Homework Set 4

Due: Thursday Nov. 20

Instructions:

1. You are welcome to work together on homework problems, but you should each turn your own work, for which you are individually responsible.

2. There will be an additional problem for graduate students, to be assigned in the near future.

3. The Proakis-Manolakis book is designated by **PM**, and the Ingle-Proakis book by **IP**.

Reading covered by this homework assignment:

1. **PM**: Chapter 8, sections 8.1 and 8.2
2. **IP**: Chapter 7.

Problems:

1. In class we stated that to get a linear phase response you need to use an FIR filter. There is are some ways around this, but with a certain restriction. Do problem 4.100 in the PM book (on page 391). Can you see any types of signal processing scenarios when this method would not be useable ?

2. Problem 8.8 from PM, page 727.

and the following problem:

**PROBLEM P1.**

In this problem you will design two sets of FIR filters to filter the same ECG signal which I used for a demonstration of linear phase effects in class. One set of filters will try to attenuate the power line noise in the signal by designing low-pass filters. The other set will use notch (in other words, narrow-band band-stop) filters.

The signal is available from the course web site as a Matlab .mat file. The sampling rate for the signal was 1000 samples/second.

For each filter design technique listed below, you should design both a low-pass and a notch filter. The low-pass filters should try to achieve an attenuation of at least 40dB at frequencies above 55 Hz while disturbing the signal as little as possible at frequencies below 50 Hz. The notch filters should try to have attenuation of at least 40dB between 55 and 65 Hz while disturbing the signal as little as possible at frequencies below 50 Hz and above 70 Hz. You will need to design what you think are reasonable specifications to meet this requirement. If some types of filters are not able to reach these specifications, just come as close as you can without designing any filters over 250 samples in length.

The goals are to:
1. design as short a filter as you can (in terms of the number of coefficients) to meet the specifications, and

2. distort the shape of the ECG signal as little as possible while removing the 60 Hz noise

The types of filter design techniques you should use and test are

1. a window design using a Hamming window,
2. a window design using a Kaiser window (you need to choose the $\beta$ parameter)
3. a frequency-sampling filter design, and
4. an equiripple filter using the \texttt{remez} algorithm.

This means that you need to design 8 filters: 4 types of filter designs by 2 types of filters (low-pass and notch). If you want to really play a little, also try designing a filter that places notches at 60, 180, and 240 Hz.

What you need to hand in:

1. Pole-zero plots of all 8 filter designs. Use the Matlab command \texttt{zplane} to plot them and use the \texttt{subplot} command to put many of these on one page. \textit{You should have at most two pages of pole-zero plots, one is probably sufficient.}

2. Graphs of your filtered signals on top of the original. You can put multiple results on the same graph if you use different line types and a clear legend on the graph (see \texttt{help legend} in Matlab). Make sure however that your various lines are visible in a black-and-white printout (unless you choose to hand in color plots, certainly not a requirement). You should be able to have no more than 4 graphs of these results (for example, one for each type of filter design, with both low-passed and notched on the same graph on top of the original signal). It is your responsibility to make sure your figures are properly titled, etc., so that we can \textit{easily} tell what results each graph represents.

3. Graphs of the appropriate detail of the frequency response of your various filters to ensure that they meet the specifications. Again, please try to minimize the number of pages of plots by putting more than one curve on each graph and making liberal use of the \texttt{subplot} command. However, do include graphs which zoom in on particular frequency and amplitude ranges as needed to verify the specifications.

4. A table or list of the Matlab commands you actually used for your final design for each filter. Note that this requires only 8 lines of text for the filter designs, plus in some cases another line which calls a Matlab routine to help determine the needed filter order! If you had to use a different filter order than that suggested by Matlab, make sure this is clear in this table or list. The idea is for us to be able to verify your designs by simply typing your commands in Matlab if we should wish to do so.

5. Most important: a discussion of the results. What is the tradeoff in terms of filter length vs. signal distortion between low-pass and notch filters? What is the tradeoff in terms of performance vs. filter length for the various types of filters? Are there any design methods you simply could not get to perform well for this problem?