York University

Department of Electrical Engineering and Computer Science

EECS 4214

Lab #4 Quantization

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1. Purpose

In this lab, you will be introduced to modeling, simulation, and characterization of linear quantizers. Using a computer, you will learn how to realize a linear quantizer, and then quantize analog signals of different waveforms in the time domain.

2. Objectives

By the end of this project, you will be able to: 1) realize a linear quantizer in MATLAB, 2) design a quantizer with a quantization characteristic of your own choice (with arbitrary full-scale range and resolution), and 3) characterize a quantizer and analyze its function in terms of the quantization error it produces and the associated signal-to-quantization-noise ratio.

3. References

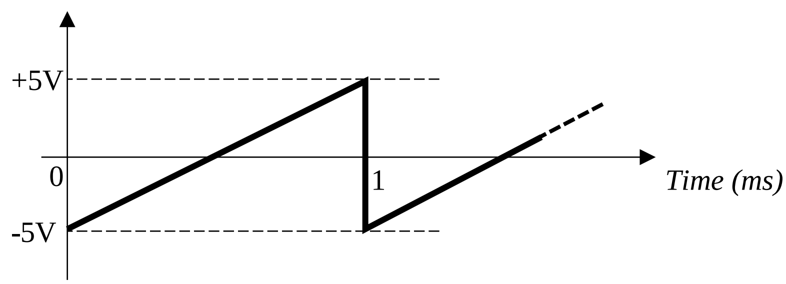
1) Handouts on "Linear Systems" available on the course homepage on Learn.Lassonde.

2) Bernard Sklar text: Chapter 2.

Problem 1 **Linear quantizer with a saw-tooth input**

In MATLAB, `floor`, `ceil`, `round`, and `fix` commands are used to approximate real numbers to integers in different ways.

1.1 Using the `floor` command, realize a linear quantizer with a full-scale range of -5V to +5V, and a resolution of 4 bits. Apply a saw-tooth signal as the input to the quantizer, with a frequency of 1kHz, peak-to-peak amplitude of 10V, and a DC offset of 0V (as shown below). Plot the input and output of the quantizer in the time domain.



1.2 Plot the input-output characteristic of the quantizer.

1.3 Plot the quantization error (also referred to as *quantization noise*) in the time domain, and find its root-mean-square (rms) value.

1.4 According to the discussions in the class, change your MATLAB program in order to reduce the rms value of the quantization error as much as you can. Let's name the improved quantizer the *quantization-error-optimum* (*QEO*) quantizer. What is the maximum possible rms improvement you can achieve for the quantization error?

➔ *Note that the quantizer resolution should remain unchanged.*

➔ *You may either use one of the other commands listed above (*`ceil`, `round`, and `fix`*) or still use the* `floor` *command but with some changes in your program.*

1.5 Change the QEO quantizer resolution to 4, 6, 8, and 10 bits, find the rms value of the quantization error, and plot the results vs. resolution.

1.6 Find the average quantization noise power for the resolutions specified in part 1.5 by (a) hand calculation using equation (2.18) of the textbook, and (b) MATLAB simulations. Compare the results.

1.7 Plot a histogram of the frequency of occurrence (# of occurrence) over a single cycle of the saw-tooth input for the quantization error values (the actual error values, not their rms) achieved in part 1.5.

Problem 2 **The case of a sine wave as the input**

2.1 Change the quantizer input from a saw-tooth signal to a sine wave with the same frequency and peak-to-peak value (*i.e.*, 1kHz and 10V(p-p), respectively), and repeat parts 1.1, 1.3, and 1.7 with the QEO quantizer with the resolution of 4 bits.

2.2 Repeat part 2.1 when the sine wave peak-to-peak amplitude is reduced to 5V(p-p). Find the *average quantization noise power* (see section 2.5.3 of the textbook) for the quantizer in both cases (*i.e.*, input amplitudes of 10V(p-p) and 5V(p-p)), and compare the results.