Filter Design
Multi-Rate Systems

Introduction

In this lab you will be using the Filter Compiler block to generate optimized filters for the Virtex4 architecture.

Note: There is a completed example in lab7/solutions folder

Objectives

After completing this lab, you will be able to:

• How to use the FIR Compiler to generate various filter implementations
• How to use the Mathworks FDA tool to generate and set the filter coefficients

Lab Setup

The following software is required to be installed on your system to successfully complete this lab

1. System Generator 8.2
2. ISE 8.2.01
3. ISE CORE Generator IP Update 1
4. MATLAB / Simulink R2006a
5. Simulink Signal Processing Blockset
Procedure

1. Launch the MATLAB program and once invoked change directory to:
   C:\SysGen_Training_Labs\lab7
2. Open up the Simulink diagram “lab7.mdl” shown in Figure 1.

![Figure 1 – Simulink Filter Model](image1)

3. Double click on the FDATool icon. FDATool is a graphical filter design program provided by
   The Mathworks. It can be used to generate filter models for both MATLAB and Simulink and, in
   this case, is integrated into the actual Simulink filter model. This has been configured to generate
   coefficients for a 16 tap, filter FIR filter.

![Figure 2 – The Mathworks FDATool](image2)

4. Click on “Design Filter” to generate the filter specified by the FDATool parameters.
5. Close FDATool and simulate the filter design in Simulink. Set the Simulation time to “inf”. You
   should see the Spectrum Scope display a similar waveform to what was displayed in the
   FDATool.
6. Double-click on the Spectrum Scope and view the properties dialog box. Note that both the
   “Buffer input” and “Specify FFT length” options are checked. This is necessary to correctly
   analyze the power spectral density of the streaming signal. Something to note of you are not
   familiar with the Spectrum Scope sink block.
7. Open up the FDATool Properties dialog box again and reconfigure the filter to be a bandpass filter with the following parameters
   - **Type = Bandpass**
   - **Specify Order = 31**
   - **Units = KHz**
   - **Sampling Frequency = 3000 Khz**
   - **Fstop 1 = 540 Khz**
   - **Fpass1 = 600 Khz**
   - **Fpass2 = 900 Khz**
   - **Fstop2 = 960 Khz**
   - **Attenuation on both sides of the passband = 54 db**
   - **Pass band ripple = 1**

![Figure 3 – FDATool Settings for Bandpass Filter](image)

8. Click on the “Design Filter” button to generate the new filter. The FDATool should now display the following waveform. Note that this will be a 32 tap filter.

![Figure 4 – Bandpass Filter Magnitude Response](image)

The desired filter response has been achieved. The next step is to save the coefficients so they can be used in the hardware implementation.

9. Using the FDATool toolbar execute the pulldown command “File -> Export”. Export the coefficients to the MATLAB workspace. Use the default variable name “Num”
The Coefficients have been saved, now we create the hardware version of this filter.

10. Create an equivalent FIR filter representation using the FIR Compiler 2.0 block from the Xilinx DSP blockset as shown in Figure 6.

11. Double click on the FIR Compiler block and edit the coefficient vector field – use the MATLAB workspace variable name “Num”, which was the variable name used when the coefficients were exported to the MATLAB workspace from the FDATool.

12. Simulate the design and compare the results from the two spectrum scopes. There will be fixed-point effects but the results should be very similar.

13. What are the min and max values for the MATLAB vector “Num”?  
   Min value:  
   Max value: 
14. Double click on the FIR Compiler and adjust the coefficient quantization to the minimum number of bits required to maintain reasonable results.

15. Notice that the FIR Compiler output is outputting a large number of bits. No bit truncation is being performed by the FIR Compiler. Insert a Convert Block to trim the output bits. What is the minimal number of bits that are required to maintain a close match to the golden reference design?

16. Using the System Generator Token, generate a bitstream for this design and record the following results

<table>
<thead>
<tr>
<th># of Slices</th>
<th># of DSP48s</th>
<th># of registers</th>
<th>Min clock period</th>
</tr>
</thead>
</table>

By default the FIR Compiler generates a high-performance unrolled FIR filter structure. We could select to implement a “rolled” FIR structure that uses a single DSP48 resources. This is done through the “over sampling” field. The FIR Compiler has already optimized the FIR filter for even coefficient symmetry and in the unrolled form is only using half the multipliers an unoptimized filter would require. It will only allow oversampling up to the number of optimized multipliers which in this case is 16.

17. Set the Oversampling field in the FIR Compiler to 16.

18. Regenerate the bit stream and re-record the results

<table>
<thead>
<tr>
<th># of Slices</th>
<th># of DSP48s</th>
<th># of registers</th>
<th>Min clock period</th>
</tr>
</thead>
</table>

19. Add the Xilinx version of the FDATool to the diagram from the Xilinx Blockset/Index library. Setup the parameters to the same values set in Step 8 and then click on “design filter”. The problem with using The Mathworks FDATool is that each time the Simulink model is opened the filter coefficients must be re-exported to the MATLAB workspace. The Xilinx version of the FDATool can be polled by the FIR compiler for the filter coefficients automatically eliminating the need to re-export to the workspace each time

![Diagram](image)

Figure 8 – Filter Design using FDATool
20. Double-click on the FIR Compiler block and change the “Coefficients vector” field to “xlfda_numerator('FDATool'). This is a System Generator function that will call the Xilinx FDATool and return the filter coefficients of the designed filter.

![Figure 9 – Specifying Filter Coefficients from the Xilinx FDA Tool](image)

21. Close the diagram and re-open it and run the simulation. The filter should display the correct waveform.

End of Filter Design Lab