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Lab 4A: FIR Filter Design and Simulation

**Questions**

1. *The first thing that should be placed in the script is generation of coefficients for each of the two filters described above.*
   1. See filter1.m and filter2.m for the code generated from running the FDATool to create these filters.
2. *Your script, when run, should also write a “.coe” file for each filter in the format shown in class.* 
   1. .coe file generation is included in the main code of the assignment, as shown in the lecture slides.



*Figure 1: Magnitude response of filter 1.*



*Figure 2: Magnitude response of filter 2.*

Summing the coefficients for both of these filters, they are close to unity gain, but not perfect. Filter 1 has a sum of 1.0821, and filter 2 has a sum of 0.9542, showing that both filters have near 0 dB gain. Thus, the first filter has about 0.69 dB of gain and the second has -0.41 dB, meaning the two in combo have a total of 0.28 dB. Due to the ripple in the filter, this small amount of gain is expected.

1. *Plot both the input and the output data for this final setup. Label the plot : “Reponse to signal in passband”*
   1. Figures 3 and 4 show the response to a signal at 2kHz, as well as the power spectrum for the signal. Note the relatively minimal gain as described above.



*Figure 3: Plot of response to 2 kHz input signal (signal in passband).*

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*Figure 4: Power spectrum of 2kHz input.*

1. *Plot both the input and output data for this case and label the plot : “Response to two-tone input”*



*Figure 5: Plot of response to summed 2 and 30 kHz two-tone input.*



*Figure 6: Power spectrum of 2 kHz and 30 kHz two-tone input. 30 kHz signal is almost entirely removed besides some residual ripple.*

1. *Run this through your filter and plot the input and output data like before, labelling the plot: “transition band experiment”. Plot the resultant spectrum. What was the attenuation of the signal at the frequency you chose? Did it match what was expected from the original design?* 
   1. As shown in figure 8, there is roughly 18.7 dB of attenuation between the passband signal and the transition band signal at 25 kHz, which closely aligns with the expected response shown in figure 9.



*Figure 7: Plot of two-tone input at 2kHz and 25kHz.*



*Figure 8: Power spectrum of 2 kHz and 25 kHz two-tone input.*

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*Figure 9: Plot of filter 2’s magnitude response, showing the expected attenuation at roughly 25 kHz is just below 18.8 dB.*

1. *+10 pts Extra Credit: In class, we talked about how different numbers of bits used to represent the coefficients could affect the performance of the filter. Scaling the coefficients to use more bits (more precision) made the end-result of the FPGA fixed point implementation more closely match that of what you originally designed. Illustrate this by doing the same experiments where your second filter uses only 3 bits used for coefficients. Show either the “Transition Band Experiment” plot or the “Response to Two-Tone Input” plot and compare it to the one you made originally*
2. Limiting the coeff\_width for filter 2 to 3 bits has little to no effect on the output, which makes sense given that the coefficients used are all floating point and less than zero, such that they sum to ~1. If coefficients were stored with a scaling factor already applied, then changing this width would affect the output.



*Figure 10: Output of transition band experiment given coeff\_width set to 3.*

* 1. However, given our approach with scaling done based on the number of fractional bits, limiting coeff\_fract\_width to 3 is more telling. In figure 11, we see that the output of filter 2 is now all zero, which makes sense given that the coefficients are all around 10-3 or smaller. Thus, only 3 bits of fractional width does not provide the scaling necessary for these coefficients to be greater than zero when implemented and the filter output is entirely zero.



*Figure 11: Output of transition band experiment given coeff\_fract\_width set to 3.*