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

Date: March 11, 2016 Course: EE 445S Evans

Name: ____
Last, First

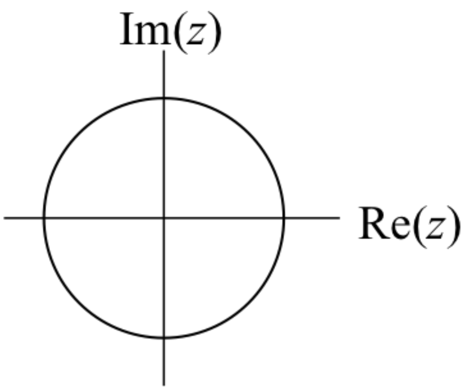
- The exam is scheduled to last 50 minutes.
- Open books and open notes. You may refer to your homework assignments and the homework solution sets.
- Calculators are allowed.
- You may use any standalone computer system, i.e. one that is not connected to a network. ***Please disable all wireless connections 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 Design & Analysis
2	24		BIBO Stability
3	24		Upsampling
4	24		Potpourri
Total	100		

Problem 1.1 *Filter Design & Analysis*. 28 points.

Design and analyze a first-order discrete-time infinite impulse response filter to remove DC, which is a discrete-time frequency of 0 rad/sample.

(a) Place the pole and zero on the pole-zero diagram below. *4 points*



(b) Give numeric values of the pole and zero in part (a). Why did you choose these values? *4 points*

(c) Give a formula for the discrete-time frequency response and draw the magnitude response. *6 points.*

(d) Give the difference equation relating output $y[n]$ and input $x[n]$ including the initial conditions. *4 points*

(e) Draw the block diagram for the filter. *4 points*.

(f) Why is removing the DC offset (average value) important in speech and audio systems? *6 points*.

Problem 1.2 *Stability.* 24 points.

For a discrete-time linear time-invariant system with impulse response $h[n]$, the system is bounded-input bounded-output (BIBO) stable if and only if

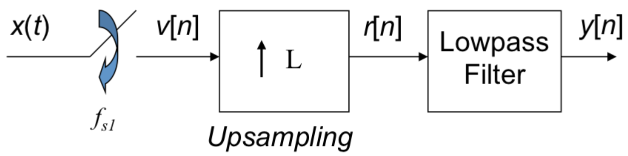
$$\sum_{n=-\infty}^{\infty} |h[n]| < \infty$$

(a) Using the above definition, prove that a discrete-time finite impulse response (FIR) filter is always BIBO stable. *12 points*.

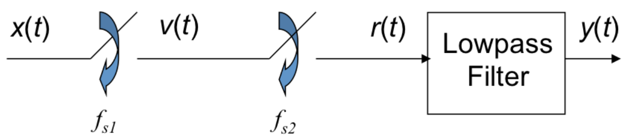
(b) Give an example of a BIBO unstable linear time-invariant system, an application that uses the BIBO unstable system, and how the application uses the BIBO unstable system. *12 points*.

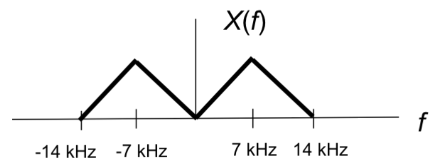
Problem 1.3 *Upsampling.* 24 points.

Consider the following block diagram to sample an audio signal $x(t)$ at f_{s1} = 32 kHz to produce a discrete-time signal $v[n]$ and then change the sampling rate to f_{s2} = 96 kHz via the discrete-time operation of upsampling by 3 (i.e. $L = 3$) followed by a discrete-time lowpass filter to produce $y[n]$.



The continuous-time equivalent to the above block diagram is





Using $X(f)$ given above to the right, which is the continuous-time Fourier transform of $x(t)$, please complete the following analysis:

(a) Draw $V(f)$, which is the continuous-time Fourier transform of $v(t)$. *6 points.*

(b) Draw $R(f)$, which is the continuous-time Fourier transform of $r(t)$. *6 points.*

(c) Give the passband and stopband frequencies in Hz for the continuous-time lowpass filter to use to recover $x(t)$ from $r(t)$. *4 points.*

f_{pass} =

f_{stop} =

(d) Give the passband and stopband frequencies in rad/sample for the discrete-time lowpass filter in the upper block diagram to recover $v[n]$ from $r[n]$. *4 points.*

ω_{pass} =

ω_{stop} =

(e) For the discrete-time lowpass filter, would you advocate to use a finite impulse response (FIR) filter or an infinite impulse response (IIR) filter? Why? *4 points.*

Problem 1.4. *Potpourri.* 24 points.

(a) In lab #2, you implemented a cosine generator on the digital signal processing board in lab using a causal linear time-invariant filter with the difference equation

$$y[n] = (2 \cos \omega_0)\, y[n-1] - y[n-2] + x[n] - (\cos \omega_0)\, x[n-1]$$

for input signal $x[n]$ and output signal $y[n]$.

1. What are the initial conditions and what should their values be? *3 points*.

2. What would you use as the input signal $x[n]$? *3 points*.

3. Give the output signal $y[n]$ that is a solution to the above difference equation for the input signal $x[n]$ given in part 2 above? *3 points*.

4. Describe an efficient implementation of the interrupt service routine so that $\cos \omega_0$ is not computed every time a sample of $y[n]$ is computed. *6 points*.

(b) In lab #3, you implemented discrete-time infinite impulse response (IIR) filters in 32-bit IEEE floating-point data and coefficients on the digital signal processor board. What distortion could the **continuous-time output signal** of the digital-to-analog converter have if you were to implement the discrete-time IIR filter as a cascade of biquads but not implement the gain for each biquad? *9 points*.