Lab #8: Fourier Transforms & Block-Based Processing

Purpose

In this lab, we will use the Discrete Fourier Transform (DFT) to analyze the frequency content of an input signal using block-based processing. The lab is comprised of 3 parts: 1. Create your own DFT in C using the sample-based processing techniques used thus far in class. 2. Recreate your Sound In/Sound Out using the DMA and Ping Pong Buffer and then implement your real-time DFT using the new DMA and block-based processing. Part 3. Use the DMA and TI's FFT function to create a spectrum analyzer.

Part I. 512 point DFT Spectrum Analyzer.

1. Write your own 512 point DFT in C.

2. Sample N = 512 values (fs = 48kHz) and then run them through your DFT. Compute the magnitude for each complex output and store them to memory. Sweep a sine wave and check to make sure the appropriate bin has maximum energy for a given sine wave input.

3. Sample, run your DFT, and find the maximum magnitude, convert the bin number to the frequency value in Hz and display on your LCD and repeat. i.e. Max Freq = XXXX Hz Also display the maximum magnitude in dBs on your LCD. i.e. Max Mag = XXXX dBs, where XXXX = 10 log(max magnitude). Note: We use 10 here instead of 20 because we consider the magnitude to be the **POWER** of a particular sine/bin at a given frequency which is 10 log(x).

4. ***Time your DFT code operation using your Digilent LSA as was done in a previous lab.*** Most likely you will not be able to run a 512 pt. DFT in 1/48000 sec. i.e. New FFT computation every time a new sample is received. Instead, buffer N samples and then compute the DFT on this buffer while sampling to a second buffer which will be processed next. Using this bank switching/ping pong method you should be able to continuously run FFTs without missing a sample.

5. For testing, sweep a sine wave to verify your spectrum analyzer is functional. Also, try inputting a known guitar or piano note into your analyzer. i.e. 'A' below middle 'C', middle 'C', notes two octaves above middle 'C', etc. Note: You should be able to find these waveforms out on the web and can play them into your board via your laptop or phone headphone output.

Prelab Questions: For fs = 48kHz and DFT size of 512, what are the frequencies represented by the lowest 10 bins? (1-10 based indexing where 1 is the DC term, as is done in Matlab.) Is this DFT running in real-time where you don't skip any samples in your DFT buffer?

Part II. DMA based Sound In Sound Out for your DFT

1. Use DMA to perform your sampling and dual buffer ping-ponging.

2. Display the maximum frequency and magnitude dB value as before in Part I. Using your DAD, measure the time that it takes to fill an N sample buffer and the time that it takes to compute the DFT.

3. Show/Compare computation DFT times for N = 128, 256 and 512. What is the frequency resolution for each of these DFT's? How much time does each DFT take?

Note: You don't have to use your LCD and can simply observe expressions in your debugger watch window. Use the continuous 'Refresh Button' to observe your variables changing in debug memory.

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Part III. DMA + TI's FFT Routine

Use **TI's FPU Real FFT** function in the C2000ware library and repeat part II. Repeat the Part II experiment (same N values, same display, same timing measurements) using this the newly acquired TI FFT routine. Compute the executions times for 128, 256 and 512 pt. FFTs.

Parts I-III. Pre-Lab Requirements

Flow-Charts/Pseudo Code
Answers to Prelab Questions

Parts I-III. In-Lab Requirements.

Part I. Demonstrate, show & explain your sample-based DFT to your TA. Use the DAD to measure DFT execution time.
Part II. Demonstrate your DMA block-based Sound In/ Sound Out running with your DFT.
Part III. Demonstrate your DMA block-based Sound In/ Sound Out running with TI's FFT. Measure FFT execution time.

Lab Point Break-down

Short In-Lab Quiz	25%
Part I-II Pre-lab Materials	5% of each total below
Functional Part I In-Lab	25%
Functional Part II In-Lab	25%
Functional Part III In-Lab	25%