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

Date: October 22, 2025 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 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	24		IIR Filter Analysis
2	27		Predistortion
3	27		Sinusoidal Amplitude Modulation
4	22		Design Tradeoffs
Total	100		

Problem 1.1 *IIR Filter Analysis*. 24 points.

Consider a causal linear time-invariant (LTI) discrete-time infinite impulse response (IIR) filter with input $x[n]$ and output $y[n]$ observed for $n \geq 0$ is described by

$$y[n] = \alpha\, y[n-1] + (1-\alpha)\, x[n]$$

where α is a real-valued constant $0 < \alpha < 1$.

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

(b) Draw a block diagram. Be sure to use arrows to indicate the order of operations. *3 points*.

(c) Compute the transfer function in the z-domain including the region of convergence. 6 *points*.

(d) Is the filter bounded-input bounded-output (BIBO) stable for all allowable values of α which are $0 < \alpha < 1$? Why or why not? *6 points*.

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

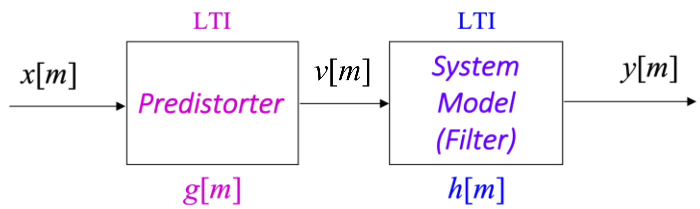
(f) For what values for α over $0 < \alpha < 1$ will the filter be lowpass? *3 points*.

Problem 1.2 *Predistortion.* 27 points.

Predistortion compensates the distortion that occurs in later processing of the signal.

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.

A predistorter is bounded-input bounded-output stable.

Distortion. The input-output relationship for the LTI distortion (reverberation) is

$$y[m] = v[m] - \alpha\, v[m-K]$$

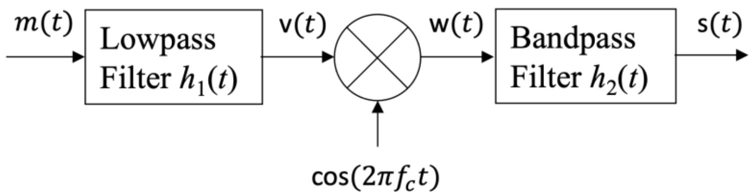
where α is any non-zero real number and K is a positive finite integer.

(a) Give the zeros of the LTI distortion $h[m]$ as expressions involving α and K. *9 points.*

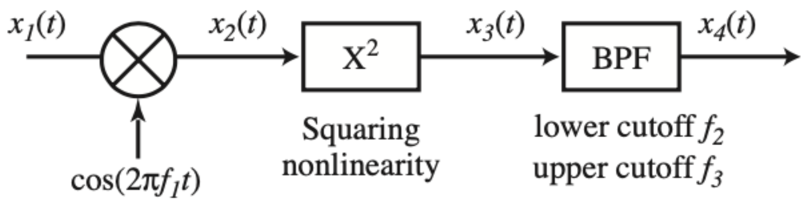
(b) Give the poles of the predistorter $g[m]$ as expressions involving α and K to guarantee bounded-input bounded-output stability. *18 points.*

Problem 1.3. *Sinusoidal Amplitude Modulation*. 27 points.

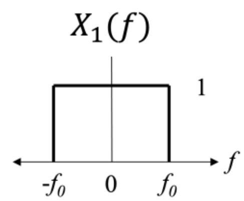
Sinusoidal amplitude modulation can be used to convey a baseband message signal $m(t)$ wirelessly as a bandpass RF signal $s(t)$ that can propagate further. Here's a block diagram representation:



An alternate modulation approach uses a squaring block and is shown below:



Using the baseband signal $x_1(t)$ whose spectrum is plotted on the right and using the parameters for f_0 and f_1 shown on the right,



$f_0 = 4$ MHz

$f_1 = 28$ MHz

(a) Draw the spectrum for $X_2(f)$. *6 points.*

(b) Draw the spectrum for $X_3(f)$. *9 points.*

(c) Give values of f_2 and f_3 to keep only bandpass part of the spectrum of $X_3(f)$ in positive frequencies. The bandpass filter will also keep negative frequencies from $-f_3$ to $-f_2$. *6 points.*

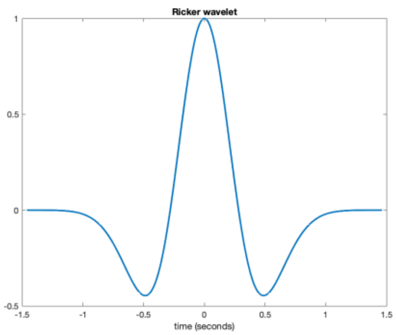
(d) Draw the spectrum for $X_4(f)$. *6 points.*

Problem 1.4. *Design Tradeoffs*. 22 points.

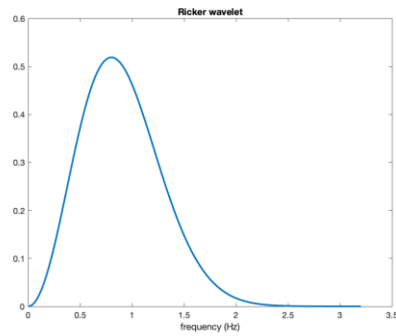
The Laplace of Gaussian filter is used to detect edges in images. It is the equivalent to a cascade of a Laplace highpass filter (second derivative) and a Gaussian lowpass filter to smooth the result.

An example continuous-time impulse response of a 1-D Laplace of Gaussian filter is the Ricker wavelet. The Richer wavelet is infinite in extent, and is plotted in the time and frequency domains below:

Continuous Time (CT) Domain



CT Frequency Domain



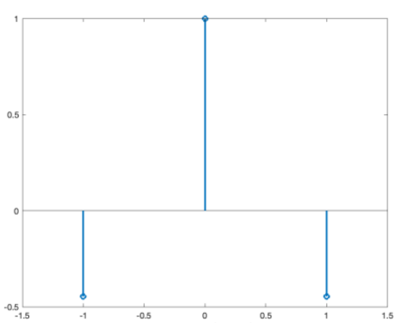
Below are two sampled versions of the Ricker wavelet (left) to be used as finite impulse response (FIR) impulse responses. The associated frequency response is plotted on the right. For each sampled version,

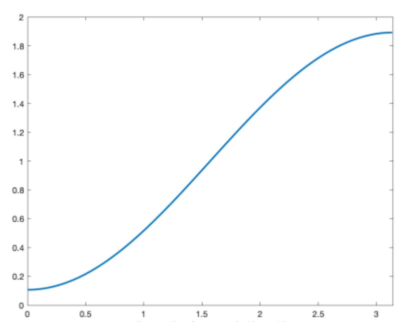
(a) Describe the signal quality in the time and frequency domains vs. the CT Ricker wavelet

(b) Give a formula for run-time computational complexity with each filter running at sampling rate f_s

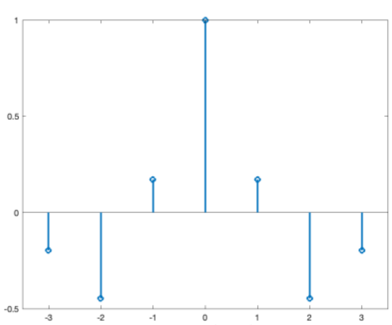
Discrete-Time (DT) Domain

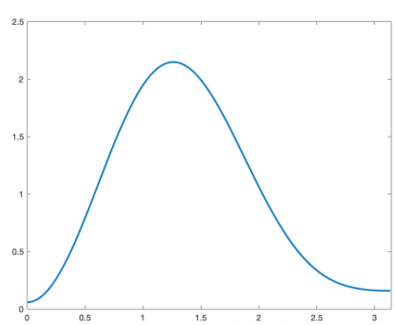
DT Frequency Domain





3-coefficient Ricker filter (*6 points*)





7-coefficient Ricker filter (*6 points*)

(c) Under what conditions would you advocate using the 3-point vs. the 7-point Ricker filter? *10 points*.