2.161 Signal Processing: Continuous and Discrete
Fall 2008

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING

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# Problem Set 3: Analog Filter design

**Assigned:** Sept. 25, 2008 **Due:** Oct. 2, 2008

**Problem 1:** Consider the following two filter specifications:

| | Filter A | Filter B |
|---|---|---|
| Passband | 0-10 kHz | 0-10 kHz |
| Minimum power gain at $\Omega_c$ | 0.5 | 0.5 |
| Start of stop-band | 15 kHz | 11.75 kHz |
| Maximum power gain at $\Omega_r$ | 0.1 | 0.1 |

**(a)** What is the order of filter A if a Butterworth design is used.

**(b)** What is the order of filter A if a Chebyshev design is used.

**(c)** What is the order of filter B if a Butterworth design is used.

**(d)** What is the order of filter B if a Chebyshev design is used.

**(e)** Plot the power gain function $|H(j\Omega)|^2$ of the Butterworth filter A using linear scales. (Use Matlab - don't do it by hand.) Use the plot to show that the filter meets the specifications.

**(f)** Use Matlab to design a Chebyshev Type 2 filter based on specifications for filter B. Then use Matlab to convert this prototype design to a band-pass filter with a passband of 5-15 kHz. Plot the Bode plots for the bandpass filter.

**Problem 2:** Design a high-pass filter that will attenuate all components below 20 Hz by at least 40 dB, and pass all components above 50 Hz with a maximum attenuation of 3 dB. (Feel free to use Matlab)

**Problem 3:** Another way to design a high-pass filter is to design a unity gain low-pass filter $H_{lp}(j\Omega)$ and then create the high-pass filter as

$$H_{hp}(j(\Omega) = 1 - H_{lp}(j(\Omega)$$

**(a)** Compare the zeros of a high-pass filter created by this method with those created using the transformation method described in the class handout by using a third order prototype low-pass filter.

**(b)** Comment on the attenuation rate as $\Omega \to 0$ for high-pass filters developed by each method.

**(c)** Comment on the phase response of each filter as $\Omega \to 0$.

**(d)** Is the high frequency gain the same in each high-pass filter?

**Problem 4:** An experimental set-up transmits three measurements over a single cable by encoding the information as the amplitude of three sinusoidal signals at 30Hz, 60 Hz, and 90 Hz. Design a filter that will select out the 60 Hz component and attenuate the other two by at least 40 dB. Submit frequency response plots for your filter. (I realize that this is a very "loose" specification - but that's the way it is in the real world!)