Final Solutions
June 9, 2003

ECE 223: Signals and Systems II
Dr. McNames

- Write the first letter in your last name, your 6-digit identification number, and your student identification number below.
- Do not open the exam until instructed to do so.
- Do not use separate scratch paper. If you need more space, use the backs of the exam pages and write a note directing my attention to these pages.
- You will have 100 minutes to complete the exam.
- If you have extra time, double check your answers.
- Remember to include units with each of your answers.
- You are not allowed to use a calculator during this exam.

Problem 1: _____ / 15
Problem 2: _____ / 10
Problem 3: _____ / 15
Problem 4: _____ / 10

Total: _____ / 50

First Letter in Last Name: ______________
6-Digit Identification Number: ______________
Student Identification Number: ______________
1. Fundamental Concepts (15 pts)

a. (1 pt) A signal $x(t)$ is recorded on audio tape. This signal has all of its energy equally distributed between 0 and 3 kHz. When the signal is played back at at half the original recording speed, what fraction of the signal energy is located between 1 kHz and 3 kHz?
   
   $P = 1/3$ (33%)

b. (1 pt) What is an equivalent signal and simpler expression for $x[n] = \cos(32\pi n)$?
   
   $x[n] = 1$

c. (1 pt) Under what condition is the z-transform of a signal evaluated at $z = e^{j\omega}$ equal to the DTFT of the signal?
   
   Only if the z-transform converges on the unit circle.

d. (1 pt) If the ROC of $H(z)$, the z-transform of an LTI system impulse response, consists of a ring with a radius spanning from 0.2 to 2.7, what properties does the system have?

   Causal  Anti-causal  Non-causal  Stable  Unstable

   **Non-causal**

e. (1 pt) If the ROC of $H(z)$, the z-transform of an LTI system impulse response, consists of a circle with a radius of 2.7, what properties does the system have?

   Causal  Anti-causal  Non-causal  Stable  Unstable

   **Non-causal**

f. (1 pt) What is the transfer function of an LTI system defined by $y(n) = -0.7 x(n-38)$?
   
   $H(z) = -0.7 z^{-38}$

g. (1 pt) What is the impulse response of the ideal interpolation filter for reconstructing a bandlimited signals?
   
   $h(t) = \left( T_s \omega_c / \pi \right) \frac{\sin(\omega_c t / \pi)}{\sin(\omega_c T_s / \pi)}$

h. (1 pt) Why can’t this be used in practical applications?
   
   **Infinite duration & noncausal**

An engineer wishes to analyze the power spectral density of the vibration of an engine. She knows that the engine operates at a constant frequency of 6000 revolutions per minute (rpm) and is willing to assume that the vibration is a periodic signal.

i. (1 pt) If she wishes to record the signal for offline analysis, what is the minimum rate that she must sample the signal in units of Hz?
   
   $f_s = 200$ Hz

j. (1 pt) If she decides to sample the vibration signal at 100 Hz, what type of filter must she use to prevent aliasing?
   
   **Lowpass**  Highpass  Bandpass  Bandstop  Can’t tell

k. (1 pt) If she decides to use a Butterworth anti-aliasing filter, what is the highest possible stopband frequency?
   
   $f_s = 100$ Hz
1. **Fundamental Concepts Continued (15 pts)**

1. (1 pt) Which of the following signals are periodic?

\[
\begin{align*}
\cos(1.38\pi n) & \quad \exp(j7n) & \quad \cos(1.38\pi t) & \quad \exp(j7t) & \quad u(t) & \quad \delta[n]
\end{align*}
\]

m. (1 pt) What is the fundamental period of \(x[n] = 17 – 3 \sin(7\pi/3n) + 48 \cos(2\pi/5n)\)?

\[N_0 = 30 \text{ samples}\]

n. (1 pt) What is the highest discernible frequency of \(x[n] = 17 – 3 \sin(7\pi/3n) + 48 \cos(2\pi/5n)\)?

\[f_{\text{max}} = 0.4 \pi \text{ rads/sample}\]

o. (1 pt) If a sinusoidal signal with a frequency of 2000 Hz is sampled at 700 Hz, what frequency does the signal appear to have due to aliasing?

\[f = 100 \text{ Hz}\]
2. Transform Concepts (10 pts)

Circle the appropriate answers to the multiple choice questions below. The following abbreviations are used: FT = Fourier Transform, FS = Fourier Series, DT = Discrete-Time, and CT = Continuous-Time, ZT = two-sided $z$-Transform, LT = one-sided Laplace Transform.

a. (1 pt) Which transform(s) can be used to analyze **unstable** LTI systems?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT

b. (1 pt) Which transform(s) can be used to analyze **stable and causal** LTI systems?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT

c. (1 pt) Which transforms converge (are finite valued) for periodic signals with finite power?
   - CTFS
   - DTFS
   - CTFT
   - DTFT


d. (1 pt) Which transforms can be used for discrete-time signals?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT


e. (1 pt) Which transforms can be used to analyze two-sided signals?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT

f. (1 pt) Which of the transforms are nonlinear?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT

g. (1 pt) Which transforms can be calculated efficiently with the FFT for all signals (including those that are not bandlimited or time-limited)?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT

h. (1 pt) Which transforms require knowledge of the region of convergence to synthesize the signal?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT

i. (1 pt) Which transforms converge for a unit impulse?
   - CTFT
   - DTFT
   - ZT
   - LT

j. (1 pt) Which transforms can reconstruct a continuous-time square wave exactly where the square wave is equal to the DC average at the points of discontinuity?
   - CTFS
   - DTFS
   - CTFT
   - DTFT
   - ZT
   - LT
3. Pole-Zero Maps and Magnitude Plots (15 pts)
Ten pole-zero plots and ten magnitude plots are shown below. Each LTI system has a rational transfer function and each has the same number of poles and zeros. In some cases, the more than one zero is at the same location.

Signal A: 7  Signal B: 3  Signal C: 10  Signal D: 9  Signal E: 6
Signal F: 2  Signal G: 4  Signal H: 5  Signal I: 8  Signal J: 1
3. Pole-Zero Maps and Magnitude Plots Continued (15 pts)
Each of the systems shown on the previous page were generated from one of the four filter types that we discussed in class. Use the magnitude plots shown on the right to answer the following questions. Circle all that apply.

a. (1 pt) Which of the magnitude plots are representative of a **Butterworth** filter?

```
1  2  3  4  5  6  7  8  9  10
```

b. (1 pt) Which of the magnitude plots are representative of an **Elliptic** filter?

```
1  2  3  4  5  6  7  8  9  10
```

c. (1 pt) Which of the magnitude plots are representative of a **Chebyshev type II** filter?

```
1  2  3  4  5  6  7  8  9  10
```

d. (1 pt) Which of the pole-zero plots could represent an **anti-causal** system?

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A  B  C  D  E  F  G  H  I  J
```

e. (1 pt) Which of the pole-zero plots could represent a **causal and stable** system?

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A  B  C  D  E  F  G  H  I  J
```
4. Communications Concepts (10 pts)

Six signals are shown below. Match the signal with the type of signal. The following abbreviations are used: BBS = Baseband signal, CS = Carrier Signal, AAM = Asynchronous Amplitude Modulation, SAM = Synchronous Amplitude Modulation, FM = Frequency Modulation, PM = Phase Modulation, PAM = Pulse Amplitude Modulation, PCM = Pulse Code Modulation.

Circle the appropriate answers to the multiple choice questions below.

a. (1 pt) Which type(s) of modulation enable transmission at maximum power continuously?
   - AAM
   - SAM
   - FM
   - PM

b. (1 pt) Which type(s) of modulation uses twice the bandwidth of the baseband signal?
   - AAM
   - SAM


c. (1 pt) Which type(s) of modulation embed the baseband signal in the angle of the carrier signal?
   - AAM
   - SAM
   - FM
   - PM
   - PAM
   - PCM


d. (1 pt) Which type(s) of modulation can be demodulated with a simple envelope detector?
   - AAM
   - SAM
   - FM
   - PM