សាកលវិទ្យាល័យភូមិន្ទភ្នំពេញ

Royal University of Phnom Penh

Data Communication I

Chapter 3.1 : Digital transmission

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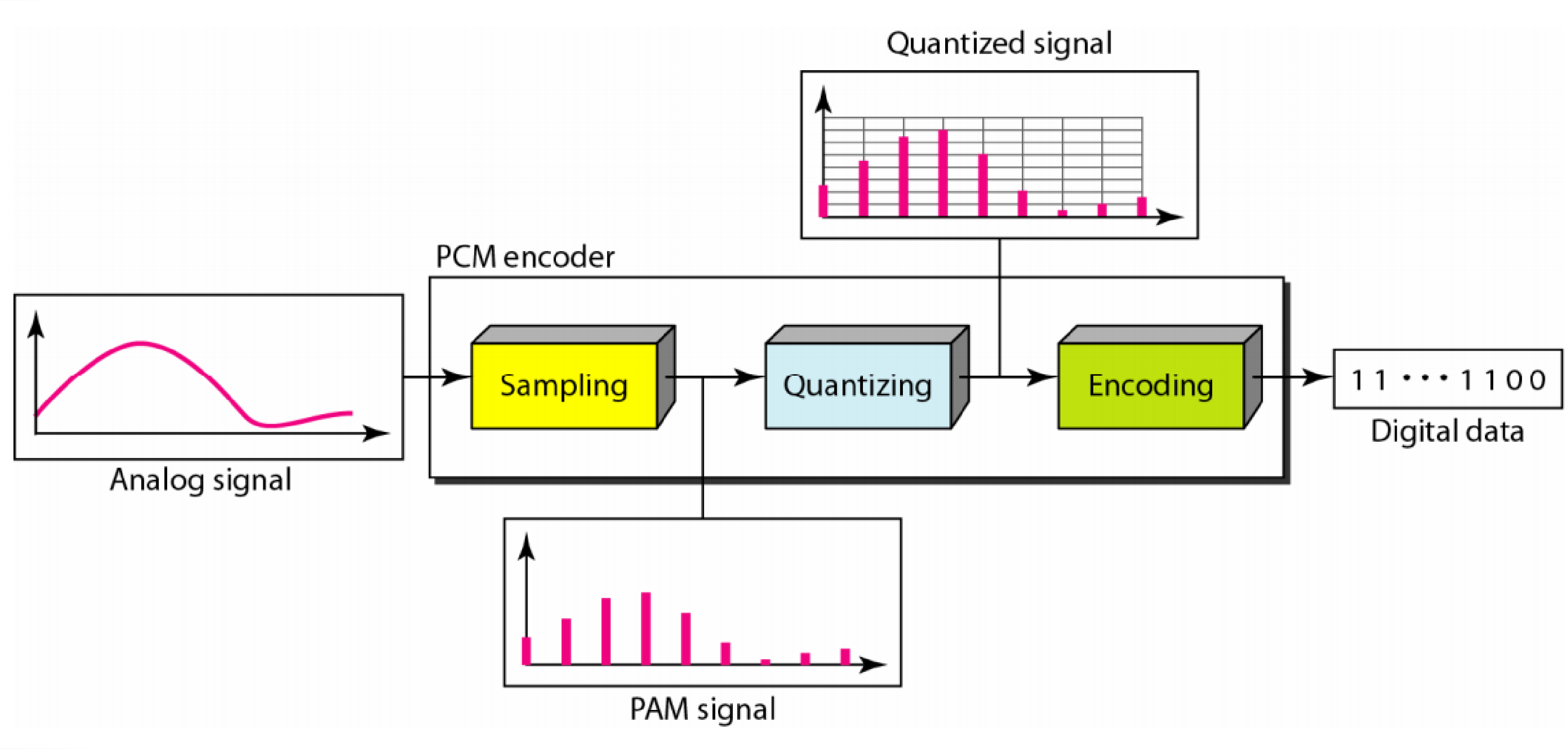
Outline

- Analog to digital conversion
  - Sampling
  - Quantization
  - Encoding
- Line Coding
- ADC Types
- Transmission Mode

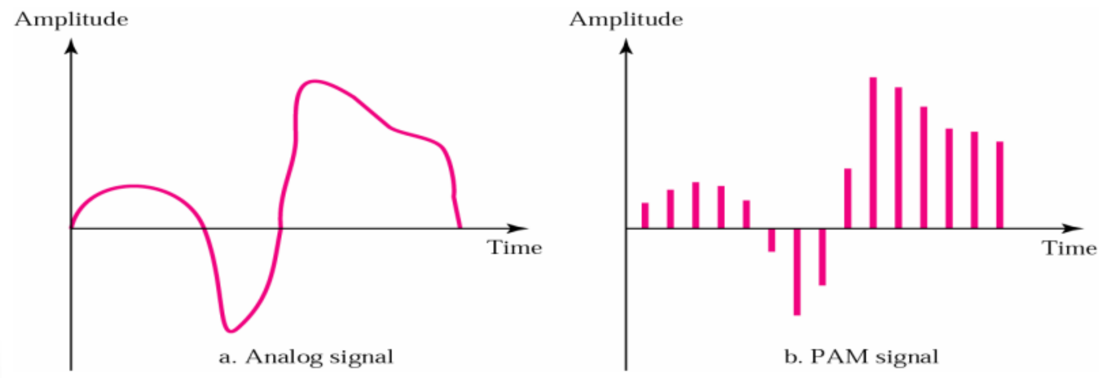
Analog to digital conversion



Summary scheme of Analog to Digital Conversion

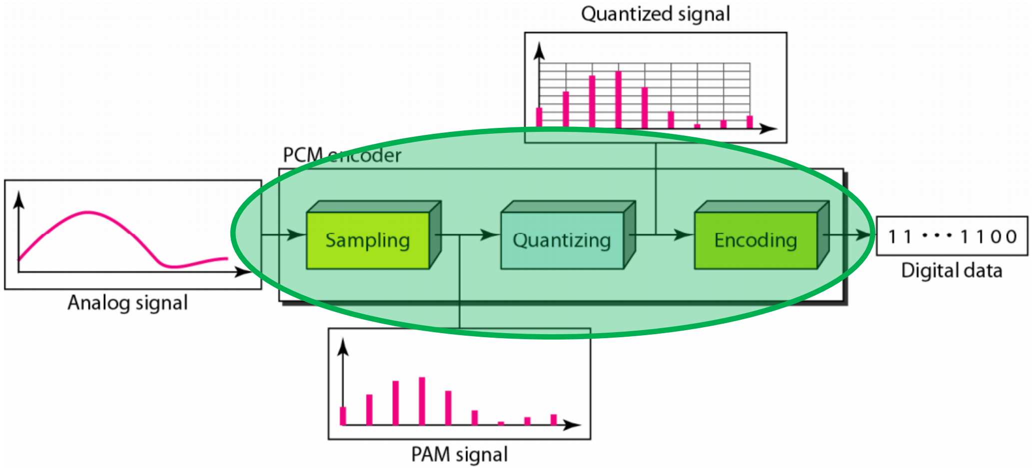
Analog to digital conversion

- Microphone creates analog voice and Camera creates analog videos which is called analog data.
- To transmit this analog data over digital signals we need an analog to digital conversion.
- Pulse Amplitude Modulation (PAM), takes an analog signal, samples it and generates a series of pulses based on the results of sampling.



Analog to digital conversion

- However PAM is not useful in data communications because even though it translates the original waveform to a series of pulses, these pulses are still an analog.
- To make them digital we modify them using Pulse Code Modulation (PCM).
- There are three steps in PCM: **Sampling**, **Quantization** and **Encoding**.

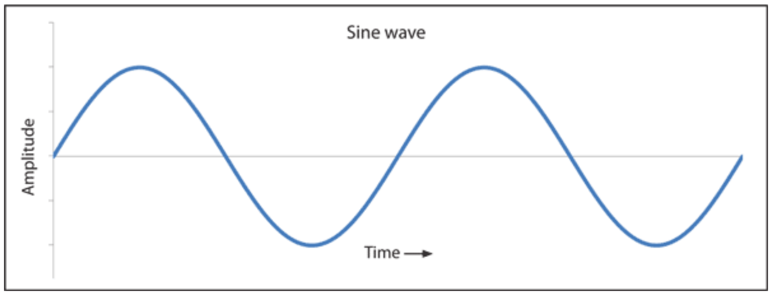


Analog to digital conversion

1. Sampling

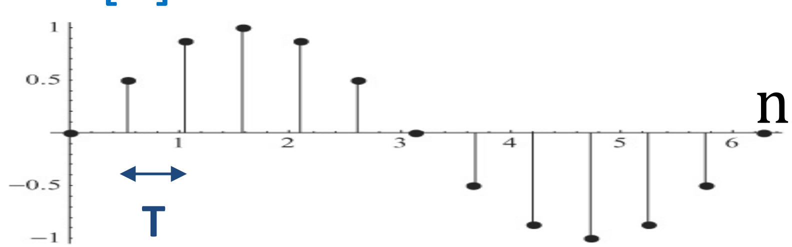
What is Sampling Mean?

$x(t)$



Sampling

x[n]



Analog to digital conversion

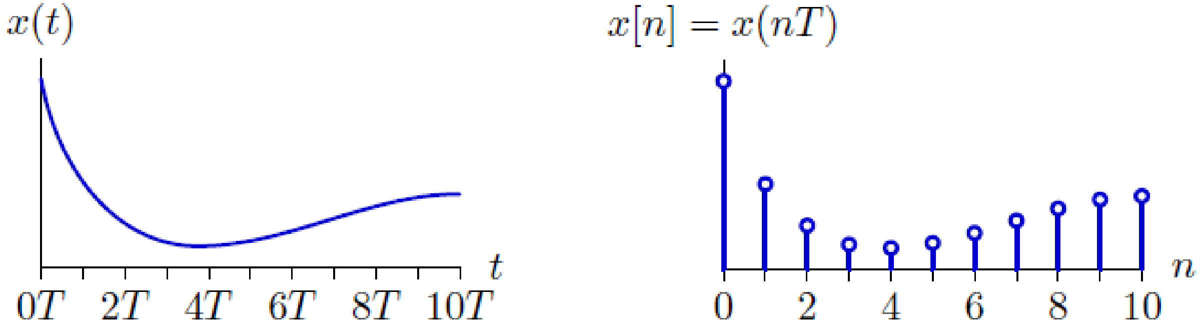
1. Sampling: the process of convert analog signal into digital signal.

$\boldsymbol{x}(\boldsymbol{t})$ is analog signals

$\boldsymbol{x}[\boldsymbol{n}]$ is digital signals

$$\boldsymbol{x}[\boldsymbol{n}] = \boldsymbol{x}(\boldsymbol{t})|_{\boldsymbol{t}=\boldsymbol{nT}} = \boldsymbol{x}(\boldsymbol{nT})$$

- x(t): analog signal
- x[n]: digital signal
- n : is sample number
- T : is sampling interval



T = sampling interval

Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.

Example:

1. $$x(t) = e^{at} \xrightarrow[t = nT]{} x[n] = e^{anT} = e^{\frac{an}{Fs}}$$

time

Sample number [0, 1, 2, 3,.....]

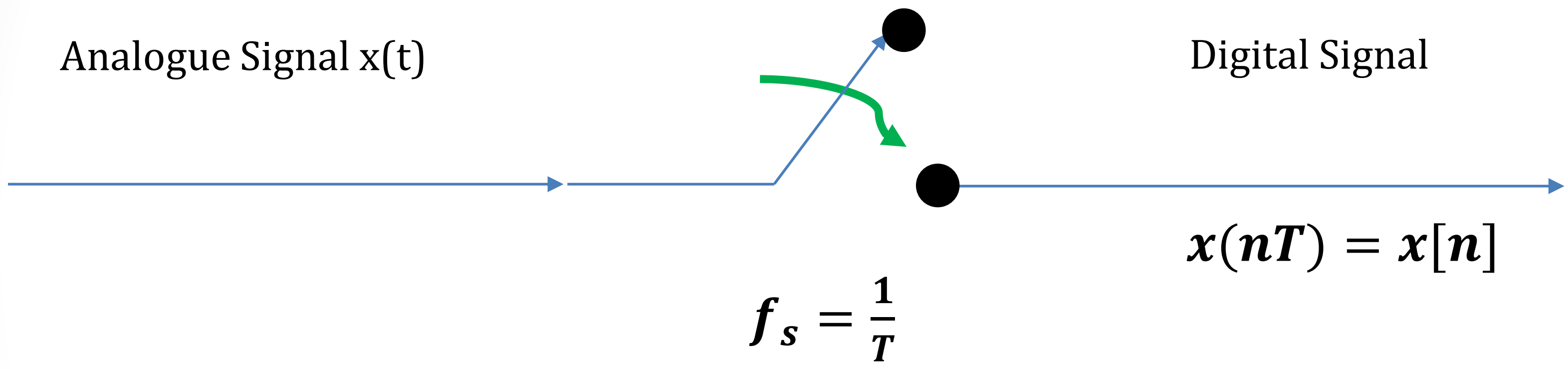
Sampling Period (T)

2. $$x(t) = 10e^{-t} - 5e^{-0.5t} \xrightarrow[t = nT]{} x[n] = 10e^{-nT} - 5e^{-0.5nT}$$

$$= 10e^{\frac{-n}{Fs}} - 5e^{\frac{-0.5n}{Fs}}$$

Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.



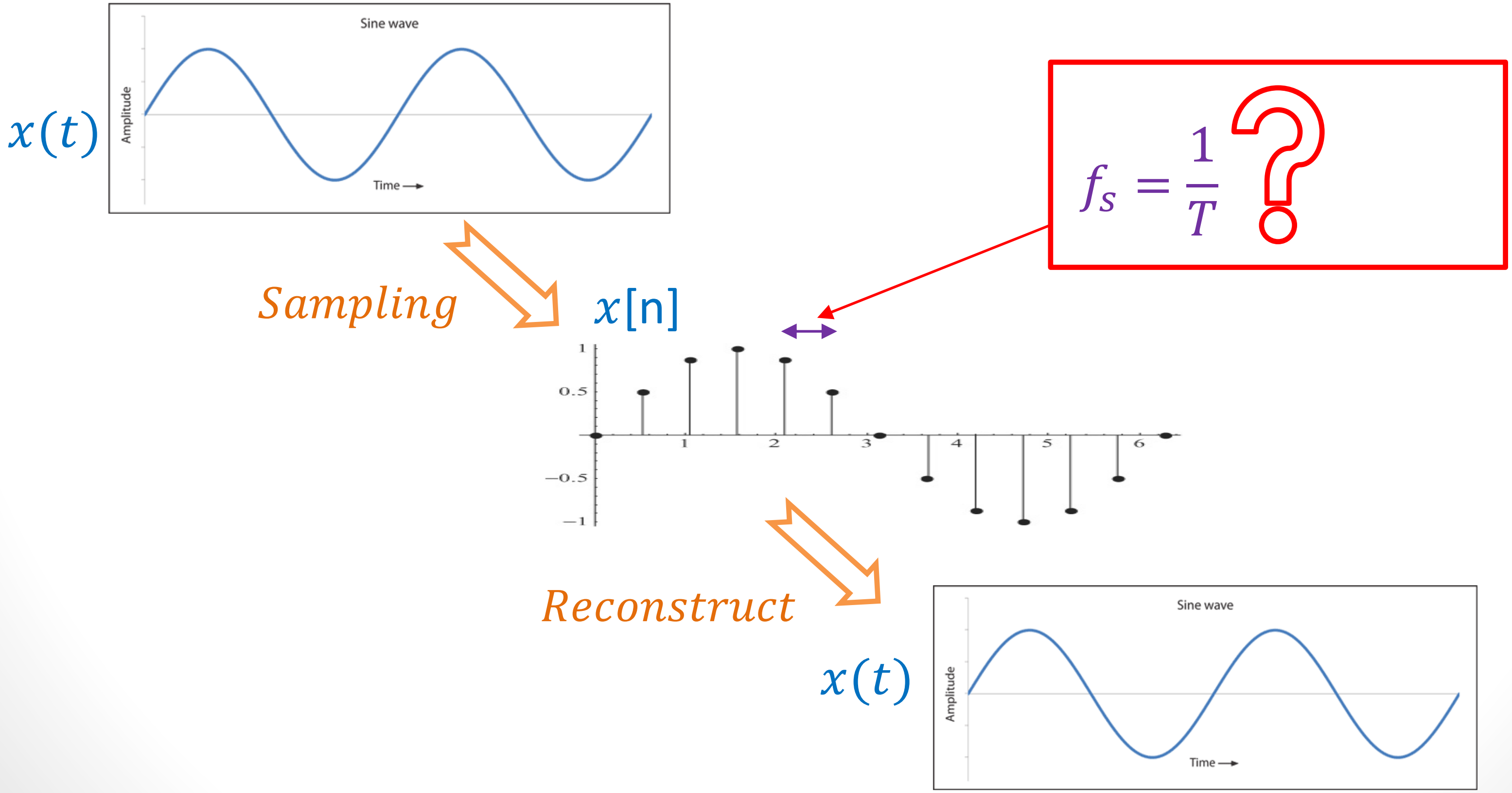
The constant T is the sampling interval or period and the sampling frequency:

$$f_s = \frac{1}{T} Hz$$

Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.

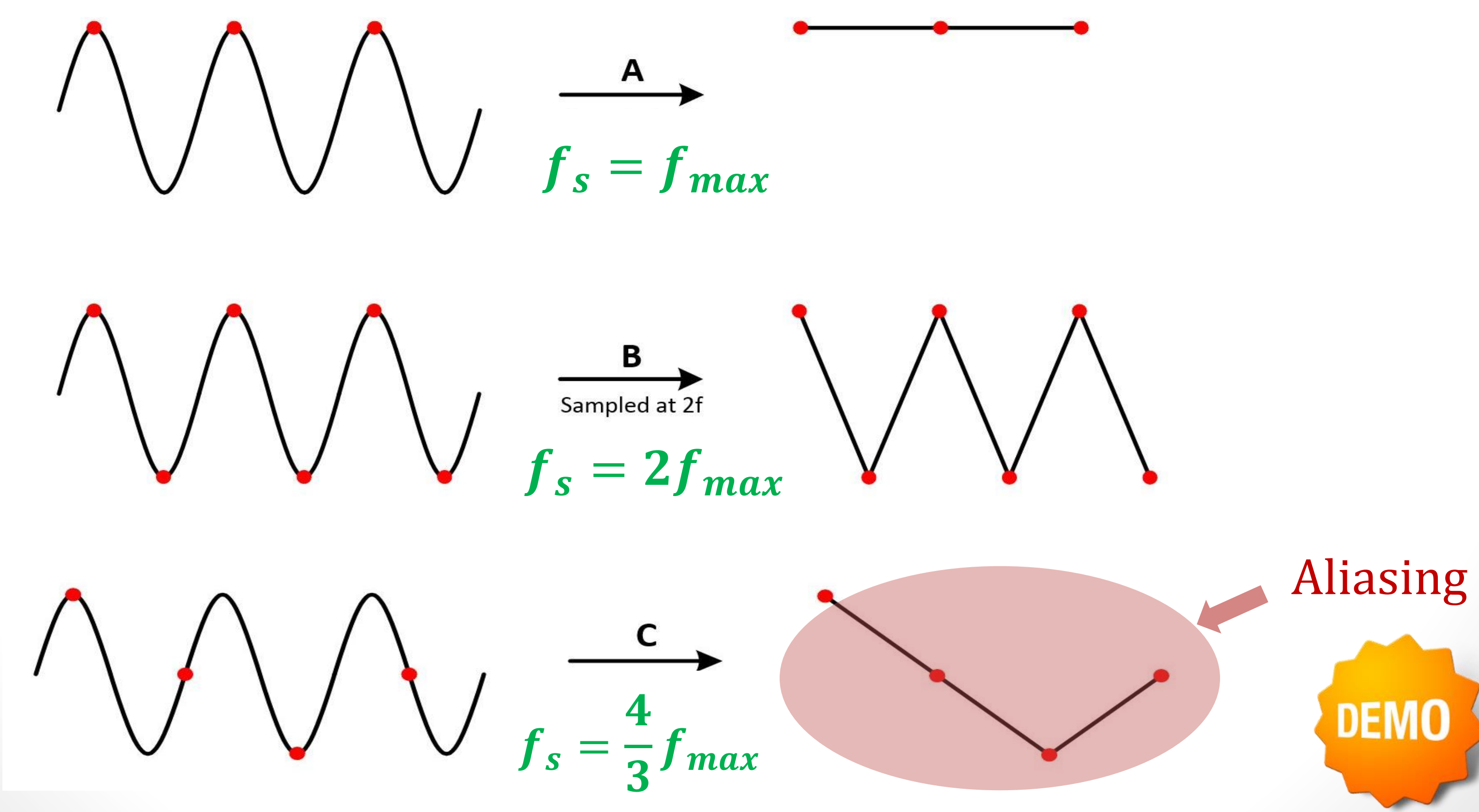
How to choose Fs?



Analog to digital conversion

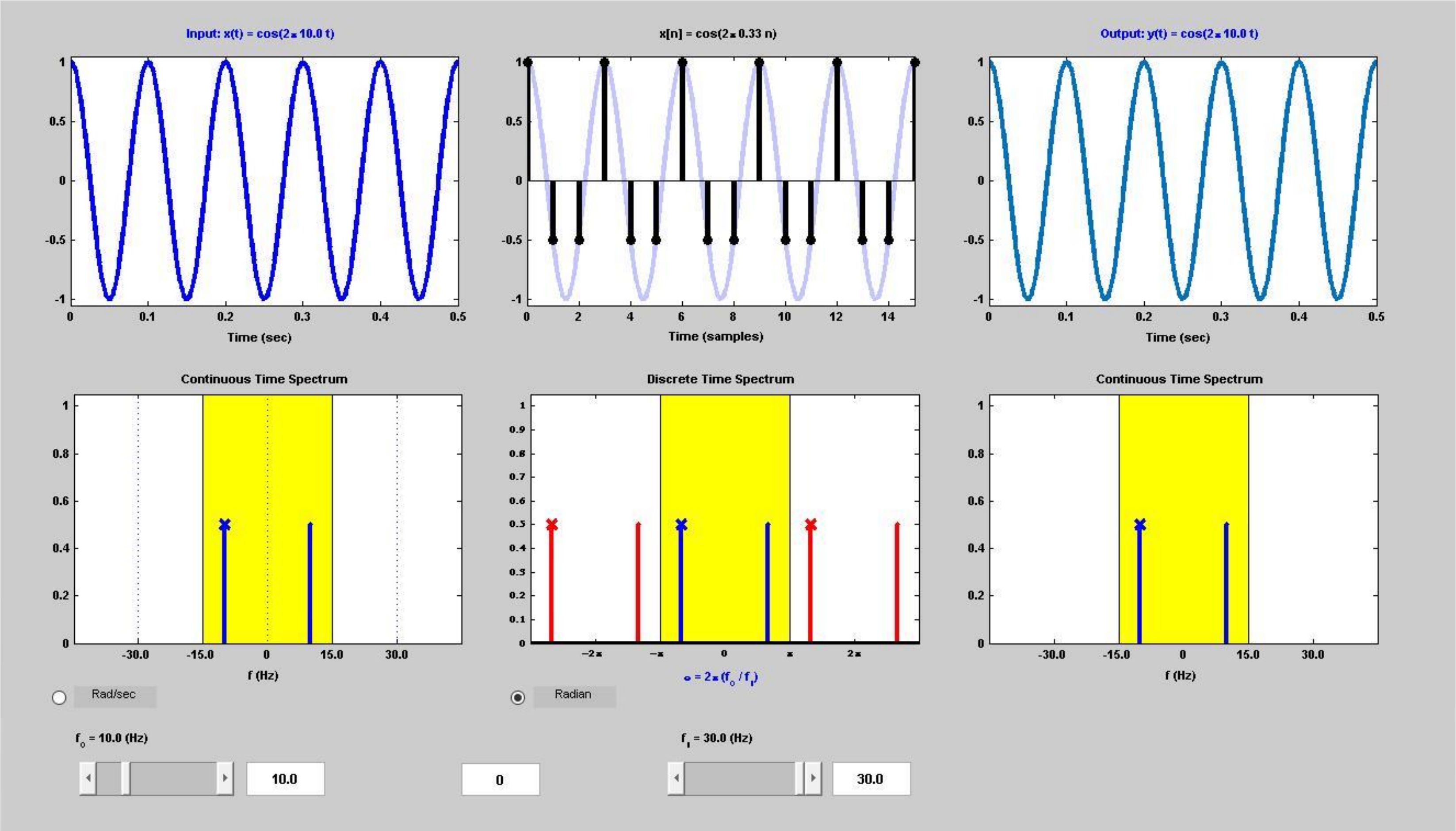
1. Sampling: the process of convert analog signal into digital signal.

How to choose Fs?



Analog to digital conversion

Sampling Application Demo



Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.

Nyquist Theorem

- If the highest frequency contained in an analog signal x(t) is f_{max} then
- The signal must be sampled at the following rate

$$f_s \geq 2f_{max}$$

- Hence Analog Signal **x(t)** can be exactly recovered from its sample values using an interpolation function.

Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.

   Example: Audio CDs use a sampling rate, $f_s\ of\ 44.1kHz$ for storage of the digital audio signal.

   - This sampling frequency is slight more than $2f_{max}[f_{max} = 20kHz]$, which is generally accepted upper limit of human hearing and perception of music sound.
   - Human hearing: *20Hz < f <20kHz*

DEMO

Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.

Example

Define the maximum frequency for below signal:

a) $x(t) = 2\sin(2\pi 200t) + \cos(300\pi t)$

b) $x(t) = 5\cos(200\pi t) + \cos(300t) + \cos(\frac{1000}{\pi}t)$

Analog to digital conversion

1. Sampling: the process of convert analog signal into digital signal.

Exercise

Consider the analog signal: $x\ (t) = 3\cos 100\pi t$

a) Determine sampling rate required to avoid aliasing.

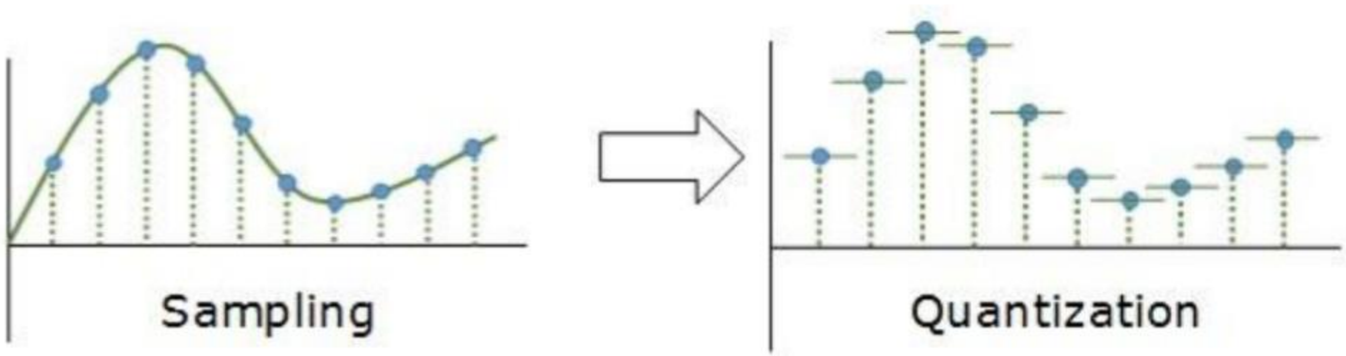
b) Suppose that the signal is sampled at the rate of **Fs = 200 Hz**, what is the discrete time signal obtained after sampling?

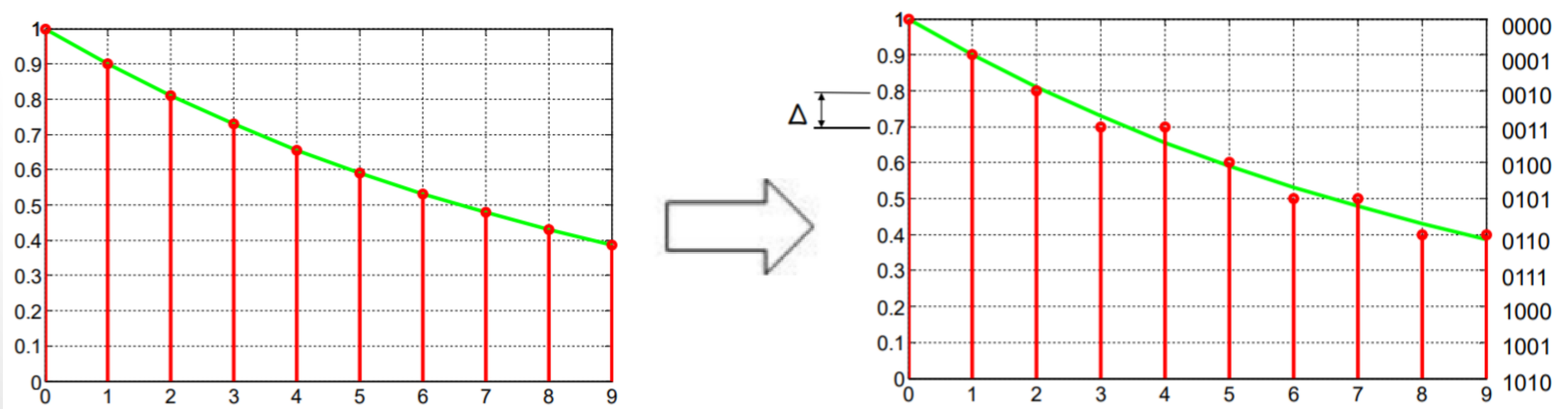
c) Suppose that the signal is sampled at the rate of **Fs = 75 Hz**, what is the discrete time signal obtained after sampling?

Analog to digital conversion

2. Quantization

What is Quantization mean?

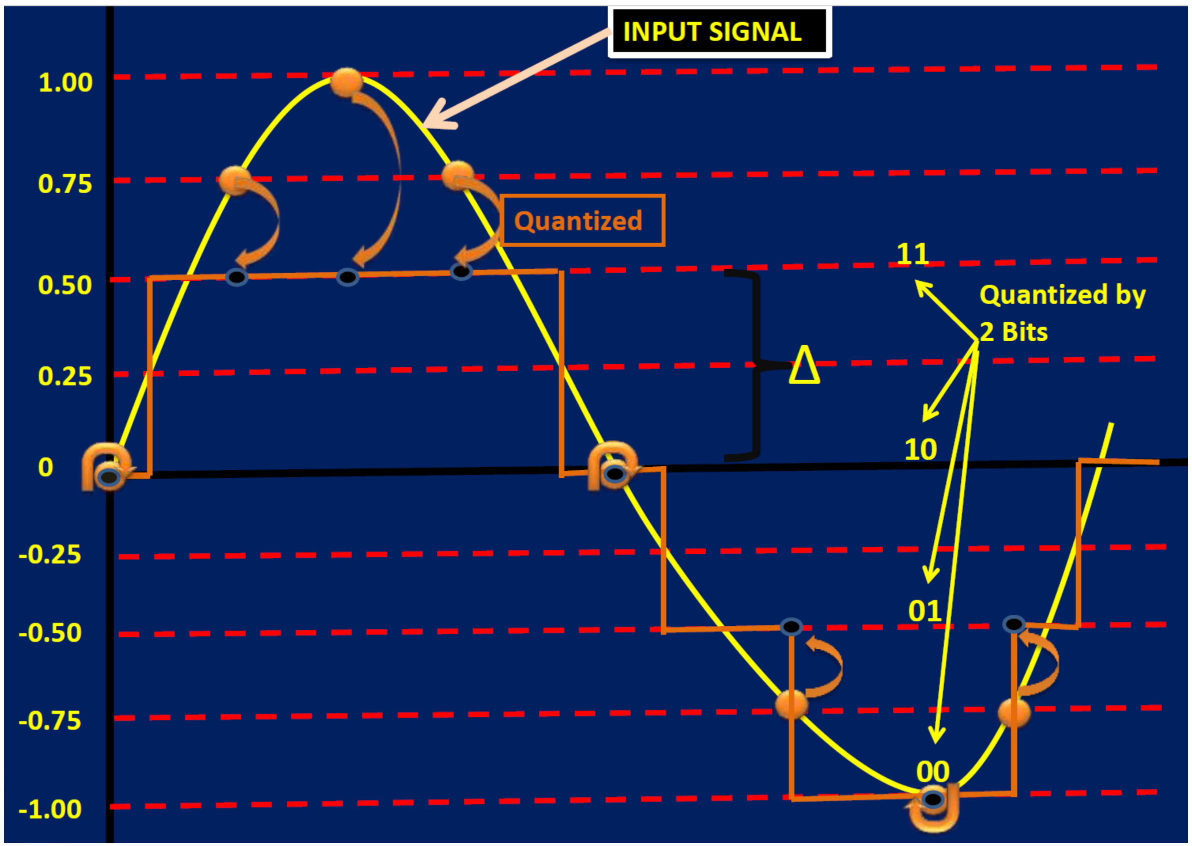




Analog to digital conversion

2. Quantization: the process whereby a continuous of amplitude values is represented by a finite set of discrete value. Quantization will round off the samples to the nearest quantization level

Quantized Step Sized $(\Delta) = 0.5$



Quantized by
2 bits

Level 4

Level 3

Level 2

Level 1

Analog to digital conversion

2. Quantization: the process whereby a continuous of amplitude values is represented by a finite set of discrete value. Quantization will round off the samples to the nearest quantization level.

- n=2 bits mean L=4 Levels in quantization
- Quantized step sided (Δ) or Resolution of quantizer(q)

$$(\Delta) = (q) = \frac{\{X_{(max)}-X_{(min)}\}}{L} = \frac{\{X_{(max)}-X_{(min)}\}}{2^n}$$

- From previous slide:

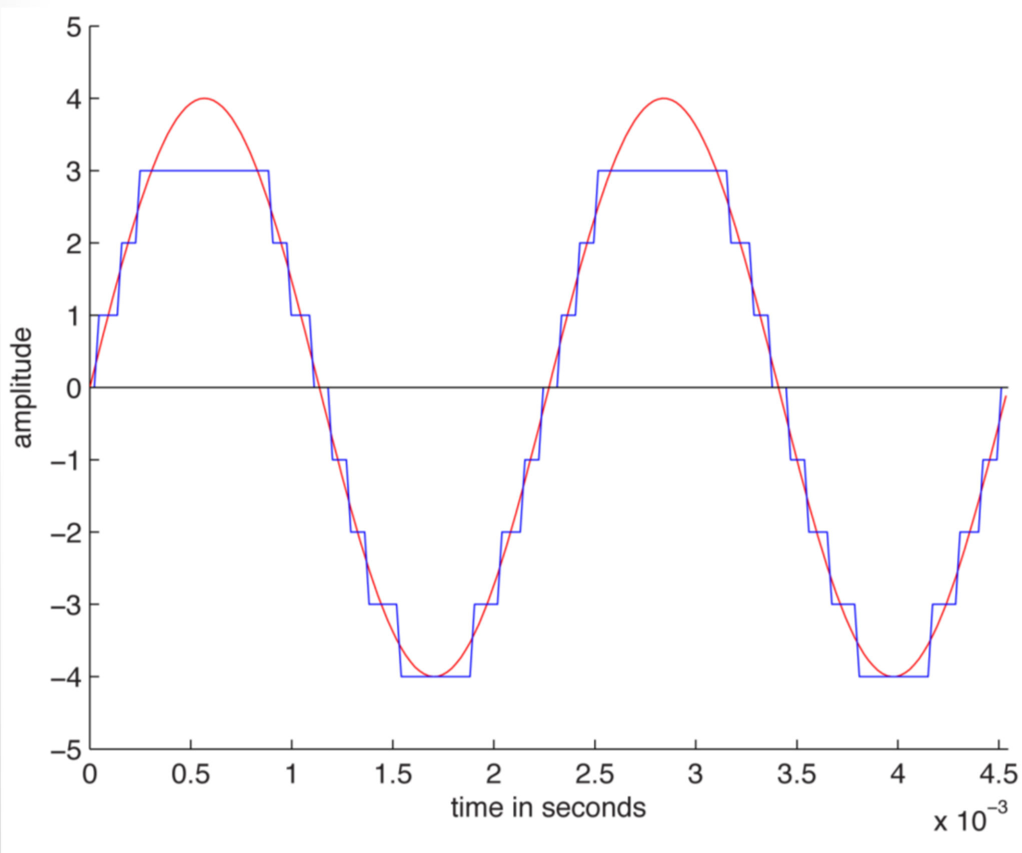
Quantized step sided $(\Delta) = \frac{\{1-(-1)\}}{4} = 0.5V$

Analog to digital conversion

Example: Answer the questions from looking the graph

a. How many level in the quantizing?

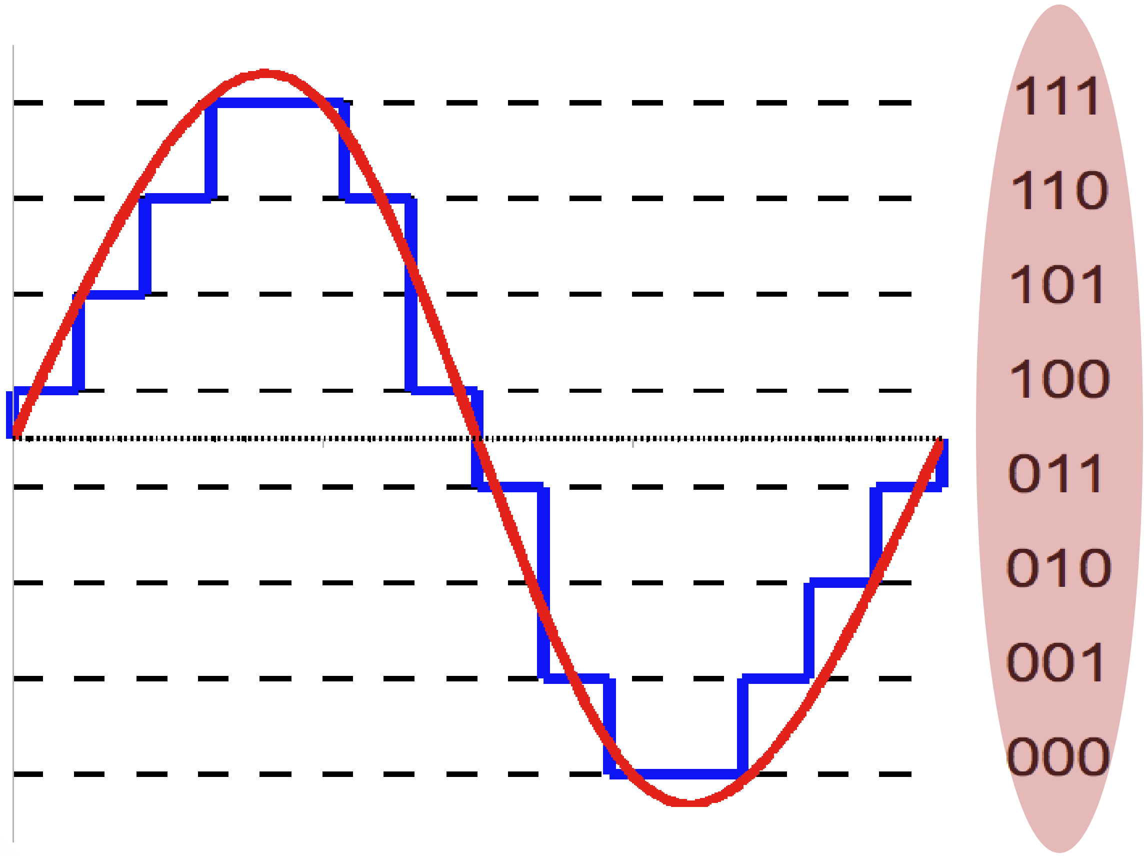
b. Find Quantized step sided (Δ)?



Analog to digital conversion

3. Encoding:

What is Encoding mean?



Analog to digital conversion

3. Encoding: (Binary Encoding) will convert each quantized value into a codeword consisting of binary bits.

- Binary encoding for 4 levels:

  00, 01, 10, 11

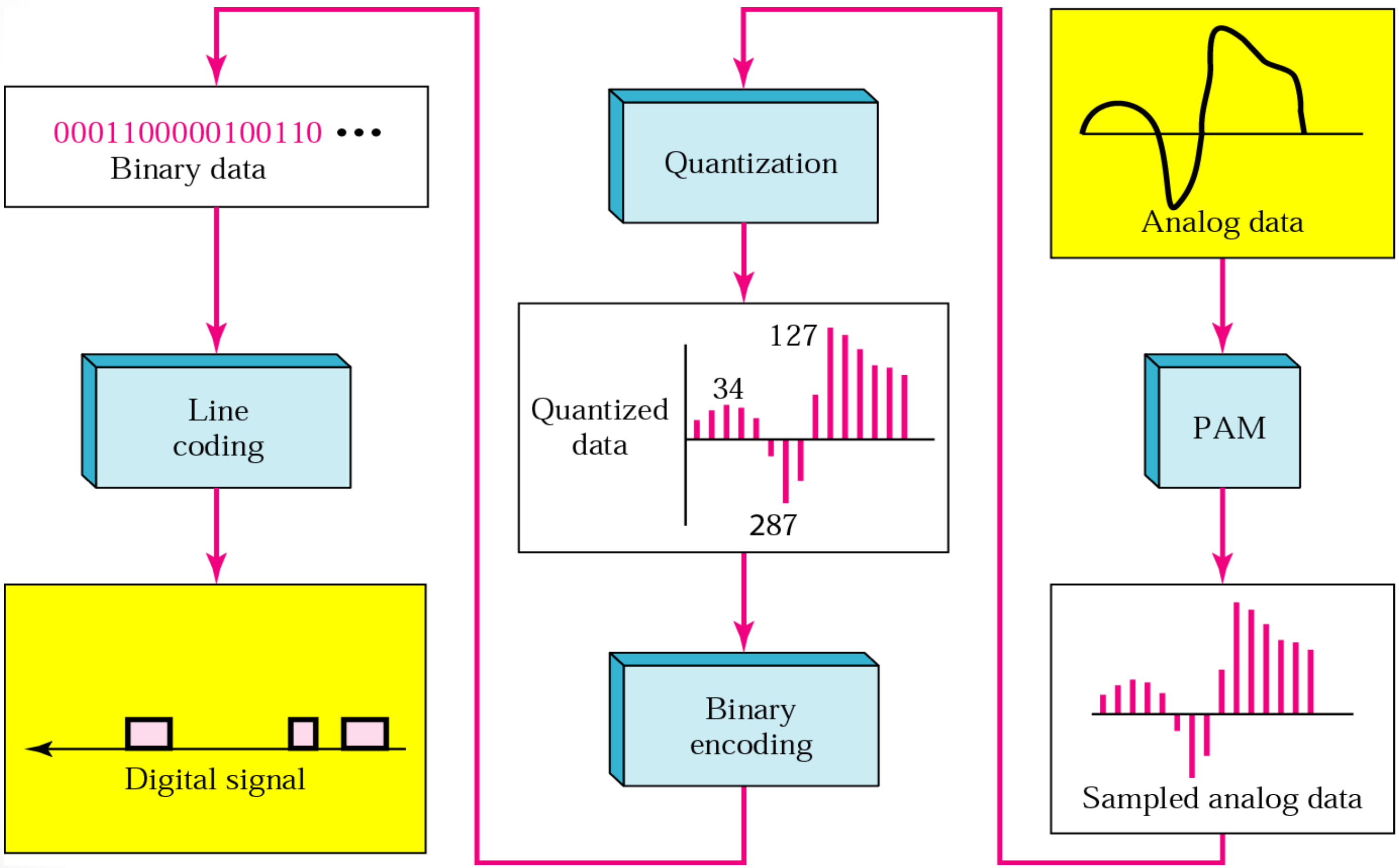
- Binary encoding for 8 levels:

  000, 001, 010, 011, 100, 101, 110, 111

- Example

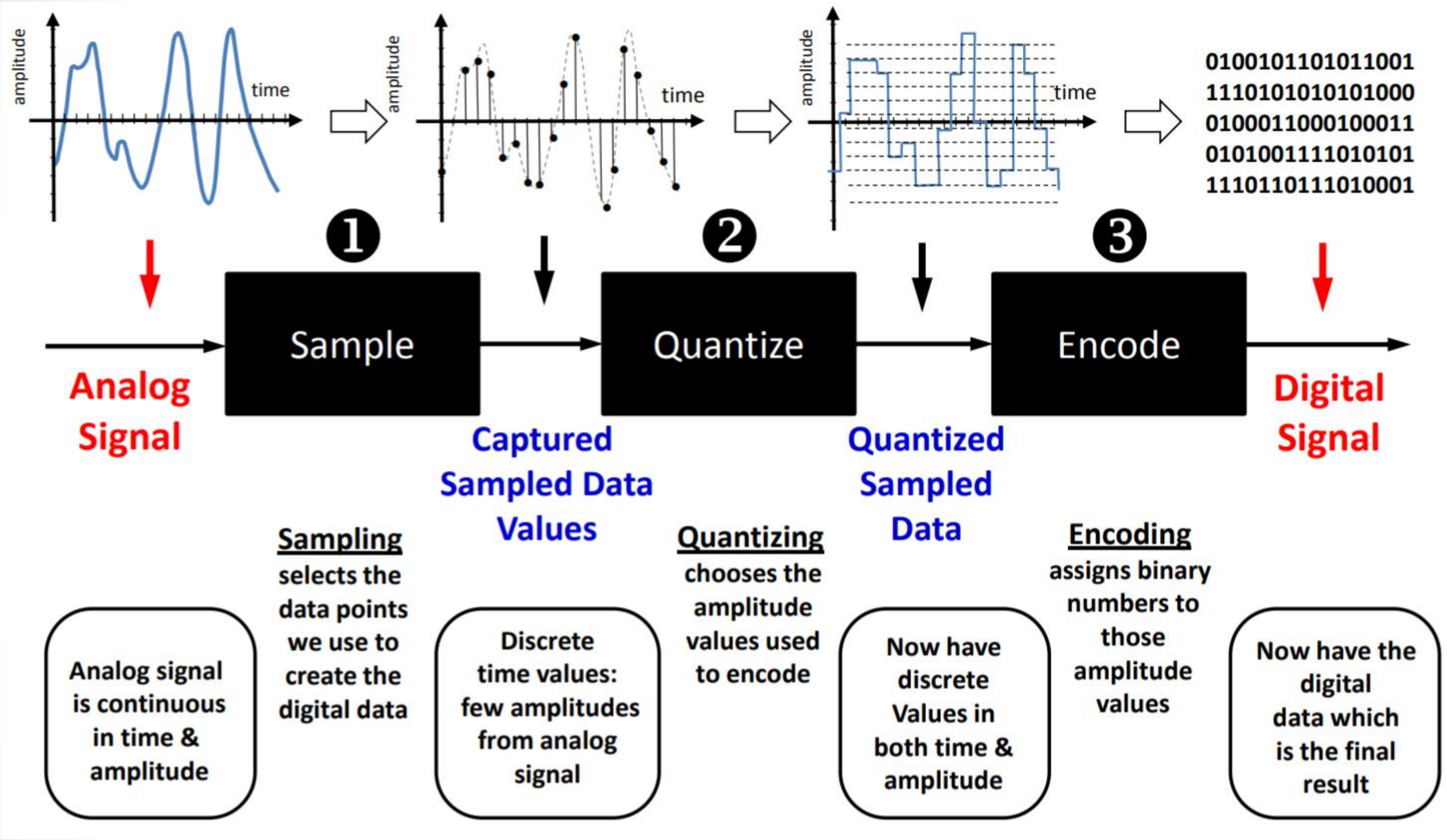
Original sampling signal	0	0.707	1	0.707	0	-0.707	-1	-0.707
Quantized value	0	0.5	0.5	0.5	0	-0.5	-1	-0.5
Binary value	**10**	**11**	**11**	**11**	**10**	**01**	**00**	**01**

Analog to digital conversion



Summary scheme of Analog to Digital Conversion 1

Analog to digital conversion

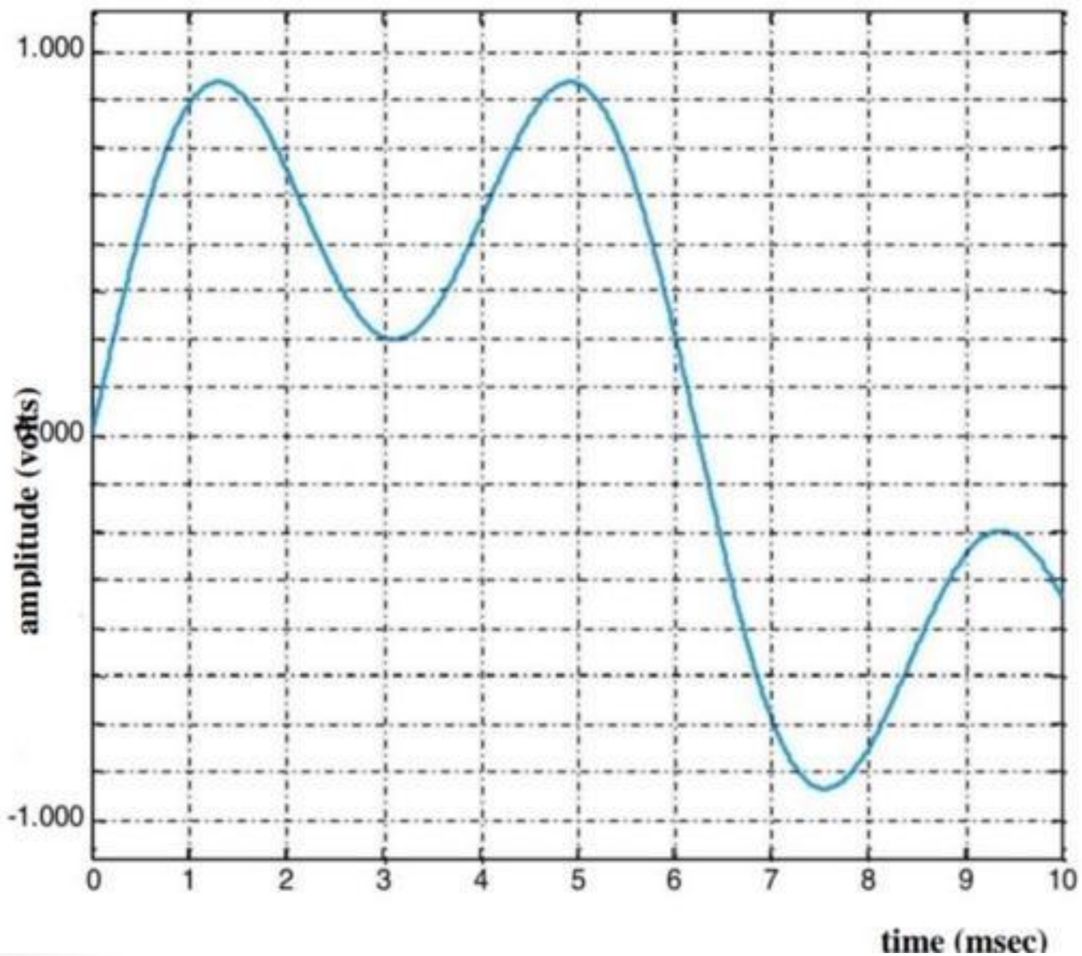


Summary scheme of Analog to Digital Conversion 2

ADC: Exercise

Consider the following analog waveform. This waveform is sampled at a 500 Hz rate and quantized with a 2-bit quantizer (i.e., A/D converter) The input range is -1.0 to +1.0 V.

(a) Circle the sample points (first sample is at time $t = 0$ sec).
(b) Indicate the quantization intervals and corresponding digital words.
(c) Indicate the digital word assigned to each sample point.
(d) What is the stream of binary bits generated after the A/D conversion is complete?.
(e) What is the resulting bit rate from this A/D?

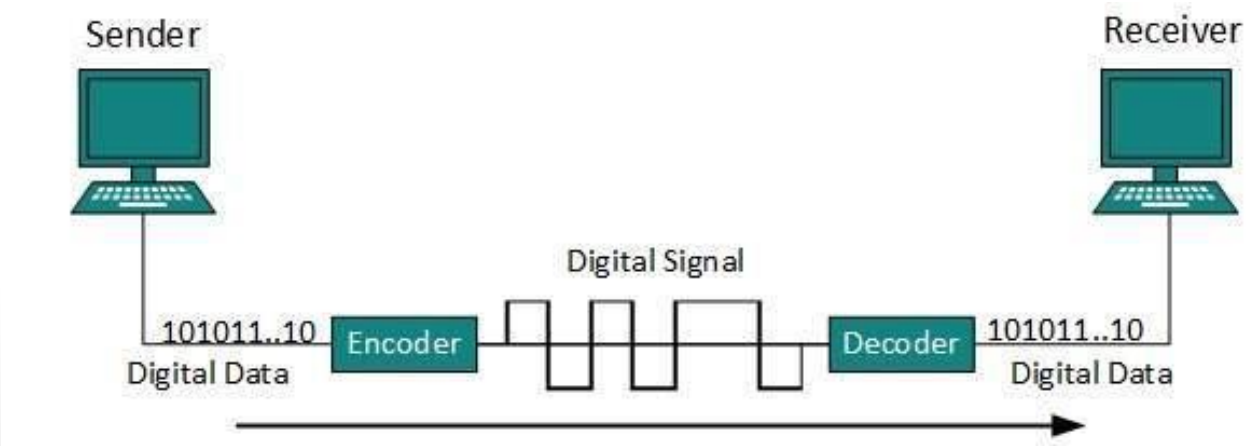


Where we are now?

- Analog to digital conversion
- Line Coding
- Transmission Mode

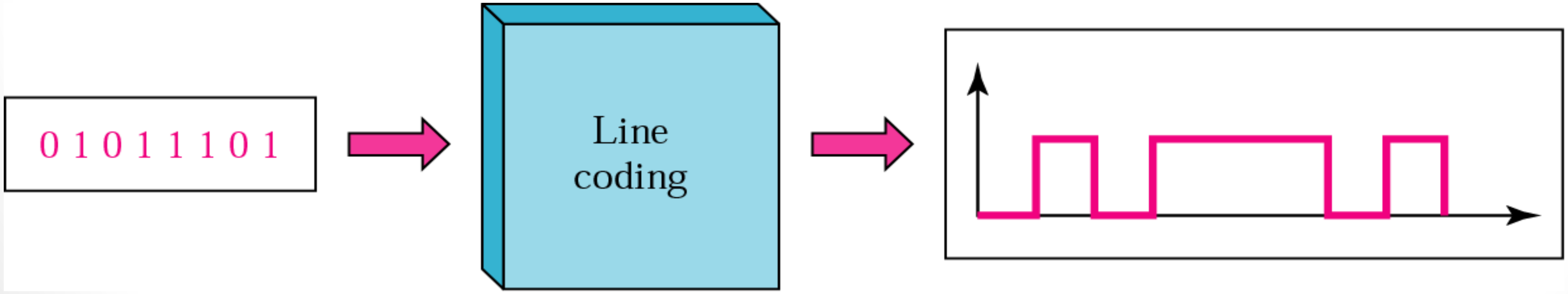
Line Coding

- Data or information can be stored in two ways, analog or digital. Like data, signals can also be in analog or digital form.
- Digital data must convert into digital signal before transmit to another channel.
- To do this, we will use Line Coding.



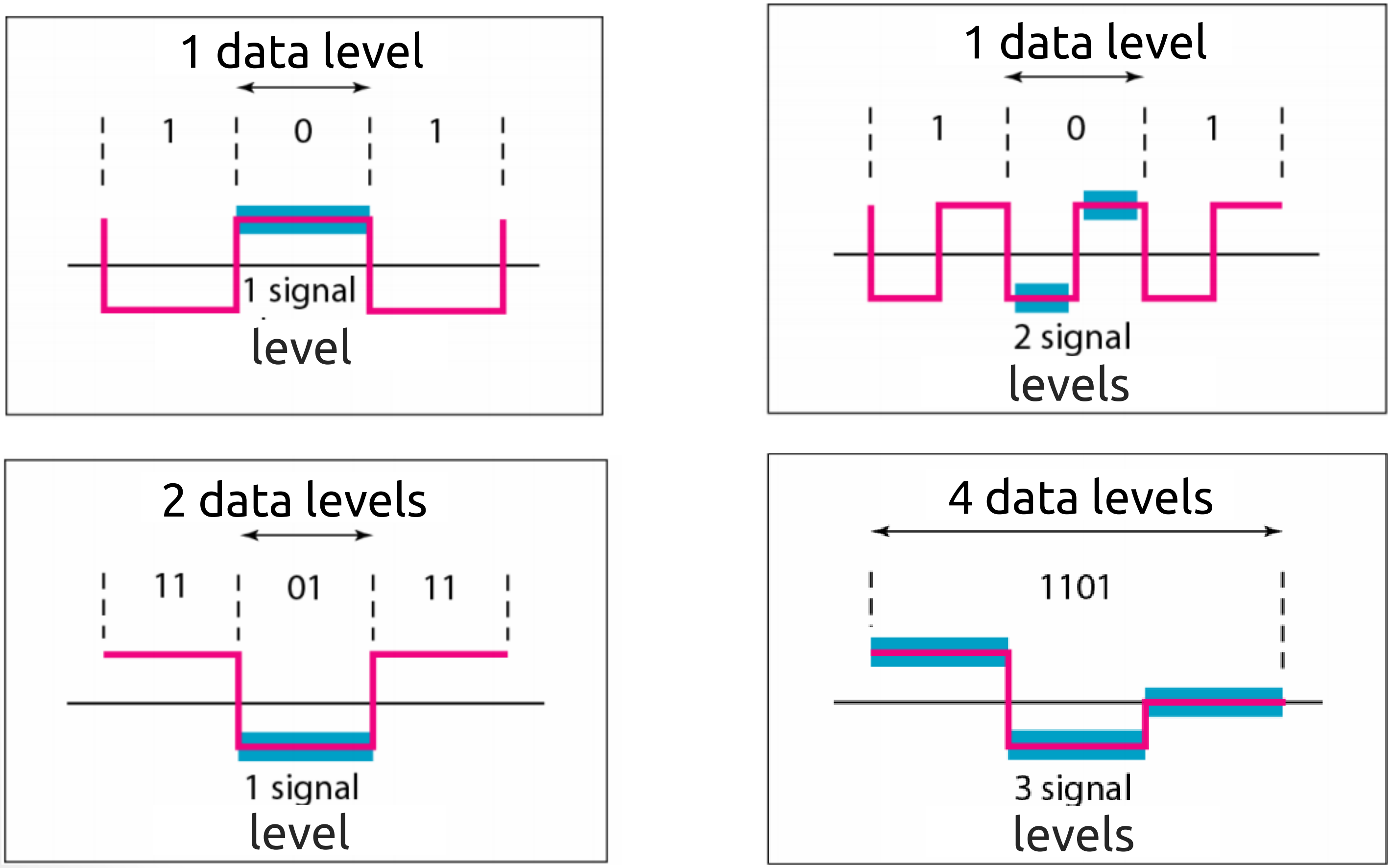
Line Coding

- A line coding is the code used for data transmission of a digital signal over a transmission line.
- The process of coding is chosen so as to avoid overlap and distortion of signal such as inter-symbol interference.



Line Coding

- Signal Level: number of values allowed in a particular signal
- Data Level: number of values used to represent data (**1 or 0**)



Line Coding

- Pulse Rate: define the number of pulse per second

  A pulse is the minimum amount of time required to transmit a symbol. (baud or pulse per second)
- Bit Rate: define the maximum number of bit per second. (bit per second)

- The relationship between Pulse rate and Bit rate:

$$Bit\ Rate = Pulse\ Rate\ x\ \log_2 L$$

- L is the number of data levels of the signal

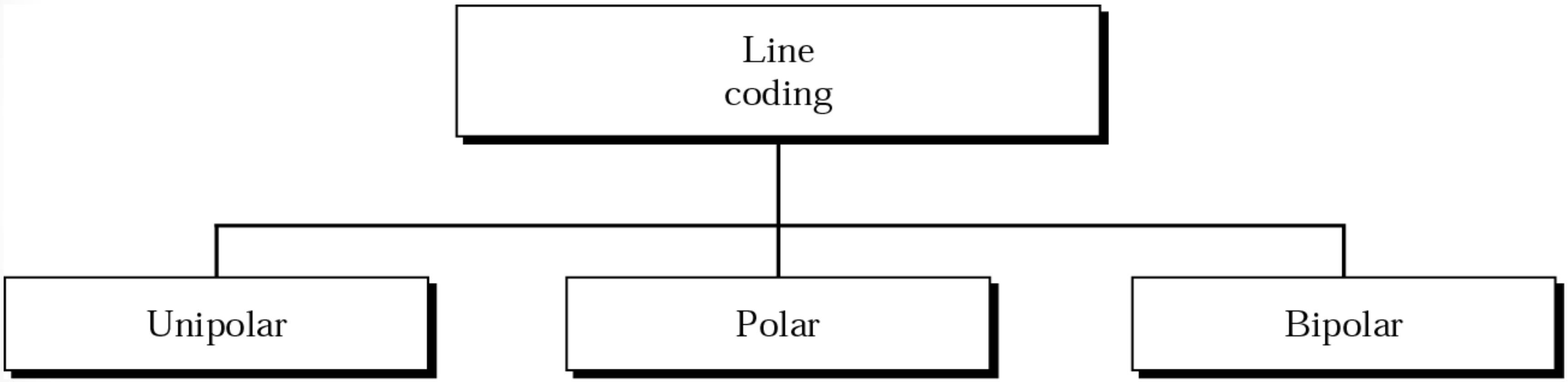
- If a pulse carries only 1 bit → pulse rate = a bit rate
- If a pulse rate carries >1 bit → a bit rate is greater then the pulse rate

Line Coding

Example: A signal has four data levels with a pulse duration of 1ms. Find the Pulse Rate and Bit Rate?

Line Coding

- There are three types of line coding:



NRZ

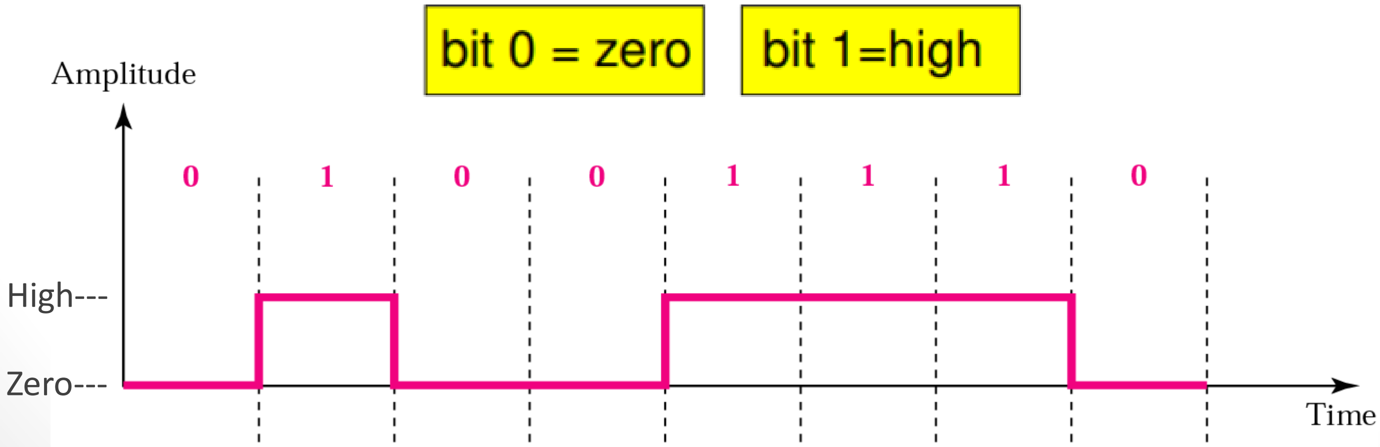
NRZ, RZ, Manchester

AMI

Line Coding

1. Unipolar

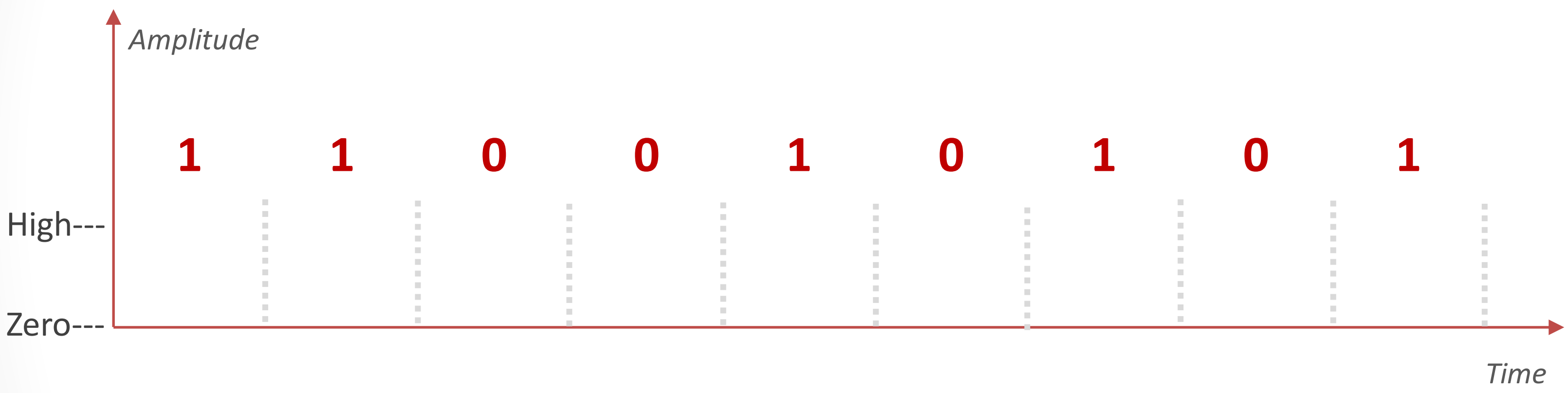
- Unipolar encoding schemes uses single voltage level to represent data.
- In this case, to represent binary 1 High voltage is transmitted and to represent 0 no voltage is transmitted.
- It is also called Unipolar NRZ (Non Return Zero)



Line Coding

1. Unipolar

Example: Draw the Unipolar of below bits stream



Line Coding

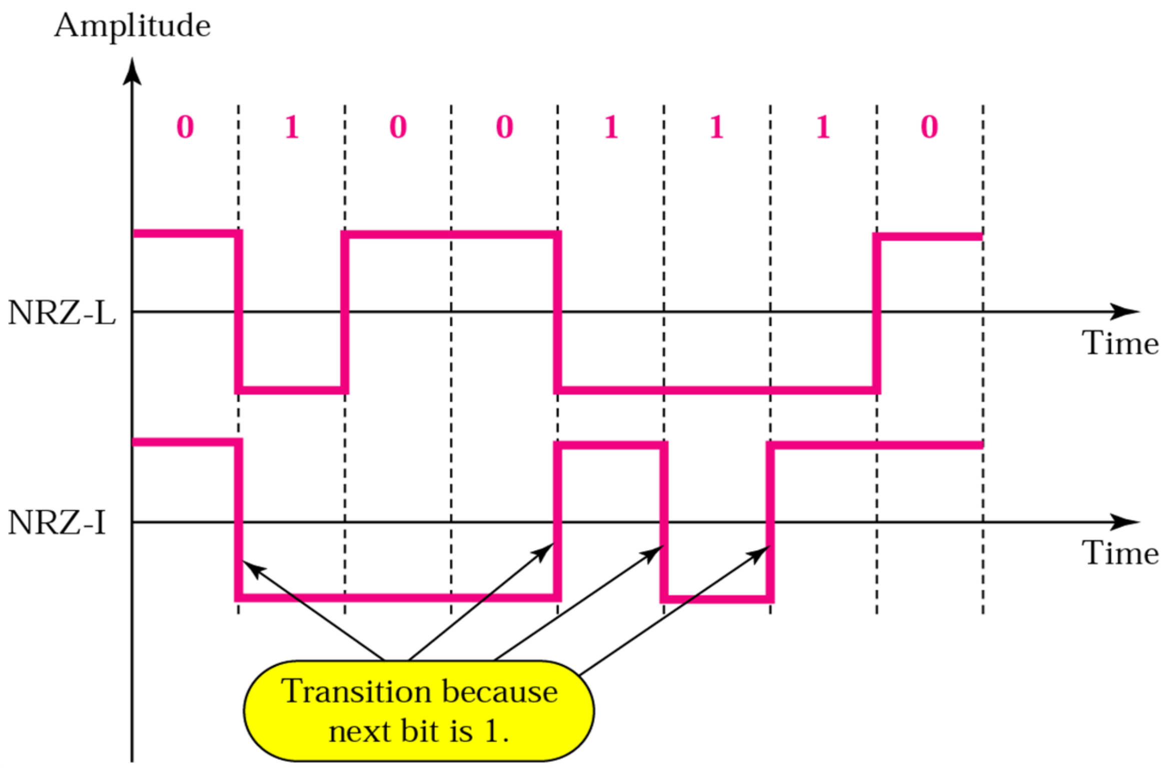
2. Polar

- Polar encoding schemes multiple voltage levels are used to represent binary values.
- Polar encodings are available in four types:
    1. NRZ-L
    2. NRZ-I
    3. RZ
    4. MANCHESTER

Line Coding

2. Polar

- NRZ-L encoding normally *bit 0= High, bit 1= Low*
- NRZ-I encoding the signal is *inverted if 1 is encountered*

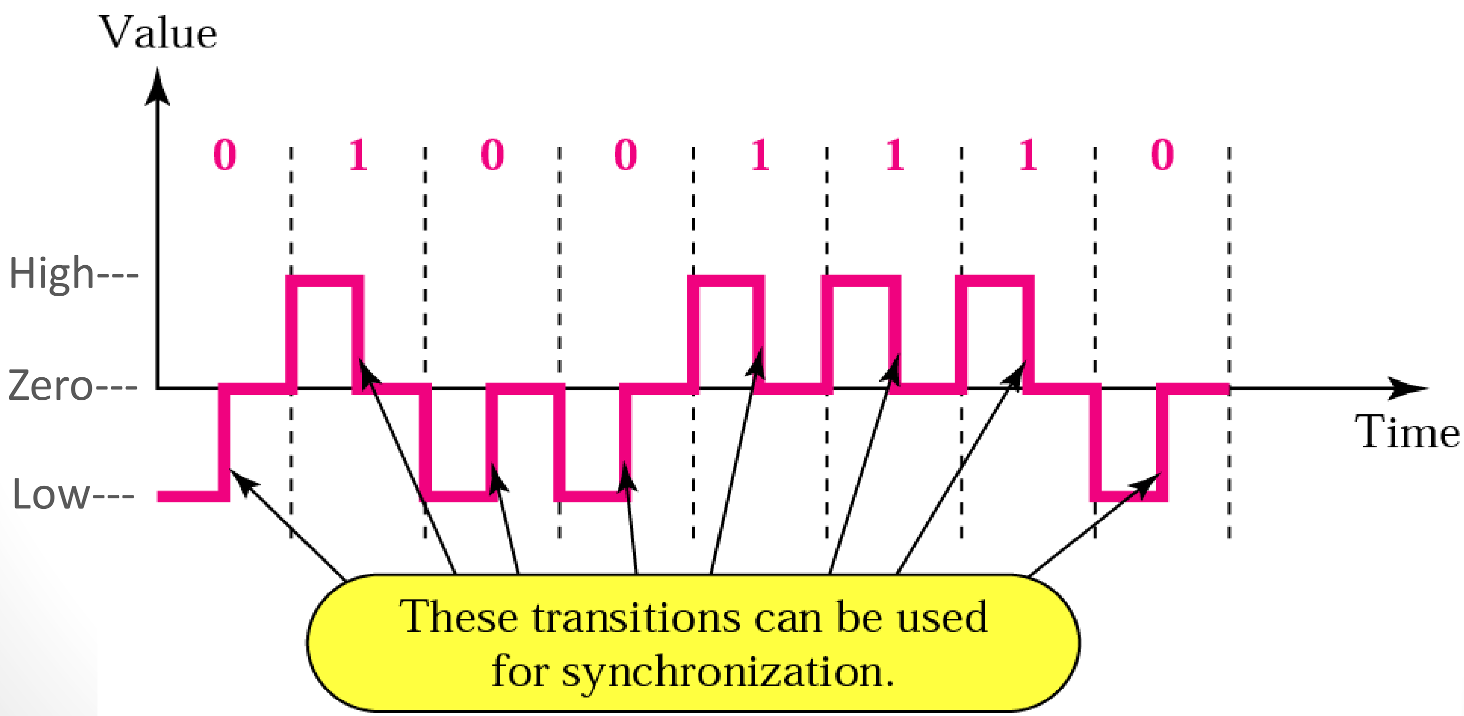


Line Coding

2. Polar

- RZ encoding the signal changes during each bit, not between bits: *bit 1 = high-to-zero*

  bit 0 = low-to-zero

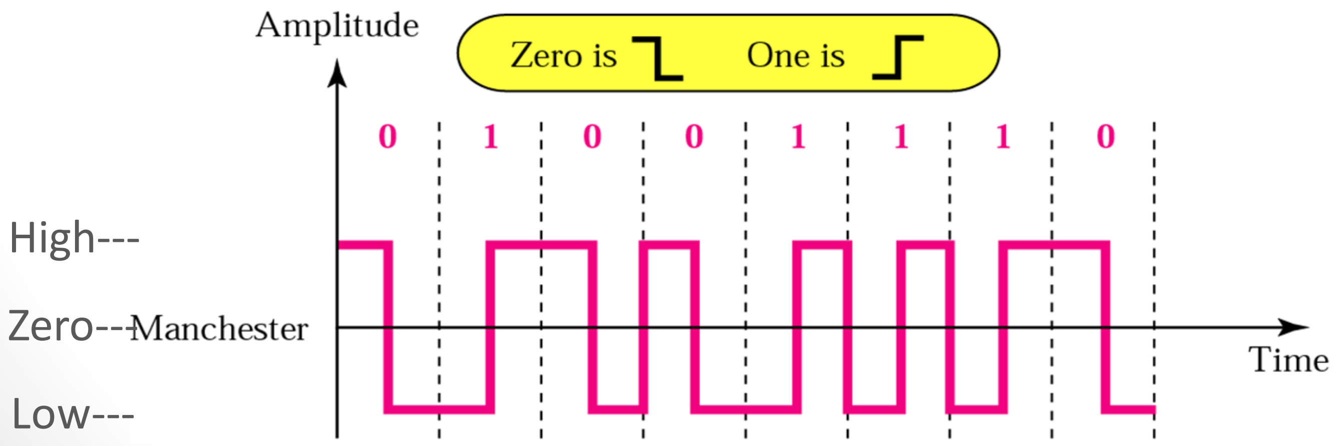


Line Coding

2. Polar

- MANCHESTER, this encoding scheme is a combination of RZ and NRZ-L.
- The transitions is at the middle of the bit and changes phase when difference bit is encountered.
- MANCHESTER encoding: *bit 1= low-to-high*

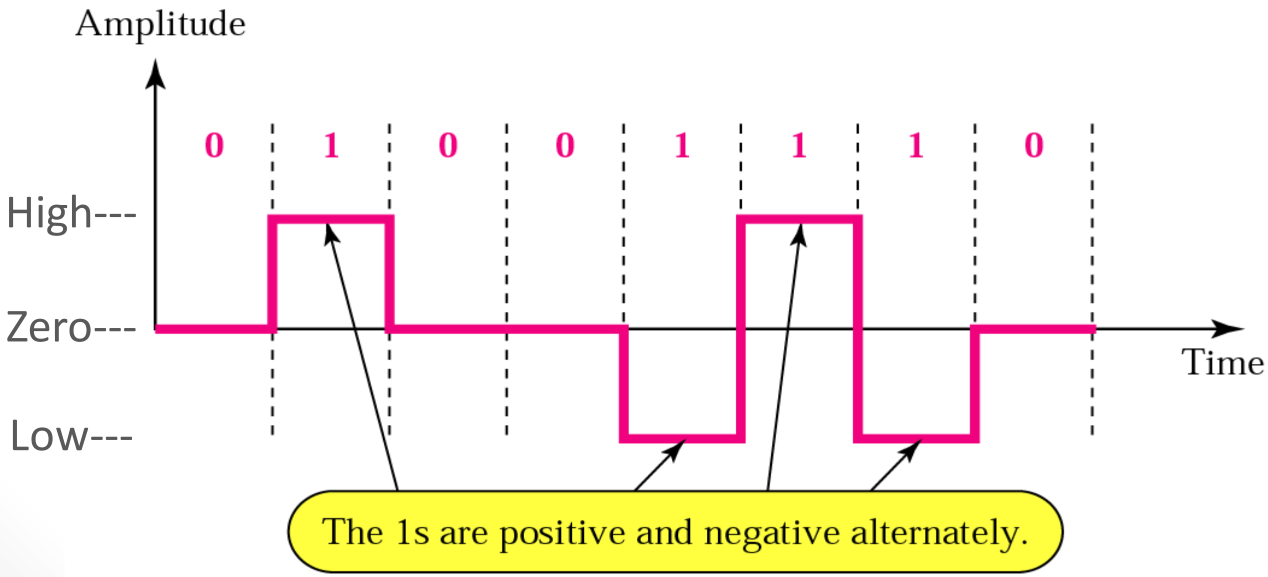
  bit 0= high to low



Line Coding

3. Bipolar

- Bipolar encoding uses three voltage levels: positive, negative and zero.
- Zero voltage represents binary 0 and bits 1 is represented by altering positive and negative voltages which is called AMI (Alternative Mask Inversion).



Line Coding

Exercise

NRZ-I and AMI start with High

	1	1	0	1	1	0	0	0	0	0	0	0	0	1
Unipolar NRZ														
NRZ-L														
NRZ-I														
RZ														
Manchester														
AMI														

Line Coding

Exercise

Consider the following analog wave form. This waveform is sampled at a 1KHz rate and Quantized with a 3 bit quantizer (i.e., A/D converter). The input range is -1.0 to +1.0 V. Answer the following question:

a) What is the resolution of this quantizer?

b) Circle the sample points (first sample is at time t = 0s)

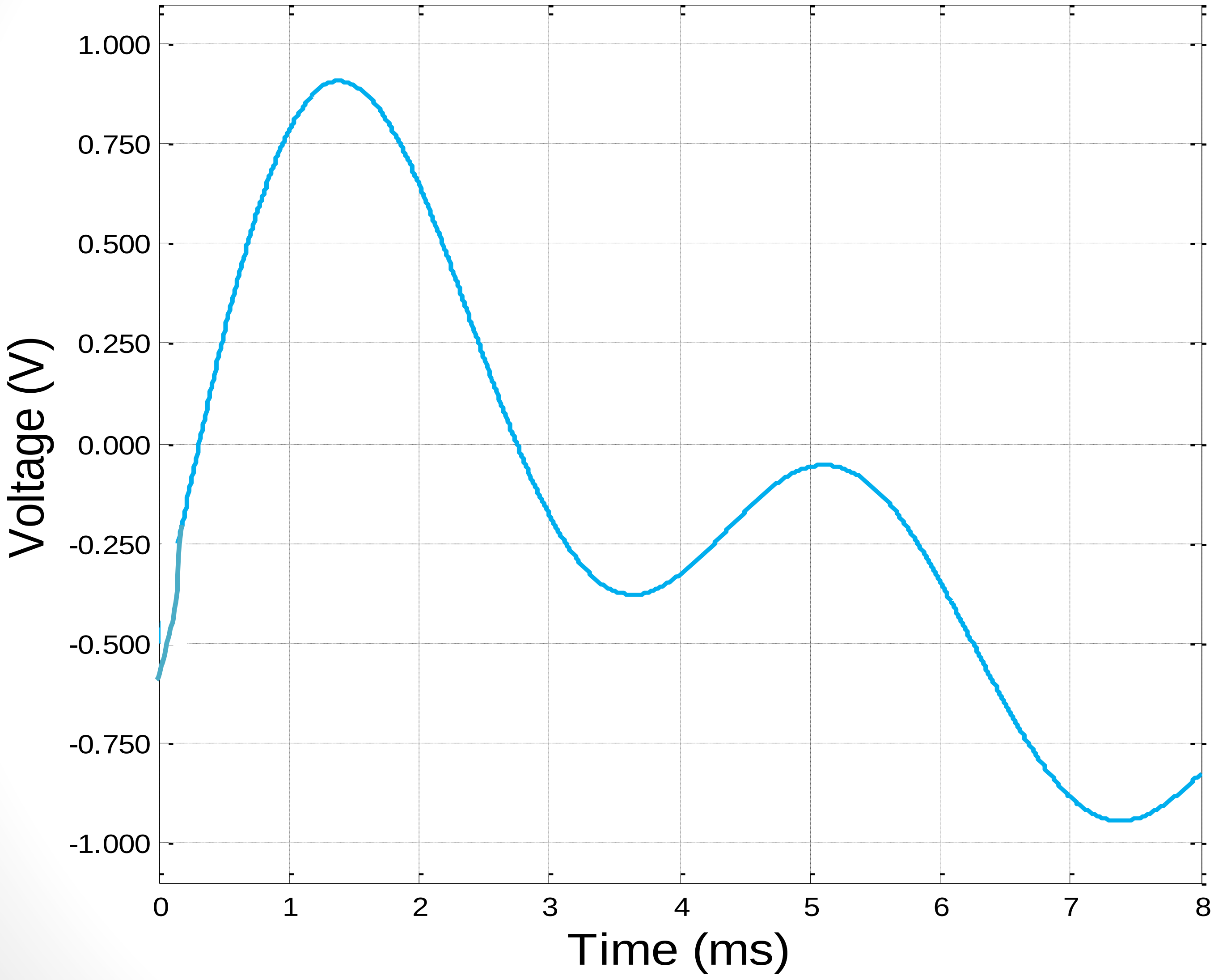
c) Indicate the quantization intervals and corresponding digital words.

d) Indicate the digital word assigned to each sample point.

e) What is the stream of binary bits generated after A/D conversion is complete?

f) What is the resulting bit rate from this A/D conversion?

Line Coding



1.000
0.750
0.500
0.250
0.000
-0.250
-0.500
-0.750
-1.000
Voltage (V)
0
1
2
3
4
5
6
7
8
Time (ms)

Line Coding

Exercise

Resulting bit stream from previous exercise find the digital signal using the following techniques: NRZ-I and AMI start with High

Bit stream are:

Unipolar NRZ

NRZ-L

NRZ-I

RZ

Manchester

AMI

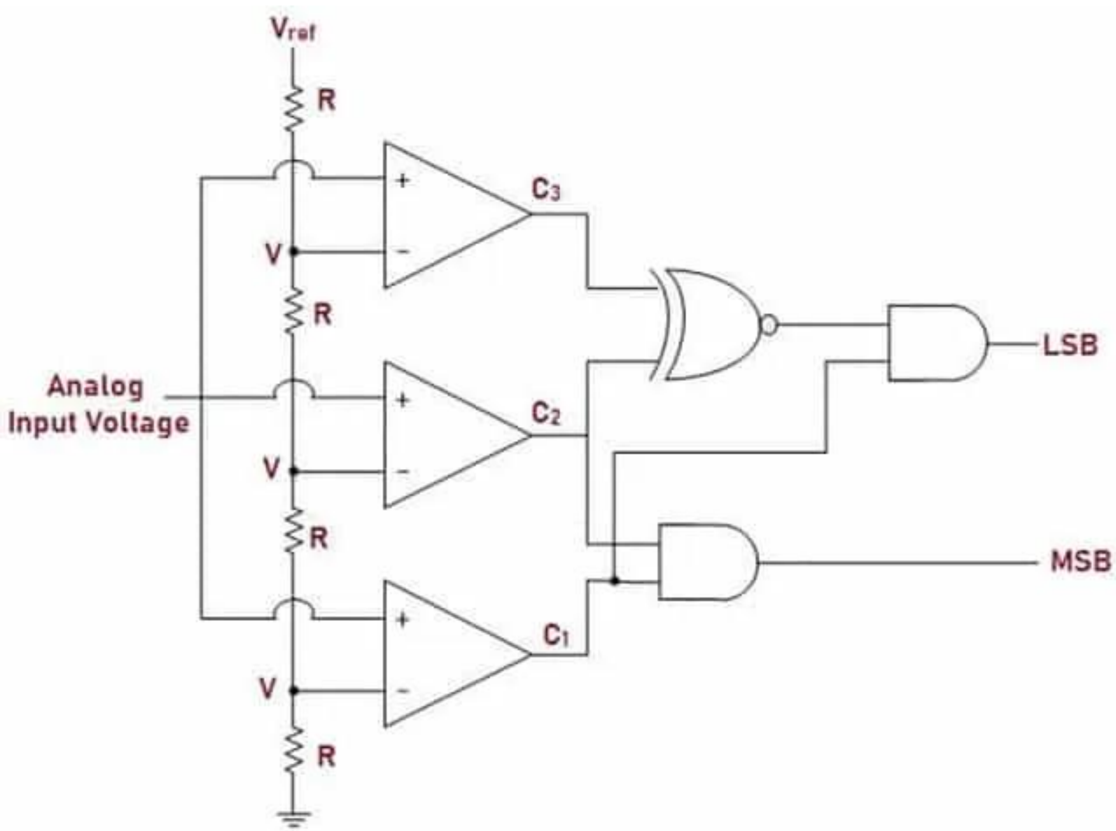
ADC Types

The difference type of ADC are:

1. Flash ADC
2. Pipelined ADC
3. Sigma Delta ADC
4. Successive Approximation ADC

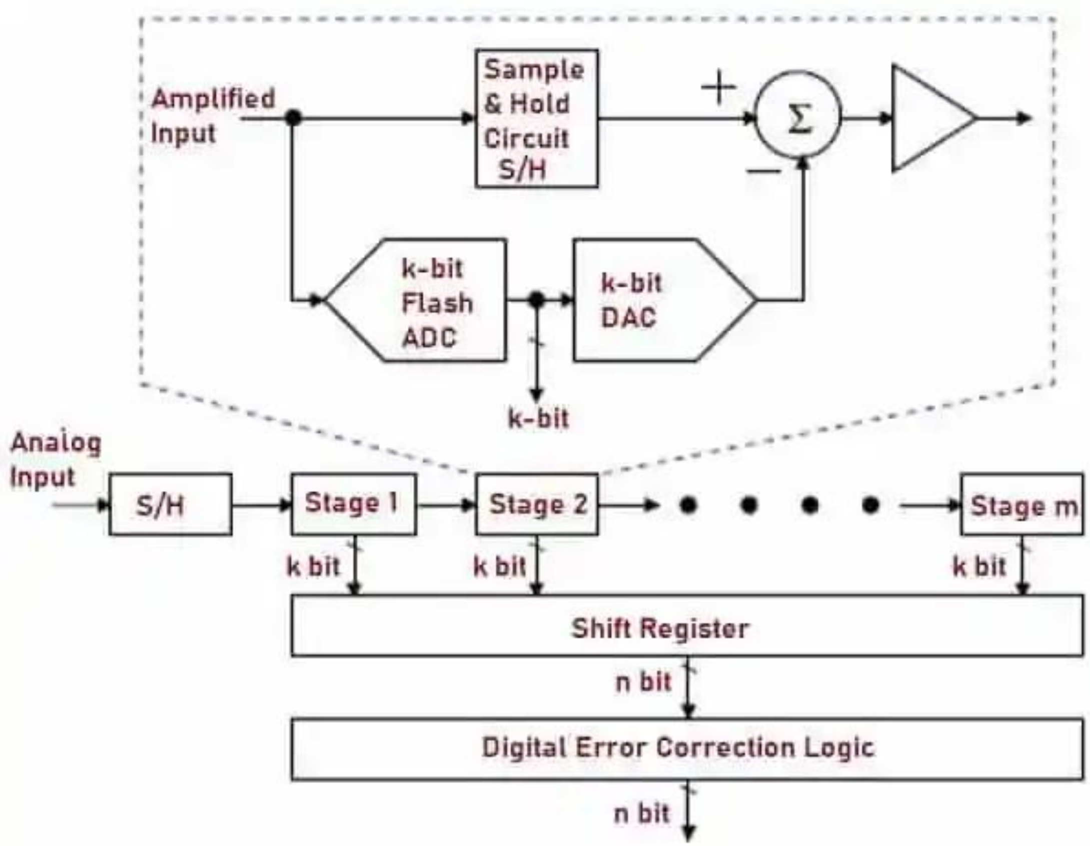
ADC Types

1. Flash ADC: are used in the applications which requires High-Speed and large bandwidth such as *radar detection.* It is also known as **Parallel ADC**.



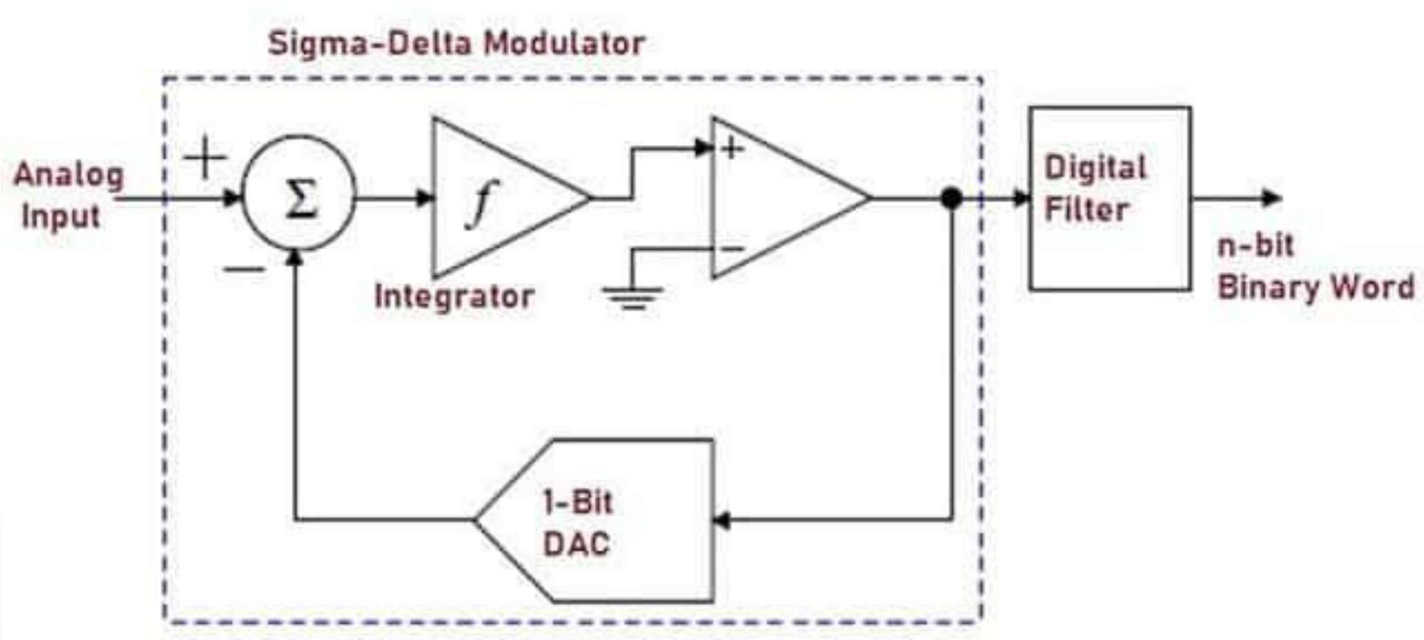
ADC Types

2. Pipelined ADC: are designed using two or more low resolution Flash ADCs. It’s mainly used in *digital oscilloscopes, spectrum analyzers.*



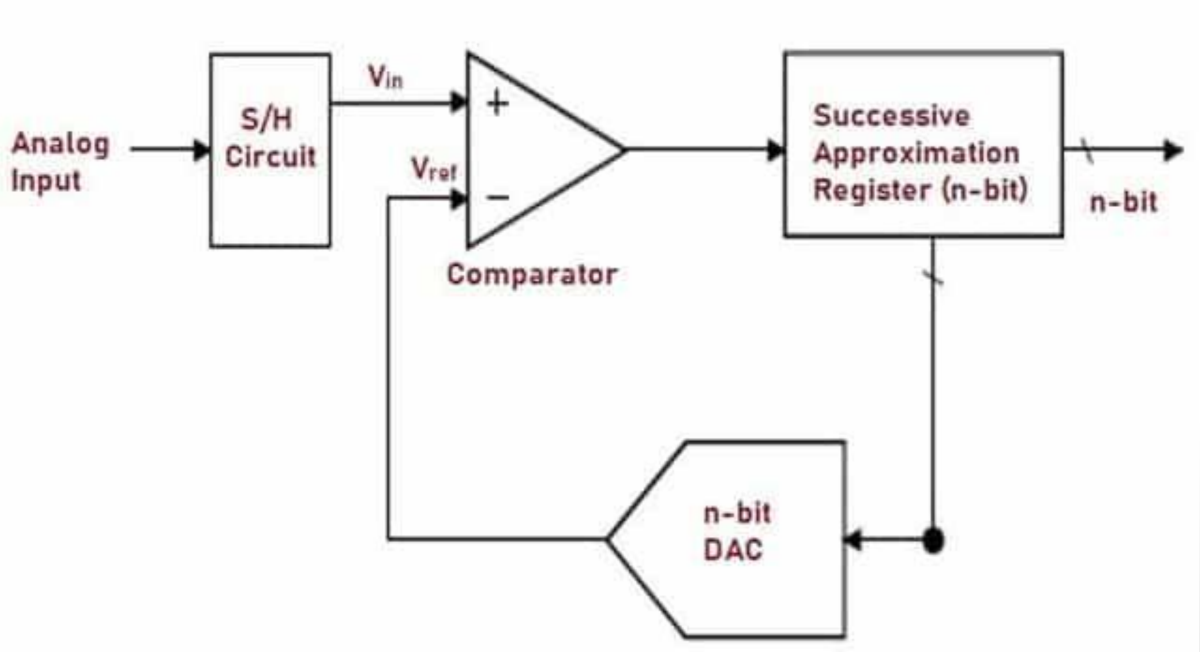
ADC Types

3. Sigma Delta ADC: The architecture of Sigma-Delta (Σ-Δ) converters, also called as Oversampling Converters is quite simple. It consists of two main block: sigma-delta modulator and Digital filter. It's mainly used in *telephone* and *radio communications*.



ADC Types

4. Successive Approximation ADC: This type of Analog to Digital Converter incorporates Successive Approximation Algorithm to convert analog input to a digital binary code. It's mainly used *in CMOS Image sensors for mobile applications.*

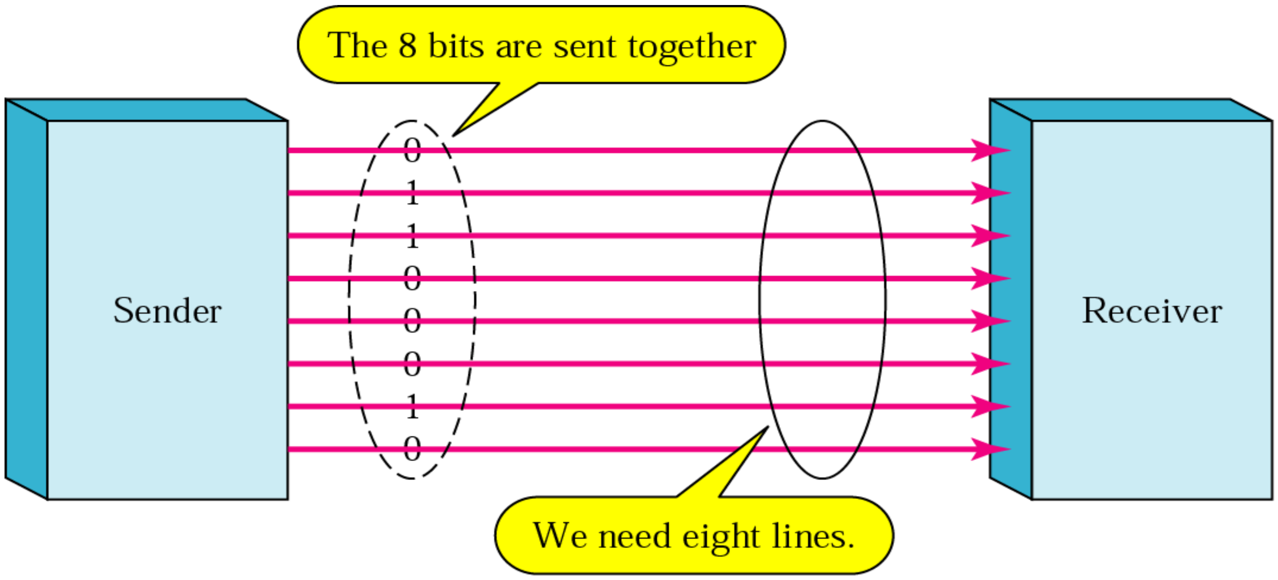


Transmission Mode

- Parallel Transmission
- Serial Transmission

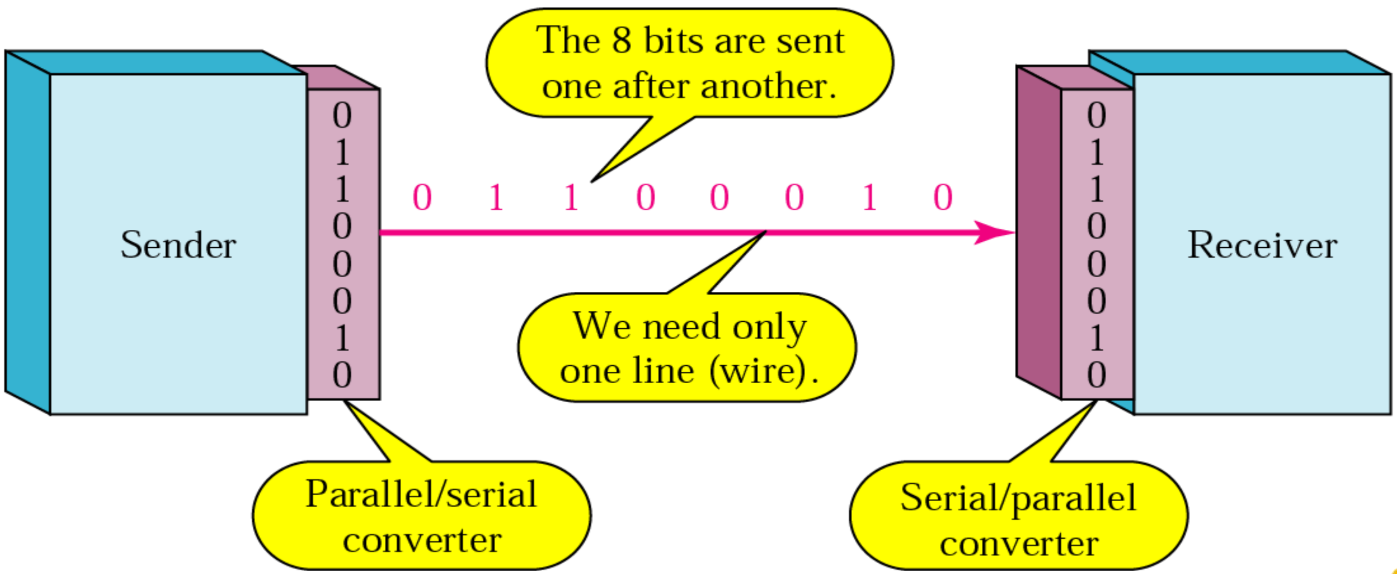
Transmission Mode

1. Parallel Transmission: multiple data bits are transmitted over multiple channels at the same time. This mean that data can be sent much faster than using serial transmission mode.



Transmission Mode

2. Serial Transmission: the data bits are organized in a specific order, since they can only be sent one after another. The order of data bit is important because it's dictates how the transmission is organized when it's received.



Transmission Mode

Description	Serial	Parallel
Number of bits transmitted at one clock pulse	**One** bit	**n** bit
Number of line required to transmit n bits	**One** lines	**n** lines
Speed of data transfer	Slow	Fast
Cost of Transmission	Low as one line is required	Higher as **n** lines are required
Application	Long Distance communication between two computer	Short distance communication like computer to printer
Interference	No Crosstalk problem	Crosstalk creates interference between the parallel lines
Bandwidth	The bandwidth of serial wires is much higher	The bandwidth of parallel wires is much lower
Flexibility	Serial interface is more flexible to upgrade, without changing the hardware	Parallel data transfer mechanism rely on hardware resource and hence not flexible to upgrade

Differences table between Serial and Parallel transmission mode

Homework

1. Pro and Cons of Unipolar, polar, and Bipolar
2. Why do we need to do Sampling?
3. Why do we need Quantization?
4. Why do we need Binary Encoding?
5. Pro and Cons of Serial and Parallel Transmission

Q&A