MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING

2.161 Signal Processing - Continuous and Discrete
Spring Term 2005

Problem Set 2: Analog Filter design

Assigned: Feb. 16, 2005 **Due:** Feb. 23, 2005

Problem 1: Consider the following two filter specifications:

	Filter A	Filter B
Passband	0-10 kHz	0-10 kHz
Minimum power gain at ω_c	0.5	0.5
Start of stop-band	15 kHz	11.75 kHz
Maximum power gain at ω_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. (Use Matlab - don't do it by hand.)

(f) Use Matlab to design a Chebyshev 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.

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.

Problem 3: Use Matlab to design sixth-order low-pass filters with a -3 dB cut-off frequency of 50 rad/sec using 1) Butterworth, 2) Chebyshev Type 2, 3) Bessel, and 4) elliptic designs.

(a) Plot the power gain functions of each on a single plot, and comment on the nature of the transition band off each filter type.

(b) Plot the phase response of each filter (on a linear scale) and compare the Bessel filter with the others.

(c) Plot the step response of each filter (on a single plot). Which filter would you recommend if the waveform to be filtered was "pulse-like".

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!)

Some useful Matlab routines for this assignment:

IIR filter order estimation.

buttord - Butterworth filter order estimation.
cheb1ord - Chebyshev Type I filter order estimation.
cheb2ord - Chebyshev Type II filter order estimation.
ellipord - Elliptic filter order estimation.

Analog lowpass filter prototypes.

besselap - Bessel filter prototype.
buttap - Butterworth filter prototype.
cheb1ap - Chebyshev Type I filter prototype (passband ripple).
cheb2ap - Chebyshev Type II filter prototype (stopband ripple).
ellipap - Elliptic filter prototype.

Analog filter design.

besself - Bessel analog filter design.
butter - Butterworth filter design.
cheby1 - Chebyshev Type I filter design.
cheby2 - Chebyshev Type II filter design.
ellip - Elliptic filter design.

Analog filter transformation.

lp2bp - Lowpass to bandpass analog filter transformation.
lp2bs - Lowpass to bandstop analog filter transformation.
lp2hp - Lowpass to highpass analog filter transformation.
lp2lp - Lowpass to lowpass analog filter transformation.

Linear system transformations.

zp2sos - Zero-pole to second-order sections conversion.
zp2ss - Zero-pole to state-space conversion.
zp2tf - Zero-pole to transfer function conversion.

Frequency Response

bode - Bode magnitude and phase plots
freqresp - Compute frequency response (complex).