Homework #6

***Infinite Impulse Response (IIR) Filters***

Assigned on Friday, October 27, 2017
Due on Friday, November 3, 2017, by 12:30 pm via Canvas submission

*Late homework will not be accepted.*

***Reading***: McClellan, Schafer & Yoder, *Signal Processing First*, 2003, Ch. 7-8.
Companion Web site with demos and other supplemental information: http://dspfirst.gatech.edu/
Web site contains solutions to selected homework problems from *DSP First*.

Contact information for the teaching assistant, Ms. Ghosh, is available at

https://utexas.instructure.com/files/43676674/download?download_frd=1

Office hours for Ms. Ghosh and Prof. Evans follow, as well as Prof. Evans' coffee hours on Friday.

| ***Time Slot*** | ***Monday*** | ***Tuesday*** | ***Wednesday*** | ***Thursday*** | ***Friday*** |
|---|---|---|---|---|---|
| **9:00 am** | | | **Ghosh** | | |
| **9:30 am** | | | **Ghosh** | | |
| **10:00 am** | | | **Ghosh** | | |
| **10:30 am** | | | | | |
| **11:00 am** | | **Ghosh** | | **Ghosh** | |
| **11:30 am** | | **Ghosh** | | **Ghosh** | |
| **12:00 pm** | | **Ghosh** | | **Ghosh** | Evans (EER cafe) |
| **12:30 pm** | | Evans (EER 1.516) | | Evans (EER 1.516) | Evans (EER cafe) |
| **1:00 pm** | | Evans (EER 1.516) | Evans (EER 6.882) | Evans (EER 1.516) | |
| **1:30 pm** | | Evans (EER 1.516) | Evans (EER 6.882) | Evans (EER 1.516) | |
| **2:00 pm** | | | Evans (EER 6.882) | Evans (EER 6.882) | |
| **2:30 pm** | | | | Evans (EER 6.882) | |
| **3:00 pm** | | | | Evans (EER 6.882) | |

EE 313 tutoring is available on Mondays through Thursdays from 7:00pm to 10:00pm in ETC 4.150:

http://www.ece.utexas.edu/undergraduate/tutoring

***** ASSUME THAT ALL FILTERS IN THIS HOMEWORK SET ARE LINEAR AND TIME-INVARIANT. *****

**1. Transfer Function, Difference Equation and Frequency Response Connections.** ***25 points.***

*Signal Processing First*, problem P-8.13, page 240. *Please also answer the following questions.*

Plot the frequency response for each filter represented by a pole-zero plot. Once you match the pole-zero plot to the difference equation, use `freqz(numer, denom)` where `numer` is the vector of feed-forward coefficients $[b_0\ \ b_1\ \ \ldots\ \ b_M]$ and `denom` is the vector of feedback coefficients $[1\ \ -a_1\ \ -a_2\ \ \ldots\ \ -a_N]$. (Note: I had forgotten the leading 1 in `denom` on lecture slide 11-9.) The `numer` and `denom` vectors are also the coefficients in the numerator and denominator of the z-domain transfer function.

Indicate each filter's frequency selectivity as lowpass, highpass, bandpass, bandstop, allpass or notch.

**2. First-Order IIR Filter.** ***25 points.***

*Signal Processing First*, problem P-8.15, page 241. Also: (c) Draw the block diagram of the IIR filter.

**3. Second-Order IIR Filter.** ***25 points.***

*Signal Processing First*, problem P-8.19, page 243. Please complete the following additional part:

(d) Plot the frequency response using `freqz`. What is the frequency selectivity of the filter? Lowpass, highpass, bandpass, bandstop, allpass, or notch.

**4. Convolution of Infinite-Length Signals.** ***25 points.***

Sometimes it's easier to work a problem in the time domain, and other tines, it's easier to work the problem in a transform domain.

(a) $y[n] = x_1[n] * x_2[n]$ where $x_1[n] = a^n\, u[n]$ and $x_2[n] = b^n\, u[n]$. Handout F "Convolution of Two Causal Exponential Sequences" computes the convolution in the time domain as Case #1 at

http://users.ece.utexas.edu/~bevans/courses/signals/handouts/Appendix%20F%20Convolution%20Exp%20Sequences.pdf

Find $y[n]$ using $z$-transforms.

*Hint: You may need to use partial fractions decomposition of the product $X_1(z)\, X_2(z)$. Please see Section 8-7.2 in Signal Processing First.*

(b) $y[n] = x_1[n] * x_2[n]$ where $x_1[n] = b^n\, u[n]$ and $x_2[n] = b^n\, u[n]$. Handout F "Convolution of Two Causal Exponential Sequences" computes the convolution in the time domain as Case #2. See the Web address in part (a).

Find $y[n]$ using $z$-transforms. When $x_1[n] = x_2[n]$, we have resonance.

*Hint: You may need to use partial fractions decomposition of the product $X_1(z)\, X_2(z)$. Please see Section 8-7.2 in Signal Processing First. The product $X_1(z)\, X_2(z)$ has a repeated pole.*

As stated on the course descriptor, "Discussion of homework questions is encouraged. Please be sure to submit your own independent homework solution."

NOTE: In your solutions, please put all work for problem 1 together, then all work for problem 2 together, etc. Please see additional homework guidelines on the homework page.