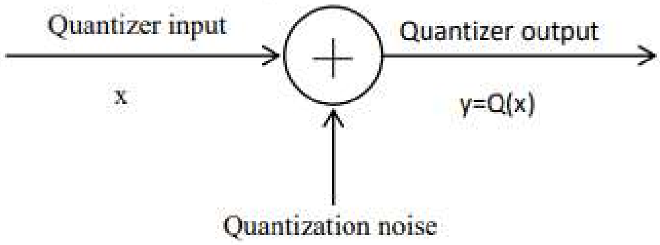
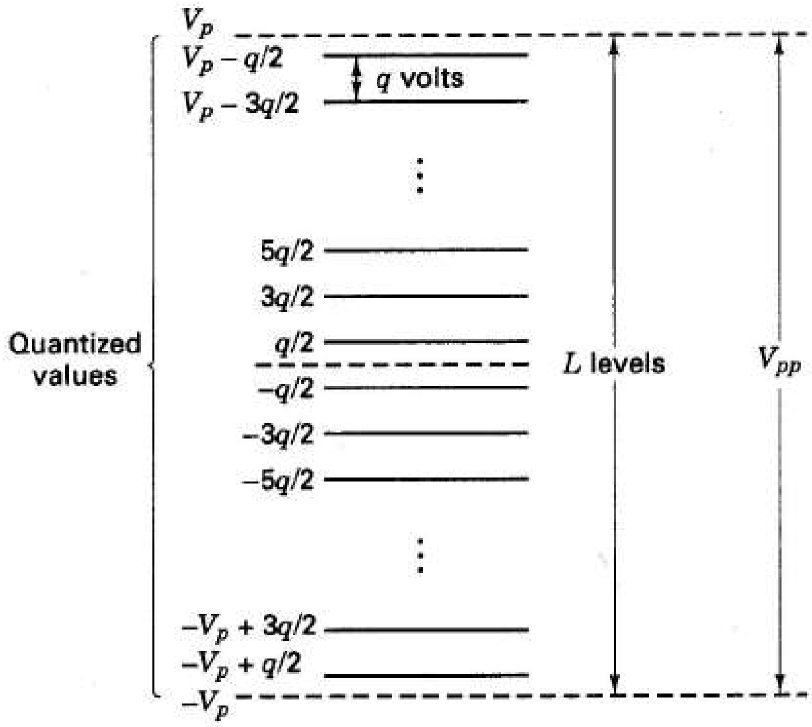
QUANTIZATION

The process of representing a large (possibly infinite) set of values with a much smaller set of values is called quantization.



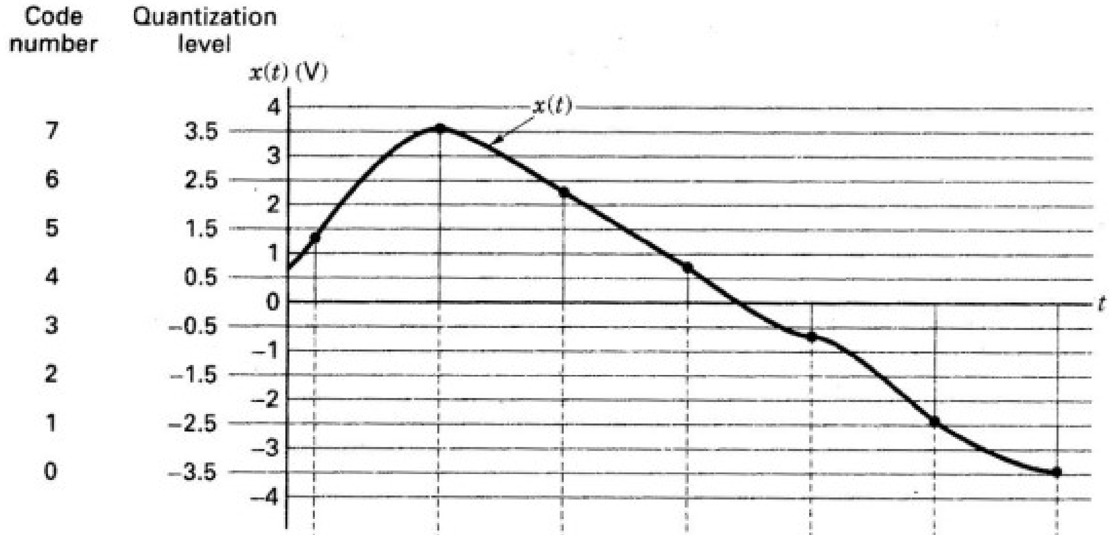
The source information is sampled and quantized to one of 'L' levels. Then each quantized sample is digitally encoded into an l-bit codeword, where $l=\log_2 L$. For baseband transmission, the codeword bits will then be transformed to pulse waveforms.



Quantization Levels

The Figure illustrates an L-level linear quantizer for an analog signal with a peak-to peak voltage range of $V_{pp}=V_p-(-V_p) = 2\ V_p$ volts. The quantized pulses assume positive and negative values. The stepsize between quantization levels, called the quantile interval, is denoted by q volts. When the quantization levels are uniformly distributed over the full range, the quantizer is called a uniform or linear quantizer. Each sample value of the analog waveform is approximated with a quantized pulse. The degradation of the signal due to quantization is therefore limited to half a quanitle interval, $\pm\frac{q}{2}$volts.

Figure below shows an analog signal x(t) limited in its excursions to the range -4 to +4V. The stepsize between quantization levels has been set at 1V. Thus, eight quantization levels are employed. These are located at -3.5, -2.5,……+3.5V. Assign the code number 0 to the level at -3.5V, code number 1 to the level at -2.5V, and so on, until the level at 3.5V, which is assigned the code number 7.



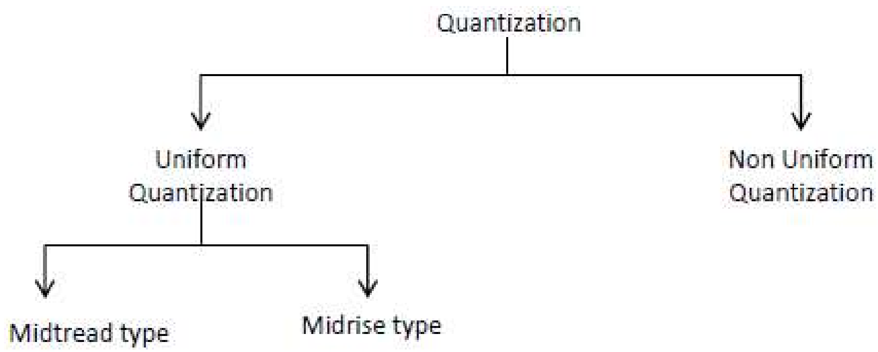
Natural sample value	1.3	3.6	2.3	0.7	−0.7	−2.4	−3.4
Quantized sample value	1.5	3.5	2.5	0.5	−0.5	−2.5	−3.5
Code number	5	7	6	4	3	1	0
PCM sequence	101	111	110	100	011	001	000

Each code number has its representation in binary arithmetic, ranging from 000 for code number 0 to 111 for code number 7. The quantile intervals between the levels should be equal. The ordinate in Figure above is labeled with quantization levels and

their code numbers. Each sample of the analog signal is assigned to the quantization level closest to the value of the sample. There are four representations of x(t) as follows: the natural sample values, the quantized sample values, the code numbers, and the PCM sequence.
Here, each sample is assigned to one of eight levels or a three-bit PCM sequence. Increasing the number of levels will reduce the quantization noise. If we double the number of levels to 16, each analog sample will be represented as a four-bit PCM sequence. But when there are more bits per sample, the data rate is increased, and the cost is a greater transmission bandwidth. Thus, we can obtain better fidelity at the cost of more transmission bandwidth.

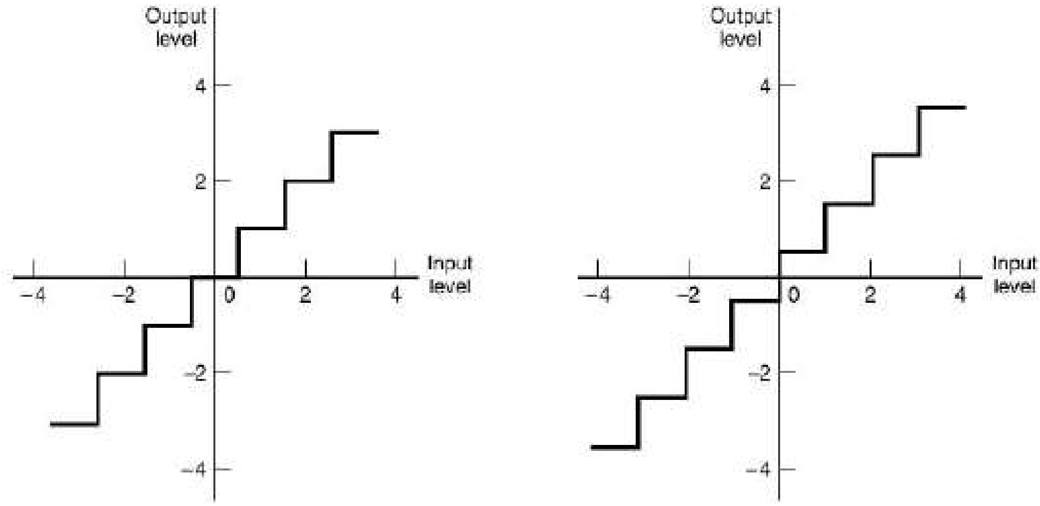
UNIFORM AND NON-UNIFORM QUANTIZATION

The quantization process converts the continuous amplitude values into a finite (discrete) set of allowable values. This process is called "discretization" in time and amplitude.



1. Uniform quantization

When the quantization levels are uniformly distributed over the full amplitude range of the input signal, the quantizer is called an uniform or linear quantizer. In uniform quantization, the stepsize between quantization levels remains the same throughout the input range. The quantizer characteristic can also be midtread or midrise type, as shown below:



a) Midtread Type b) Midrise Type

Two types of Uniform Quantization

Both the midtread and midrise types of uniform quantizers are symmertric about the origin. Hence, they are also called as **symmetric quantizer**.

2. Non-uniform quantization

If the quantizer characteristic is nonlinear, then the quantization is known as non-uniform quantization. In non-uniform quantization, the step size is not constant. The step size is variable, depending on the amplitude of input signal.

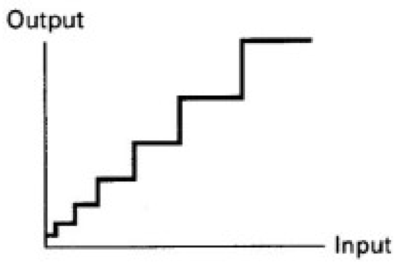
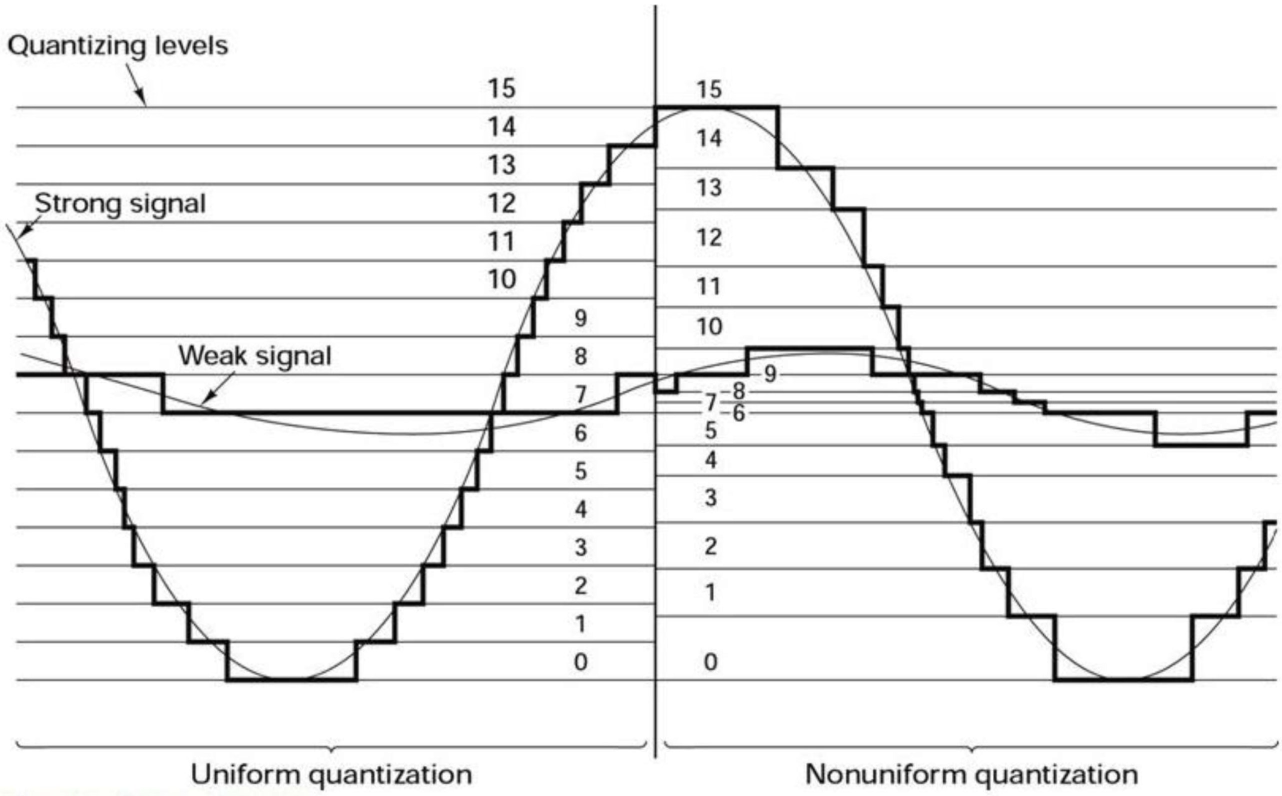


Figure below compares the quantization of a strong signal versus a weak signal for uniform and non-uniform quantization.



Quantization process:

A continuous signal, such as voice, has a continuous range of amplitudes and therefore its samples have a continuous amplitude range. In other words, within the finite amplitude range of the signal, we find an infinite number of amplitude levels.

In a linear analog system, the transfer characteristic representing the relation between the input and the output is a straight line. For a quantizer, the transfer characteristic is staircase like in appearance.

The quantizing process has a two-fold effect:

1) The peak-to-peak range of input sample values is subdivided into a finite set of decision levels or decision threshold that are aligned with the “risers” of the staircase, and
2) The output is assigned a discrete value selected from a finite set of representation levels or reconstruction values that are aligned with the “treads” of the staircase.

The combination of sampler and quantizer is called Analog-to-Digital(A/D) converter or digitizer.

Quantization noise

The distortion inherent in quantization is a round-off or truncation error. The sample values of an analog baseband signal are rounded-off to the nearest permissible representation levels of the quantizer. This rounding-off or approximation involves discarding some of the original analog information. The distortion introduced by the need to approximate the analog waveform with quantized samples, is referred to as quantization noise. The amount of such noise is inversely proportional to the number of levels employed in the quantization process.