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

Date: Oct. 13, 2021 Course: EE 445S Evans

Name: ____
Last, First

- **Exam duration**. The exam is scheduled to last 75 minutes.
- **Materials allowed**. You may use books, notes, your laptop/tablet, and a calculator.
- **Disable all networks**. Please disable all network connections on all computer systems. You may not access the Internet or other networks during the exam.
- **Electronics.** Power down phones. No headphones. Mute your computer systems.
- **Fully justify your answers**. When justifying your answers, reference your source and page number as well as quote the particular content in the source for your justification. You could reference homework solutions, test solutions, etc.
- **Matlab**. No question on the test requires you to write or interpret Matlab code. If you base an answer on Matlab code, then please provide the code as part of the justification.
- **Put all work on the test**. All work should be performed on the quiz itself. If more space is needed, then use the backs of the pages.
- **Academic integrity.** By submitting this exam, you affirm that you have not received help directly or indirectly on this test from another human except your instructor, Prof. Evans, and that you did not provide help, directly or indirectly, to another student taking this exam.

Problem	*Point Value*	*Your score*	*Topic*
1	24		Sinusoidal Generation
2	24		FIR Filter Design
3	28		Discrete-Time Audio Effects
4	24		Mystery Systems
Total	100		

Problem 1.1. *Sinusoidal Generation*. 24 points.

You're asked to generate one period of a discrete-time cosine signal $y[n]$:

- The continuous-time frequency is 131 Hz ('C' note on the Western scale in the third octave).
- The sampling rate f_s is 8,000 Hz.

(a) What is the discrete-time frequency in rad/sample of the discrete-time cosine signal? *4 points*.

(b) What is the fundamental period of the discrete-time cosine signal in samples? *4 points*.

(c) Give a difference equation whose impulse response will generate the discrete-time cosine signal. *4 points*.

(d) Compare the run-time complexity for the difference equation and the lookup table method. The lookup table would store an entire period of cosine values computed offline. *8 points*.

Method	**Total Memory Needed**	**Multiplications per output sample**	**Reads per output sample**	**Writes per output sample**
Difference equation				
Lookup table				

(e) How would you use the lookup table for the cosine signal to generate a discrete-time sine signal with the same frequency? *4 points*.

Problem 1.2 *FIR Filter Design.* 24 points.

You're asked to design a lowpass linear phase finite impulse response (FIR) filter to meet the following specifications:

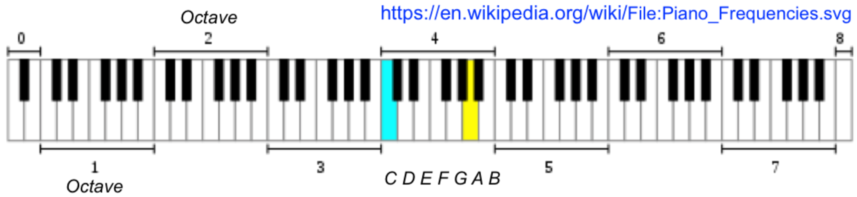
- Pass frequencies in octave 0, Western scale, from 16.35160 Hz ('C') to 30.8611 Hz ('B')
- Zero out odd harmonics of the 60 Hz powerline frequency (60 Hz, 180 Hz, 300 Hz, etc.)
- Sampling rate is less than 1000 Hz

(a) What sampling rate would you choose? Why? *12 points*

(b) Give the coefficients of the FIR filter to meet the specifications. *12 points*.

Problem 1.3 *Discrete-Time Audio Effects.* 28 points.

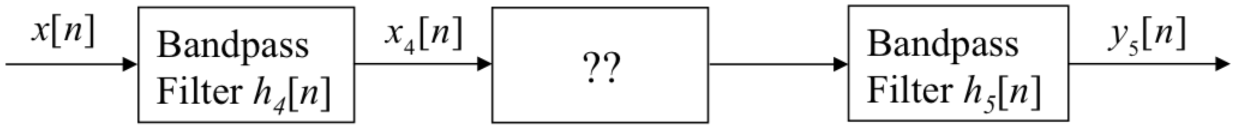
The notes on the Western scale on an 88-key piano keyboard grouped into octaves follow:



The frequency of note A4 (i.e. 'A' in the 4th octave) at 440 Hz is twice the frequency of A3 at 220 Hz.

This type of octave spacing occurs for all the notes on the Western scale.

Design a **discrete-time** audio effects system that will extract the fourth octave of frequencies and then alter that octave of frequencies to be in the next higher octave:



All notes on the fourth octave should appear as the same notes in the next higher octave.

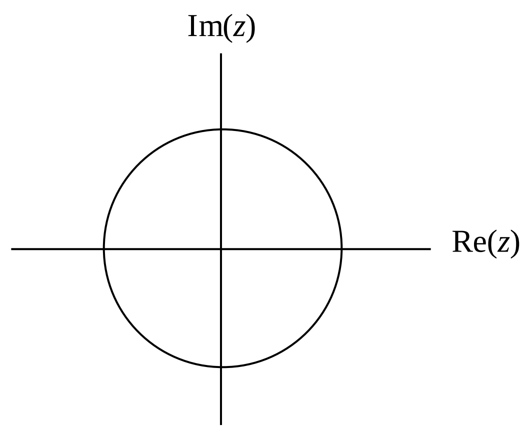
Bandpass filter $h_k[n]$ passes frequencies in the kth octave and attenuates other frequencies.

For signals $x[n]$ and $x_4[n]$, the sampling rate f_s is 8,000 Hz.

(a) Design a second-order infinite impulse response (IIR) bandpass filter $h_4[n]$ to pass the fourth octave and attenuate the other octaves. In the fourth octave, the lowest note is 262 Hz and highest note is 494 Hz. *12 points.*

i. Give formulas for the pole and zero locations.

ii. Plot poles and zeros on the diagram on the right.



(b) What system would you use for the ?? block? Why? *9 points.*

(c) What would the output be for your proposed system if two notes in the fourth octave were being played at the same time? *7 points.*

Problem 1.4. *Mystery Systems.* 24 points.

You're trying to identify unknown discrete-time systems.

You input a discrete-time chirp signal $x[n]$ and look at the output to figure out what the system is.

The discrete-time chirp is formed by sampling a chirp signal that sweeps 0 to 4000 Hz over 0 to 5s

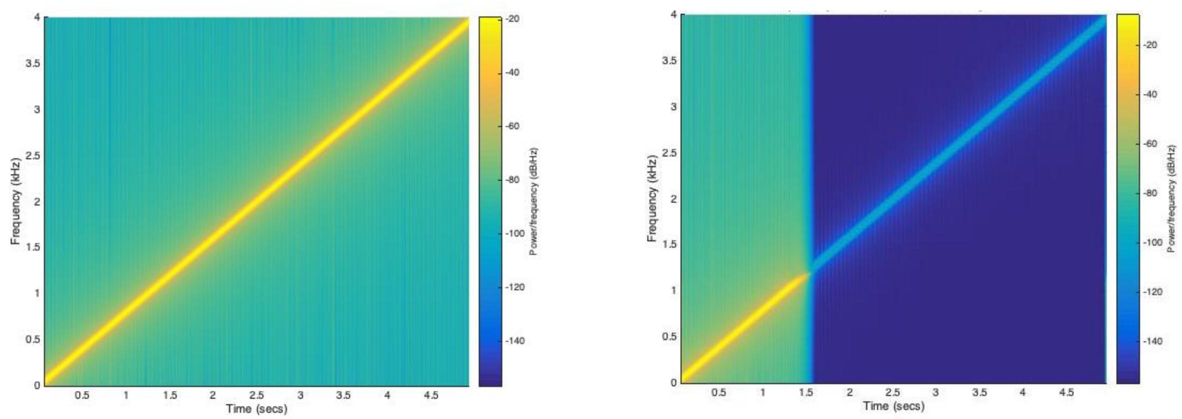
$$x(t) = \cos(2\pi f_1 t + 2\pi \mu t^2)$$

where $f_1 = 0$ Hz, $f_2 = 4000$ Hz, and $\mu = \frac{f_2 - f_1}{2\, t_{\max}} = \frac{4000 \text{ Hz}}{10\, s} = 400 \text{ Hz}^2$. Sampling rate f_s is 8000 Hz.

In each part below, identify the unknown system as one of the following:

1. filter – give selectivity (lowpass, highpass, bandpass, bandstop) and passband/stopband frequencies
2. upsampler – give upsampling factor
3. downsampler – give downsampling factor

(a) Given spectrograms of the chirp input signal $x[n]$ (left) and output signal $y[n]$ (right). *12 points.*



(b) Given spectrograms of the chirp input signal $x[n]$ (left) and output signal $y[n]$ (right). *12 points.*