Final
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 half the original recording speed, what fraction of the signal energy is located between 1 kHz and 3 kHz?

\[ P = \frac{1}{3} \]

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

\[ x[n] = \cos(32\pi n) \]

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?

- \( e^{-j\omega} \) (for \( \omega \) in the DTFT domain)


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

Causal Anti-causal Non-causal Stable Unstable

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

Causal Anti-causal Non-causal Stable Unstable

f. (1 pt) What is the transfer function of an LTI system defined by \( y(n) = -0.7 x(n-38) \)?

\[ H(z) = -0.7 \]

g. (1 pt) What is the impulse response of the ideal interpolation filter for reconstructing a bandlimited signal?

h(\( t \)) = \( \delta(t) \)

h. (1 pt) Why can’t this be used in practical applications?

- Aliasing issues

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?

\[ f_s = \frac{6000}{60} \text{ Hz} = 100 \text{ Hz} \]

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

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?

\[ f_s = \frac{1000}{60} \text{ Hz} = 16.67 \text{ Hz} \]


1. Fundamental Concepts Continued (15 pts)

l. (1 pt) Which of the following signals are periodic?
   \[
   \cos(1.38\pi n) \exp(j7n) \cos(1.38\pi t) \exp(j7t) u(t) \delta[n]
   \]

m. (1 pt) What is the fundamental period of \( x[n] = 17 - 3 \sin(7\pi/3n) + 48 \cos(2\pi/5n) \)?
   \[ N_o = \text{___________ samples} \]

n. (1 pt) What is the highest discernible frequency of \( x[n] = 17 - 3 \sin(7\pi/3n) + 48 \cos(2\pi/5n) \)?
   \[ f_{\text{max}} = \text{___________ rads/sample} \]

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?
   \[ f = \text{___________ Hz} \]
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.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Which transform(s) can be used to analyze unstable LTI systems?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>b. Which transform(s) can be used to analyze stable and causal LTI systems?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>c. Which transforms converge (are finite valued) for periodic signals with finite power?</td>
<td>CTFS DTFS CTFT DTFT</td>
</tr>
<tr>
<td>d. Which transforms can be used for discrete-time signals?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>e. Which transforms can be used to analyze two-sided signals?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>f. Which of the transforms are nonlinear?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>g. Which transforms can be calculated efficiently with the FFT for all signals (including those that are not bandlimited or time-limited)?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>h. Which transforms require knowledge of the region of convergence to synthesize the signal?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>i. Which transforms converge for a unit impulse?</td>
<td>CTFT DTFT ZT LT</td>
</tr>
<tr>
<td>j. 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?</td>
<td>CTFS DTFS CTFT DTFT ZT LT</td>
</tr>
</tbody>
</table>
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: ____  Signal B: ____  Signal C: ____  Signal D: ____  Signal E: ____

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?
   
   ![Magnitude Plots](1 2 3 4 5 6 7 8 9 10)

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

   ![Magnitude Plots](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?
   
   ![Magnitude Plots](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?

   ![Pole-Zero Plots](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?

   ![Pole-Zero Plots](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.

Baseband Signal: _____ Carrier:_____ AAM: _____
SAM: _____ FM: _____ PM: _____

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