The University of Texas at Austin
Dept. of Electrical and Computer Engineering
Midterm #1

Date: October 16, 2024 Course: EE 445S Evans

Name: ____
Last, First

- **Exam duration**. The exam is scheduled to last 75 minutes.
- **Materials allowed**. You may use books, notes, your laptop/tablet, and a calculator.
- **Disable all networks**. Please disable all network connections on all computer systems. You may not access the Internet or other networks during the exam.
- **No AI tools allowed**. As mentioned on the course syllabus, you may not use GPT or other AI tools during the exam.
- **Electronics.** Power down phones. No headphones. Mute your computer systems.
- **Fully justify your answers**. When justifying your answers, reference your source and page number as well as quote the particular content in the source for your justification. You could reference homework solutions, test solutions, etc.
- **Matlab**. No question on the test requires you to write or interpret Matlab code. If you base an answer on Matlab code, then please provide the code as part of the justification.
- **Put all work on the test**. All work should be performed on the quiz itself. If more space is needed, then use the backs of the pages.
- **Academic integrity.** By submitting this exam, you affirm that you have not received help directly or indirectly on this test from another human except the proctor for the test, and that you did not provide help, directly or indirectly, to another student taking this exam.

Problem	*Point Value*	*Your score*	*Topic*
1	25		FIR Filter Analysis
2	27		Predistortion
3	24		Discrete-time Feedback System
4	24		Mystery Systems
Total	100		

Problem 1.1 *FIR Filter Analysis*. 25 points.

Consider a causal linear time-invariant (LTI) discrete-time finite impulse response (FIR) filter with input $x[n]$ and output $y[n]$ observed for $n \geq 0$. The transfer function in the z-domain is

$$H(z) = a + b\, z^{-100} \quad \text{for } \; z \neq 0$$

where a and b are real-valued, non-zero constants.

(a) Give the equation for output $y[n]$ in terms of the input $x[n]$ in the discrete-time domain for $n \geq 0$. *6 points*.

(b) What are the initial condition(s) and their value(s)? Why? *3 points*.

(c) In managing the memory for storing the previous input values, would you advocate for a linear buffer or a circular buffer? Why? *3 points*

(d) Derive a formula for the discrete-time frequency response of the filter. *3 points*.

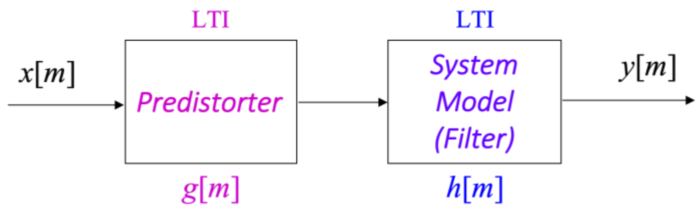
(e) Give all possible conditions on the constants a and b so that the FIR filter has constant group delay. Compute the constant group delay. *10 points*.

Problem 1.2 *Predistortion.* 27 points.

Predistortion is a technique used to compensate the distortion in another system.

An example is applying predistortion to an audio signal before being played by an audio system.

The block diagram illustrates the use of predistortion when the predistorter is a linear time invariant (LTI) system and the distortion is modeled as LTI.

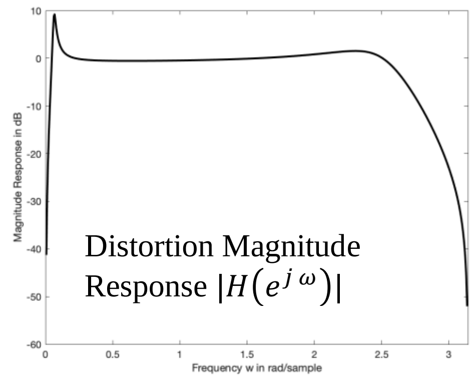


- sampling rate f_s is 44100 Hz.
- $g[m]$ is the impulse response of the discrete-time LTI predistorter
- $h[m]$ is the impulse response of a discrete-time LTI model of the distortion in a playback system.

A predistorter is bounded-input bounded-output stable.

Distortion. Its poles and zeros are given below and its magnitude response $|H(e^{j\,\omega})|$ is on given on the right.

Poles	Zeros
$p_0 = 0.75\, e^{j\,0.8\,\pi}$	$z_0 = 1$
$p_1 = 0.75\, e^{-j\,0.8\,\pi}$	$z_1 = -1$
$p_2 = 0.99\, e^{j\,0.02\,\pi}$	$z_2 = 1$
$p_3 = 0.99\, e^{-j\,0.02\,\pi}$	$z_3 = -1.25$



(a) What continuous-time frequency corresponds to pole location p_2? *3 points.*

(b) Give the zeros of the predistorter. Explain how you determined each one. *12 points.*

(c) Give the poles of the predistorter. Explain how you determined each one. *12 points.*

Problem 1.3. *Discrete-Time Feedback System*. 24 points.

Consider a discrete-time linear time-invariant (LTI) system with input signal $x[n]$ and output signal $y[n]$ that is governed by the following second-order difference equation for $n \geq 0$:

$$y[n] = 1.6\, y[n-1] - K\, y[n-2] + x[n]$$

where K is a real-valued constant.

(a) What are the initial conditions of the system and what values should they have? *6 points*.

(b) Derive the transfer function $H(z)$ for the system, which will depend on K. *6 points*.

(c) Give the range of values for K for which the system is bounded-input bounded-output (BIBO) stable. *6 points*.

(d) Describe the possible frequency selectivity (lowpass, highpass, bandpass, bandstop, allpass or notch) that the system could exhibit for different values of K for which the system is BIBO stable. *6 points*.

Problem 1.4. *Mystery Systems*. 24 points.

You're trying to identify unknown discrete-time systems.

You input a discrete-time chirp signal $x[n]$ and look at the output to figure out what the system is.

The discrete-time chirp is formed by sampling a chirp signal that sweeps 0 to 8000 Hz over 0 to 5s

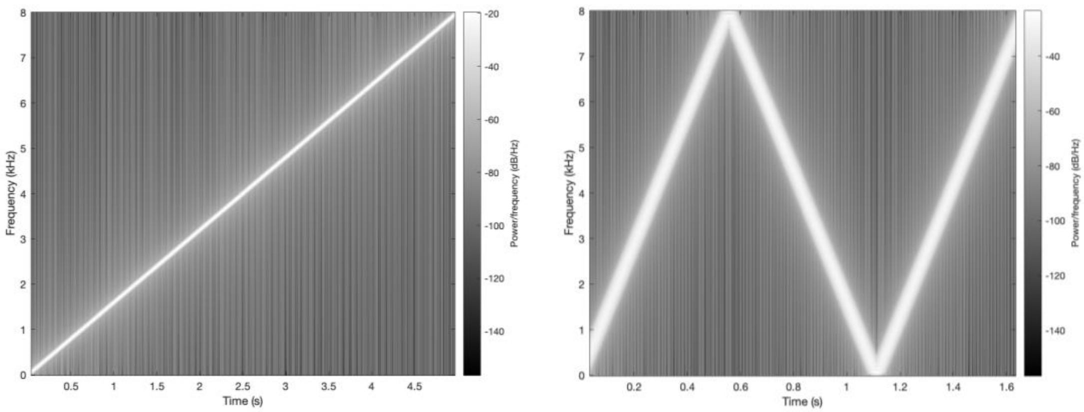
$$x(t) = \cos(2\pi f_1 t + 2\pi \mu t^2)$$

where $f_1 = 0$ Hz, $f_2 = 8000$ Hz, and $\mu = \frac{f_2 - f_1}{2\, t_{\max}} = \frac{8000 \text{ Hz}}{10\, s} = 800 \text{ Hz}^2$. Sampling rate f_s is 16000 Hz.

In each part below, identify the unknown system as one of the following **with justification**:

1. filter – give selectivity (lowpass, highpass, bandpass, bandstop) and passband/stopband frequencies
2. upsampler – give upsampling factor
3. downsampler – give downsampling factor
4. pointwise nonlinearity – give the integer exponent k to produce the output $y[n] = x^k[n]$

(a) Given spectrograms of the chirp input signal $x[n]$ (left) and output signal $y[n]$ (right). *12 points*.



(b) Given spectrograms of the chirp input signal $x[n]$ (left) and output signal $y[n]$ (right). *12 points.*