ECE561 Double Notch Filter Project

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1. The problem

This project involves designing and implementing a narrow double notch filter to remove two undesired tones from an audio signal while leaving most of the signal untouched. In particular, we have a band-limited audio signal sampled sampling period of T=1/8192 seconds. This is a speech clip with a bandwidth of that of a phone signal. The digital signal can be found in the data file x.mat. The original analog signal is corrupted by the tones created by a phone when pressing the number 1. The tones created originally had continuous-time frequencies of f1 $f_1 = 697$ Hz and $f_2 = 1209$ Hz. You can listen to the file in MATLAB after loading it (using >>load x.mat), using the command >>sound(x,Fs). Here Fs =8192 is the sampling frequency.

You are going to process the digital signal to remove the tones while keeping as much of the signal intact as possible. A discrete double notch filter with two pairs of finite poles and two pairs of finite zeros must be designed to surgically eliminate these undesired tones from the signal (using the pole-zero placement filter design method). Once you know where you want your poles and zeros, specify *H(z)* and derive your system difference equation from *H(z)*. Implement the system and processing the data in the file x.mat. Use the filter() command or put the difference equation for the system in a loop. Convince yourself the system is performing correctly by listening to the output and inspecting the input and output spectrograms (specgram() or spectrogram( ) in MATLAB).

2. What to include in your report

Prepare a journal paper style report for this project using. You may use Word or LaTeX, but produce and submit a .pdf version of the paper (**only submit the .pdf** and do not compress or archive it).

You should begin with a title page. Then using **numbered** section headings include the following sections: 1. Introduction, 2. Filter Design, 3. Experimental Results, and 4. Conclusions. Include an Appendix section that includes your MATLAB code. In the Introduction, explain the problem in your own words. In the Filter Design section, include the following items:

- Calculations of the discrete notch frequencies, given that T=1/8192. Note that as a result of sampling, the tone frequencies become $\omega_k = 2\pi f_k T$ radians/sample in the discrete time signal. These are the discrete frequencies that we must eliminate with our filter.

- Include a pole/zero plot for your system. You can use fvtool() or zplane() to help.

- Choose exact pole-zero locations and specify the z-domain transfer function *H(z)*.

- Calculate the difference equation coefficients, based on *H(z)*. Include some key steps and the final the difference equation in the report. You may use MATLAB's poly() to help in going from the poles and zeros you specified to the polynomial version of *H(z)*.

- Plot the magnitude frequency response of your discrete-time system, $|H(\omega)|$, showing the two notches at the discrete frequencies specified. As with any plot, be sure to label the axes and include appropriate units.

All figures should have a numbered caption with brief description and ALSO be referred to in the body of the text. That is, introduce each figure by number and explain it in the section text (not just the caption). For example, in the Filter Design Section you might have a sentence like this: "Figure 2 shows a pole zero plot for the filter design. Note that ..." Also, all equations should be part of complete sentences with proper punctuation. That means you would put a period at the end of a sentence even it ends with an equation. Capitalize with word "figure" if referring to a specific one by number. Same for "equation" and "section", etc.

In the Experimental Results section, show and explain a spectrogram of the input (with the undesired tones) and a spectrogram of the processed signal (output of your notch filter). Use 1000 time bins in the specgram() function (i.e., use "specgram(x,1000,8192)"). The colormap for specgram is relative to the signal range. To make comparing the input and output easier. You can concatenate the input and output signals and do just one spectrogram like so: "specgram([x,y],1000,8192)". Note that x and y must be row vectors to combine them as shown. Just be sure to explain what you are showing. They key is that the undesired tones should show up in the input spectrogram and be greatly reduced in the output.

Include all MATLAB code used for the project in the appendix. Be sure the code is clear, concise, and well commented. It should run without error if copied and pasted into the command window.

Make sure to include all of the results listed above. The body of your text should be contiguous (approximately 1-2 pages of text). Embed figures or include them at the end. The body of the text should refer to each figure by number and explain it clearly. See the notation convention page regarding the use of variables in your equations. See my document "Technical Writing.pdf" for a list of do's and don'ts to help with your technical writing.

Each student must do this project individually (no group efforts), and the work must be uniquely your own. Any related conversations must be general concepts only. No showing or sharing code in any way! If you need help, see me.