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ELEC 5410
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Project #6: IIR Filter Design

1. **Analyze a 5th order LP IIR filter**

Use the MATLAB command butter to design a 5th-order lowpass IIR filter with a passband cutoff of 0.15π. Plot the magnitude and phase frequency responses using `freqz`. *Plot the pole and zero location diagram using* `zplane`. *Plot the significant part of the impulse response using filter to give around 25 output values. (Think of the filter function with the coefficients as the implementation of a system. What input to the system must you use to get the impulse response out?) Discuss briefly how the magnitude response makes sense from the pole-zero plot.*
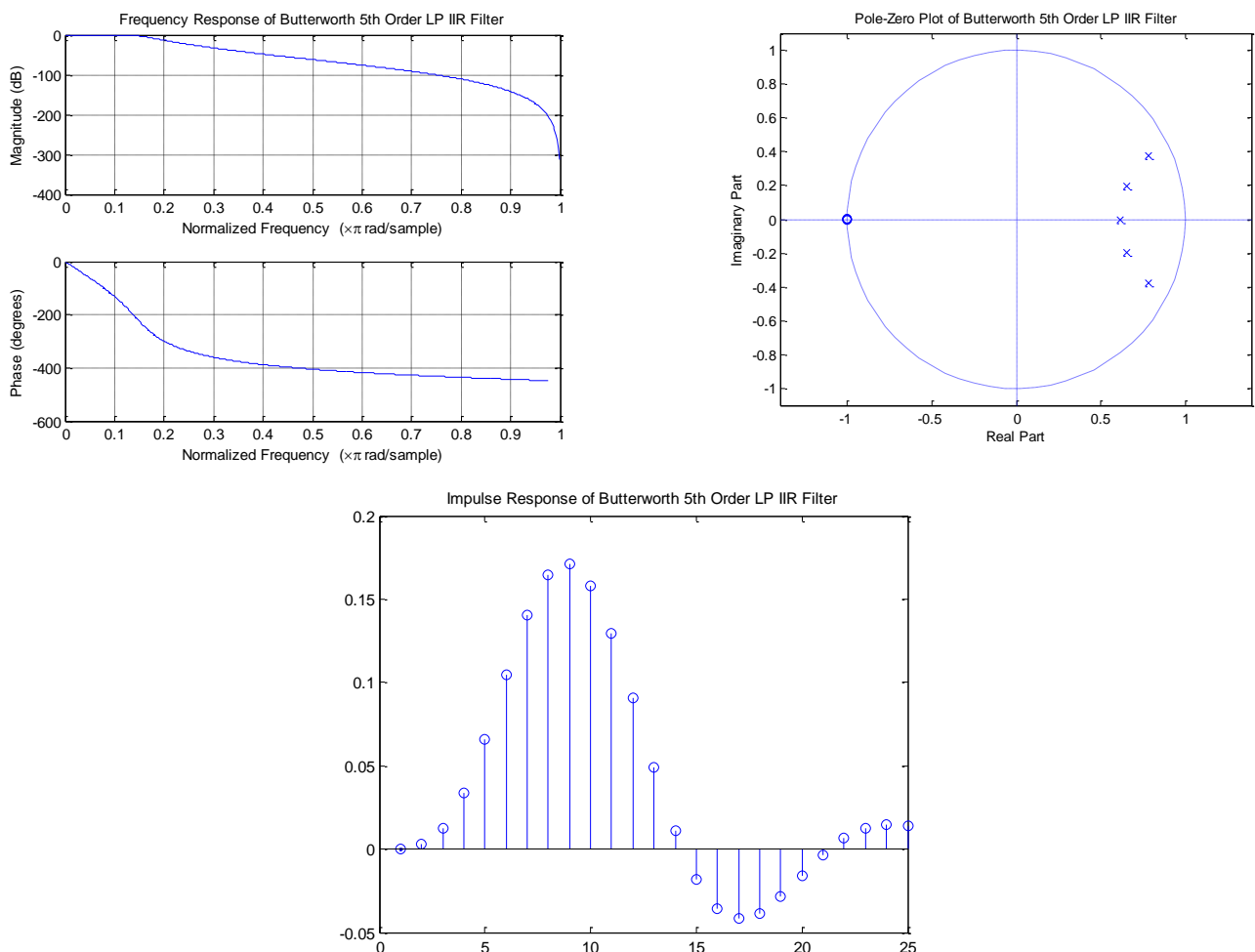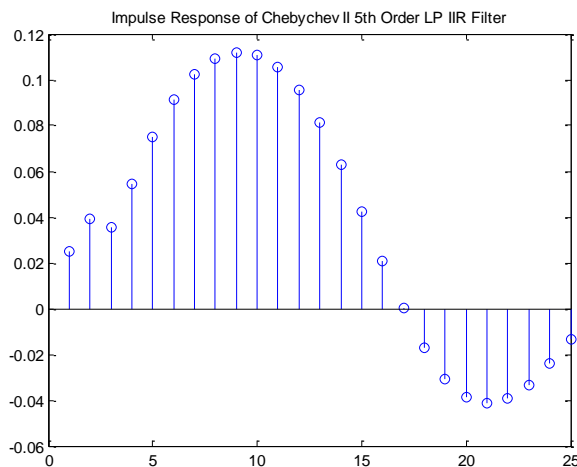

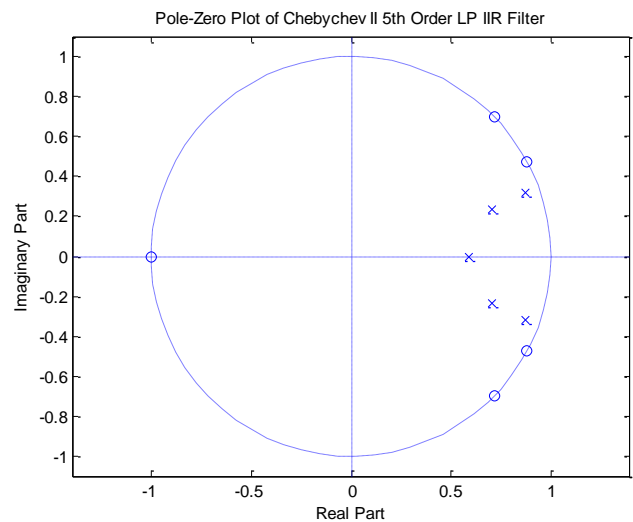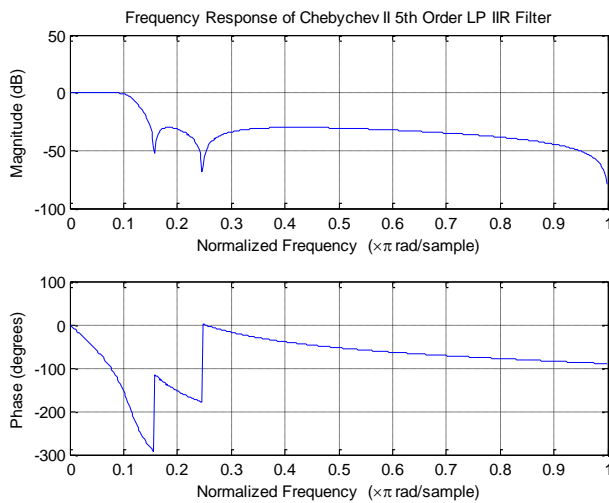The magnitude response makes sense if one takes into account the pole-zero plot. Starting at 0π and then traversing counterclockwise on the pole-zero plot, by observing the magnitude response, we see that the maximum magnitude should occur at 0π radians. Then at about 3π/20 radians or (0.15π rad), the magnitude will start decreasing. Finally at π radians, the magnitude will be at its lowest point.

Use the MATLAB command `cheby1` *to design a 5th-order lowpass IIR filter with a passband cutoff of*

0.15π and a passband ripple of 0.5 dB. Plot the magnitude and the phase frequency responses, as well as

the impulse response. Plot the pole and zero location diagram. Discuss briefly how the magnitude

response makes sense from the pole-zero plot.
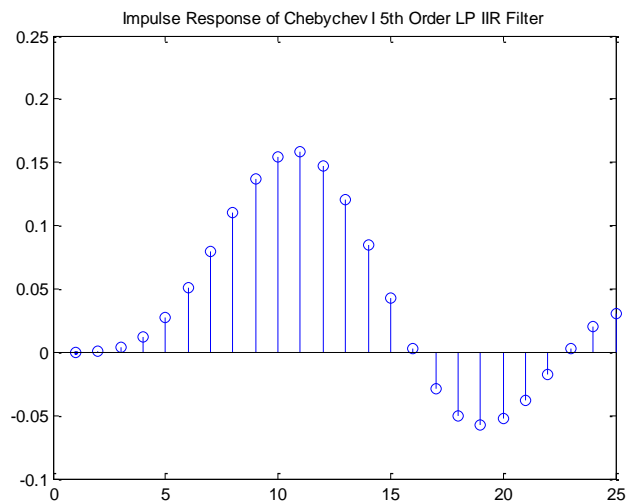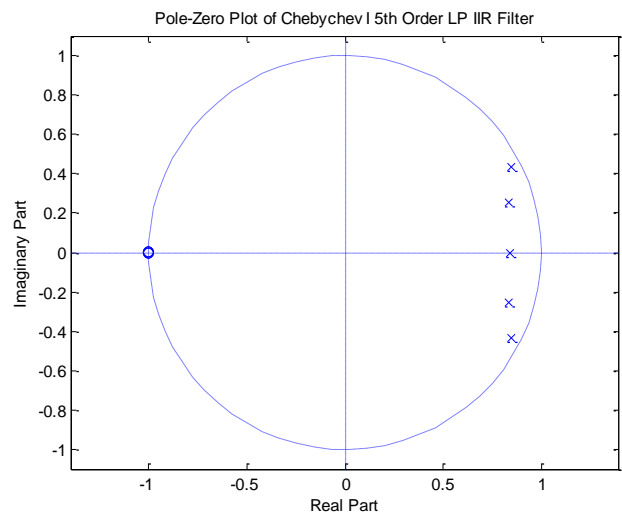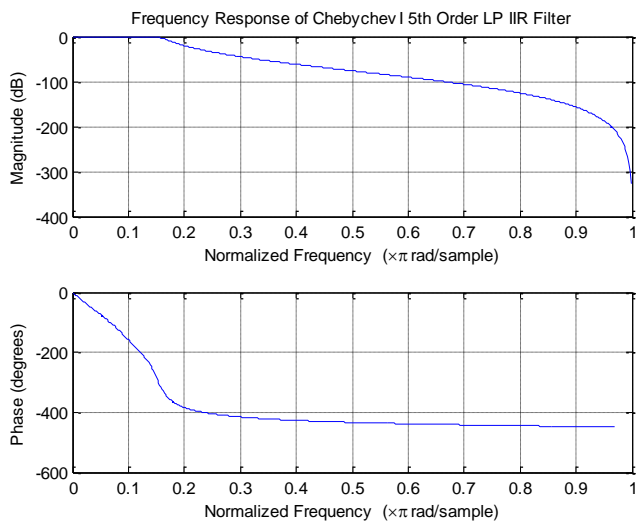
The magnitude response makes sense if one takes into account the pole-zero plot. Starting at 0 then

traversing counterclockwise, by observing the magnitude response, we see that the maximum

magnitude should occur at 0π radians. Then at about 3π/20 radians, the magnitude will start

decreasing. Also notice that here, the frequency response drops faster than the Butterworth (below -

100dB at 0.65π here and 0.75π on the previous filter) due to the poles being closer to 0π. Finally at π

radians, the magnitude will be at its lowest point.

Use the MATLAB command `cheby2` *to design a 5th-order lowpass IIR filter with a passband cutoff of*

0.15π and a maximum stopband ripple 30 dB below the passband response. (Hint: You may need to use

`cheb2ord` *in a trial-and-error fashion to meet the stopband requirement and the passband cutoff. Note*

that `cheb2ord` *returns the stopband frequency that must be used in* `cheby2`*.) Plot the magnitude and*

the phase frequency responses, as well as the impulse response. Plot the pole and zero location diagram.

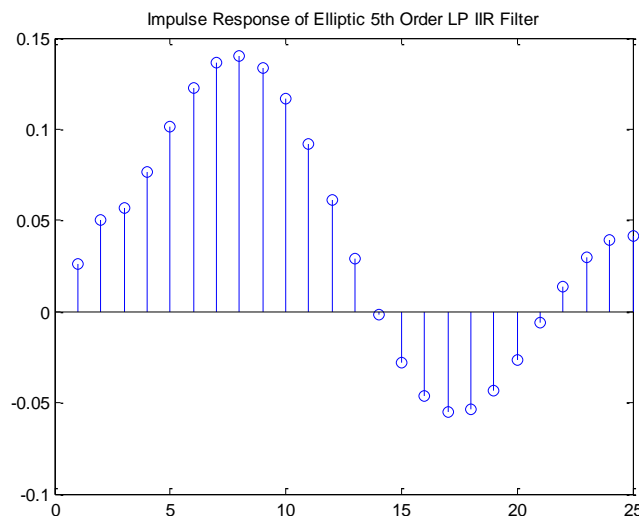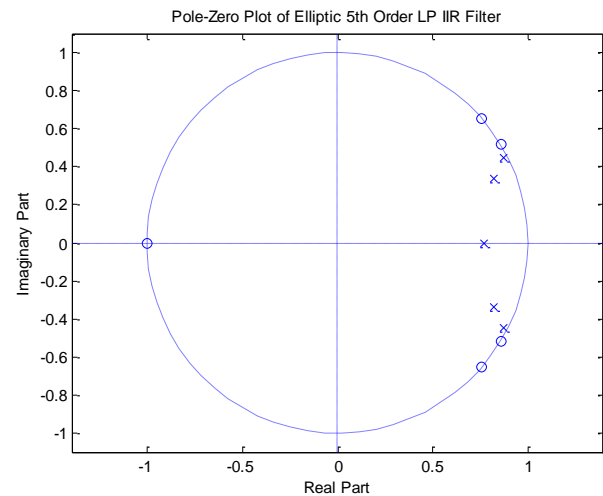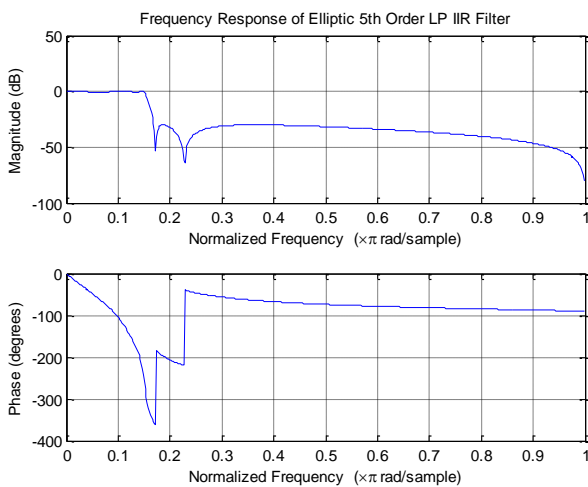*Discuss briefly how the magnitude response makes sense from the pole-zero plot.*

The magnitude response makes sense if one takes into account the pole-zero plot. Starting at 0π then

traversing counterclockwise, by observing the magnitude response, we see that the maximum

magnitude should occur at 0π radians. Then at about 3π/20 radians or, the magnitude will start

decreasing to a dip at about π/2 rad and then again at about π/4 rad corresponding to the locations of

the first two poles. Finally at π radians, the magnitude will decrease to a dip once again at the last pole

location.

Use the MATLAB command `ellip` to design a 5th-order lowpass IIR filter with a passband cutoff of 0.15π, a passband ripple of 0.5 dB, and a maximum stopband ripple 30 dB below the passband response. Plot the magnitude and the phase frequency responses, as well as the impulse response. Plot the pole and zero location diagram. Discuss briefly how the magnitude response makes sense from the pole-zero plot.

The magnitude response makes sense if one takes into account the pole-zero plot. Starting at 0π then traversing counterclockwise, by observing the magnitude response, we see that the maximum magnitude should occur at 0π radians. Then at about 3π/20 radians or (0.15π rad), the magnitude will start decreasing to a dip at about 0.17π rad and then again at about 0.23π rad corresponding to the locations of the first two poles. Finally at π radians, the magnitude will decrease to a dip once again at the last pole location.

In what way(s) can the performance of these filters be compared since their specifications are not the same?

Since the filter specifications are different, we can observe the impulse responses of each filter. We can evaluate a filter's performance based off of how continuous or smooth the sinc function is for each impulse response. The smoother the sinc function, the better the filter.

Do the impulse responses approximate the impulse response of an ideal lowpass filter? Explain.

Yes, the impulse response of an ideal lowpass filter is a sinc function and the impulse responses of my filters are portions of a sinc function.

2. **Compare the order of the four designs**

The filtering specifications for a particular job have a passband ripple of 0.5 dB, passband edge of 0.15π, stopband edge of 0.6π, and a stopband ripple below 30 dB. What order Butterworth, Chebyshev, Chebyshev II, and elliptic filters will meet these requirements? Use the `buttord`*,* `cheb1ord`*,* `cheb2ord`*, and* `ellipord` *commands. Why does the elliptic filter have the lowest order?*

Butterworth requires a **3rd order** filter. Chebyshev requires a **3rd order** filter. Chebyshev II requires a **3rd order** filter. Elliptic requires a **2nd order** filter. The elliptic filter has the lowest order because it can spread the error along the passband and stopband ripple. The other filters have either a passband, stopband, or no band to spread errors across.

3. **Design a lowpass filter for an audio signal**

Read in the audio file (right-click the link) ftp://ftp.eng.auburn.edu/pub/sjreeves/classes/doorbell.au

using auread. Using the fft function, determine the frequencies of the upper and lower tone of the

doorbell. Design a filter such that the lower tone is attenuated no more than 3 dB while the upper tone is

attenuated at least 15 dB. Design all four types of filter. Listen to the filtered signal for each case.

Compare the results for each of the filters in terms of sound and filter order.

The upper tone frequency is about 712.4 Hz and the lower tone frequency is about 567.4 Hz.

Butterworth requires an **8th order** filter. Chebyshev requires a **4th order** filter. Chebyshev II requires a **4th**

order filter. Elliptic requires a **3rd order** filter. The Butterworth has a muffled sound, but little distortion.

This is due no error spread across the passband or stopband ripple that the other filters used. The

Chebyshev has a less muffled sound compared to the Butterworth, but has some distortion in the lower

frequencies. This is due to the error spread across the passband ripple. The Chebyshev II also has a less

muffled sound than Butterworth but has some distortion across the higher frequencies. This is due to

the error spread across the stopband ripple. The elliptic filter sounds the loudest but has the most

distortion there. This is due to the error spread across the passband and the stopband ripple.