**Solution for Week 1 Tutorial**

**Solution 1**

1. Quantisation step size can be calculated as follows:

SQNR dB = 4.8 + 6n – α dB where α = dynamic range

n = (SQNR + α – 4.8) / 6 = (40 dB + 13 dB – 4.8) / 6 = 8.03.

Therefore, the n=8 bits.

With n=8

Quantisation level, m = 2n = 28 = 256

Quantisation step size, q = Vpp / m = 5v / 256 = 0.01953 v

1. Quantisation error (in percentage) with respect to the peak signal amplitude:

q/2 = (0.01953 /2) / 2.5 x 100% = 0.3906%

**Solution 2**

Given that the signal is quantised **to 4 bits code** per sample.

Bandwidth of each signal = 5000 Hz

Hence, Nyquist rate = 2 x 5000 Hz = 10,000 Hz for each signal

For 4 analogue signals, the sampling rate is 4 x 10,000 Hz = 40,000 samples/sec

Therefore, the minimum bit rate = **40,000 \* 4 bit = 160,000 bps = 160 kbps**

**Solution 3**

Step 1:

Nyquist sampling rate = 2 \* 3000 Hz = 6000 Hz (samples/second), but the actual rate is a 33.33% higher than the Nyquist sampling rate, so that is 6000 Hz + (33.33% x 6000) = 8000 Hz.

Step 2:

The quantized levels are separated by Δv . The maximum error for any sample point’s quantised value is at most .

Given the quantisation error, should be 0.5% of peak amplitude mp , we can write:

Therefore, L = 200

For binary coding, *L*, must be a power of two; therefore, knowing that *L* = 27 = 128 and 28 = 256, we must choose *n* = 8 to guarantee better than a 0.5% error.

Total number of bits per second = 8 bits x 8000 Hz = 64,000 bps.

Step 3:

We can calculate the required channel bandwidth using Nyquist bandwidth formula:

C = 2B log2 M

Where C is the channel capacity, B is the channel bandwidth, M is the multilevel signal

64,000 bps = 2Blog2 4

B = 64,000 / 2 (2) = 16,000 Hz.

**Solution 4**

1. Determine the Huffman code for each symbol

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Symbol (S) | S0 | S1 | S2 | S3 | S4 |
| Probability (Pk) | 0.55 | 0.15 | 0.15 | 0.10 | 0.05 |
| Huffman code (Ik) | 0 | 11 | 100 | 1010 | 1011 |

1. Determine the average code length

bits

1. Determine the **entropy** of the source

= 1.84 bits

1. Determine the coding efficiency of this code