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

Date: October 19, 2018 Course: EE 445S Evans

Name: ____
Last, First

- The exam is scheduled to last 50 minutes.
- Open books and open notes. You may refer to your homework assignments and the homework solution sets.
- 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 computer system(s).***
- Please turn off all cell phones.
- No headphones allowed.
- All work should be performed on the quiz itself. 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	28		Filter Analysis
2	27		Minimum Phase FIR Filters
3	24		Bluetooth Receiver
4	21		Potpourri
Total	100		

Problem 1.1 *Filter Analysis*. 28 points.

Consider the following causal linear time-invariant (LTI) discrete-time filter with input $x[n]$ and output $y[n]$ described by

$$y[n] = x[n] + a\, x[n\text{-}2] + a^2\, x[n\text{-}4]$$

for $n \geq 0$, where a is a real-valued coefficient where $0 < a < 1$.

(a) Is this a finite impulse response (FIR) or infinite impulse response (IIR) filter? Why? *3 points*.

(b) What are the initial conditions and their values? Why? *6 points*.

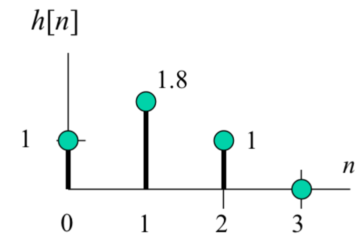
(c) Draw the block diagram of the filter relating input $x[n]$ and output $y[n]$. *6 points*.

(d) Derive a formula for the transfer function in the z-domain. *4 points*.

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

(f) Does the filter have linear phase over all frequencies? Why or why not? *6 points*.

Problem 1.2 *Minimum Phase FIR Filters.* 27 points.



Minimum phase finite impulse response (FIR) filters have shorter length and lower group delay compared with linear phase FIR filters that meet the same magnitude specification.

We will use an algorithm by Herrman and Schüssler to convert an odd-length linear phase FIR filter to a minimum phase FIR filter.

Consider a linear phase FIR filter has the causal three-point impulse response $h[n]$ given above. Filter order M is 2. The filter is lowpass with stopband attenuation $A_{stop} = 0.2$ in linear units (–13.9794 dB).

(a) What is the group delay in samples through the linear phase FIR filter $h[n]$? *3 points*.

(b) Please implement the steps in the Herrman and Schüssler algorithm below.

i. Compute the impulse response for a linear phase FIR filter $g[n] = A_{stop}\,\delta[n - (M/2)] + h[n]$ where A_{stop} is in linear units. Plot $g[n]$. *6 points*.

ii. Compute $G(z)$. *6 points*.

iii. Form the minimum phase FIR filter $V(z)$ by keeping any zeros of $G(z)$ inside the unit circle and keeping one zero in each pair of repeated zeros on the unit circle in $G(z)$. *6 points.*

iv. Compute the gain for $V(z)$ so that its response at $\omega = 0$ is the same as the response of $H(z)$ at $\omega = 0$. *6 points.*

Problem 1.3 *Bluetooth Receiver.* 24 points.

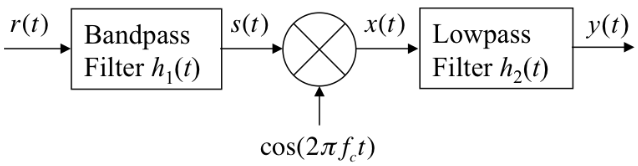
Bluetooth operates in the 2400-2499 MHz unlicensed band.

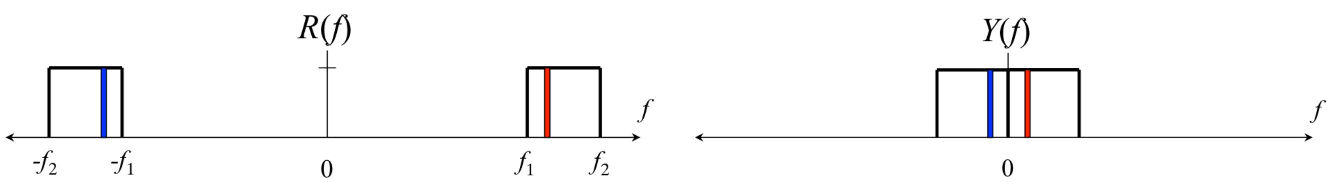
At any given time, Bluetooth will transmit on one of 79 channels, and each channel is 1 MHz wide.

Channel k begins at $(2402 + k)$ MHz where $k = 0, 1, \ldots, 78$.

The Bluetooth receiver below has an analog/RF front end and a digital baseband receiver.

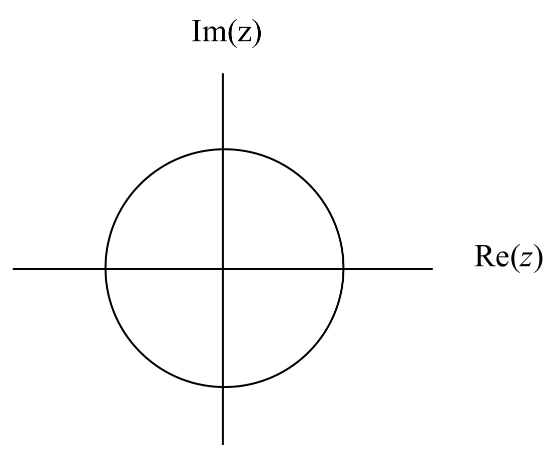
(a) **Analog/RF front end** block diagram is given below, where $r(t)$ is the received RF signal. In the plot for $R(f)$, one of the 1 MHz channels is shaded, and its counterpart in negative frequencies is also shaded. The spectrum of the analog/RF front end output signal, $y(t)$, is also shown. *6 points.*





What is the carrier frequency f_c?

(b) Design a **second-order discrete-time** linear time-invariant (LTI) infinite impulse response (IIR) filter to extract channel k from $y[n]$ where $y(t)$ is sampled at a sampling rate of f_s to obtain $y[n]$ where $f_s \geq 200$ MHz. Give formulas for, and plot, the poles and zeros. *18 points.*



Problem 1.4. *Potpourri.* 21 points.

(a) Compare the implementation complexity of an infinite impulse response (IIR) filter with N poles and N zeros for the different filter structures below. A biquad is a second-order IIR filter.

i. Complete the table below while providing justification for each entry. Your answers would be in terms of N. *12 points*.

Filter Structure	**Number of coefficients**	**Number of input and output values to store**	**Multiplications per output sample**	**Additions per output sample**
Direct Form				
Cascade of Biquads (N even)				
Cascade of Biquads (N odd)				

ii. What is the percentage increase in implementation complexity for the cascade of biquads vs. direct form when $N = 10$? *3 points*.

(b) For infinite impulse response (IIR) filter orders greater than two, what is the primary advantage of using a cascade of biquads vs. a direct form filter structure? *6 points.*

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