**Purpose**

The purpose of the lab is to look at the effects of A/D quantization. We will analyze the A/D in the oscilloscope by capturing several different waveforms to CVS files and then analyzing the waveforms in Matlab. The waveforms will looked at to determine the quantization noise floor, the peak to peak voltage range, and the quantization levels M for sever setting of the oscilloscope.

**Components Required:**

* **YOU WILL NEED A FLOPPY DISK FOR THIS LAB.**

**Reference Sources**

Couch section 3-4, page 155 eq 3-25, 3-26a Proakis chapter 7.4.1, equations 7.4.1 to 7.4.3 as attached

Additional information attached is from Proakis chapter 7.4.1, equations 7.4.1 to 7.4.3

**Prelab**

* What is the quantization noise power Pq for an 8-bit A/D with an input range of +1V to -1V? (n=8 and xmax=1V)
* Does this noise power depend on the sample frequency? Explain
* The power spectral density, PSD, of the noise is  Watts/Hz. This is the quantization noise floor of the A/D. What is the noise floor PSD when Fs is 10Ks/sec?
* What would the Signal to quantization noise ratio SQNR be if the input signal is a 2Vp-p sine wave, xmax=1V, and n=8 bits? (SQNR=Psignal/Pq)

**METHOD:**

Capture the following signals on a floppy disk as csv files for analysis in Matlab. You may do the data analysis at your leisure before the next lab.

1. Set the oscilloscope for a sample rate of 100 Ks/sec, 20MHz BW, 10,000 points, and **1mV/div**. Disconnect the probe from the scope. This is the minimum resolution of the scope.

* Record the mean, Pk-Pk, and RMS noise voltages using the scope measurements
* **Capture the trace to a .csv type data file**
* Write a Matlab file to read the data file and:
  + Plot the data in time
  + Calculate the mean, Pk-Pk and RMS noise voltages. Compare the results to what you recorded on the oscilloscope.
  + Plot the power spectral density (PSD) in Watts/Hz. Be sure to correct for the resolution bandwidth of the FFT. You may assume R=1
  + Estimate the smallest voltage resolution, V, of the A/D) by finding the minimum non-zero voltage change between points. (expand the stem plot in Matlab)
  + The full scale range of the A/D is V x 512 (9-bit). How does this compare to the full scale range of 8 mV as seen on the scope screen? Explain

2. Set the oscilloscope for a sample rate of 100 Ks/sec, 20MHz BW, 10,000 points, and **200mV/div**. Disconnect the probe from the scope.

* **Capture the trace to a data file**
* Repeat part 1 using this data.

3. Using the same settings from 2, connect a signal generator and apply a 1 KHz sine wave of 1 Vp-p.

* **Capture the trace to a data file.**
* Repeat the analysis of part 1 using this new data.
* Estimate the full scale range of the scope, +/1 Xmax, under these settings. How does this compare to the displayed +/- 800 mV signal on the scope display.
* Estimate the dynamic range of the scope in dB, SNQRmax=20\*log(Xmax/Vnoise). Vnoise is the no input rms noise voltage from 2.
* Compare the level of the noise you expect to see for the sine wave with what you see in the FFT plot. Explain. (Hint: Resolution Bandwidth)

4. Set the oscilloscope for a sample rate of 100 Ks/sec, 10,000 points, and 200mV/div. Now connect a signal generator and apply a 1 KHz sine wave of 2 Vp-p.

* **Capture the trace to a data file.**
* Repeat the analysis of part 1 using this new data. Is the sine wave distorted in the Matlab plots? Explain

5. Change the input waveform to a 100 Hz triangle waveform 4 Vp-p

* **Capture the trace to a data file.**
* Repeat the analysis of part 1 using this new data.
* Is the triangle wave distorted in the Matlab plots? You may use the maximum levels found in Matlab to find Vmax of the A/D, and the stem plot to find the smallest V to then calculate the number of bits in the A/D

**Supplemental material from class notes:**



* **M is the number of quantization levels**
* **n is the number of bits**
* **Vmax is ½ the A/D input range**

**mple data analysis from Matlab program:**

Screen shots from EELE44512lab5.m Matlab file. You should see something similar.









Zoom was used on the above graph to see the individual quantization steps. 4mV in this case.

**To be added to:**