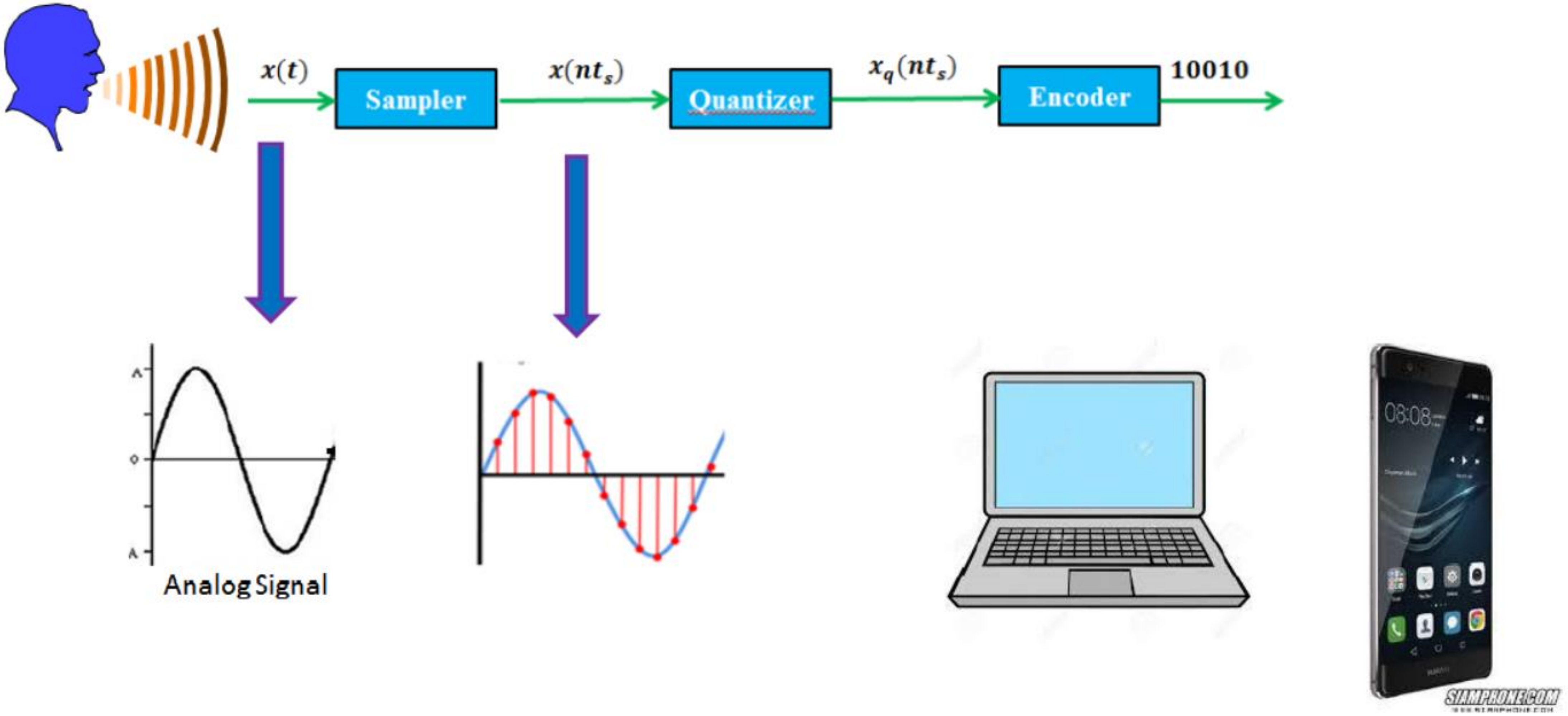
Al-Mustaqbal University
College of Science
Intelligent Medical System Department

University of Information Technology and Communications

قســـــــــم الانـــظـــمـــة الـــطبـيـة الــذكـــيـــة

Lecture 10- Analog to Digital Conversation Types

Asst. Prof. Dr. Mehdi Ebady Manaa

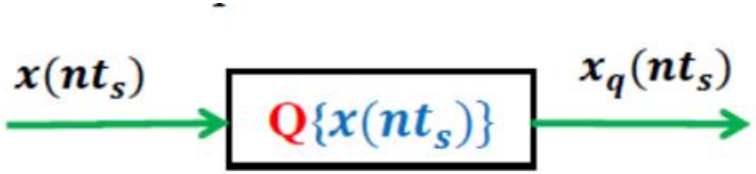


x(t)
Sampler
x(nt_s)
Quantizer
x_q(nt_s)
Encoder
10010
A
0
A
Analog Signal

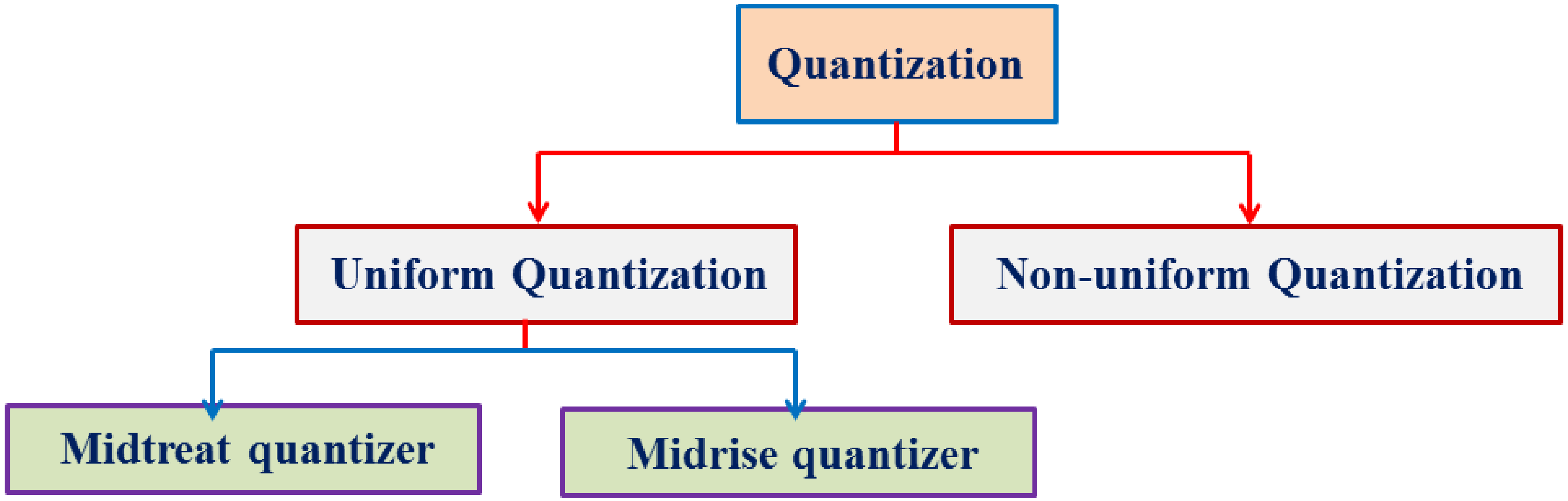
Quantization & Encoding

Quantization

Quantization: The process of transforming the continuous amplitude samples $x(nts)$ into a discrete amplitude samples $xq(nts)$ taken from a finite set of possible levels.

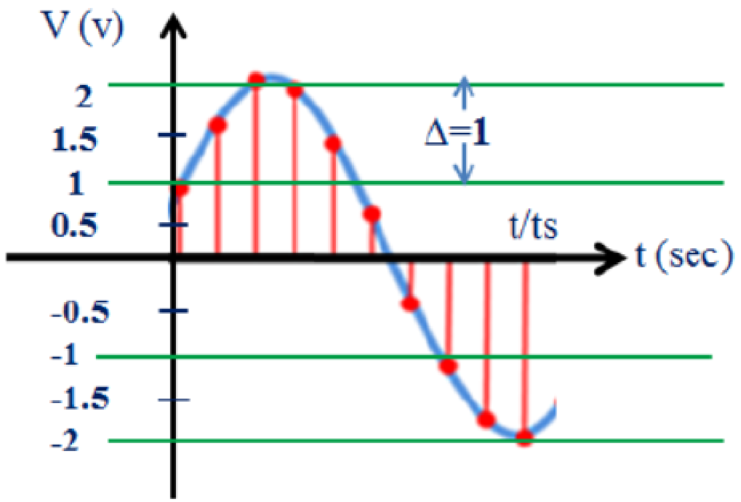


Quantization is a nonlinear and noninvertable process.

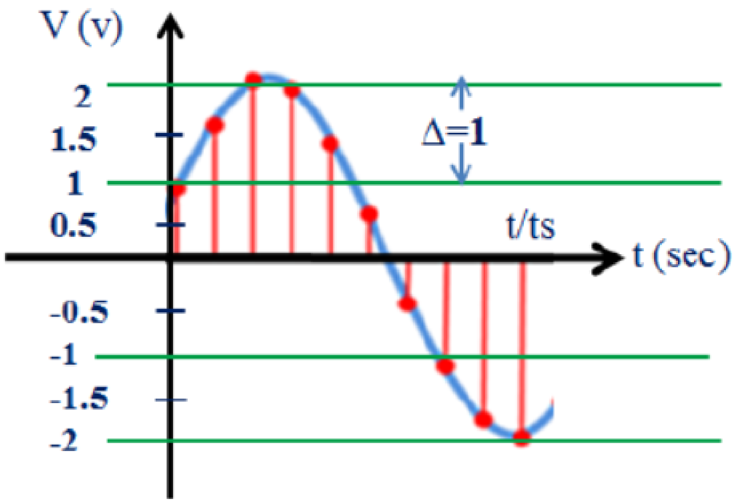


Uniform (Linear) Quantizer

Midtreat : Zero is assigned a quantization level.



Midrise : Zero is assigned a decision level.



Signal amplitude of *range R* between X_{min} and X_{max} is divided into *L quantization levels* each of *step size Δ*

$$\Delta = \frac{X_{max} - X_{min}}{L} = \frac{R}{L}$$

Δ : Step size

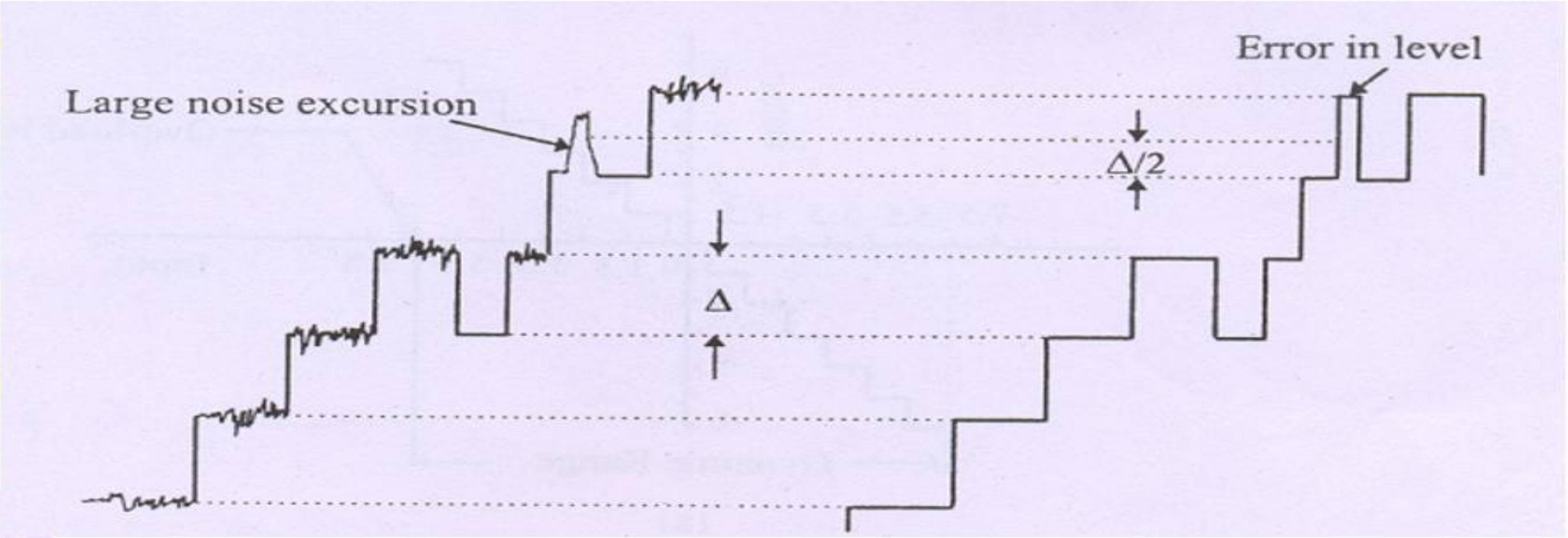
R : Range of amplitude

L: Quantization level

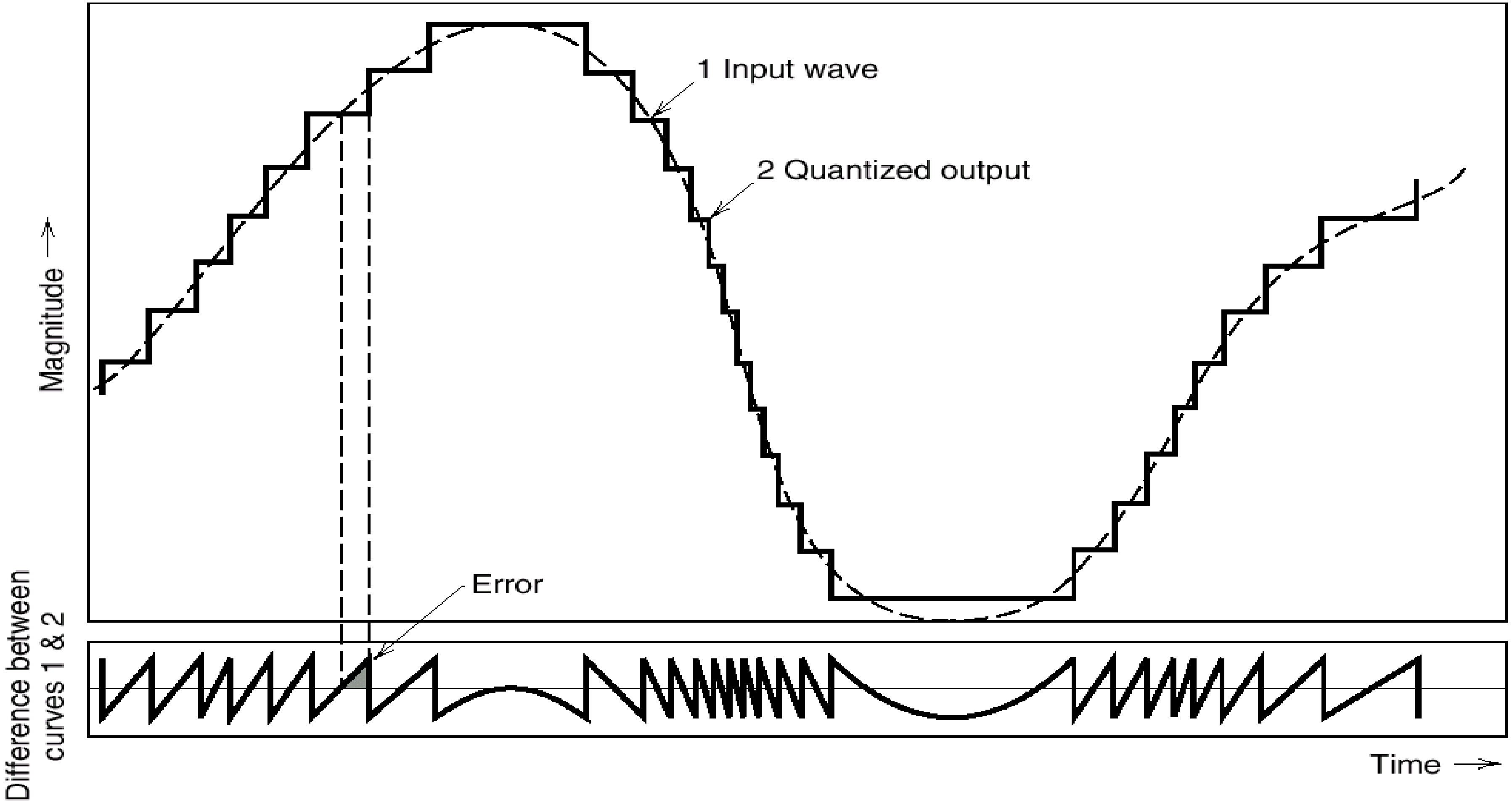
$$Eq = \frac{\Delta}{2}$$

Eq : Maximum quantization error

Quantization Error



Quantization Noise



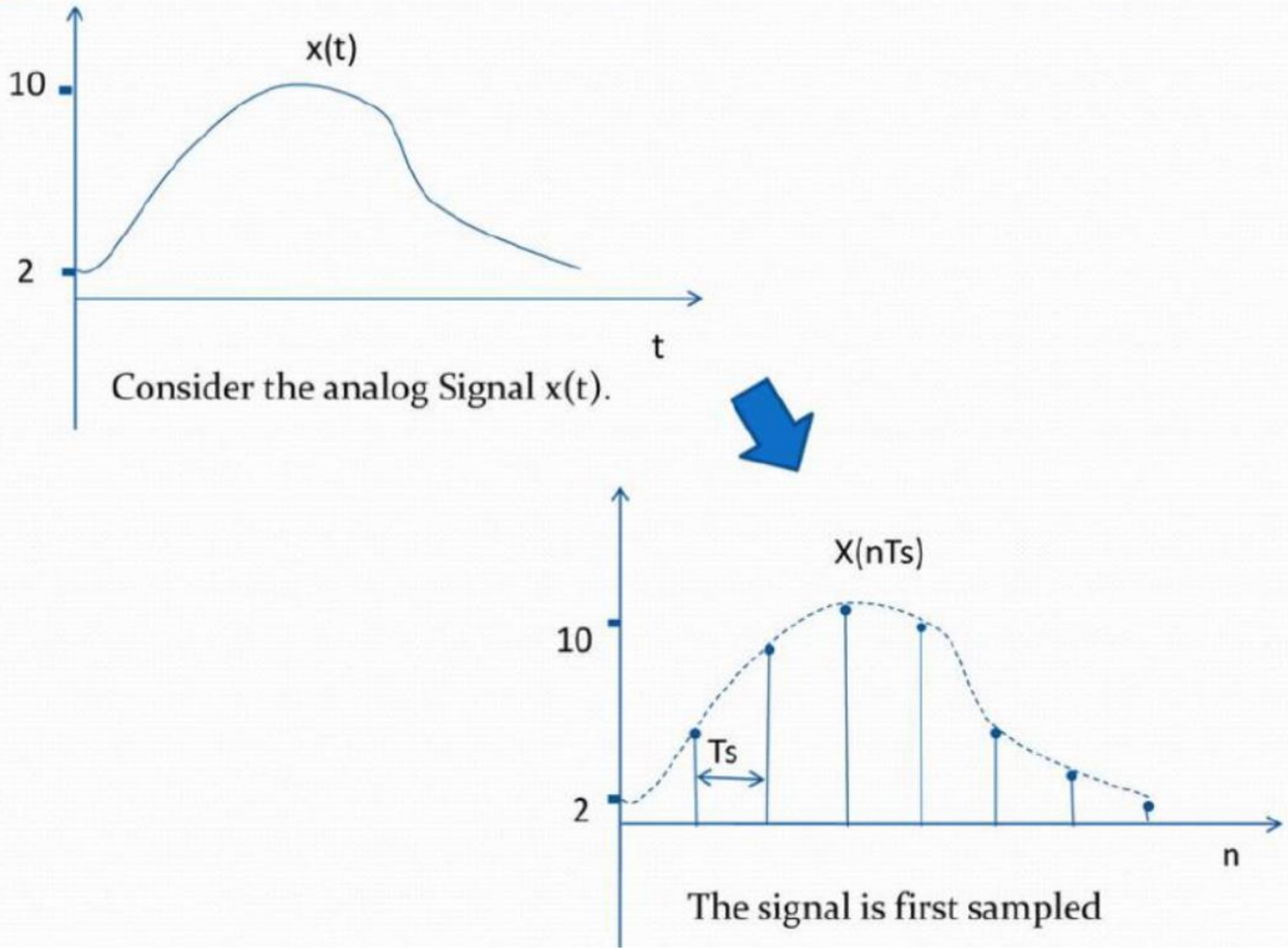
Encoding

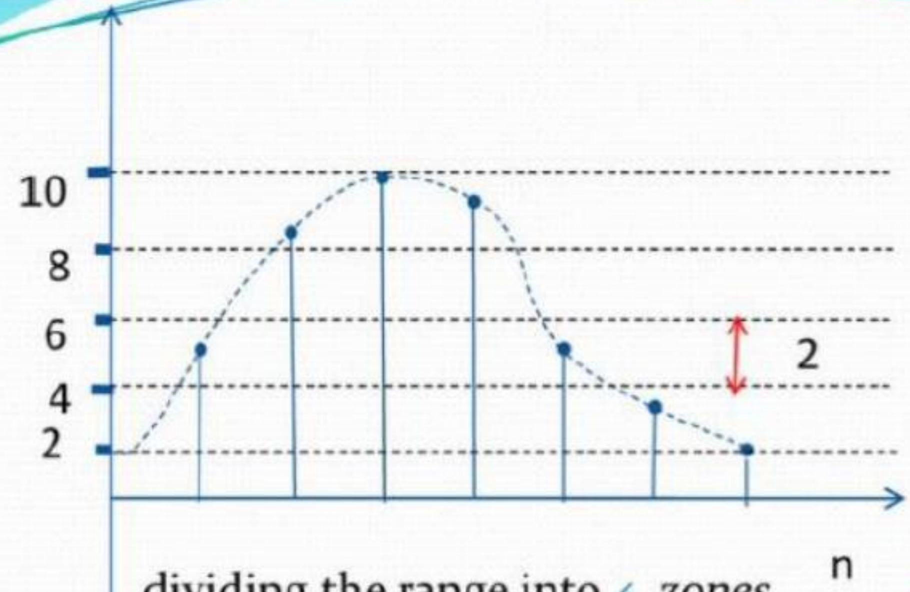
In combining the process of sampling and quantization, the specification of the continuous-time analog signal becomes limited to a discrete set of values.

Representing each of this discrete set of values as a code called **encoding** process.

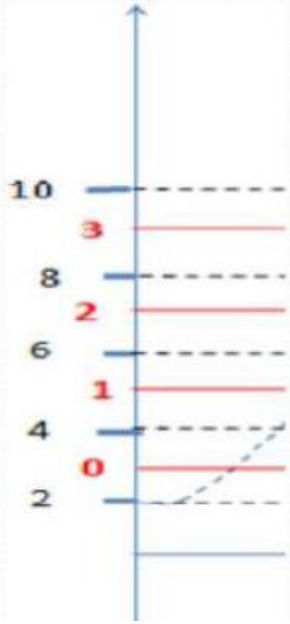
Code consists of a number of code elements called symbols.

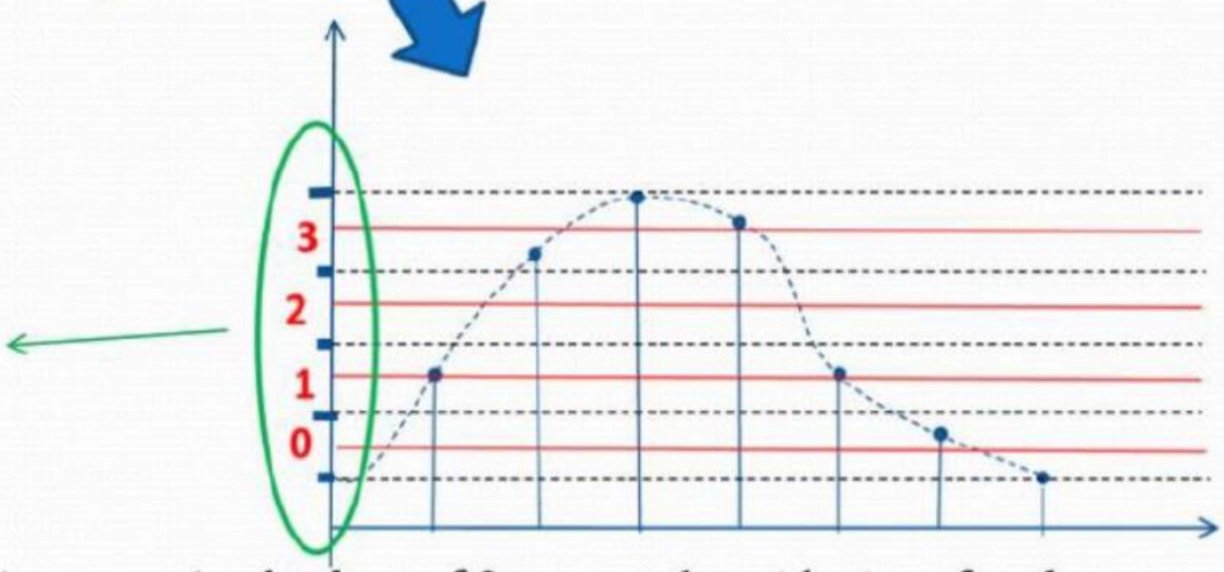
- In binary coding, the symbol take one of two distinct values. in ternary coding the symbol may be one of three distinct values and so on for the other codes.


x(t)
10
2
t
Consider the analog Signal x(t).
X(nTs)
10
Ts
2
n
The signal is first sampled

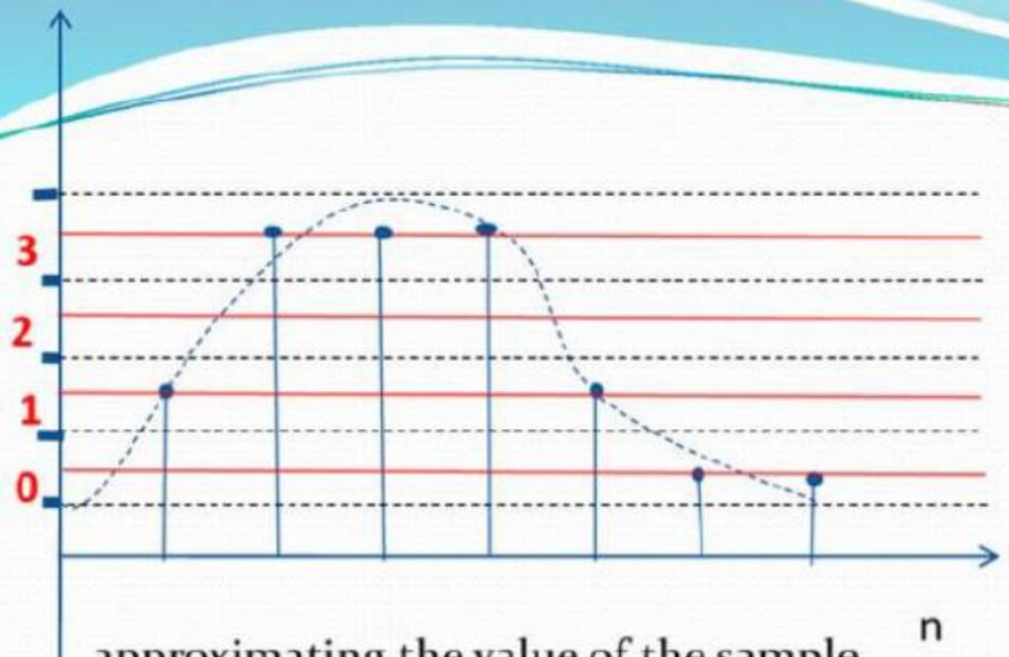


dividing the range into *4 zones*

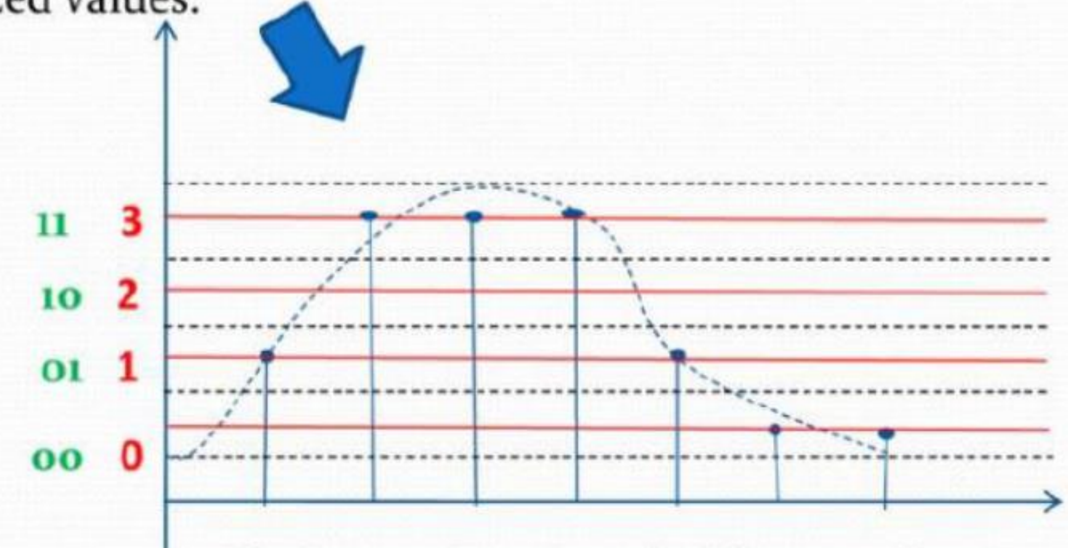




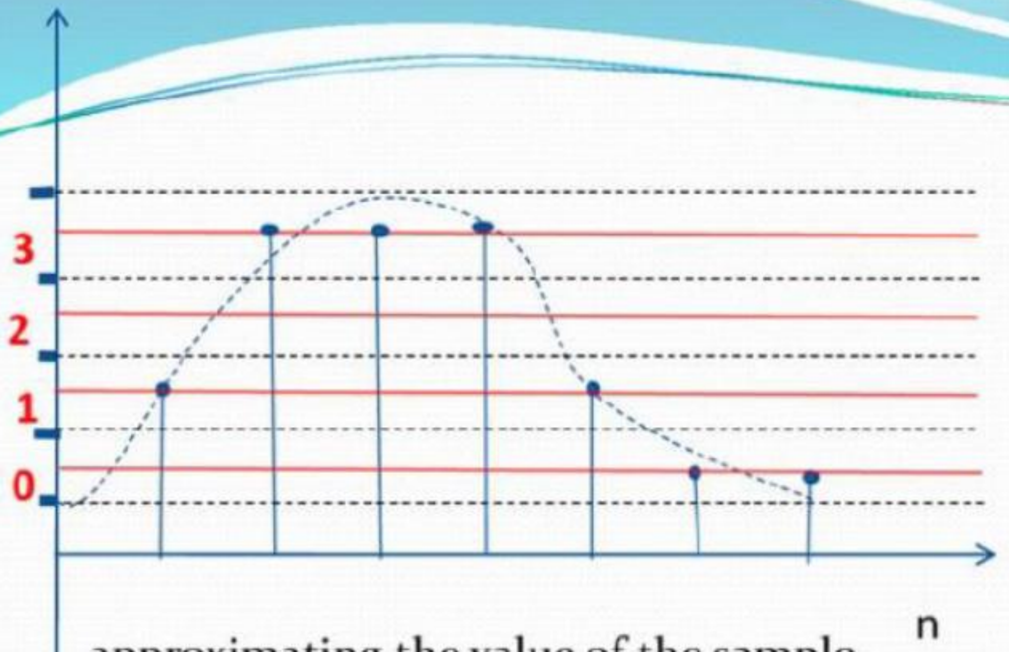
assign quantized values of 0 to 3 *to the midpoint of each zone.*



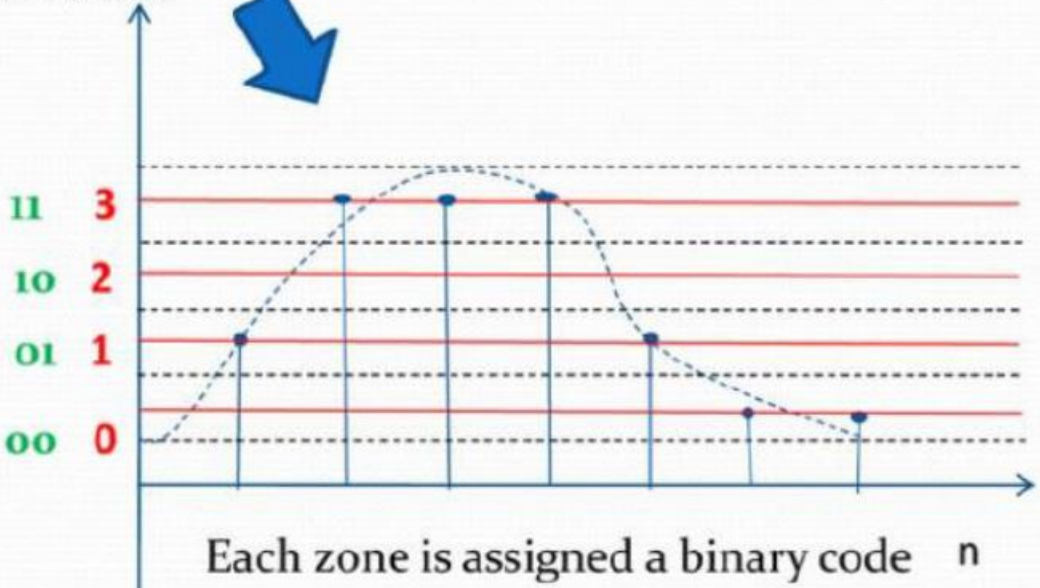
approximating the value of the sample amplitude to the quantized values.



Each zone is assigned a binary code



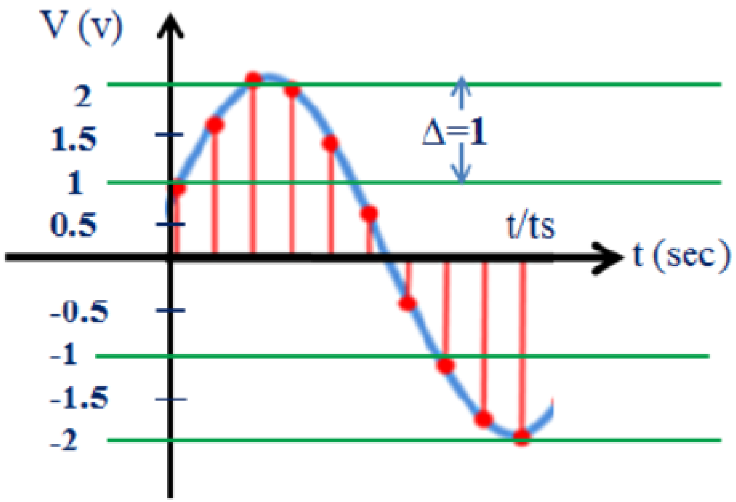
approximating the value of the sample amplitude to the quantized values.



Each zone is assigned a binary code

Encoding (Coding or Digitizing)

Encoding: it's converts each quantized sample $x_q(nt_s)$ into " b " bits codeword.



$$L = 2^b$$

L: Quantization level

b : Number of bits

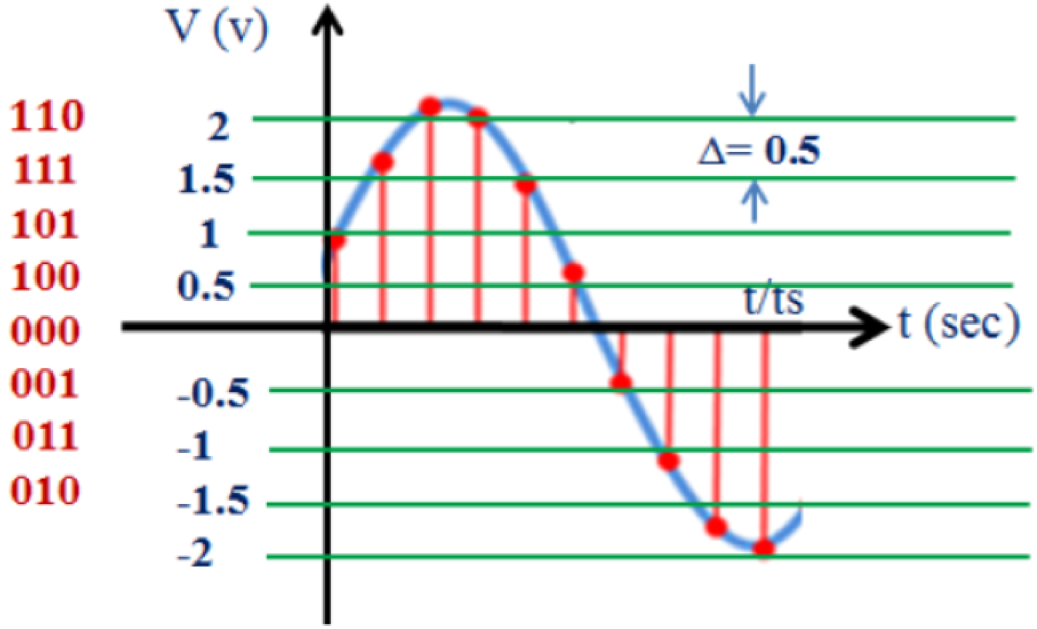
$$b = \frac{Log\ L}{Log\ 2}$$

Example: Gray coding for $L = 8$ levels (b=3 bits).

$$L = 2^b$$

$$b = \frac{Log\ L}{Log\ 2}$$

Quantizer level	2	1.5	1	0.5	0	-0.5	-1	-1.5
Codeword	110	111	101	100	000	001	011	010



Binary to Gray Code

The truth table for the conversion is-

Binary				Gray Code			
b_3	b_2	b_1	b_0	g_3	g_2	g_1	g_0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	0
0	1	0	1	0	1	1	1
0	1	1	0	0	1	0	1
0	1	1	1	0	1	0	0
1	0	0	0	1	1	0	0
1	0	0	1	1	1	0	1
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	1
1	1	1	1	1	0	0	0

Signal to quantization noise ratio (SN_qR)

$$P_x = \frac{R^2}{16}$$

P_x : Power of signal

$$N_q = \frac{\Delta^2}{12}$$

N_q: Power of quantization noise

$$SN_qR = \frac{P_x}{N_q}$$

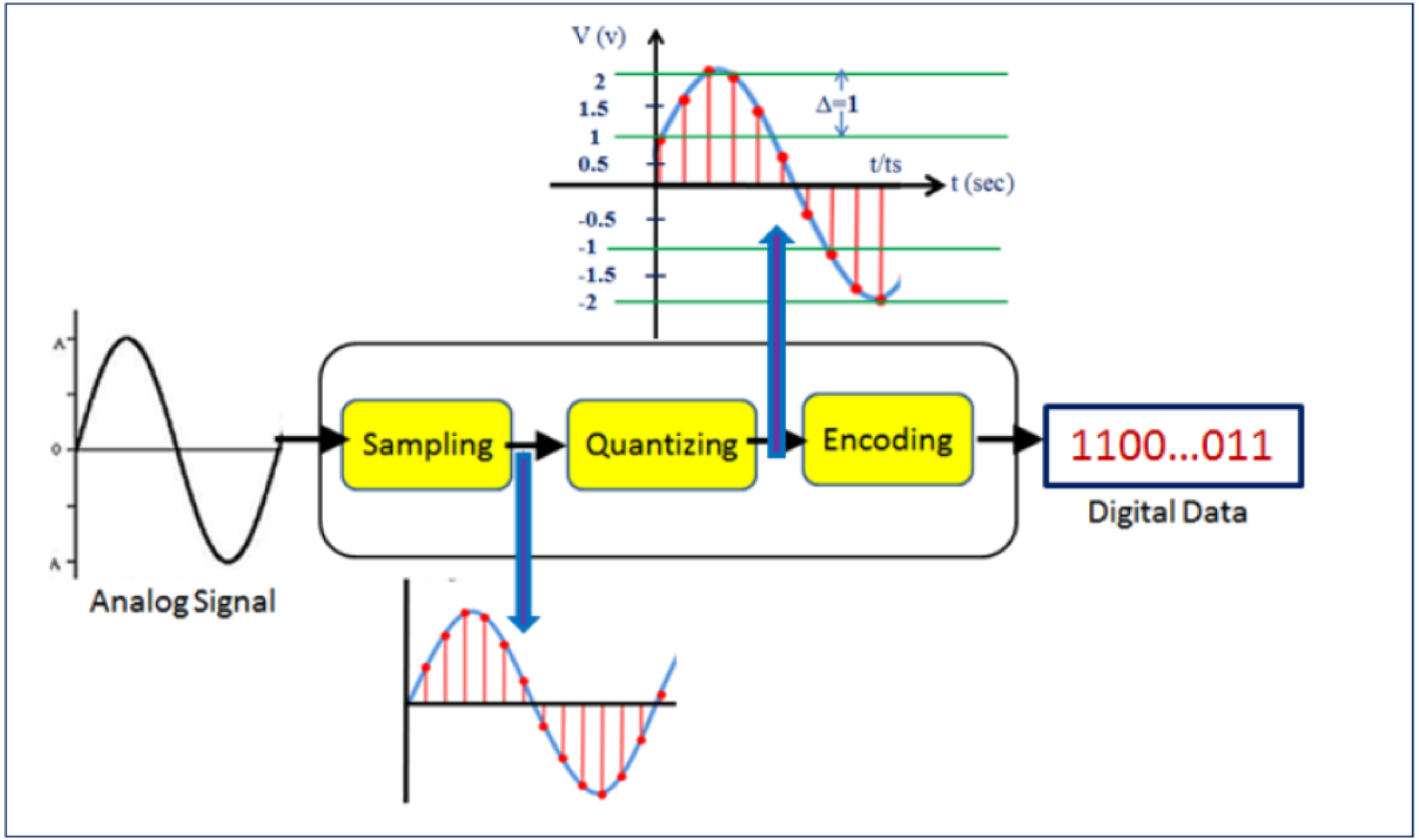
SN_qR : Signal to quantization noise ratio

$$(SN_qR)_{dB} = 10\ Log_{10} \frac{P_x}{N_q} \quad [dB]$$

SN_qR of a b-bit

$$SN_qR = 6(b) - 1.25 \quad [dB]$$

Analog to Digital Conversion (ADC)



1 $$\Delta = \frac{X_{max} - X_{min}}{L} = \frac{R}{L}$$

Δ : Step size
R : Range of amplitude
L: Quantization level

2 $$Eq = \frac{\Delta}{2}$$

Eq : Maximum quantization error

3 $$L = 2^b$$

b : Number of bits
L: Quantization level

$$b = \frac{Log\ L}{Log\ 2}$$

4 $$P_x = \frac{R^2}{16}$$

P_x : Power of signal

5 $$N_q = \frac{\Delta^2}{12}$$

N_q: Power of quantization noise

6 $$SN_qR = \frac{P_x}{N_q}$$

SN_qR : Signal to quantization noise ratio

$$(SN_qR)_{dB} = 10\ Log_{10} \frac{P_x}{N_q} \quad [dB]$$

7 SN_qR of a b-bit

$$SN_qR = 6(b) - 1.25 \quad [dB]$$

Ex:- An **ADC** is used to digitize the analog signal **$x(t) = \cos(1000\pi t)$** at sampling frequency of **f_s=2 KHz**. The ADC uses a **8- Levels** quantizer and binary encoder the signal is **P_x = 50 mw**.

1- Calculate the amplitude range (R).
2- Calculate the step size (Δ).
3- Calculate the Nyquist rate and sampling period.
4- Calculate the power of the quantization noise (N_q).
5- Calculate the minimum number of bits (b) required for the encoder.
6- Calculate the (SN_qR) in linear and decibel (dB) scales.
7- If the number of bits increased by 2. What is the (SN_qR) in (dB).

Solution:-

1

$P_x = \frac{R^2}{16} \longrightarrow R^2 = 16 * P_x$

$R^2 = 16 * 50m$

$R = \sqrt{16 * 50 * 10^{-3}}$

$\therefore R = 0.89 \approx 0.9$

3

$F_N = 2 f_m$

$= 2 * 500$

$\therefore F_N = 1000\ HZ$

$\because \omega = 2\pi f$

$1000\pi = 2\pi f$

$\therefore f = 500\ HZ = f_m$

$T_s = \frac{1}{f_s} = \frac{1}{2K}$

$\therefore T_s = 0.5\ m\sec$

2

$\Delta = \frac{R}{L} = \frac{0.9}{8}$

$\therefore \Delta = 0.11$

4

$$N_q = \frac{\Delta^2}{12} = \frac{(0.11)^2}{12}$$

$$\therefore N_q = 1m = 1 * 10^{-3}$$

5

$$L = 2^b$$

$$b = \frac{\text{Log } L}{\text{Log}_2} = \frac{\text{Log } 8}{\text{Log}_2}$$

$$\therefore b = 3 \text{ bits}$$

6

$$SN_qR = \frac{P_x}{N_q} = \frac{50m}{1m} = 50$$

$$(SN_qR)_{dB} = 10 \text{ Log}_{10} \frac{P_x}{N_q}$$

$$= 10 \text{ Log}_{10}(50)$$

$$(SN_qR)_{dB} = 16.9 \text{ (dB)}$$

7

no. of bit increased by 2

$$b+2 \longrightarrow 3+2 = 5 \text{ bit}$$

$$(SN_qR)_{dB} = 6(b) - 1.25$$

$$= 6(5) - 1.25$$

$$(SN_qR)_{dB} = 28.75 \text{ (dB)}$$

3.33 x 7.50 in