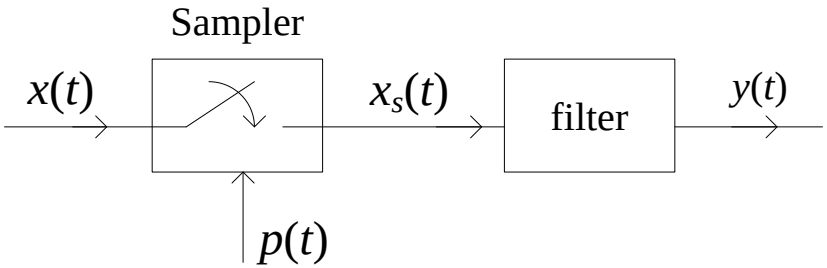
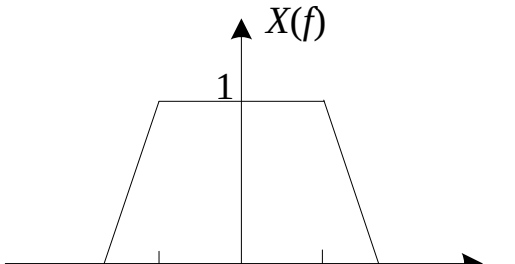
Tutorial 5 Sampling and Quantization

Problem 1 (Natural Sampling)

A baseband signal $x(t)$ is sampled with a pulse train $p(t)$, producing an output $x_s(t)$, as shown in Fig. 1(a). The sampling process here is termed **natural sampling**. The sampled signal $x_s(t)$ is then applied to a filter for further processing.



(a)



(b)

If the Fourier spectrum of $x(t)$ is given by Fig. 1(b), and if the pulse train $p(t)$ has unit amplitude and a period of $T_0 = 10^{-5}$ second and a pulse duration of $\tau = 2\text{x}10^{-6}$ second, determine:

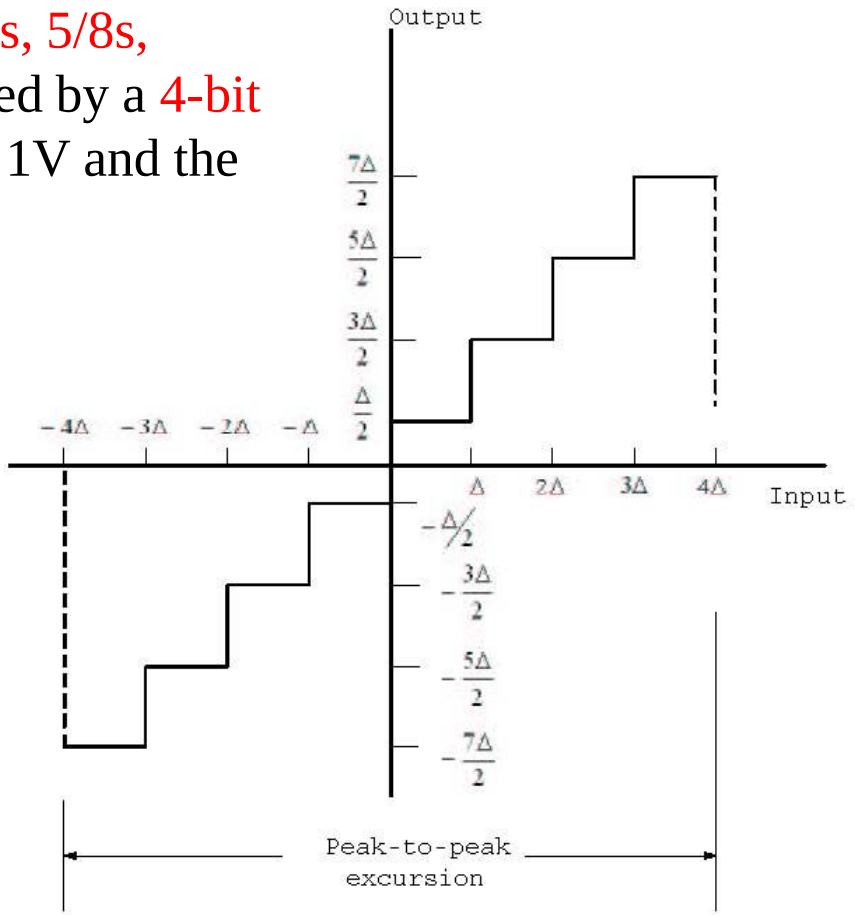
1. The Fourier spectrum of $y(t)$ if the filter is a low-pass filter with bandwidth 1kHz;
2. What kind of filter should be used if we expect $y(t)$ to be an AM-DSB-SC signal with carrier frequency at 200 kHz ?

Problem 2 (Midriser)

Assume sampling a signal $m(t)=6\sin(2\pi t)$ at 4 samples per second taken at t=1/8s, 3/8s, 5/8s, 7/8s …… The samples are then quantized by a 4-bit midriser (see Fig. 1) with a step size of 1V and the following codebook:

0.5→0000	-0.5 → 1000
1.5→0001	-1.5 → 1001
2.5→0010	-2.5 → 1010
…	
4.5→0100	-4.5 → 1100
5.5→0101	-5.5 → 1101
…	

Sketch the resulting sequence of the quantized samples for one cycle of the input.



Problem 3 (Quantization Error)

Consider a signal with dynamic range (-3V, 3V). Suppose the signal is sampled and each sample is uniformly quantized using 6 bits.

i) What is the quantization step size?

ii) What is the maximum quantization error?

iii) What is the quantization noise power?

iv) How many bits per sample are needed to reduce the maximum quantization error to 12.5 millivolts?

Problem 4 (SQNR)

A full-scale uniformly distributed signal is applied to a uniform quantizer. Determine the output SQNR (in the form of dB).

Note: "full-scale" means that the dynamic range of the signal amplitude is identical to the dynamic range of the quantizer.

Problem 5 (SQNR)

A 10-bit uniform quantizer is designed to operate over a dynamic range of (-5V,5V).

i) For a full-scale sinusoid, determine the output SQNR;

ii) For a sinusoid with peak amplitude 0.05V, determine the output SQNR.

(write the SQNR in the form of dB)

Problem 6 (Gray Code)

A signal with dynamic range (-8V, 8V) is applied to a 3-bit midriser.
Assume the samples have the following amplitudes:
4.6V, 0.8V, -0.2V, 1.6V, 3.4V, -6.4V.
Assign the Gray codes to each layer from low to high.

Sketch the resulting sequence of the quantized samples.