EE093IU
DIGITAL SIGNAL PROCESSING LABORATORY

LAB 2

SAMPLING, QUANTIZING AND CODING WITH MATLAB

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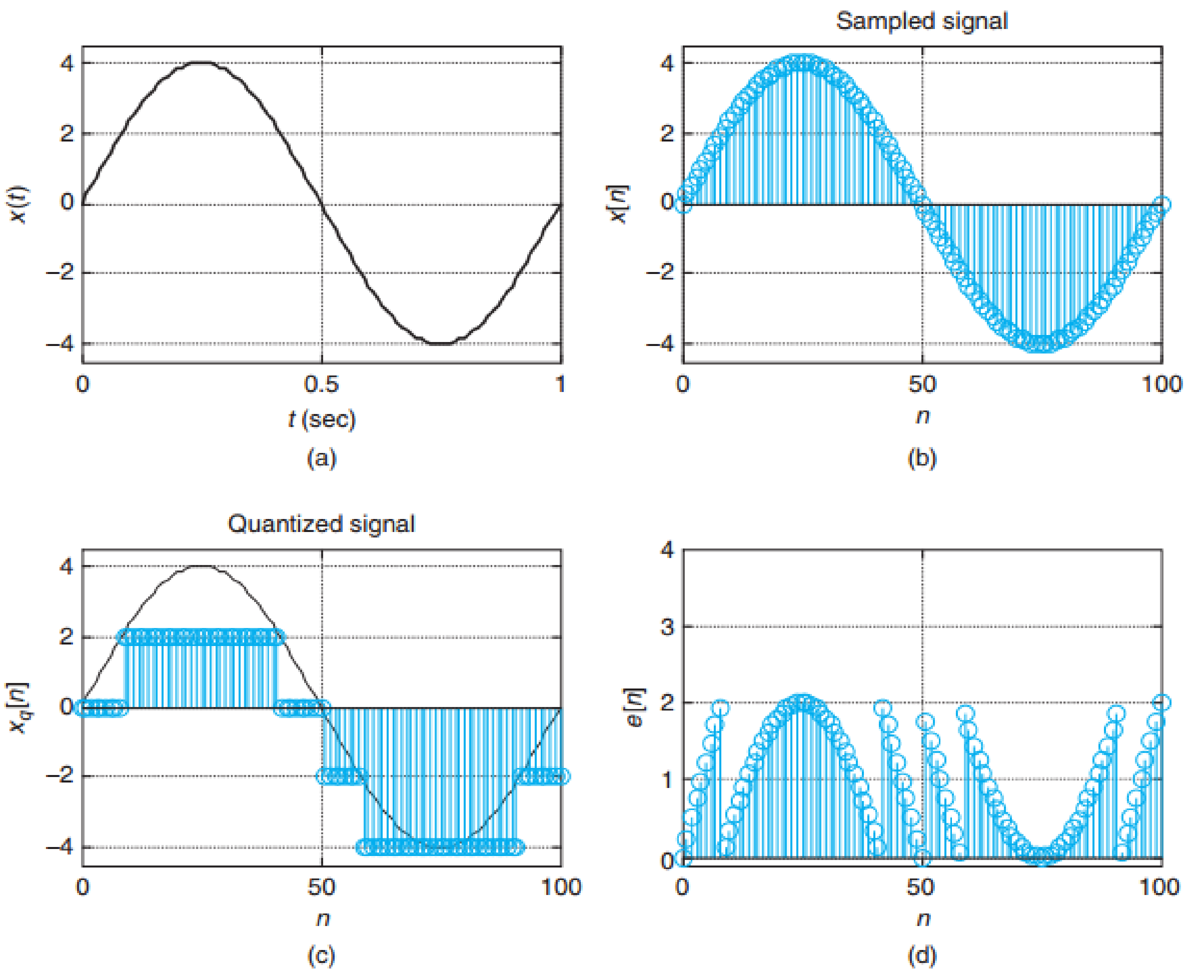
FUNDAMENTAL DISCUSSION

The conversion of an analog signal into a digital signal consists of three steps: sampling, quantization, and coding. These are the three operations an ADC does. To illustrate them, consider a sinusoid: $x(t) = 4cos(2\pi t)$. Its sampling period, according to the Nyquist sampling rate condition, is:

$$T_s \leq \frac{\pi}{\Omega_{max}} = 0.5 \text{ (sec/sample)},$$

as the maximum frequency of $x(t)$ is $\Omega_{max} = 2\pi$. We let $T_s = 0.01$ (sec/sample) to obtain a sampled signal $x_s(nT_s) = 4cos(2\pi nT_s) = 4cos(2\pi\, n/100)$, a discrete sinusoid of period 100. The following scipt is used to get the sampled $x[n]$ and the quantized $x_q[n]$ signals and the quantization error $\varepsilon[n]$



(a) original sinusoid, (b) sampled sinusoid signal,
(c) quantized sinusoid using four levels, (d) quantization error.

The quantization of the sampled signal is implemented by comparing each of the samples $x_s(nT_s)$ with four levels and assigns to each of the corresponding level. Notice the approximation of the values given by the quantized signal samples to the actual values of the signals. The difference between the original signal, or the quantization error, $\varepsilon(nT_s)$, is also computed and shown in Figure 1.

The binary signal corresponding to the quantized signal is computed using the binary codes '10', '11', '00', and '01' to the four possible levels of the quantizer. The result is a sequence of 0s and 1s, each pair of digits sequentially corresponding to each of the samples of the quantized signal.

LAB PROCEDURE

Problem 1:

Given the original signal to be $x(t) = 8cos(4\pi t)$. We sample the signal using the sampling rate $T_s = 0.01\ (sec/sample)$ to obtain a sampled signal $x_s(nT_s) = 8cos(2\pi nT_s) = 8cos\left(4\pi \frac{n}{100}\right)$. Find the quantization signals $x_q[n]$, given that the quantization levels Q with Q = 8. Write your own quantization function for this task.

Plot 2 figures: the sampled signal $x_s(nT_s)$ and the quantized signal $x_q[n]$ alongside with the original signal $x(t)$.

Problem 2:

Using the same signals $x(t)$ as in Problem 1, obtain and plot the quantization error $\varepsilon[n]$, in which:

$$\varepsilon[n] = x[n] - x_q[n]$$

Also, obtain and display the code sequence represent the 8 levels of quantization in Problem 1, follow by the rules:

$\hat{x}(nT_s) = -4\Delta$	$\rightarrow$	100	$\hat{x}(nT_s) = 0$	$\rightarrow$	000
$\hat{x}(nT_s) = -3\Delta$	$\rightarrow$	111	$\hat{x}(nT_s) = 1\Delta$	$\rightarrow$	001
$\hat{x}(nT_s) = -2\Delta$	$\rightarrow$	110	$\hat{x}(nT_s) = 2\Delta$	$\rightarrow$	010
$\hat{x}(nT_s) = -1\Delta$	$\rightarrow$	101	$\hat{x}(nT_s) = 3\Delta$	$\rightarrow$	011

With Δ being the quantization step. Write your own coding function.

Problem 3:

Quantization is done by replacing each value of an analog signal $x(t)$ by the value of the nearest quantization level. To exemplify this operation, let's simulate a unipolar ADC (Analog to Digital Converter) having the technical specifications: R Volts (full-scale range) and B (number of bits), in which R and B are the to be input using ***input*** function.

(a) Write a MATLAB function y = quantized_example(x, R, B) where x and y are vectors containing the input signal and the quantized signal, respectively;

(b) Test your function with an input sinusoid signal ranging from $-\frac{R}{2}$ to $\frac{R}{2}$ Volts (with B determines the number of steps in the quantization process);

(c) On the same graph, use the plot and stem functions to display the input signal and quantized signal, respectively;