EELE445 - LAB 1 Introduction to Signals in the Time and Frequency Domain

PURPOSE

The purpose of the lab is for the student to become familiar with the use of the Tektronix TDS-3054 oscilloscope with the TDS3FFT module to analyze signals in the time domain and the frequency domain. Each student will learn how to properly set up the scope FFT to measure the frequency content of a signal and should understand the advantages and limitations of FFT spectral analysis.

REFERENCE SOURCES

Couch example 2.4 and example 2-12,.
Tektronix MDO3034 manual, Tektronix website for additional information and application notes:

http://www.tek.com/search/apachesolr_search/TDS3034

PRE_LAB:

Be able to answer the following questions in lab. Be sure to include in your report the theoretical values you calculate to the values you measure in lab.

- What is the voltage measurement accuracy of the TDS-3054 oscilloscope? (scope manual or data sheet)
- Use the Fourier Transform to determine the signal rms amplitudes and frequencies you expect to see in the frequency domain. (The FFT measures in Vrms) for:
    - A 2V p-p 2.5 KHz sinewave
    - A 2V p-p 2.5 KHz squarewave (calculate the values to the 10th harmonic)
- What is the relationship between a Complex Fourier coefficient, c_n, of a waveform and what is seen on a spectrum analyzer displaying rms volts/Hz? (hint text 2-103, 2-106, fig 2-11)
- What is the rms amplitude of a 1 volt peak sinusoid in dBV (dB relative to 1volt)?
- Define Nyquist Sample Rate.

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METHOD:

After an initial lecture concerning signals, spectrum analyzers, and the FFT, the student will:

Sinewave in the Frequency and Time Domain.

1) Use a signal generator to get a 2V p-p 2.5 KHz sinusoid. Observe the signal with an oscilloscope:
    - a)   1ms/div and 500mV/div
    - b)   Acquisition mode: 2
    - c)   Horizontal Resolution 10000 points
    - d)   FFT on: (Math; FFT)
    - e)   FFT window: Hanning (Math, FFT, window; Hanning)
    - f)   FFT search: set to magnify the horizontal axis to display about 10KHz

    - What is the sample rate of the scope given the above settings?
    - What is the maximum frequency that can be analyzed without aliasing?
    - Use the scope markers to determine the amplitude in dBV and the frequency of the input signal. How do these compare to the theoretical values?
    - What is the frequency resolution of the FFT for these settings? How could you increase the resolution?

2) Increase the scope input channel vertical sensitivity in steps to 100 mV/div.
    - Does the spectrum display change? Return the vertical sensitivity to 500 mV/div

3) Increase the frequency in 1 KHz steps to 37.5 KHz and then to 62.5 KHz. Use the internal frequency counter of the oscilloscope to measure the frequency of the time domain signal.
    - Why doesn't the counter read correctly for frequencies above 25 KHz? (Hint: what is the sample rate?)
    - show the mathematical relationship between f_{in}, f_{out} and f_{sample} when $f_{in} > f_{nyquist}$

4) Set the signal generator to 12.5 KHz sinewave. Adjust the FFT display to center the signal on the horizontal axis. Set the frequency span for 250 Hz/div and the vertical scale for 10dB/div. Change the FFT window from Hanning to Rectangular, Hamming, and Blackman-Harris.
    - Which window results in the best frequency resolution? (>dV/df)
    - Which window gives the best amplitude accuracy?
    - Describe the purpose of windowing in your report. (Tektronix booklet for FFT module)

Square wave in the Frequency and Time Domain.

5) Change the input signal to a 2V p-p square wave.
    - Record the frequencies and <u>linear</u> magnitudes of the first 5 spectral components visible.
    - <u>Make a table and compare the values recorded to the theoretical values you calculate.</u>

6) Change the input frequency to 2.4 KHz.
   - What are all of the additional spectral components due to?
   - How would you eliminate this effect?

Report:

Turn in the completed report form next week at the beginning of lab
Grading will consist of:
   - Prelab question answers
   - Clarity and completeness of graphs
   - Answers to the lab questions. Your analysis aspects of data collected (theory vs. measured results)

Be sure your answers to the lab questions are easy to find!

EELE445 - LAB 1 Student Report

Section_____ Date_____ Name_____

- **Attach your pre-lab work to this report.**

Sinewave in the Frequency and Time Domain.

1) Use a signal generator to get a 2V p-p 2.5 KHz sinusoid. Observe the signal with an oscilloscope:
   - What is the sample rate of the scope given the above settings?

   - What is the maximum frequency that can be analyzed without aliasing?

   - Use the scope markers to determine the amplitude in dBV and the frequency of the input signal. How do these compare to the theoretical values?

   - What is the frequency resolution of the FFT for these settings? How could you increase the resolution?

2) How does the FFT display change?

3) Why does the spectrum display change?

4) Why doesn't the counter read correctly for frequencies above 25 KHz?
   - show the mathematical relationship between f_{in}, f_{out} and f_{sample} when $f_{in} > f_{nyquist}$

5) Change the FFT window from Hanning to Rectangular, Hamming, and Blackman-Harris.
   - Which window results in the best frequency resolution? ($>dV/df$)

   - Which window gives the best amplitude accuracy?

   - Describe the purpose of windowing in your report. (Tektronix booklet for FFT module)

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Section_____   **Date**_____   **Name**_____

Square wave in the Frequency and Time Domain.

6) Record the frequencies and <u>linear</u> amplitudes of the 5 spectral components visible.
   - <u>Make a table and compare the values recorded to the theoretical values you calculate.</u> Discuss the cause of any error you see.

7) Change the input frequency to 2.4 KHz.
   - What are all of the additional spectral components due to? Explain where they come from.

   - How would you eliminate this effect?