Electrical Engineering 434
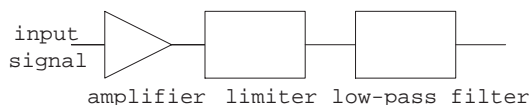## Sample GR 1 Questions, Fall 1998

1. **Given:** The signal $x(t) = 2\cos(2\pi 2000 t)$ is sampled at $F_s = 8$ kHz to yield $x[n]$. Write the correct expression for $x[n]$.

2. **Given:** You have just four possible A/D converters from which to choose as shown in the table below. All use the rounding form of quantization. Note F_s specified in the table is just the maximum useable value.

Model	A	B	C	D
Input range (volts)	-2 to $+2$	-3 to $+3$	-5 to $+5$	-2 to $+2$
Bits per sample	8	8	12	9
Sampling frequency F_s (Hz)	20k	50k	100k	40k

Your data consists of audio taken from a standard commercial FM radio station, so the highest information frequency is 15 kHz. You wish to acquire this data in digital form such that you minimize any possible aliasing, have a maximum possible SQNR of at least 52 dB, ensure the maximum quantization error for any given sample does not exceed 4 mV, and that the data rate from the A/D converter cannot exceed 300 kbps. Assume the signal can be scaled as needed to fit your input range.

   (a) Specify which A/D converter you would choose and *show* how it meets all the design criteria.

   (b) You decide to use the following preprocessing on the signal prior to the A/D converter:

   input signal → amplifier → limiter → low-pass filter

   Your input signal amplitude ranges from -10 to $+10$ volts. Note: the limiter is used to prevent overfilling the A/D converter; assume it is set to the input range of your chosen A/D converter. In order to work best with the A/D converter you chose from the table above, answer (and *briefly justify* your answer to) the following questions.

   i. What should the amplifier gain be?

   ii. What cutoff frequency shold be used for the LPF?

   iii. What purpose does the LPF serve?

3. **Given:** Using the information given in Question 1, assume you have only the first 16 samples ($N = 16$) that were taken from the original continuous-time signal $x(t)$ for your $x[n]$ to use in this question. No more data is available, and you aren't allowed to zero pad the data.

   (a) Sketch the magnitude (you may ignore phase in this case) spectrum that results from taking the DFT of $x[n]$. You aren't allowed to use the **fftshift** operation. *Hint: Does your data contain an integer number of cycles of $x(t)$?*

   (b) In terms of *normalized discrete frequency*, what is the value of $\Delta\theta$ for your DFT output?

   (c) In terms of *real-world* frequency, what is the value of Δf for your DFT output?

   (d) What is the highest negative real-world frequency that shows up as an *actual* data point on your DFT output?

   (e) At what value of k does this highest negative frequency occur in your DFT output?

   (f) In simple terms, what is the relationship between the DFT and the FFT?

   (g) What is the average (or DC) value of the signal $x[n]$?

   (h) What is the purpose of the fftshift operation in MATLAB?

   (i) If you had been provided with 18 samples instead of 16, in what ways (if any) would the output of the DFT have been different?

4. **Given:** Suppose you wanted to perform a linear convolution $x * h = y$ by using the DFT. Let

$$x[n] = [0, 1, 7, 4, 9, 3, 8, 3, 6, 2, 0, 4]$$
$$h[n] = [2, 4, 4, 2]$$

Briefly list *each* step (in the correct order) you would take to use the DFT to perform this convolution.

5. **Given:** You have acquired $N = 128$ samples of data using $F_s = 8192$ Hz. The data contains an unknown number of sinusoidal signals, and wish to use the DFT for some basic spectral analysis. You know you should always consider carefully what type of window to use and how to apply it to your data.

   (a) You suspect there may be two sinusoidal frequencies as close together as 100 Hz on the frequency axis in your data. Will you be able to use a von Hann window on your data and be able to see individual peaks for these two sinusoids? Explain.

   (b) As another way to analyze your data, you've decided to use a Hamming window. You need to get a "visual" frequency resolution for the DFT plot of $\Delta f = 32$ Hz. Describe the correct action (in the correct order) you need to take with your data, with the Hamming window, and with the DFT to achieve this result.

Window Characteristics

Window (length N)	Main Lobe Width	Side-lobe Level (dB)
rectangular	$4\pi/N$	-13.5
Bartlett	$8\pi/N$	-27
von Hann	$8\pi/N$	-32
Hamming	$8\pi/N$	-43
Blackman	$12\pi/N$	-57