Experiment 3: Fast Fourier Transform - Answer Book

- **Name:** **Lab Date:**
- **Student No.:** **Day of the week:** **Time:**
- **Name:** **TA Signature:**
- **Student No.:** **Grade:**

3. Experiment

3.1 The FFT of a Single Sinusoid

Based on the model you built from the experiment outline (Figures 1 and 2), answer the questions below. Recall that your sampling rate is 8KHz. Figures 2a and 2b on the experiment outline present the outputs of the `Array Plot` and the `Spectrum Analyzer` block. Since they both result from an FFT operation, both represent Frequency Domain. Run your simulation and answer the following questions:

- *Why does the* `Spectrum Analyzer` *output show positive and negative frequencies?*

- *Why does the x-axis* `Spectrum Analyzer` *output shows KHz and the* `Array Plot` *output shows no dimension/unit (what does it represent)?*

- *How does the x-axis of one output map onto the other? (show your explanation and calculation with numbers)*

- *What is the resolution presented to you by the* `Array Plot`*?*

- *How could you improve the resolution of your system?*

- *What is the cost of improving the resolution of your calculated FFT?*

- *Repeat the simulation two more times, using 64 points for both buffer size and FFT size, and then for 1024 points for buffer size and FFT size. Report the magnitude values on the output of the* `Array Plot` *block. Remember, on your* `Magnitude FFT` *block, you are using* `Magnitude` ***NOT*** `Magnitude Squared`*. Report the magnitude values from the simulation, as well as a calculation to justify them (that is, from 1V_p to the value you read).*

- *How does the magnitude value on the* `Spectrum Analyzer` *block map to the* $1V_p$ *you are using in your simulation (zoom into the peak)?*

- *If you change the frequency of the sinusoid to 600Hz for cases above (different buffer/FFT sizes), what do you observe on the* `Array Plot`*? Can you calculate the magnitude of the largest frequency component observed on the output?*

3.1.1 Implementation

Make your FFT program run on the DSP platform.

- *How many computation cycles does it take for the routine to be run once? Put a software breaker point at the beginning of the FFT routine, observe and report the cycle count. Go under the menu:*`Run/Clock/Enable`*, and then you need to double-click the clock when the program reaches the breakpoint at the beginning of the routine that you want to monitor.*

- *Move your input frequency up to 27kHz. Explain what happened and why.*

- *Set your frequency to 5kHz. Measure (and report) the actual frequency component displayed after the 64 point FFT. Why is it not exactly 5kHz? (Hint: between two DC peaks the interval is "worth" 48kHz.)*

- *With the frequency still at 5kHz, change the number of points to 1024. Build it and run it. Now perform the same measurement as above, adjusting the display appropriately. Does it provide for a more accurate measurement? Why?*

- *Now that you know how to monitor the computation cycles in* `Code Composer Studio`*, we want to evaluate whether this matches the* $N\log_2 N$ *where* N *is the number of points of the FFT. Read and record the cycles for the* $N \in \{64, 128, 256, 512, 1024\}$*. Run the script called* `FFT_cycles_script.m` *in* `Matlab`*. Record the curve below.*

3.2 FFT Resolution for Two Sinusoids

3.2.1 Simulation

Based on the model built for two sinusoids, answer the questions below. Use 8KHz as your sampling rate, and 64 as your buffer size and FFT size.

- *Draw what you would expect to see in the frequency domain as a result of one 3kHz sinusoid multiplied by one 500Hz sinusoid, both at* $1V_p$*. Present some numbers for the x-axis as well.*

- *Run your simulation and draw below the output of the* `Array Plot`*. It is definitely* **not** *showing what you would expected to see. You may try to change the* `style` *(right-click and choose) from "stem" to "line". Why is that?*

- *If you increase the number of points of the buffer and the FFT will you solve the problem? What size would you consider acceptable? Are the amplitude values what you expected? What are the ones expected?*

3.2.2 Implementation

First, on your signal generator (AFG3021B), select your input waveform by pressing `Arb - User 1 - OK`. Connect the signal generator to the oscilloscope and set the oscilloscope to FFT mode. You will see a signal with two frequency components of slightly different amplitudes.

After you adjust the signal generator you are using to the correct settings described in the outline, answer the questions below.

- *Draw the output displayed on the scope. Use cursors as a tool to calculate the frequency in which the sinusoids are located, and present your calculation. What does this signal appear to be?*

- *Change the number of points to 1024. Compile and run it without changing the input. Draw the output displayed on the scope. What does this signal appear to be?*

3.3 Butterflies

3.3.1 Simulation

Based on the given model for the 8-point DIT FFT, answer the questions below.

- *Based on the model, explain the property of homogeneity. Hint: change the amplitude of the sine wave at the input to the 8-point FFT model and follow the values to the output.*

- *Fill out the piece of code below, which runs at the initialization done prior to an FFT function definition and call. It is meant to set up two arrays with the base functions used by the FFT function. N is the number of points of the desired FFT*

```
typedef struct{
float real, imag;
} COMPLEX

COMPLEX w[N];

for (i=0; i < N; i++)
    {
        w[i].real = ______________________________________;


        w[i].imag = ______________________________________;
    }
```

- *Show a calculation for the base functions (twiddle factors) used in the model.*

- *The model is missing a block at the output of the third stage, which would allow you to visualize the spectrum of the sine as represented by an 8 point FFT (prior to the* `Array Plot`*). What is the block and what does it do?*