LAB FFT: INTRODUCTION TO FAST FOURIER TRANSFORM
(10 points)

In this lab you will be introduced to the design for a Fast Fourier Transform (FFT). The FFT is one of the most important DSP objects and is used not only to compute an approximation of the Fourier Transform, but also to enable fast convolution, a very time consuming filtering operation when done in time domain. 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 an 8 point radix-2 FFT using the principle of decimation in frequency.

Lab Objectives

After completing this lab you should be able to

- Develop a radix-2 FFT and compute test data
- Understand the difference between DFT and FFT
- Design and simulate FFT using the principle of decimation in frequency using Simulink

Pre-lab (3 points)

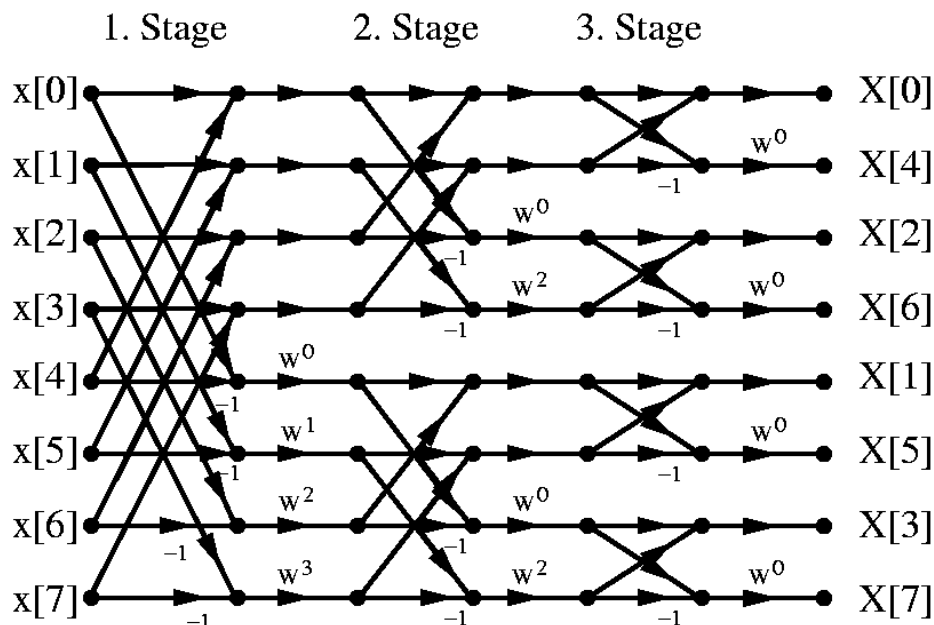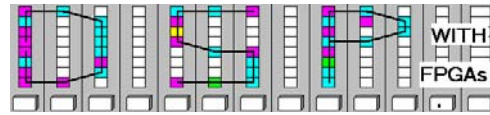The following figure shows the 8 point radix-2 FFT using the principle of decimation in frequency:

Fig. 1

**LABORATORY
FFT**

1. From the signal flow graph in Fig.1, determine for each stage the number of blocks required from each type of butterfly.

	1. stage	2. stage	3. stage
Butterfly with w^0			
Butterfly with w^1			
Butterfly with w^2			
Butterfly with w^3			

2. Redraw the radix-2 signal flow graph from **Fig.1** such that the butterfly operations do not overlap and input/output are in natural rather than bit-reverse order, by completing the following figure:
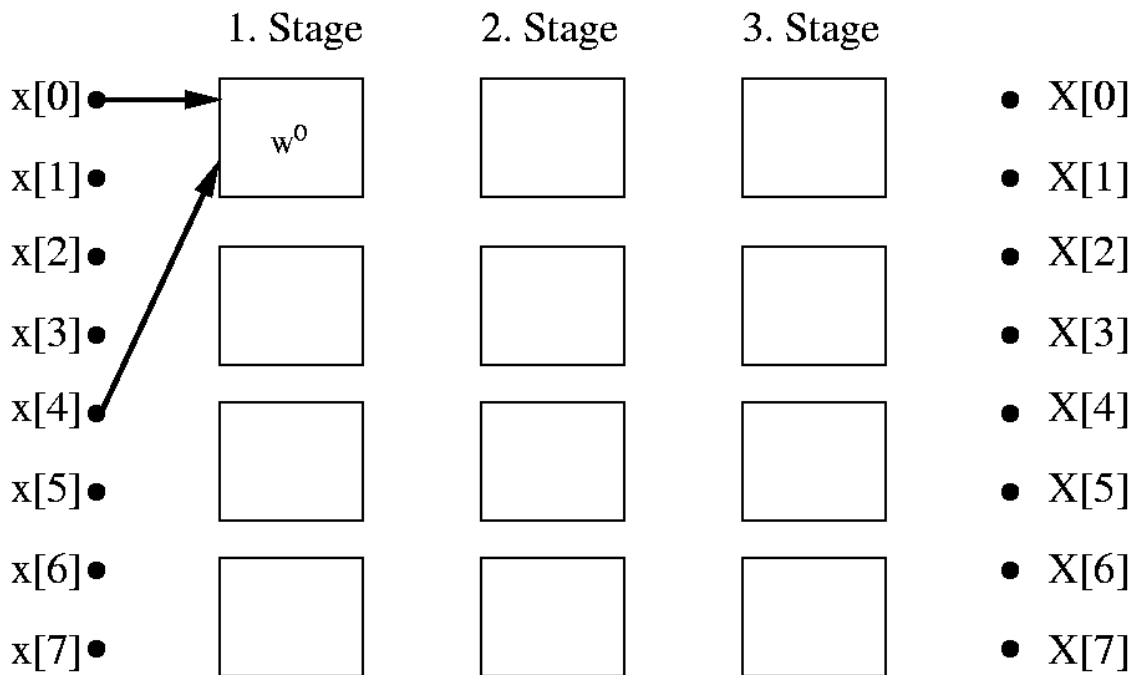

Fig. 2

3. Each butterfly $k \in [0,3]$ performs a complex value operation of the type
$$D = A+B; \quad \text{and} \quad E = (A-B)W^k$$

Complete the following table for the given input values

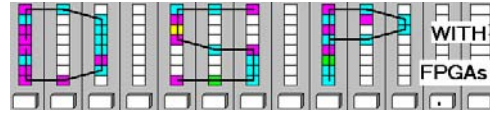|	A	B	D	E
Butterfly with w^0	2	10		
Butterfly with w^1	4	12		
Butterfly with w^2	6	14		
Butterfly with w^3	8	16		

Hint: Use a pocket calculator or MatLab for w^1 or w^3

4. Using MatLab, compute for x=2:2:16 the FFT, X = fft(x), and complete the following table:

	X[0]	X[1]	X[2]	X[3]	X[4]	X[5]	X[6]	X[7]
Real								
Imag								

Simulink Design-lab (7 points)

Follow the directions below to implement the 8-point radix-2 FFT circuit.

A. Getting Started

If you are in room B114 or the digital logic lab:
1.   On the desktop, double click on the **Engineering Folder**.

2.   Double click on the MatLab icon [icon] to start MatLab. It will take a few seconds to load.

3.   From the top icon list in the **MatLab** window click on the **Simulink** icon [icon] to start **Simulink.**

4.   Create a New Folder on your mapped network drive and name it **DSPwFPGAs.** Use this folder to save your designs. Never save your files to the local drive, use your network drive or a USB drive instead**.**


B. Design the W1 and W3 Butterflies

1.   Download the file `dif8.mdl` from the class webpage and place it in your **DSPwFPGAs** folder.

2.   Click on the "Current Directory" selection icon [icon] and select as current directory your **DSPwFPGAs** folder.

3.   The files in the **DSPwFPGAs** folder will now be visible in the upper left MatLab window. Double click on the `dif8.mdl` file. After a moment, you should see the incomplete design shown in the figure below.
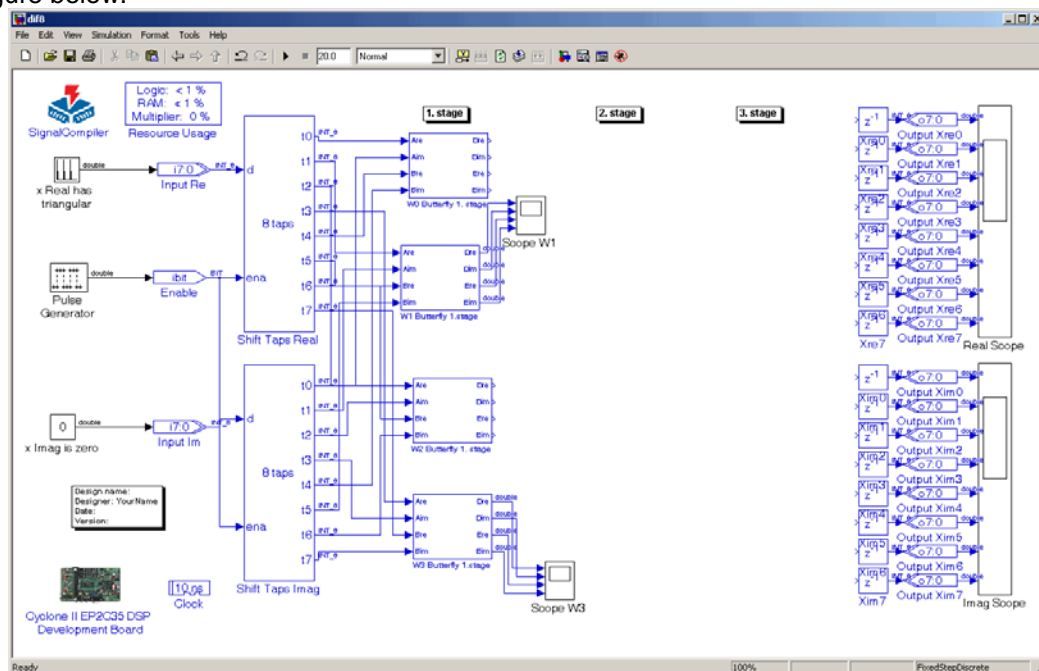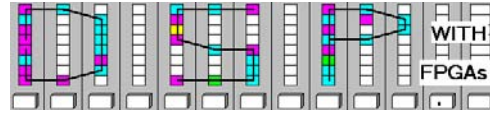
4. Complete the butterfly blocks **w^1** and **w^3** such that you match the values computed in the pre-lab, D=16 E=-6+j6 for **w^1** and D=24 E=6+j6 for **w^3**. Simulate your design and compare the results shown by the provided scopes for **w^1** and **w^3** with the data you computed for the pre-lab. To do so, you will have to temporarily delete the output gateways for the overall design as Simulink will not successfully simulate with "unconnected inputs." Alternatively, you can connect all **Delay** inputs to an Altera **Constant** "zero". Remember that you may use the 3*/5+ complex multiplier block you used in lab 7.

5. Print out the simulation waveform for **w^1** and **w^3**

C. Completion of the 8-point radix-2 FFT

1. Complete your design using the signal flow graph you developed in the pre-lab.

2. Copy and paste the necessary 8 additional subsystems and then wire them as determined in the pre-lab.

3. Simulate your design and compare the results shown by the provided scopes with the data you computed for the pre-lab. Check that both the real and imaginary parts are correct. Print the simulation waveform for the real and imaginary parts.

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

   Logic Cells = _____

   DSP 9x9 = _____

   Slack = _____

   from the report files or the **Resource Usage** block.

5. In case the slack from the `Slow Model Setup: 'Clock'` in C.4 is negative, introduce pipeline registers for all signals (i.e., 16) between 1. and 2. stage of your FFT. Make sure the simulation in the **Real** and **Imag Scope** are still correct. Then recompile using **Signal Compiler** and determine

   Logic Cells = _____

   DSP 9x9 = _____

   Slack = _____

   from the report files or the **Resource Usage** block.

F. Deliverables:

1. Solve the problems of the pre-lab. (3 points).

2. Print the MDF file `dif8.mdl` and the 4 Simulink simulations, i.e. W1,W3, Real, and Imag scope (7 points).

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