

LAB 1

SIGNAL PROCESSING CONCEPTS REVIEW

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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 MATLAB. 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 MATLAB (use the **freqz** command). 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 two signals $x_1(t) = \cos(2\pi F_1 t)$ and $x_2(t) = \cos(2\pi F_2 t)$, where $F_1 = 300\text{MHz}$ and $F_2 = 800\text{MHz}$. Both these signals are sampled at the same sampling frequency $F_s = 500\text{MHz}$. What can you say about the sampled data $x_1(n)$ and $x_2(n)$? Explain with simulations why this happens.
- b. Can you recover the signals $x_1(t)$ and $x_2(t)$ from $x_1(n)$ and $x_2(n)$. 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 $x_1(t)$ using $F_s = 800\text{MHz}$ at $0:T_s:T-T_s$, where $T = 10/F_1$ (i.e. 10 cycles of the cosine wave) and $T_s = 1/F_s$. Reconstruct the signal from the samples using the formula,

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

Now sample the signal at $T_s/2:T_s:T-T_s/2$ i.e. the samples are shifted by $T_s/2$. Reconstruct the signal using the same formula. Compute the error in the reconstruction in both the cases by the method of mean squares given by,

$$MSE = \text{mean}((x_r(t) - x(t))^2)$$

- e. Repeat c. for $F_s = 1000\text{MHz}$ and $F_s = 500\text{MHz}$. Report your observations.

3. DISCRETE FOURIER TRANSFORM (30%)

a. Consider the signal $x(t) = \cos(2\pi Ft)$ where $F = 200\text{MHz}$. Sample the signal at $F_s = 500\text{MHz}$. Compute a 50 point DFT in MATLAB and plot the output. (see **fft** command in MATLAB).

b. Consider another signal $y(t) = \cos(2\pi F_1 t) + \cos(2\pi F_2 t)$ where $F_1 = 200\text{ MHz}$ and $F_2 = 400\text{MHz}$. Sample this signal at $F_s = 1\text{GHz}$. Compute and plot a 50 point DFT. Can you identify the two components of the signal in the plot?

c. Repeat b. using $F_s = 500\text{MHz}$. Explain what you observe in your DFT plot.