The University of Texas at Austin
Dept. of Electrical and Computer Engineering
Midterm #2

Date: November 16, 2021 Course: EE 313 Evans

Name: ____
Last, First

- This in-person exam is scheduled to last 75 minutes.
- Open books, open notes, and open class materials, including homework assignments and solution sets and previous midterm exams and solutions.
- Calculators are allowed.
- You may use any standalone computer system, i.e. one that is not connected to a network.
- ***Please disable all wireless connections on your calculator(s) and computer system(s).***
- Please mute all computer systems.
- Please turn off all phones.
- No headphones are allowed.
- All work should be performed on the midterm exam. If more space is needed, then use the backs of the pages.
- **Fully justify your answers.** If you decide to quote text from a source, please give the quote, page number and source citation**.**

Problem	*Point Value*	*Your score*	*Topic*
1	27		System Properties
2	27		Convolution
3	26		Highpass Filters
4	20		Wireless Localization
Total	100		

Problem 2.1. *System Properties.* 27 points.

Each discrete-time system has input $x[n]$ and output $y[n]$, and $x[n]$ and $y[n]$ might be complex-valued.

Each continuous-time system has input $x(t)$ and output $y(t)$, and $x(t)$ and $y(t)$ might be complex-valued.

Determine if each system is linear or nonlinear, time-invariant or time-varying, and stable or unstable.

You must either prove that the system property holds in the case of linearity, time-invariance, or stability, or provide a counter-example that the property does not hold. Providing an answer without any justification will earn 0 points.

Part	***System Name***	***System Formula***	***Linear?***	***Time-Invariant?***	***Stable?***
(a)	Averaging Filter	$y[n] = x[n] + x[n-1]$ for $n \geq 0$ and $x[-1] = 0$			
(b)	Frequency modulation	$y(t) = \cos\left(2\pi f_c t + 2\pi k_f \int_0^t x(\lambda) d\lambda\right)$ for $t \geq 0$. f_c and k_f are real-valued constants.			
(c)	Time Reversal	$y(t) = x(-t)$ for $-\infty < t < \infty$			

(a) Averaging filter: $y[n] = x[n] + x[n-1]$for $n \geq 0$ and $x[-1] = 0$. *9 points.*

(b) Frequency Modulation: $y(t) = \cos\left(2\pi f_c t + 2\pi k_f \int_0^t x(\lambda) d\lambda\right)$ for $t \geq 0$. *9 points.*

(c) Time reversal: $y(t) = x(-t)$ for $-\infty < t < \infty$. *9 points.*

Problem 2.2 *Convolution*. 27 points.

In continuous-time systems, an linear time-invariant (LTI) integrator is a building block. Its input-output relationship is

$$y(t) = \int_{-\infty}^{t} x(\tau)\, d\tau$$

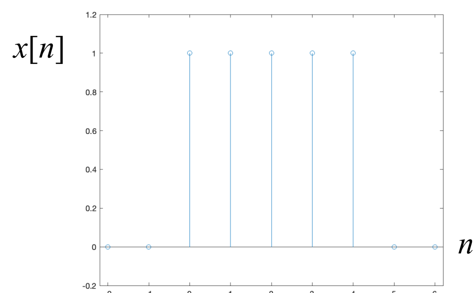
The impulse response is $h(t) = u(t)$ where $u(t)$ is 1 for $t \geq 0$ and 0 otherwise.

The equivalent system in discrete time is the LTI running summation system. Its input-output relationship is

$$y[n] = \sum_{m=-\infty}^{n} x[m]$$

The impulse response is $h[n] = u[n]$ where $u[n]$ is 1 for $n \geq 0$ and 0 otherwise.

(a) Plot the output $y[n]$ of the LTI running summation when the input is a five-point rectangular pulse $x[n] = \delta[n] + \delta[n-1] + \delta[n-2] + \delta[n-3] + \delta[n-4]$? On the right, $x[n]$ is plotted for $-2 \leq n \leq 6$. *9 points.*



(b) Give a formula for the output $y[n]$ of the LTI running summation when the input is $x[n] = u[n]$. The formula should be valid for $-\infty < n < \infty$. *9 points*.

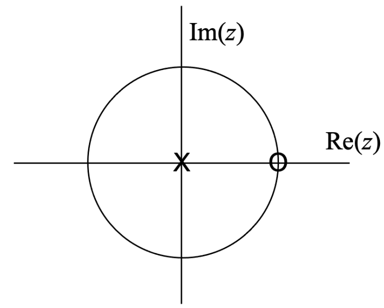
(c) Give a formula for the output $y(t)$ of the LTI integrator when the input is $x(t) = u(t)$. The formula should be valid for $-\infty < t < \infty$. *9 points*.

Problem 2.3. *Highpass Filters.* 26 points**.**

A highpass filter passes high frequencies and attenuates low frequencies.

Shown below are the pole-zero plots for two discrete-time linear time-invariant (LTI) highpass filters.

(a) LTI first-order finite impulse response (FIR) filter.
Pole-zero plot on the right. Zero at $z = 1$ and pole at $z = 0$.

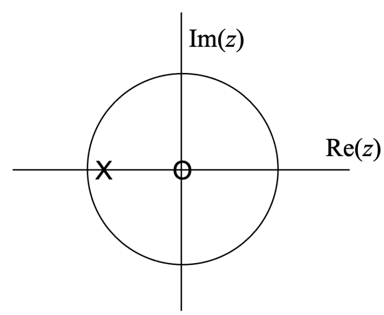


i. Write the transfer function $H(z)$ including the region of convergence. *6 points*.

ii. Give a formula for the frequency response. *3 points.*

iii. Plot the magnitude response. *4 points.*

(b) LTI first-order infinite impulse response (IIR) filter.
Pole-zero plot on the right. Pole at $z = -0.9$ and zero at $z = 0$.



i. Write the transfer function $H(z)$ including the region of convergence. *6 points*.

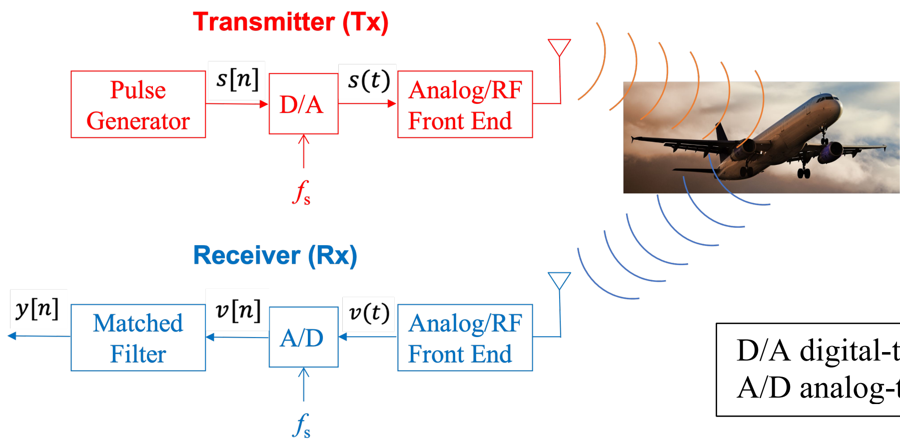
ii. Give a formula for the frequency response. *3 points*.

iii. Plot the magnitude response. *4 points*.

Problem 2.4 *Wireless Localization.* 20 points.

Mini-Project #2 used radar (electromagnetic waves and signal processing) to locate an object in an environment. Applications include automotive and 6G cellular communication systems.

A block diagram for the radar system to determine the distance to the object follows.



D/A digital-to-analog converter
A/D analog-to-digital converter

The radar system estimates the round-trip time T_d from the transmitter to the object and from the object to the receiver. Transmitter and receiver are in the same location. Distance d can be computed using $d = \frac{1}{2}\, c\, T_d$ where c is the speed of propagation of electromagnetic waves in air (speed of light).

(a) What are the advantages of using a chirp pulse for the transmitted waveform? *6 points*.

(b) Describe the role of the matched filter in the receiver. Why is it called a matched filter? What is being matched? *6 points*.

(c) How did the radar system use the chirp pulse and matched filter to estimate the round-trip time T_d from the transmitter to the object and from the object to the receiver? *8 points*.