ELEC3104: Digital Signal Processing

S1, 2017

Tutorial-Laboratory Problem Sheet 2

Question 1

Three MATLAB functions are provided to you in the form of encrypted p-files (i.e., you cannot open them and look at the code) named '*s2q6a*', '*s2q6b*' and '*s2q6c*'. Each is a discrete-time system that you can run by calling it as a MATLAB function. i.e., '$y = s2q6a(x)$' will give you the output, y, of the *s2q6a* system with the input given by x.

A. Is *s2q6a*() a linear system? Is it Time-invariant?
B. Is *s2q6b*() an LTI filter? Justify your answer.
C. *s2q6c*() is an LTI system. Is it an FIR system or an IIR system?
D. Plot the magnitude and phase spectra of *s2q6c*().

Question 2

Design three oscillators that produce sinusoidal signals of frequencies 1000 Hz, 1400 Hz and 1600 Hz respectively. Then design a notch filter to remove the 1400Hz component (only) from the sum of the outputs of the three oscillators you designed. You can assume that the sampling frequency is 4000 Hz.

[Analytical Component]

A. Give the transfer functions of all three oscillators and the notch filter. Sketch canonical structures for all of them.

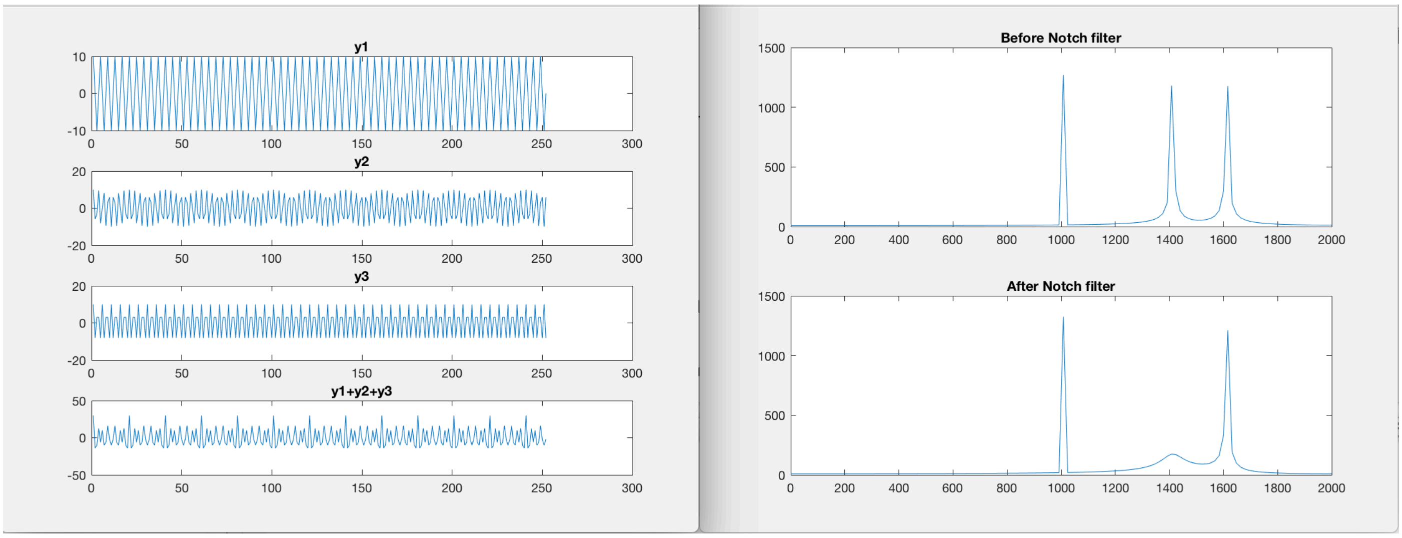
B. Sketch the pole-zero plots for all three oscillators and the notch filter.

[Laboratory Component]

C. Implement all three oscillators in MATLAB. Obtain the sum of their outputs and filter it using the notch filter you designed. Do NOT use any built-in MATLAB functions.

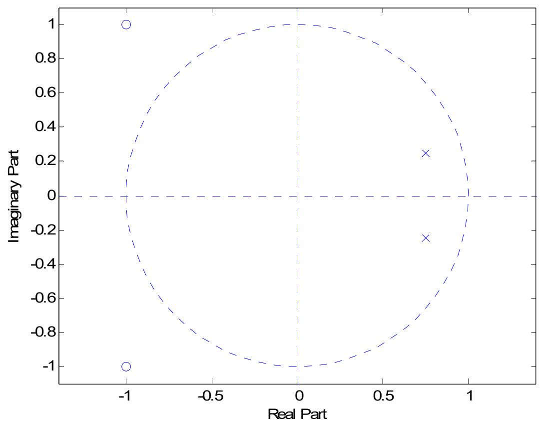
D. In MATLAB plot the magnitude spectra of the outputs of all three oscillators, of the sum of the three oscillators and the output of the notch filter. (You can reuse code from problem sheet 1 for this).

Q2



Question 3

The Pole-Zero plot of a system is given below:



[Analytical Component]

A. Represent the above system $H(z)$ as a cascade of a minimum phase system $H_m(z)$ and an all-pass system $H_{ap}(z)$. Draw pole-zero plots for each of these.

B. Draw a canonical realisation of $H_m(z)$ and $H_{ap}(z)$ and sketch their magnitude and phase spectra.

[Laboratory Component]

C. Implement $H(z)$, $H_m(z)$ and $H_{ap}(z)$ and plot their magnitude and phase spectra in MATLAB without using any built-in functions.

Question 4

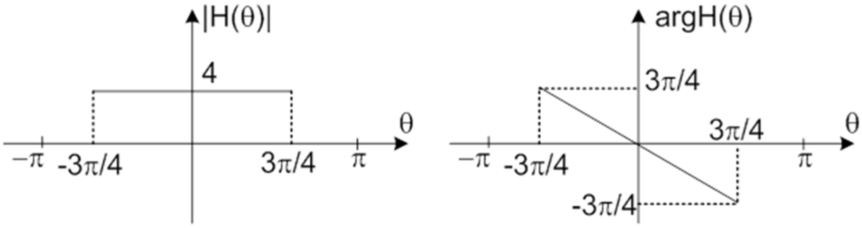
In ancient times, modems worked by transmitting digital data through telephone lines. Specifically, during transmission modems converted a stream of 1's and 0's into an audio signal where 1's were represented by a particular frequency and 0's by another frequency. A modem acting as a receiver would convert the audio signal back into a stream of 1's and 0's. You task today is to design and implement a system in MATLAB (as a MATLAB function) that will accept such audio signals ('*bit_sequence1.wav*', '*bit_sequence2.wav*', '*bit_sequence3.wav*' and '*bit_sequence4.wav*') as input and convert them into sequences of 1's and 0's accurately. You have been given the following information about the audio signal:

1. Each symbol (i.e., 0 or 1) is represented by a sinusoid of a single frequency.
2. Each transmission begins with 0101.
3. The transmission rate is 20 bits/second

1bit/0.05second

File	Decoded Bit Sequence
bit_sequence1.wav	0101 001111000110 time chunk:16
bit_sequence2.wav	0101 01000110 time chunk:12
bit_sequence3.wav	0101 001100 time chunk:10
bit_sequence4.wav	0101 10111000110 time chunk:15

Question 5
The frequency response, $\hat{h}(\theta)$, of an LTI system is shown below:

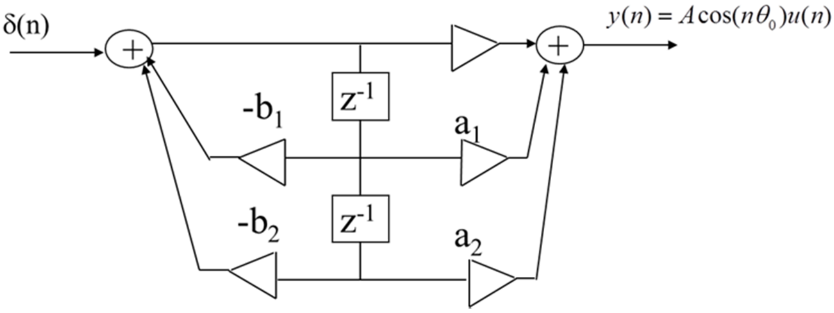


A. Determine the impulse response $h[n]$. Is this an IIR filter or an FIR filter?

FIR, because it has linear phase

B. Let $h_N[n]$ denote a truncated version of $h[n]$ retaining the first N samples. Implement the LTI filter corresponding to $h_N[n]$ in MATLAB for some value of N and plot its magnitude and phase responses. Compare the plots you obtain to the figure shown above and observe the effect of varying N. Can you explain your observations?

Question 6
An IIR oscillator initialised by an impulse is shown below. The desired impulse response is $y[n] = A\cos(n\theta_0)\,u[n]$, where θ_0 is the resonant frequency of the digital oscillator.



A. Writing appropriate equations, find the values of b_1,b_2 , a_0, a_1 and a_2 in order to sustain the oscillation.

B. Implement this oscillator in MATLAB without using any built-in functions and demonstrate that your coefficients work as required.