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

Date: March 7, 2014 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		Discrete-Time Filter Analysis
2	24		Improving Signal Quality
3	24		Filter Bank Design
4	24		Potpourri
Total	100		

Problem 1.1 *Discrete-Time Filter Analysis*. 28 points.

A causal stable discrete-time linear time-invariant filter with input $x[n]$ and output $y[n]$ is governed by the following transfer function:

$$H(z) = C\frac{(z - z_0)(z - z_1)}{(z - p_0)(z - p_1)} = C\frac{(1 - z_0 z^{-1})(1 - z_1 z^{-1})}{(1 - p_0 z^{-1})(1 - p_1 z^{-1})}$$

Constant C is real-valued and is not equal to zero. Zero locations are z_0 and z_1. Pole locations are p_0 and p_1 where $|p_0| < 1$ and $|p_1| < 1$.

(a) From the transfer function, give formulas for the feedforward coefficients and the feedback coefficients in terms of the pole locations, zero locations and constant C. *6 points*.

(b) Give the difference equation relating input $x[n]$ and output $y[n]$ in terms of the feedforward and feedback coefficients. *6 points*.

(c) What are the initial condition(s)? What value(s) should they be assigned and why? *4 points*.

(d) Draw a block diagram for the filter. *6 points*.

(e) For zeros $z_0 = -1$ and $z_1 = -1$ and poles $p_0 = 0.9$ and $p_1 = 0$, draw the pole-zero diagram. What is the best description of the frequency selectivity of the filter: lowpass, highpass, bandstop, bandpass, allpass or notch? *6 points*.

Problem 1.2 *Improving Signal Quality*. 24 points.

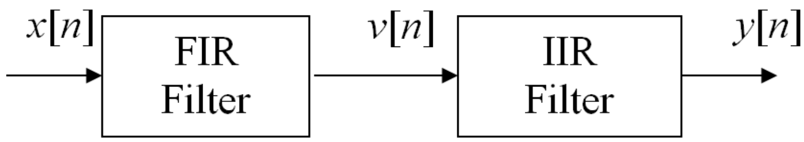
In smart grids, communication between customer power meters and the local utility can occur over the (outdoor) power line:

- Transmission band: 40-90 kHz
- Sampling rate: 400 kHz

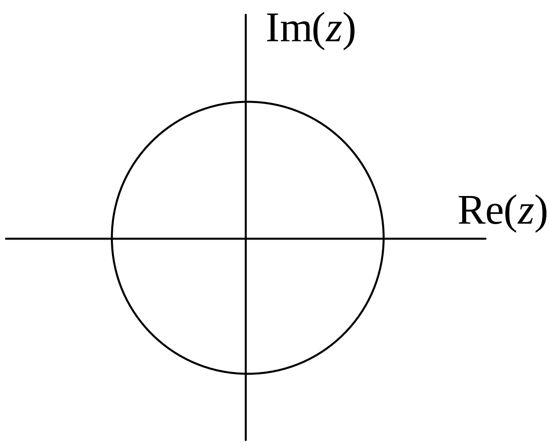
Consider the following sources of distortion:

- Additive noise
- Narrowband interferer at 50 kHz

Consider the following cascade of filters in the receiver to improve signal quality:



(a) Design a sixth-order finite impulse response (FIR) filter to reduce out-of-band additive noise by manually placing zeros on the pole-zero diagram below. *9 points*.



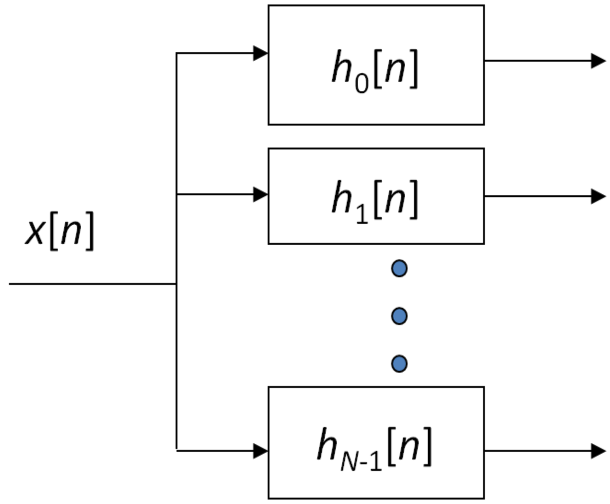
(b) Design an infinite impulse response (IIR) filter **biquad** to remove the 50 kHz interferer.

i. Give formula for discrete-time frequency ω_0 in rad/sample of the interferer. *3 points*.

ii. Give formulas for the two poles and the two zeros as functions of ω_0. *6 points*.

(c) How many instruction cycles on the TI TMS3206748 digital signal processor used in lab will take to compute one output sample $y[n]$ given one input sample $x[n]$? *6 points*.

Problem 1.3 *Filter Bank Design*. 24 points.



Show on the right is a bank of N filters to decompose signal $x[n]$ into N frequency bands.

Each filter has a finite impulse response (FIR):

- Filter $h_0[n]$ is lowpass.
- Filter $h_{N-1}[n]$ is highpass.
- All other filters are bandpass.

Each FIR filter has N coefficients.

(a) Let filter $h_0[n]$ be an averaging filter. *6 points*.

i. What is the null bandwidth? Why?

ii. What is the group delay? Why?

(b) Derive the filter $h_{N-1}[n]$ from $h_0[n]$ in part (a). *9 points*.

i. With $g[n] = (-1)^n$, show that $h_{N-1}[n] = g[n]\, h_0[n]$ is highpass.

ii. What is the group delay? Why?

(c) For the case $N = 3$, derive $h_1[n]$ from $h_0[n]$ in part (a). *9 points*.

i. Give $g_1[n]$ so that $h_1[n] = g_1[n]\, h_0[n]$ is a bandpass filter centered at $\pi/2$.

ii. What is the group delay? Why?

Problem 1.4. Potpourri. *24 points*.

(a) Assuming the use of an analog-to-digital converter at the front end of a signal processing system, what are the design tradeoffs in a signal processing system when increasing the sampling rate beyond twice the maximum frequency of interest with respect to

i. Signal quality. *6 points*.

ii. Implementation complexity. *6 points*.

(b) Due to certain digital signal processing operations, esp. in communication systems, signals can have a large DC offset. This is a particular problem when implementing a system in fixed-point (integer) data and arithmetic. How would you suggest removing the DC offset? *6 points*.

(c) You are asked to design a discrete-time bandpass filter to pass subwolfer frequencies (20-200 Hz) in a digital audio signal that has been sampled at 44.1 kHz. Would you advocate using a finite impulse response (FIR) filter or an infinite impulse response (IIR) filter? Why? *6 points*.