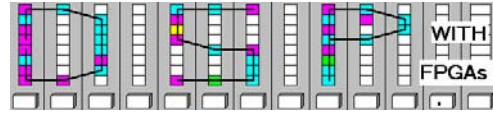


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LABORATORY IIR Filter



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LAB IIR: INTRODUCTION TO IIR FILTER (10 points)

In this lab you will be introduced to the design for IIR filters. Filters are one of the most important DSP object and are used most of the time to select a specific frequency band of the signal. IIR filter are particular interest because with just a few coefficient relatively sharp transition bands can be realized. In the **pre-lab** you will compute with "pencil-and-paper" the results you later expect in your design implementation. In the **design part** you will design a first order IIR filter and a third order system direct form filter.

Lab Objectives

After completing this lab you should be able to

- Design and simulate an first order IIR filter
- Determine magnitude, phase and pole zero diagram of IIR filters
- Design a 3. order elliptic low pass filters
- Compare IIR and FIR design parameter

Pre-lab (3 points)

1. For a first order IIR filter with a transfer function $F(z)=b/(1+az^{-1})$ determine a and b in such a way that: $|F(\omega=0)|=1$ and $|F(\omega=\pi/2)|=0.5$, i.e., the filter works like a halfband filter.

Forward gain $b =$ _____.

Feedback gain $a =$ _____.

Hint: The quadratic equation $x^2+px+q=0$ has the solution $x_{1,2}=p/2\pm\sqrt{(p/2)^2-q}$.

2. Determine the transfer function for the following system:

$F(z)=Y(z)/X(z)=$ _____

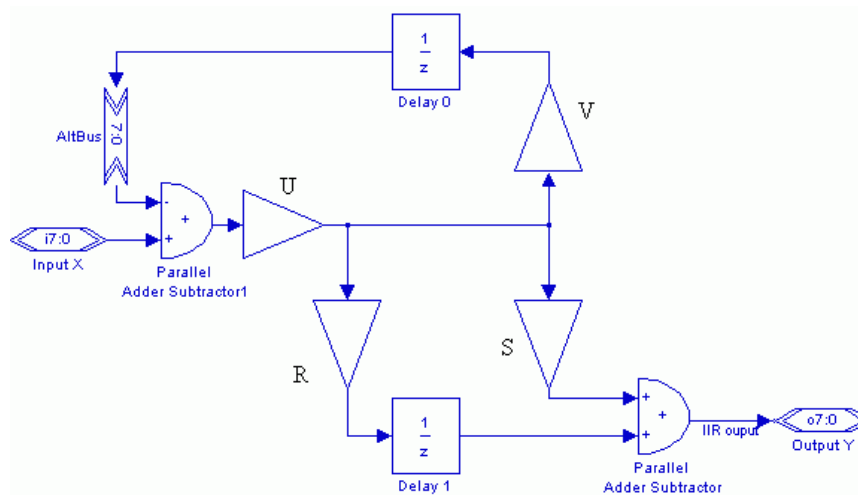
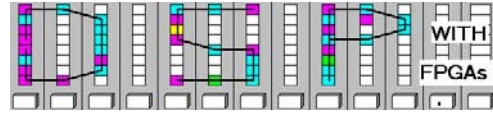


Figure 1

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**LABORATORY
IIR Filter**



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- a. Determine zero(s) and pole(s) of the system depending on the coefficients U,V,R,S.

Zeros at = _____

Poles at = _____

3. For the filter from Figure 1 determine the coefficient U,V,R,S, in such a way that the transfer function $F(z)$ from part 1 is realized.

U= _____

V= _____

R= _____

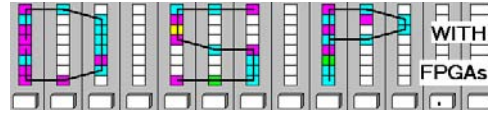
S= _____

4. Compare the FIR and IIR filters regarding the following properties

	FIR filter	IIR filter
Filter length		
Linear filter		
Coefficient design method		
Pole/zero locations		
Coefficient sensitivity to quantization		

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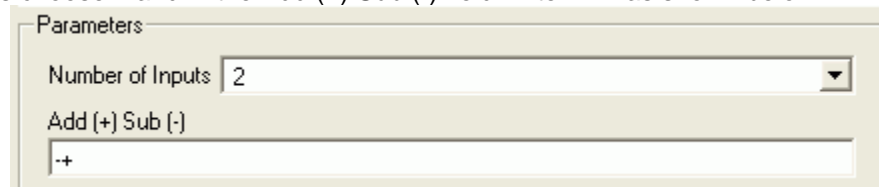


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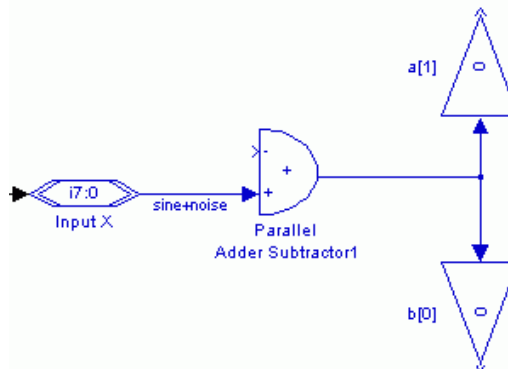
4. Complete the design:

- a. Modify the coefficient values using the data you computed in the pre-lab such that $|F(\omega=0)|=1$ and $|F(\omega=\pi/2)|=0.5$. This can be done by double-clicking in the Gain blocks and in the Parameter window changing the Gain Value.
- a. Copy the adder and delay elements from the Altera library according to Figure 1 from the pre-lab. Follow the steps described below to complete the design:

- Click on the **Library Browser** icon  and select the **Altera DSP Builder** directory.
- Under the **Arithmetic** subdirectory, choose the **Parallel Adder Subtractor** and drag it into your workspace.
- Double click on the **Parallel Adder Subtractor** to change its parameters. For Number of Inputs choose 2 and in the Add (+) Sub (-) field write in -+ as shown below:



- Connect the **Input** block to the + input of the **Parallel Adder Subtractor**.
- Place a wire from the output of the **Parallel Adder Subtractor** to the input of **Gain** block a[1], then connect the input of **Gain** block b[0] to this wire as shown below:

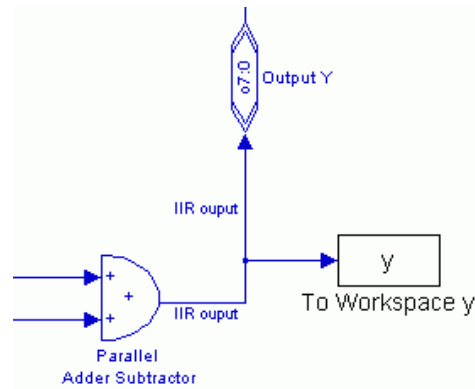
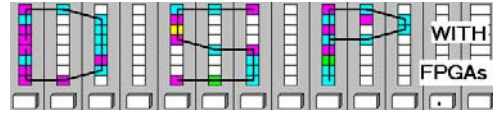


- Under the **IO & Bus** subdirectory, choose the **Altbus** block and place it in your workspace. Rotate the block by choosing **Rotate Block** under the **Format** menu or doing *CTRL+R*. Connect the - input of the **Parallel Adder Subtractor** to the **Altbus**.
- Add the **Delay** block from the **Storage** subdirectory. Flip the **Delay** block by either choosing **Flip Block** from the **Format** menu or doing *CTRL+I*. Connect the **Altbus** to the input of the **Delay** and the output of **Gain** block a[1] to the output of the **Delay**. Also connect the remaining output of the **Scope** to the input end of the **Altbus** block.
- Follow the above steps to add another **Parallel Adder Subtractor** or simply cut and paste the one already existing on the workspace. Change the Add (+) Sub (-) parameter to +. Connect the output of **Gain** block b[0] to one of the + inputs of the **Parallel Adder Subtractor**.
- Add a **Delay** block following the instructions above and connect the output of **Gain** block b[1] to the input of the **Delay**. The output of the **Delay** should be connected to the other + input of the **Parallel Adder Subtractor**.
- Wire the output of the **Parallel Adder Subtractor** to **Workspace y** and to **Output Y** as shown below:

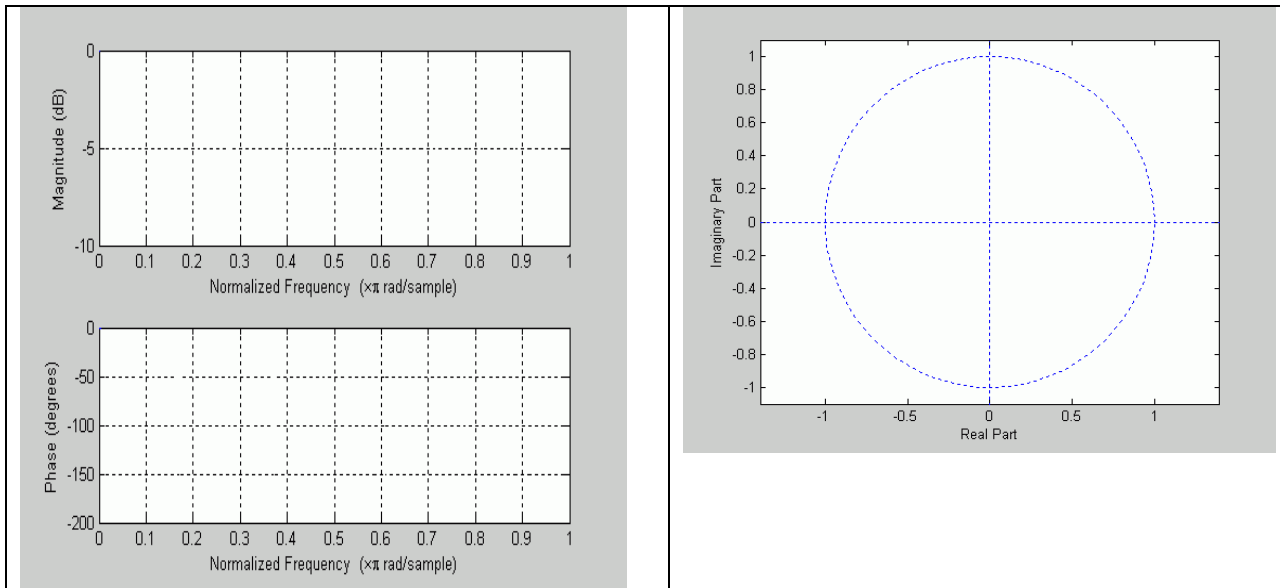
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LABORATORY IIR Filter



5. In the MatLab prompt use the predefined MatLab functions `freqz()` and `zpole()` to plot the frequency spectrum and pole/zero plot, respectively. You need to define nominator and denominator polynomials first. Complete the following diagrams:



6. Simulate the design with the two sine input signals. In the MatLab prompt use `showfft(x)` and `showfft(y)` to display the spectra. Determine the 2nd sine (i.e. noise) component amplitude before and after filtering:

before $F(\omega_2) =$ _____ after filtering $F(\omega_2) =$ _____

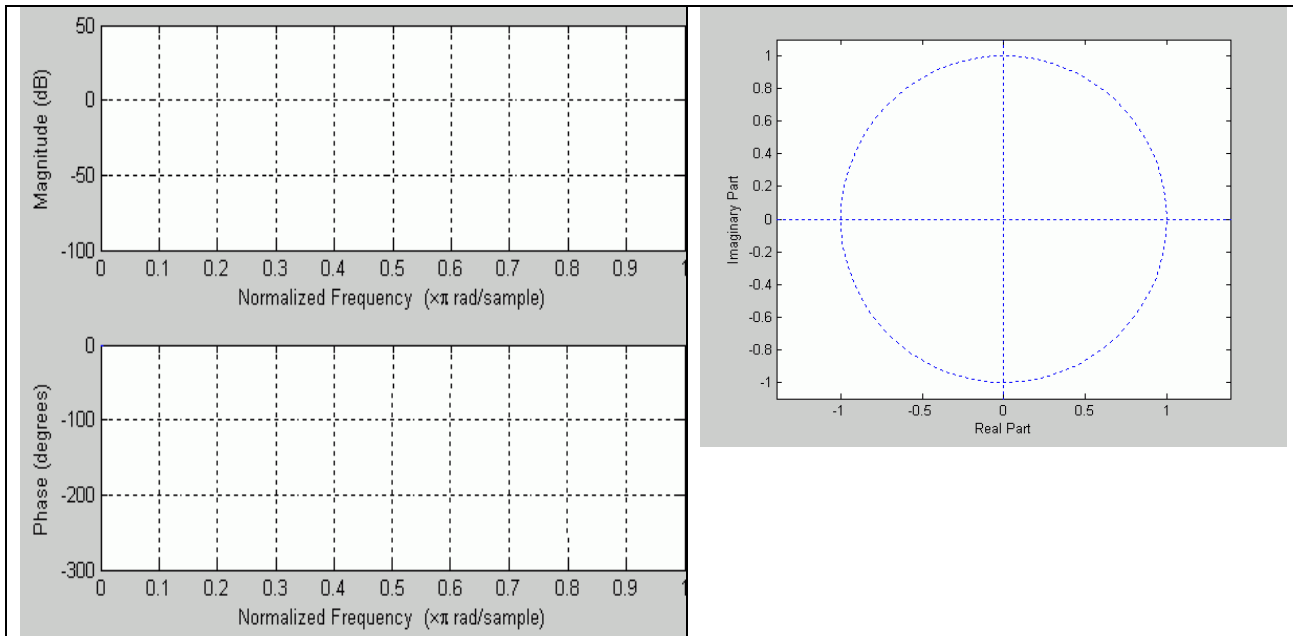
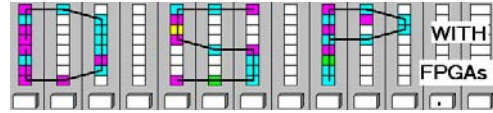
C. Designing a 3rd order System direct form Filter

1. Download the file `IIRorder3.mdl`, `setup_iir3.m` and `showfft.m` from the class webpage and put the files in the **DSPwFPGAs** folder.
2. Open the file `setup_iir3.m` with a text editor. There you will find the filter coefficient and the call to the predefined MatLab function `freqz()` and `zpole()` for the spectrum and pole/zero plot, respectively. In the MatLab prompt, type `setup_iir3` and complete the following diagrams:

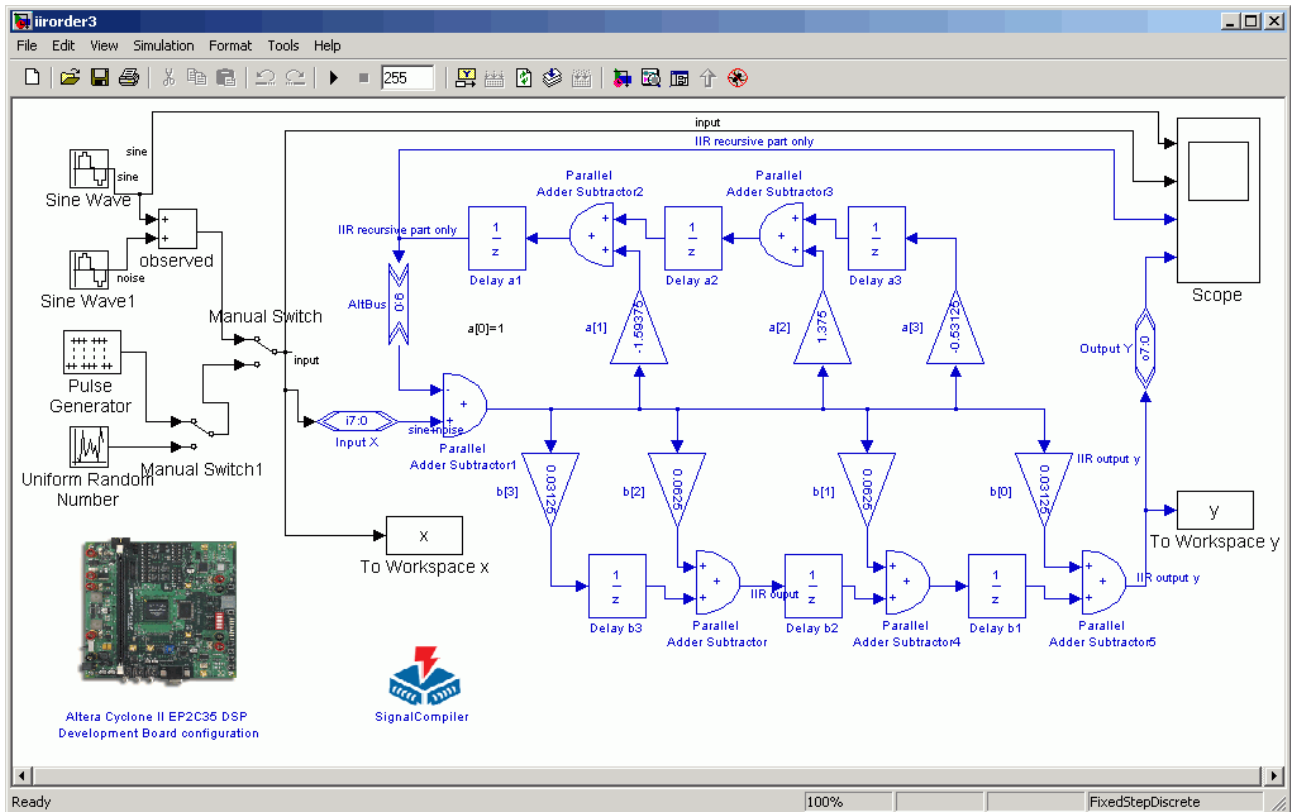
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LABORATORY IIR Filter

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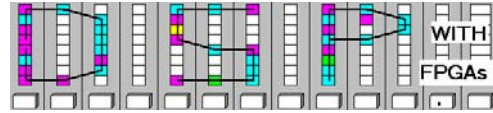


3. Complete the design: add the adder and delay elements and change the values of the different gains according to the following figure and following the steps from above:



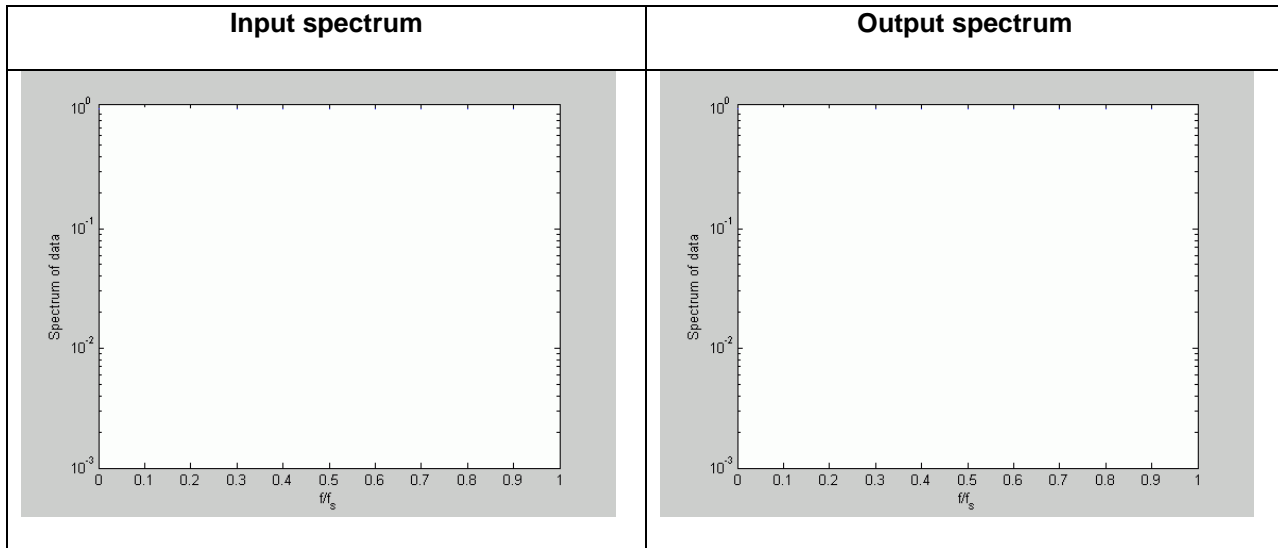
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LABORATORY IIR Filter

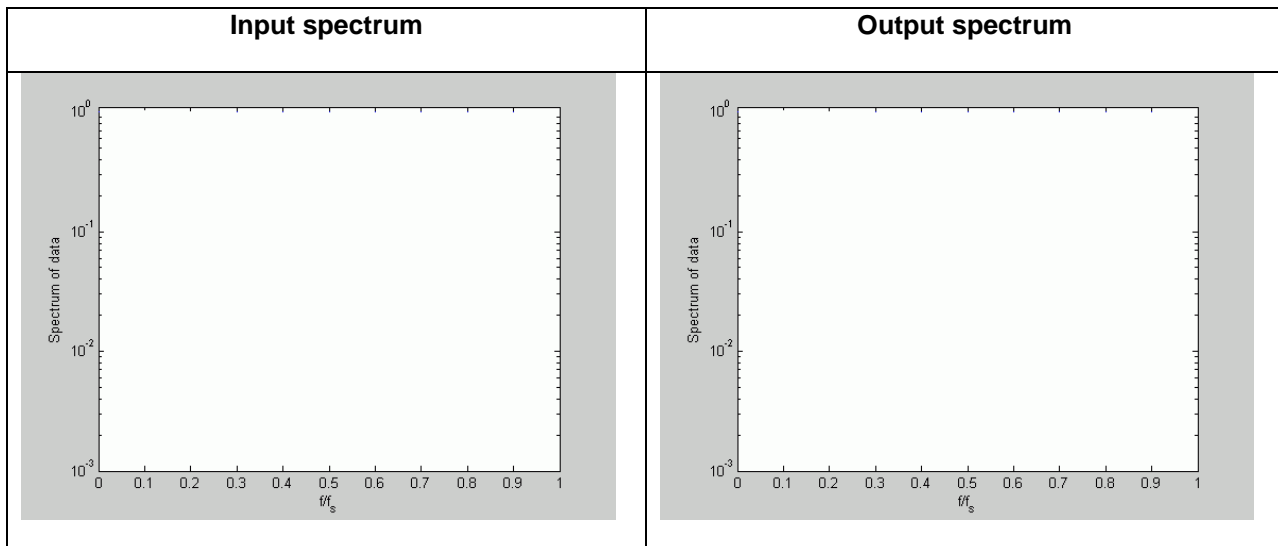


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4. Set the manual switches such that the impulse signal is the IIR filter input. Simulate the design using the **impulse** input signals and complete the spectra using `showfft(x)` and `showfft(y)`:



5. Set the manual switches such that the sine signals are the IIR filter input. Simulate the design using the sine input signals and complete the spectra:



6. Use the function `showfft(x)` and `showfft(y)` provided to “measure” the amplitude of the “noise” sine component before and after filtering. Compare the results to the first order system.

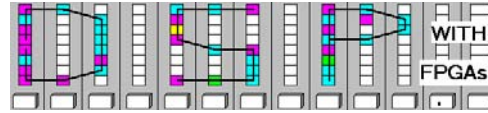
before $F(\omega_2) =$ _____

after filtering $F(\omega_2) =$ _____

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**LABORATORY
IIR Filter**

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7. Compile the design using **Signal Compiler** and determine

LEs = _____

9x9 bit embedded multiplier = _____

MHz = _____

from the report files.

F. Deliverables:

1. Solve the problems of the pre-lab. (3 points).
2. Print the MDF files and the Simulink simulations (7 points).

Make sure your name and SS is on all pages you turn in!