

Quantization in PCM with example

QUANTIZATION

The PCM signal is generated by carrying out following basic operations:

1. Band limiting (using LPF)
2. Sampling
3. Quantizing
4. Encoding

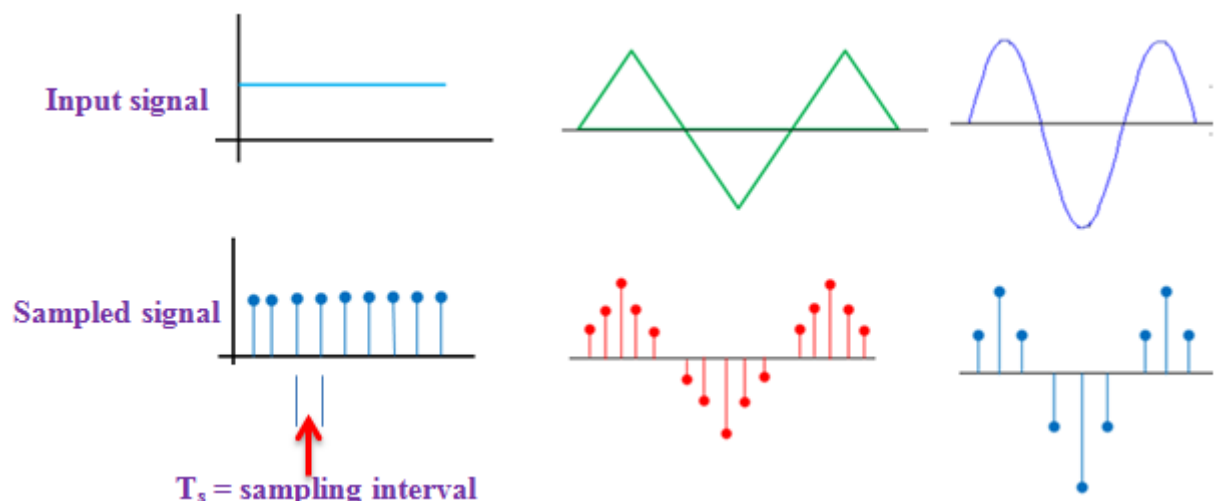
Two fundamental processes are involved in the generation of a PCM signal: **sampling , quantization and encoding.**

Sampling is Time discretization and quantization is Amplitude discretization.

In PCM, conversion of analog signal to digital signal is done in Three steps

- Sampling
- Quantization and incoding

Below figure shows sampling step:



Sampling theorem

$$T_s = 1/F_s \quad \text{with } F_s \geq 2 F_m$$

Quantization is the process of rounding of the sample value to the nearest quantization level.

Remember that number of quantization levels is predefined according to allocated bit per sample (n or v)

If n = number of bits used to represent the sample

Then, **q** = number of quantization levels = 2^n

and, $\text{Log } q = \log (2^n) = n \text{ Log } 2$

$n = \text{Log } q / \text{Log } 2$

suppose, if $n = 2$, then $q = 2^n = 2^2 = 4$ quantization levels

if $n = 8$, then $q = 2^n = 2^8 = 256$ quantization levels exist

STEPS IN QUANTIZATION

1. Total voltage range is divided into q equal intervals of step size S

$$S = \frac{V_H - V_L}{q} = \frac{V_H - V_L}{2^n}$$

where V_H = Max. voltage value

V_L = Min. voltage value

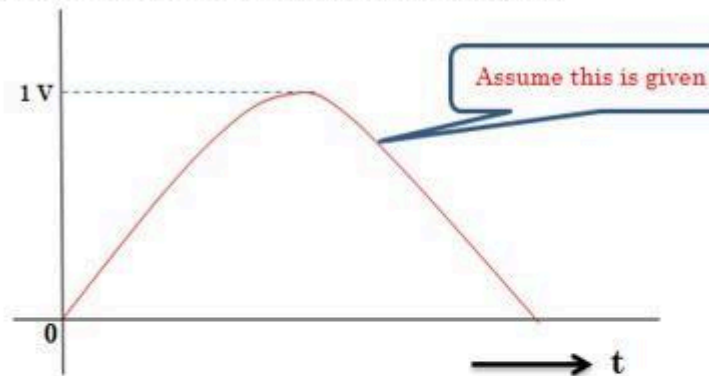
2. Draw mid lines representing quantization levels
 3. Assign binary codes (pre-defined) to each quantization level
 4. Calculate quantization error
-

Quantization Example

Q. A 2-bit PCM modulator is used with a 0-1 V signal. What is the binary digital value that will occur for the following inputs: 0.4 V, 0.78 V. What is the quantization error for these two samples?

Sol:

$n = \text{number of bits} = 2$
 $q = \text{No. of quantization levels}$
 $= 2^n$
 $= 4$



STEPS IN QUANTIZATION

1. Total voltage range is divided into q equal intervals of step size S

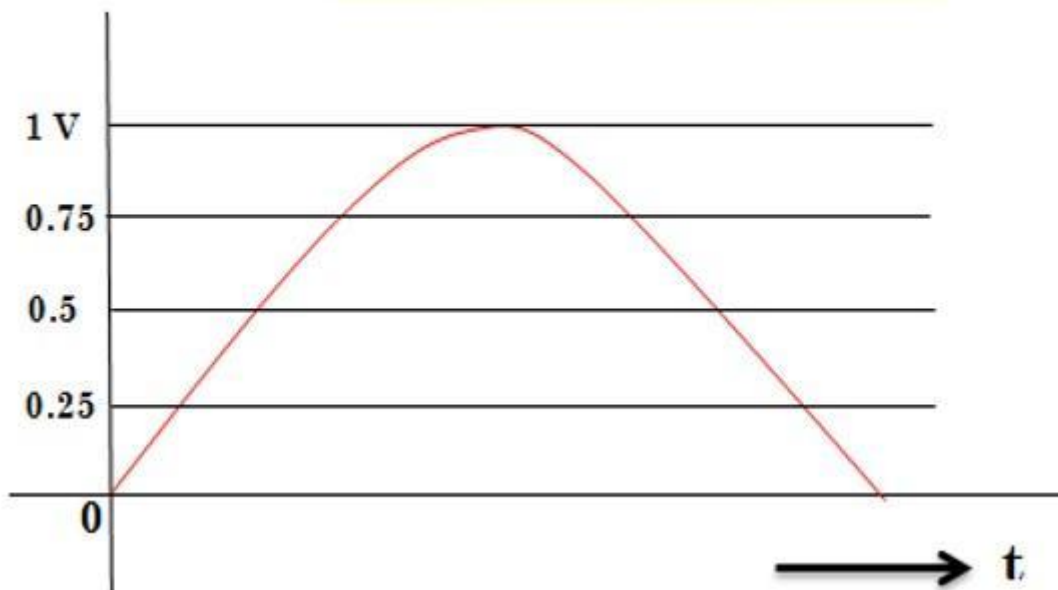
$$S = \frac{V_H - V_L}{q} = \frac{V_H - V_L}{2^n}$$

where $V_H = \text{Max. voltage value}$

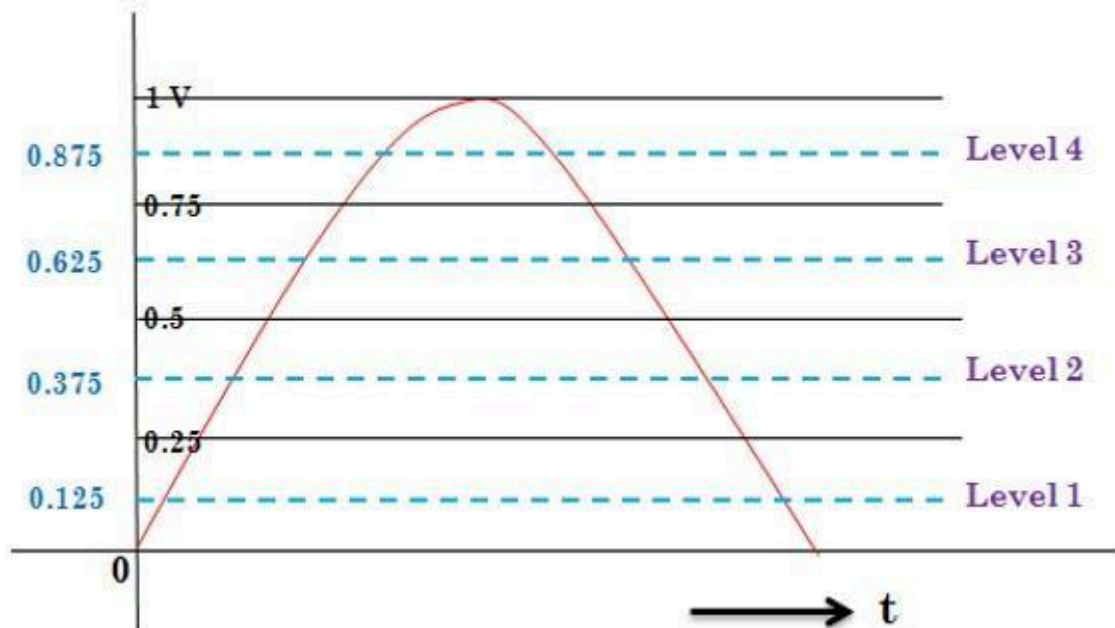
$V_L = \text{Min. voltage value}$

2. Draw mid lines representing quantization levels
3. Assign binary codes (pre-defined) to each quantization level
4. Calculate quantization error

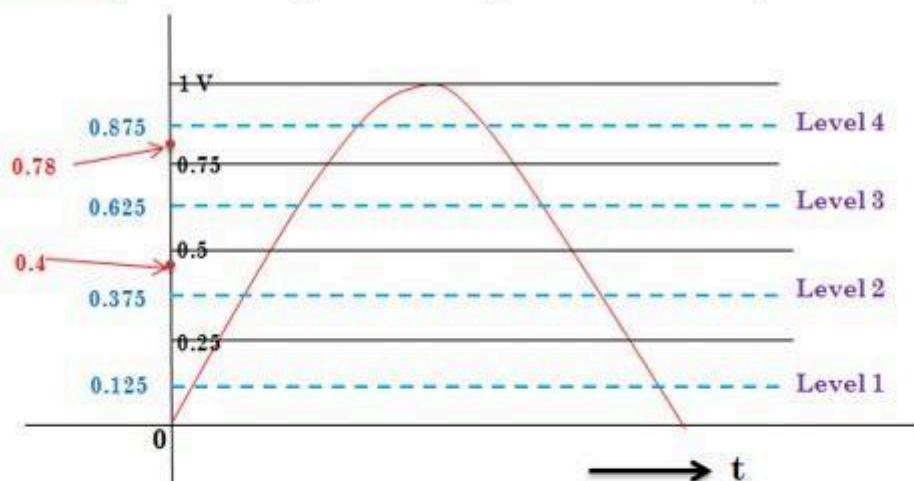
Step 1: Step size $S = \frac{V_H - V_L}{2^n} = \frac{1-0}{4} = \frac{1}{4} = 0.25$



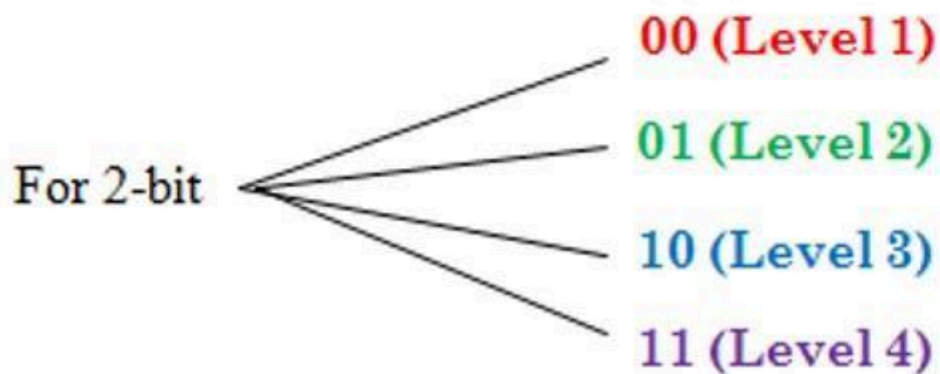
Step 2: Draw mid-lines, which represents quantization levels



Step 3: Denote given sample values i.e., 0.4 V & 0.78 V



Step 4: Represent each quantization level with predefined binary code



Quantizing 0.4 V sample value:

See that level 2 is near to 0.4 V. So, for sample voltage 0.4 V, 01 code is transmitted.

$$\text{Quantization error } e = 0.4 - 0.375 = 0.025 \text{ V}$$

Quantizing 0.78 V sample: Level 4 is nearest to 0.78 V. So, digital code 11 is transmitted.

$$\text{Quantization error } e = 0.875 - 0.78 = 0.095 \text{ V}$$

NOTE:

Quantization process introduces a certain amount of **error** or distortion.

This error known as **quantization noise** and is minimized by increasing the number of **quantization levels**. But increasing number of quantization levels increases number of bits to represents each sample and hence increases bit rate and cost of transmission.

Quantization in PCM with Example PDF