

Solution to Homework Assignment 8

Solution to Problem 1: For uniform quantization, since the quantization regions are the same size and there are 5 regions, the size of each quantization region is $\Delta = 10/5 = 2$. The quantization regions are:



$(-3, -1] \quad (-1, 1] \quad (1, 3] \quad [3, 5]$.

The quantization levels of the regions. They are

$-2, \quad 0, \quad 2, \quad 4$.

(b) The output is the following sequence: $\{-2, 2, 4, 0, 2\}$.

Solution to Problem 2:

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(a) From the quantizer

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$$\begin{aligned} \text{MSE} &= E[(M - V)^2] \\ &= \int_{-2}^0 (m + 1)^2 f_M(m) dm + \int_0^2 (m - 1)^2 f_M(m) dm \\ &= 2 \int_0^2 \left(-\frac{m}{4} + \frac{1}{2}\right)^2 dm \quad (\text{by symmetry}) \end{aligned}$$

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(b)

$$E[M^2] = \int_{-2}^2 m^2 f_M(m) dm = 2 \int_0^2 m^2 \left(-\frac{m}{4} + \frac{1}{2}\right) dm = \frac{2}{3}.$$

The SQNR is

$$\text{SQNR} = \frac{E[M^2]}{\text{MSE}} = 2 \approx 3 \text{ dB}.$$

(c) V can take 2 values: -1 and 1 .

$$\begin{aligned} P[V = -1] &= P[M \in (0, 2]] = \int_0^2 f_M(m) dm = \int_0^2 \left(-\frac{m}{4} + \frac{1}{2}\right) dm = \frac{1}{2}. \\ P[V = 1] &= P[M \in [-2, 0]] = \int_{-2}^0 f_M(m) dm = \int_{-2}^0 \left(\frac{m}{4} + \frac{1}{2}\right) dm = \frac{1}{2}. \end{aligned}$$

Solution to Problem 3:

(a) The Nyquist rate is $2W = 8M$ Hz. So the guard band has bandwidth $8M * 0.125 = 1M$ Hz. Since guard band $= f_s/2 - W$, The actual sampling rate is

$$f_s = (1M + 4M) \times 2 = 10 \text{ MHz}.$$

(b) The sampling period is

$$T_s = 1/f_s = \frac{1}{10^7} \mu s = 0.1 \mu s.$$

With 1024 levels, each sample is encoded into $\log_2 1024 = 10$ bits. To send 10 bits for every $0.1 \mu s$, the maximum permissible bit duration is

$$T_b = \frac{T_s}{10} = 0.01 \mu s$$

The bit rate is $f_b = \frac{1}{T_b} = 100$ million bits per second.



Solution to Problem 4:

(a) For any sample $x(t)$, $x(t) \in [-1.5, 3]$. To have 8 regions of the same size, the size of each region is $\Delta = 4.5/8 = 0.5625$. The quantization regions for the 8-level uniform quantizer are

$$[-1.5, -0.9375], (-0.9375, -0.375], (-0.375, 0.1875], (0.1875, 0.75], \\ (0.75, 1.3125], (1.3125, 1.875], (1.875, 2.4375], (2.4375, 3].$$

The quantization levels for the 8 regions are, respectively,

$$-1.21875, -0.65625, -0.09375, 0.46875, 1.03125, 1.59375, 2.15625, 2.71875.$$

(b) The sampled analog sequence is

$$\dots, 0.5, -1, 0.5, 0.5, -1, 0.5, \dots$$

The output digital sequence of the quantizer is

$$\dots, 0.46875, -1.21875, 0.46875, 0.46875, -1.21875, 0.46875, \dots$$

Solution to Problem 5: The codewords are 11 01 00 10 11. $N = 2^2 = 4$. For the range $[-1, 1]$, the representation levels for the uniform quantizer are

$$-3/4, -1/4, 1/4, 3/4.$$

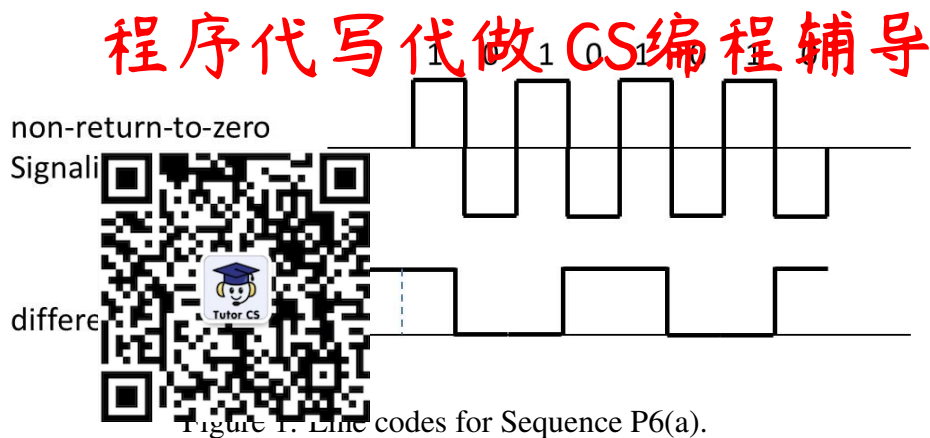
The codewords corresponding to these levels are

$$00, 01, 10, 11.$$

Thus the quantized values are:

$$3/4, -1/4, -3/4, 1/4, 3/4.$$

Solution to Problem 6:



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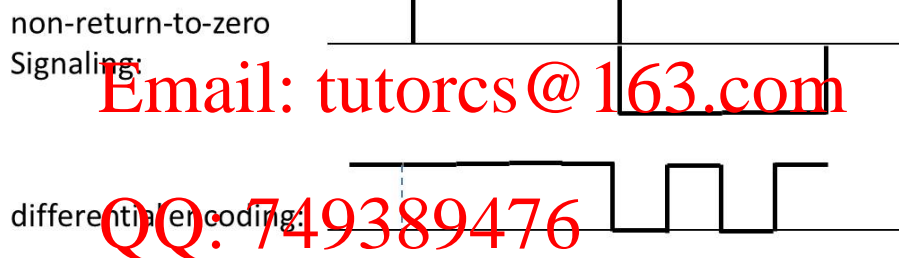


Figure 2: Line codes for Sequence P6(b).

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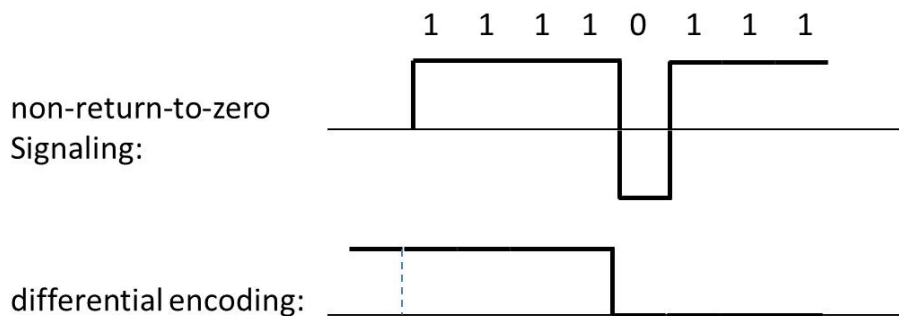


Figure 3: Line codes for Sequence P6(c).