Remember:

Lab 1 – Limitations on A/D Conversion

Lab 2 – Static and Dynamic Calibration of a Thermocouple

1. In lab 2 the static sensitivity of the thermocouple was approximately
    a. 2.E-6
    b. 2.E-2
    c. 2.E+2
    d. 2.E+4
2. In lab 2 the magnitude of the slope of the linearized error function, Γ(t), was greater for the water to air step input function than for the water to water step inputs.
    a. True
    b. False
3. The units of the static sensitivity obtained from the static calibration of the thermocouple in lab 2 needed to process the dynamic calibration data recorded by the Virtual Bench data logger were
    a. °C/V
    b. V/°C
    c. μV/°C
    d. °C /μV
    e. none of the above
4. By sequentially increasing the temperature from cold to hot in the static calibration of a thermocouple the hysteresis error is minimized:
    a. True
    b. False
5. A 4 bit ADC with an 8 volt input signal range has a finer resolution than a 3 bit ADC with a 2 volt input signal range.
    a. True
    b. False
6. The resolution of an ADC is decreased by increasing the gain of the input signal.
    a. True
    b. False
7. An ADC resolution specified in terms of *signal-to-noise* ratio in units of decibels is defined as $20\log 2^{M-1}$, where *M* is the number of bits of the ADC.
    a. True
    b. False
8. What is the maximum voltage that can be resolved without clipping by a bi-polar ADC with a full scale range of 10 volts and a gain of 50?
    a. 500
    b. 10
    c. 5
    d. 1
    e. 0.1

9. The Nyquist criteria is satisfied if the highest frequency in the signal is
    a. less than twice the sampling frequency
    b. less than the sampling frequency
    c. greater than the twice the sampling frequency
    d. less than half the sampling frequency
    e. none of the above

10. The slowest sampling frequency given that would avoid aliasing the waveform $y(t) = 5\sin(12\pi t) + 8\cos(24\pi t)$ is
    a. 12 samples/sec.
    b. 24 samples/sec.
    c. 24π samples/sec.
    d. 48π samples/sec.
    e. 16 samples/sec.

11. If t is in seconds, the frequency in Hertz of $y(t) = 12\sin(42\pi t)$ is:
    a. 12
    b. 42
    c. 42π
    d. 21
    e. none of the above.

12. The binary representation of decimal 11 is:
    a. 0011
    b. 1011
    c. 0110
    d. 1100
    e. none of the above

13. The 4 bit 2's complement representation of -3 is:
    a. 1000
    b. 0011
    c. 1011
    d. 1101
    e. none of the above

14. The variance is the square root of the standard deviation of a data set?
    a. True
    b. False

15. Using the nomenclature from the text book and class, S_x refers to the
    a. Sample standard deviation
    b. Standard deviation
    c. Variance
    d. Standard error of the fit
    e. Correlation coefficient

16. For a normally distributed data set, as S_x increases
    a. The 99% confidence interval of the estimation of the true mean gets larger.
    b. The signal variance gets larger.
    c. The probability density function becomes wider.
    d. all of the above
    e. none of the above

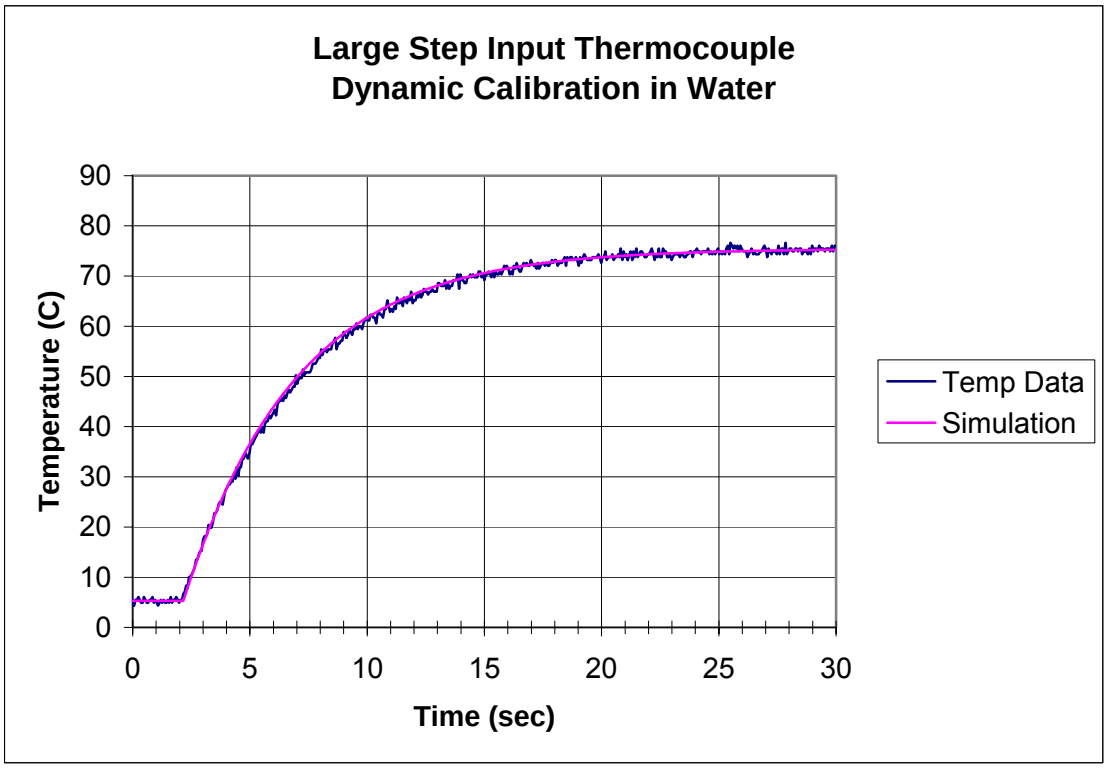

Figure 1. Data set from Lab 2 dynamic calibration.

17. The approximate time constant, τ, of the thermocouple response plotted in Figure 1 is:
    a. 2 seconds
    b. 5 seconds
    c. 10 seconds
    d. 20 seconds
    e. 25 seconds

18. The simulation plotted in Figure 1 would have used this equation to calculate the time history of the temperature response, *T(t)*, immediately following the application of the step input. (select the best answer!)
    a. $T(t) = 75 - (5-75)e^{-(t-2)/\tau}$
    b. $T(t) = 5 + (5-75)e^{-(t-2)/\tau}$
    c. $T(t) = 75 + (5-75)e^{-t/\tau}$
    d. $T(t) = 5 + 70e^{-(t-2)/\tau}$
    e. $T(t) = 75 + (5-75)e^{-(t-2)/\tau}$

19. A linear regression analysis yields the following equation, $y = 8x + 5$, for a calibration data set with 20 points. If the standard error of the fit, S_{xy}, is 1. What is the 90% confidence interval? (Use the student's t-distribution table on the last page):
    a. ±1.725
    b. ±1.729
    c. ±1.734
    d. ±2.101
    e. none of the above

20. To decrease the confidence interval size, CI, in which the predicted dependent variable value should lie we could:
    a. increase the number of calibration points.
    b. increase the CI percentage from 95% to 99%.
    c. decrease the number of calibration points.
    d. both a. and b.
    e. both b. and c.

21. A liquid-in-glass thermometer, a thermocouple, a thermistor and an RTD will behave as first order sensors.
    a. True
    b. False

22. An over damped second order system will oscillate with a greater amplitude than the input signal when forced at the natural frequency.
    a. True
    b. False

23. The histogram plot
    a. gives an indication of the standard deviation of the data set.
    b. is an approximation of the probability density function.
    c. is normally distributed for variations due to quantization error.
    d. all of the above.
    e. none of the above.

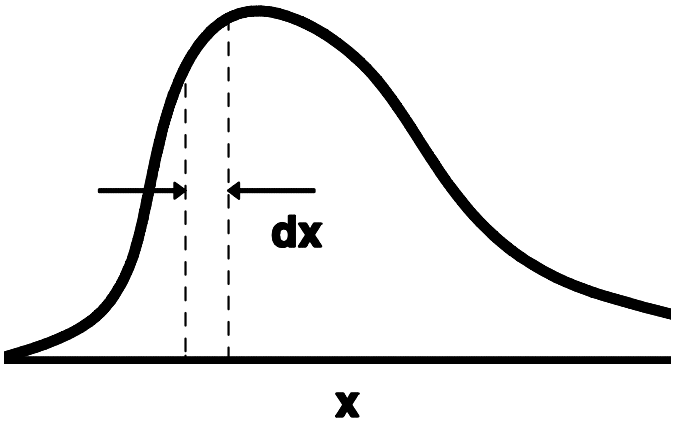

Figure 2. A probability distribution function for an infinate data set.

24. The area under the PDF function plotted in Figure 2 between the dashed lines of width, dx, is the probability that any single measurement will line within that range.
    a. True
    b. False

25. The standard deviation of the means, $S_{\overline{x}}$, is related to
    a. the standard deviation of the data set
    b. the number of points in the data set
    c. the mean value of the data set
    d. all of the above
    e. both a. and b.

Table 1. Student's t-distribution table.

	Student-t Distribution			
ν	50%	90%	95%	99%
1	1.000	6.314	12.706	63.656
2	0.816	2.920	4.303	9.925
4	0.741	2.132	2.776	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	1.796	2.201	3.106
12	0.695	1.782	2.179	3.055
13	0.694	1.771	2.160	3.012
14	0.692	1.761	2.145	2.977
15	0.691	1.753	2.131	2.947
16	0.690	1.746	2.120	2.921
17	0.689	1.740	2.110	2.898
18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845