ELEC-A5204 Homework 4

13.8.2019

Answer to all questions in given Matlab files and use Matlabs publish feature to generate a pdf file. Always return the published pdf AND Matlab files. Task are also written to Exercise4X.m files which can be downloaded from Mycourses. When an exercise ask you to draw figures, return them always with suitable axis labels and titles.

1 Filter Design from Ideal IR

Use windowed Fourier series method and design a FIR-type (causal) lowpass filter with cutoff frequency $w_c = 3\pi/4$. Impulse response of an ideal lowpass filter with cutoff frequency at w_c in Matlab is $\frac{w_c}{\pi} sinc(\frac{w_c}{\pi}\ n)$, where $w_c = 2\pi f_c/f_s$ and 'n' is sample index.

a) Generate 4th order FIR lowpass filter by windowing ideal impulse resonse with rectangular window: $w_r[n] = 1, -M =< n =< M, M = 2$ and else 0. Plot the impulse response and magnitude response.

b) Generate 4th order FIR lowpass filter by windowing ideal impulse resonse with Hamming window: $w_h[n] = 0.54 + 0.46\cos(\pi n/M), -M =< n =< M, M = 2$. Plot the impulse response and magnitude response.

c) Compare how the magnitude responses of the filters designed in (a) and (b) differ. Then do the same as in (a) and (b) but use filter order of $100(M = 50)$.

2 Filter Desgn with some algorithms

This exercise uses speksitIIR.m function from Mycourses. The function has to be in the same folder as this skript to work. You can write 'help speksitIIR' to Command Window to get information about speksitIIR function. Sampling frequency in both sections is 48000 Hz. Use legend() to name each magnitude response clearly.

Helpful functions: butter, buttord, cheb1, cheb1ord, ellip, ellipord, freqz

a) Design digital minimum order (lowest possible order) I) Butterworth, II) Chebyshev 1 and III) Elliptic **high-pass** filters that fulfill specs drawn on the figure(1) and plot them to figure(1).

b) Design digital minimum order (lowest possible order) I) Butterworth, II) Chebyshev 1, III) and Elliptic **band-pass** filters that fulfill specs drawn on the figure(2) and plot them to figure(1).

c) What are the orders of each filters and what differences: butterworth, chebyshev 1 and elliptic filter have?

3 Filter Design with Matlabs filterDesigner

Learn the connection between the magnitude response $|H(e^{j\omega})|$ and positions of poles and zeros in z-plane by playing with **filterDesigner!** Open the GUI by typing **filterDesigner** in Matlab.

Start by specifying the sampling frequency (fT = 14000 Hz in the first task). Set Fpass < Fstop < Fs/2 and click "Design Filter" button on the bottom. Otherwise, the values do not matter as these choices will be removed later.

Click on the icon "Pole-Zero Editor" on the left-bottom corner. This gives you an interactive tool to see the connection between $|H(e^{j\omega})|$ and positions of poles and zeros.

You can alter top figure by clicking icons in the top row, e.g., "magnitude response", "phase response", "group delay", "impulse response", "filter coefficients". Choose "Magnitude Response". If the range of y-axis becomes too small or large, click another icon and then "Magnitude Response" again to fix it.

In the interactive part (bottom figure and buttons and editing tools on the left), first, clear all existing crosses and circles. This can be done by choosing "Delete Pole-Zero" icon and then clicking them one by one or by drawing a rectangle around them.

Now you can add, change, and remove poles (crosses) and zeros (circles) in z-plane in the bottom figure. Just click with mouse and drag. You can instantly see the shape of magnitude response in the top figure.

You probably want to have conjugate pairs in order to have a real-valued impulse response. A single real-valued pole or zero can be set exactly at x-axis by editing values in left. The order of the filter is the maximum of the number of poles and zeros. It can be seen in "Current Filter Information" on the left-top frame

Using filterDesigner's Pole-Zero Editor, that is, by setting a set of poles and zeros,

a) create a lowpass filter with the sampling frequency fs = 14000 Hz. Let the cut-off frequency (passband/stopband) be fc = 3000 Hz. Implement both FIR (only zeros) and IIR (both zeros and poles) filter.

b) create a bandstop filter with fs = 40000 where stopband is 7600 . . . 9400 Hz. Create a 8th order IIR.

Return figures from the both cases (pole-zero plot and magnitude response). Write down the filter coefficients of your filter $H(z) = B(z)/A(z) = \ldots$, which you can get by clicking the icon **[b,a]** in the top row.

If you want to filter a signal, export the filter by clicking **File → Export...**. The sampling frequency in filterDesigner should be chosen to be that of the signal.