VLSI DATA CONVERSION CIRCUITS : PROBLEM SET 3

Problem 1

In class, we assumed that quantization "noise" can be approximated by a uniform distribution in the interval $[-\Delta/2, \Delta/2]$ where Δ is the LSB size. Further, we assumed that this noise was uncorrelated with the input signal. This problem is intended to see the range of validity of this assumption. Drive a 4-bit quantizer with a full scale sine-wave, making sure that you are using prime and integral number of input cycles. Denote the input by X and the quantized output by Xq. The *quantization error* is $Xq - X$. Divide the quantization error into 100 bins and plot a histogram. Is this uniform ? Repeat for a 6-bit, 8-bit, 10-bit and 12-bit quantizer.

Problem 2

Compute the peak Signal to Quantization Noise ratio for quantizers with resolutions of 2, 4, 6, 8, 10, 12 bits. Again, make sure that you are using a prime and integral number of input cycles, and to speed up DFT computations, choose the number of time points of the form 2^p. How do your numbers compare with the relation $\mathrm{SNR} \approx 6.02\,\mathrm{N} + 1.76\,\mathrm{dB}$?

Problem 3

A student (hereby referred to as "IT", to avoid gender bias) is testing an ideal quantizer, with N bits of resolution. IT drives the quantizer with a full scale sine-wave input, with a frequency within the Nyquist bandwidth. IT then captures 1024 output points of the quantizer, and expresses the output as a Discrete Fourier Series (DFS). IT plots the magnitudes of the DFS coefficients, (normalized to the input sine-wave amplitude), on a log scale. The resulting plot is shown in Figure 1. Assume that the "noise" floor is uniform at $-63\,\mathrm{dB}$.

- Find the frequency of the sine-wave input, in relation to the sampling frequency f_s.
- Estimate N, the resolution of the quantizer. As a reminder, make sure to CLEARLY demonstrate how you got your answer.

Problem 4

For an ideal N-bit quantizer, for N ranging from 5 to 14, and excited by a full scale sine wave, find (using MATLAB) the ratio of powers of the fundamental and the largest spur at the quantizer output. This is called the Spurious Free Dynamic Range (SFDR). For uniformity, use a 2^{15} point FFT with an input at approximately $f_s/4$. Plot the SFDR (in dB) versus N. Can you explain the slope of the curve ?

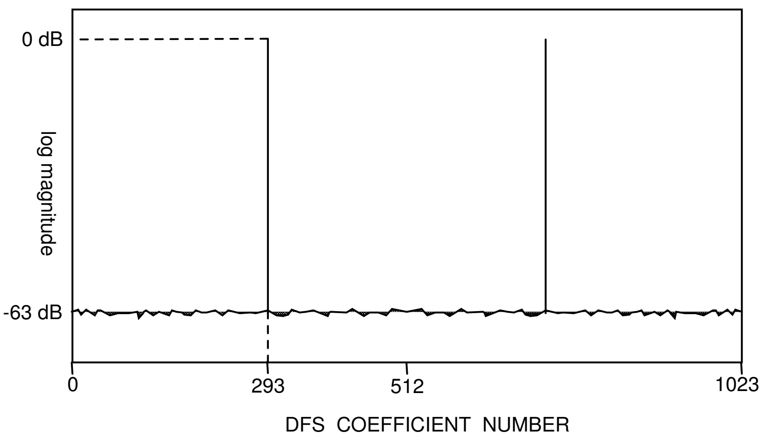

Figure 1: DFS log-magnitude plot for Problem 5.

Problem 5

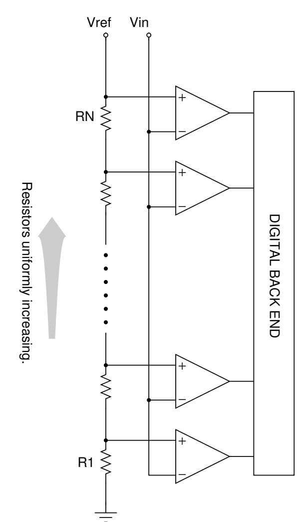

Figure 2: Flash ADC for problem 4.

A flash ADC is shown in Figure 2. Ideally, all resistors are supposed to be identical, so that the decision thresholds are all evenly spaced. On an IC, it is not possible to ensure that all resistors are equal. In this exercise, we analyze what happens to the output spectrum if there is a uniform gradient in conductivity for the material used to make the resistors. Assume an 8-bit flash ADC. Due to process imperfections, the resistors keep increasing as we progress from one end to another, so that $RN = 1.1\,R1$. Analyze and predict what happens for a full scale sinewave input. Verify your theory with MATLAB.