J. Reilly, Nov 2015.

CoE 4TL4 Lab 3
IIR filter implementation and Group Delay Equalization on the TMS 320 DSP processor

This lab is structured similarly to Lab 2. Your report is due the last day of classes, Dec 8, 2015. Work in pairs and submit one report per pair. Submit in the CoE4TL4 slot in the ITB copy room. Late penalty = 10% per day, up to a maximum of 50%.

1 Overview

This lab is an exercise in designing a group delay equalizer for an IIR filter, implemented on the DSP processors.

Check out the command "grpdelay" in Matlab. You can use it to calculate group delay from a set of transfer function coefficients.

The matlab program "butter" gives you the [b,a] coefficients for a specified Butterworth filter response.

Note that when designing IIR sections, the [a] coefficients that appear in the DSP program are the *negatives* of those that appear in the corresponding difference equation.

Recall from class that group delay can be equalized using IIR sections. There are two types of equalizer section; type I has its delay peak at DC (0 Hz) and is specified in terms of only one parameter, which is the position of the zero (pole) on the real axis. Type II has a delay peak at some non-zero frequency f_o and is specified in terms of 2 parameters; f_o and the radius of the zero (pole) pair. The radius (i.e., closeness to the unit circle) of the pole-zero pair(s) determines the "peakiness" of the delay peak– a pole/zero pair nearer the unit circle produces a taller, narrower delay response.

This lab will be much easier if you write a matlab program that inputs the delay equalizer parameter(s), calculates the group delay response of the respective section, and then adds it to the delay of the IIR Butterworth filter which you have implemented. Plot the total group delay of the filter plus the equalizer sections. You can then adjust the parameters to get the overall delay response as flat as possible, inside a specified band.

2 Procedure

Here are a few suggestions. You are welcome to try out any additional experiments you can think of.

1. Design e.g., a 3rd-order Butterworth IIR filter $H(e^{j2\pi f})$ (or any other filter structure of your choosing) and implement it on the DSP processors. You can choose a low-pass, band-pass or high-pass as you see fit. Verify the magnitude and phase responses of your filter against the theoretical values.

   Try looking at group delay characteristics of Chebyshev or elliptic function filters. How do they compare with the Butterworth GD response, for the same order? (This is not required for your writeup, but you are encouraged to try it, since you will find it enlightening).

   Using Matlab, construct a windowed sinc function whose bandwidth is just below the cutoff frequency of your filter. Thus, if the filter were distortionless, you would expect a sinc function to appear at the output. Run the sinc function through your equalized and unequalized filters, using the Matlab command "filter". Comment on the results.

2. Tyler has placed a sample IIR DSP program on the Y-drive for your reference. This program consists of a low-pass Butterworth filter implementation followed by a group delay equalizer section. The coefficients of the delay section of this sample program are not optimal, so your job is to design a set of coefficients that gives improved performance.

3. Design two group delay equalizer sections (one type I, with the bump at 0 Hz, and the other type II, which has the bump at some specified frequency f_o). It is likely that f_o will be just outside the passband of the filter. Design the delay sections using Matlab, so that when they are cascaded with the Butterworth filter section, the overall group delay response is as flat as possible.

4. It is also possible to design an FIR filter structure that can be used as an appropriate delay equalizer. Extra brownie points are definitely to be awarded for anyone who wants to try this option!

5. If you display input and output (sinusoidal) waveforms simultaneously on the scope, you will see the two waveforms sliding by each other as the frequency is varied. Use this idea to assess the flatness of the group delay characteristic of the overall structure.

6. Compare the impulse responses of the unequalized filter alone and of the overall structure. Does the latter look more like a sinc function? Explain.

3 Write-up

Briefly explain why constant group delay is desirable. Show on a graph that the measured magnitude and phase responses of the unequalized filter agree with your theoretical predictions. Draw your equalized filter block diagram showing all coefficient values. Show graphs of the final magnitude and group delay responses.

Also comment on the differences between the equalized and unequalized outputs due to the sinc function input, and also explain why the impulse response of the equalized filter looks more like a sinc than the unequalized impulse response.

Do FIR filters require group delay equalization? Explain.