ECEN610:Mixed-Signal Interfaces

LAB 1: Signal Processing Concepts Review

1. DIGITAL FILTERS (20%)

a. Digital filters are broadly classified into FIR and IIR filters. Give an example of an FIR filter and IIR filter (transfer function). Plot the transfer function in Python. Identify the poles and zeros on the plot.

b. Consider the transfer functions,

$$H(z) = 1 + z^{-1} + z^{-2} + z^{-3} + z^{-4}$$

$$H(z) = \frac{1 + z^{-1}}{1 - z^{-1}}$$

Identify the FIR and IIR filter. Plot the FIR filter in (use **freqz** function in the **SciPy** signal processing toolbox). Where are the poles and zeros of the filter located? Validate your theory using simulations.

c. Comment on the stability of the FIR and IIR filters. Use simple simulations to explain your ideas.

2. SAMPLING (50%)

a. Consider the two signals $x1(t) = cos(2\pi \cdot F1 \cdot t)$ and $x2(t) = cos(2\pi \cdot F2 \cdot t)$, where F1 = 300MHz and F2 = 800MHz. Both these signals are sampled at the same sampling frequency Fs = 500MHz. What can you say about the sampled data x1(n) and x2(n)? Explain with simulations why this happens.

b. Can you recover the signals x1(t) and x2(t) from x1(n) and x2(n). If not, what is your suggestion to overcome this problem?

c. Find the ideal signal reconstruction (interpolation) equation for a zero-order hold sampling system with pulse width W and sampling rate T. Assume that Nyquist rate criteria is satisfied and the sampling point is at the end of the pulse width.

d. Sample the signal x1(t) using Fs = 800MHz at 0:Ts:T-Ts, where T = 10/F1 (i.e. 10 cycles of the cosine wave) and Ts = 1/Fs. Reconstruct the signal from the samples using the formula,

$$x_r(t) = \sum_{n=-\infty}^{n=\infty} x(n) \frac{\sin[\pi(t - nTs)/Ts]}{\pi(t - nTs)/Ts}$$

Now sample the signal at Ts/2:Ts:T-Ts/2 i.e. the samples are shifted by Ts/2. Reconstruct the signal using the same formula. Compute the mean square error (MSE) in the reconstruction in both the cases by using,

$$MSE = mean((x_r(t) - x(t))^2)$$

e. Repeat d. for Fs = 1000MHz and Fs = 500MHz. Report your observations.

3. DISCRETE FOURIER TRANSFORM (30%)

a. Consider the signal $x(t) = cos(2\pi \cdot F \cdot t)$ where F = 2MHz. Sample the signal at Fs = 5MHz. Compute a 64 point DFT in Python and plot the output. (see **fft** command in SciPy documentation).

b. Consider another signal $y(t) = cos(2\pi \cdot F1 \cdot t) + cos(2\pi \cdot F2 \cdot t)$ where F1 = 200MHz and F2 = 400MHz. Sample this signal at Fs = 1GHz. Compute and plot a 64 point DFT. Can you identify the two components of the signal in the plot?

c. Repeat b. using Fs = 500MHz. Explain what you observe in your DFT plot.

d. Now apply a Blackman window as an envelope to the signal x(t) and y(t) and repeat the analysis. Please explain the differences.