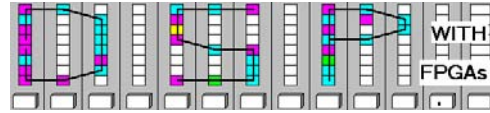


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**LABORATORY
DFT**



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**LAB DFT: INTRODUCTION TO DISCRETE FOURIER TRANSFORM
(10 points)**

In this lab you will be introduced to the design for a Discrete Fourier Transform (DFT) using the Goertzel iterative computation. The DFT is described by the following equation:

$$X[k] = \sum_{n=0}^{N-1} x[n]W_N^{kn} \quad k = 0,1,\dots,N-1 \quad (1)$$

$$\text{with } W_N^{kn} = e^{-j2\pi kn/N} \quad (2)$$

The DFT is an important DSP object and are used not only to compute an approximation of the Fourier Transform. The Goertzel algorithm can be used to implement a single DFT component via a first order IIR filter.

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 DFT using the Goertzel algorithm.

Lab Objectives

After completing this lab you should be able to

- Develop a basic Goertzel IIR loop and compute test data
- Configure a sub design with I/O ports
- Instantiate previously develop block
- Design and simulate selected DFT component

Pre-lab (3 points)

The following figure shows the basic building block used to build the Goertzel DFT:

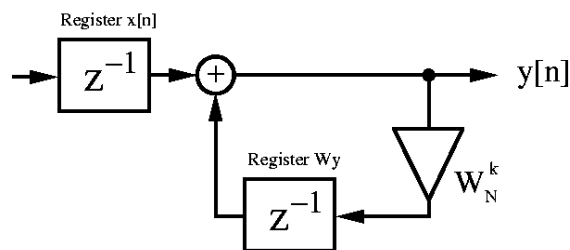


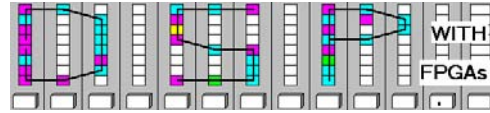
Fig. 1

1. Determine for N=8 the values W_N^k for $k=0,1,2$ and 3 . Use no more than 3 fractional digits for W_N^k . Compute the value \sin and \cos scaled by 128 and quantized to signed integers $[-128,128]$. Also compute $\cos+\sin$, and $\cos-\sin$ used for the complex multiplier.

k =	0	1	2	3
$W_N^k =$				
cos				
sin				
cos+sin				
cos-sin				

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2. Determine for $N=8$ and $k=0$ from Fig.1 the values for Register W_y and $y[n]$. Note that the incoming data $x[n]$ are applied last value first. Both, real and imaginary part show a triangular input sequence. Use integer value for register W_y and $y[n]$. Hint: write a short MatLab script that computes the results.

Time step	0	1	2	3	4	5	6	7
Register $x[n]$	$16+j16$	$14+j14$	$12+j12$	$10+j10$	$8+j8$	$6+j6$	$4+j4$	$2+j2$
Register W_y	0	$16+j16$	$30+j30$					
$y[n]$	$16+j16$	$30+j30$						$72+j72$

3. Repeat (2) for $k=1$. Use integer value for final values in register W_y and $y[n]$.

Time step	0	1	2	3	4	5	6	7
Register $x[n]$	$16+j16$	$14+j14$	$12+j12$	$10+j10$	$8+j8$	$6+j6$	$4+j4$	$2+j2$
Register W_y	0							
$y[n]$	$16+j16$							

4. Repeat (2) for $k=2$. Use integer value for register W_y and $y[n]$.

Time step	0	1	2	3	4	5	6	7
Register $x[n]$	$16+j16$	$14+j14$	$12+j12$	$10+j10$	$8+j8$	$6+j6$	$4+j4$	$2+j2$
Register W_y	0	$16-j16$						
$y[n]$	$16+j16$	$30-j2$						

5. Repeat (2) for $k=3$. Use integer value for register W_y and $y[n]$.

Time step	0	1	2	3	4	5	6	7
Register $x[n]$	$16+j16$	$14+j14$	$12+j12$	$10+j10$	$8+j8$	$6+j6$	$4+j4$	$2+j2$
Register W_y	0							
$y[n]$	$16+j16$							

6. Using MatLab compute for $t=2:2:16; x=t+j*t$ the FFT $X=\text{fft}(x)$ and complete the following table:

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

Verify the results from 6 with the data computed in 2-5. Do all final values $y[7]$ and $X[k]$ match?

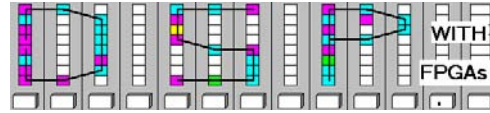
7. Discuss advantages and disadvantage of the Goertzel algorithm in term of algorithm flexibility, design size, sensitivity to coefficient quantization and latency of the computation.

Advantage:

Disadvantage:

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LABORATORY DFT





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Simulink Design-lab (7 points)


Follow the directions below to implement the 8-point Goertzel DFT circuit.

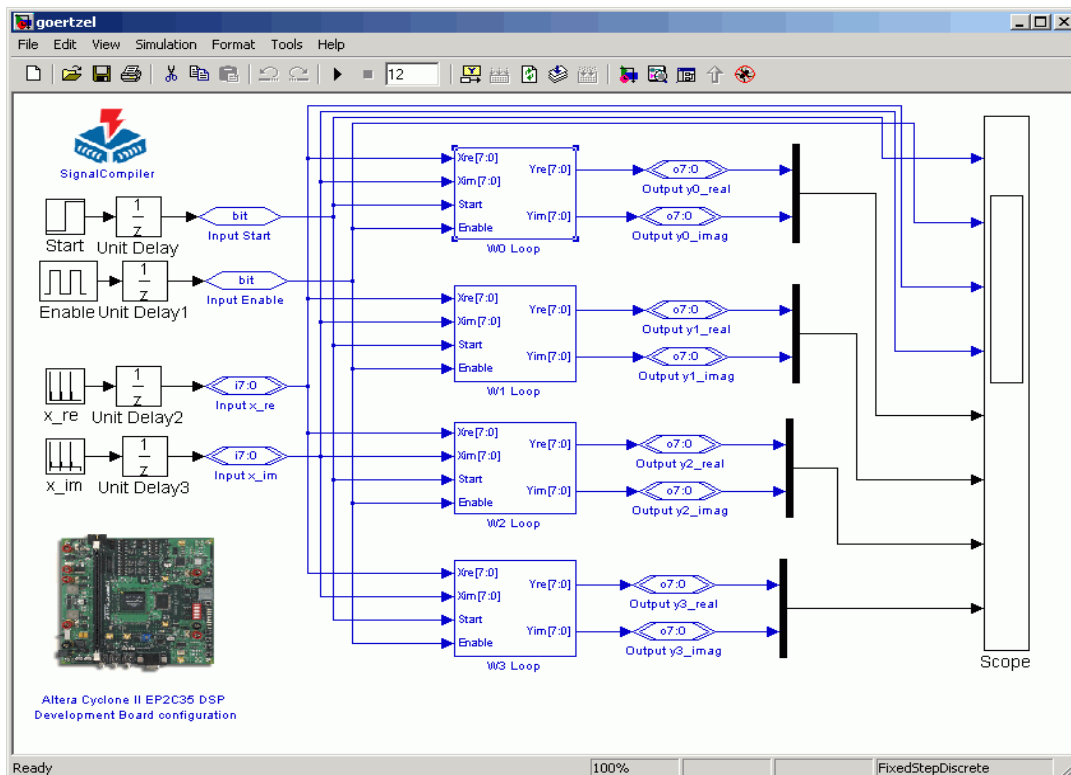
A. Getting Started

If you are in B114 or the digital logic lab:

1. On the desktop double click on **Engineering folder**.
2. Double click on the **MatLab** icon  to start **MatLab**.
3. From the top icon list in the **MatLab** window click on the **Simulink** icon  to start **Simulink**.
4. You should not save anything on the local hard disk. You will have to use a Zip, a floppy disc, or your "mapped" home directory to save the files. Create a New Folder named **DSPwFPGAs** on your mapped network drive.

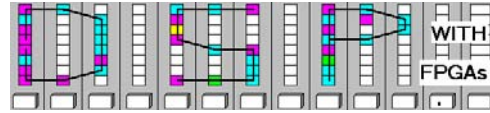
B. Design the W0 and W1 Butterflies

1. Download the file `goertzel.mdl` from the class webpage and put the file in the **DSPwFPGAs** folder.
2. Click on the "Current Directory" selection icon  and select as current directory the **DSPwFPGAs** folder.
3. The files in the **DSPwFPGAs** folder are now visible in the upper left **MatLab** window. Double click on the `goertzel.mdl` file and after a moment you should see the design:



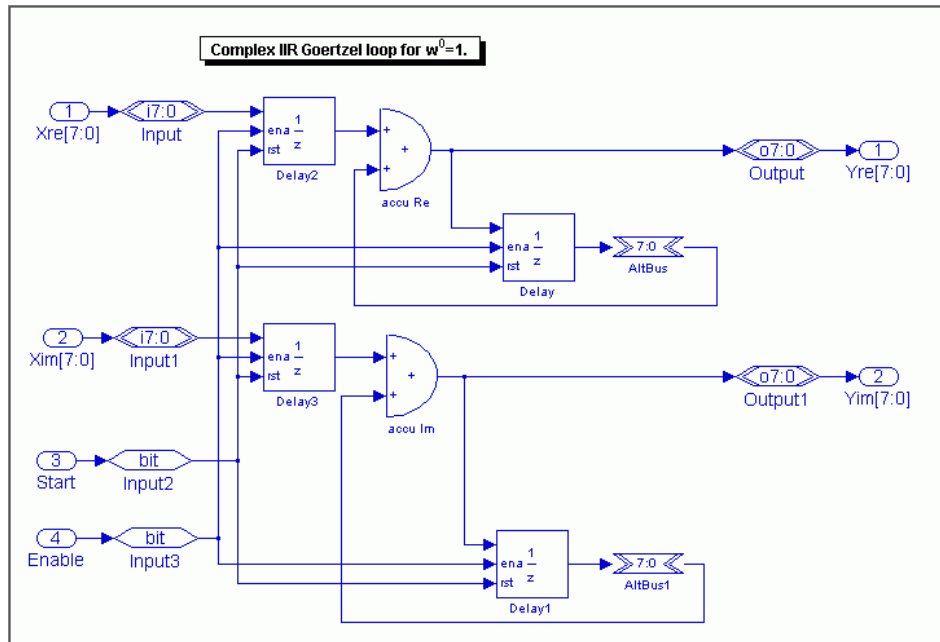
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LABORATORY DFT

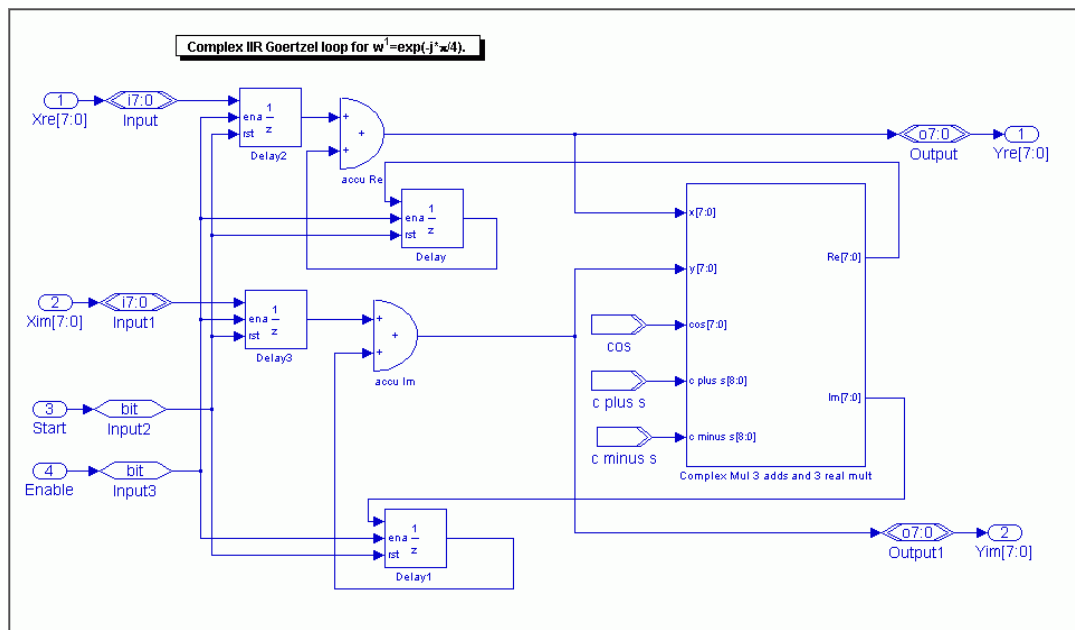


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4. Modify the block for w^0 such that you match the following figure. Verify the correct result via a Simulink simulation using the provided scope and your data from the Prelab.
Hint: you do not need a $3^*/5+$ complex multiplier for this subdesign.

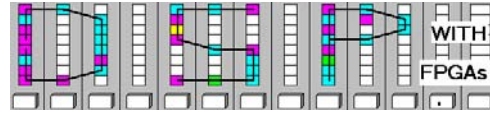


5. Modify the block for w^1 such that you match the following figure. Use the data for \cos , $\cos+\sin$ and $\cos-\sin$ as computed in the Prelab. Verify the correct result via a Simulink simulation using the provided scope and your data from the Prelab.
Hint: you may use the $3^*/5+$ complex multiplier you had designed in lab 3 to design the filter.



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**LABORATORY
DFT**



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C. Completion of the 8-point DFT

1. Complete your design using 2 more subsystems. Start with w^2 and finally design w^3 .
2. Copy the HDL SubSystem block from the **AltLab** library under the **Altera DSP Builder** library. Double click the block and modify the I/O ports so that they match those in the w^0 SubSystem. Now design the w^2 block using the data from the Prelab. Note you do not need a complex multiplier for w^2 .
3. Repeat the same steps for the w^3 subsystem and connect the appropriate I/O.
4. Verify w^2 and w^3 via a Simulink simulation using the provided scope and your data from the Prelab
5. Run a simulation of the completed design. Verify the correct real and imaginary part using the provide scopes and the data you computed in the pre-lab.
6. 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 file and the Simulink simulation (7 points).

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