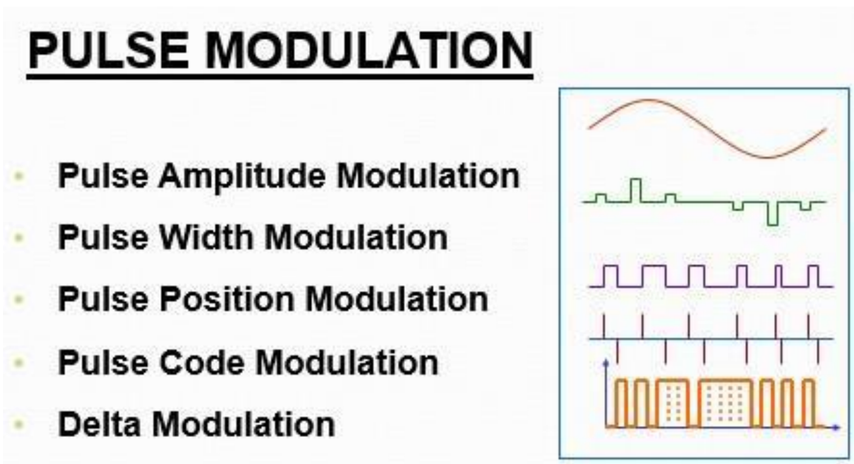
Digital Transmission of Analog Signals

In *pulse modulation*, some parameter of a *pulse train* is varied in accordance with the message signal. In this context, we may distinguish two families of pulse modulation, *analog pulse modulation* and *digital pulse modulation*, depending on how the modulation is performed.
in analog pulse modulation, information is transmitted basically in analog form, but the transmission takes place at discrete times. In digital pulse modulation, on the other hand, the message signal is represented in a form that is discrete in both time and amplitude, thereby permitting its transmission in digital form as a sequence of coded pulses.



What is the need for Pulse Modulation?

1. Many Signals in Modern Communication Systems are digital
2. Also, analog signals are transmitted digitally.
3. Reduced distortion and improvement in signal to noise ratios.
4. PAM, PWM, PPM, PCM and DM.
5. In CW modulation schemes some parameter of modulated wave varies continuously with message.
6. In Analog pulse modulation some parameter of each pulse is modulated by a particular sample value of the message.
7. Pulse modulation is of two types :

- Analog Pulse Modulation
  - Pulse Amplitude Modulation (PAM)
  - Pulse width Modulation (PWM)

- Pulse Position Modulation (PPM)
- Digital Pulse Modulation
  - Pulse code Modulation (PCM)
  - Delta Modulation (DM)

Sampling Theorem

Sampling of the signals is the fundamental operation in signal-processing. A continuous-time signal is first converted to discrete-time signal by sampling process. Sampling theorem gives the complete idea about the sampling of signals. The output of the sampling process is called pulse amplitude modulation (PAM).

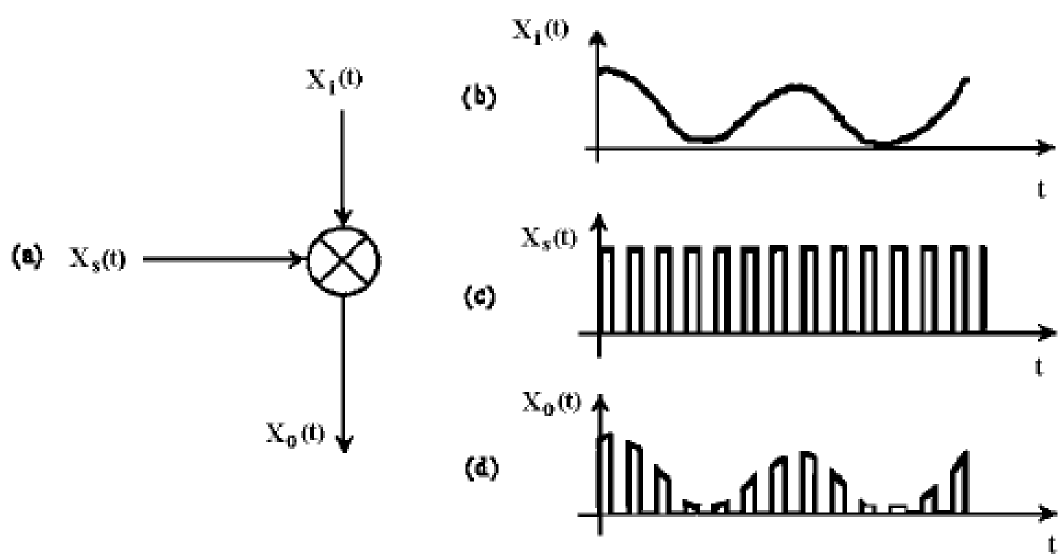


Fig. 2. Generation of Sampled Signals

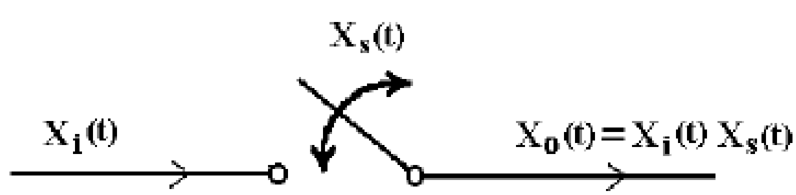
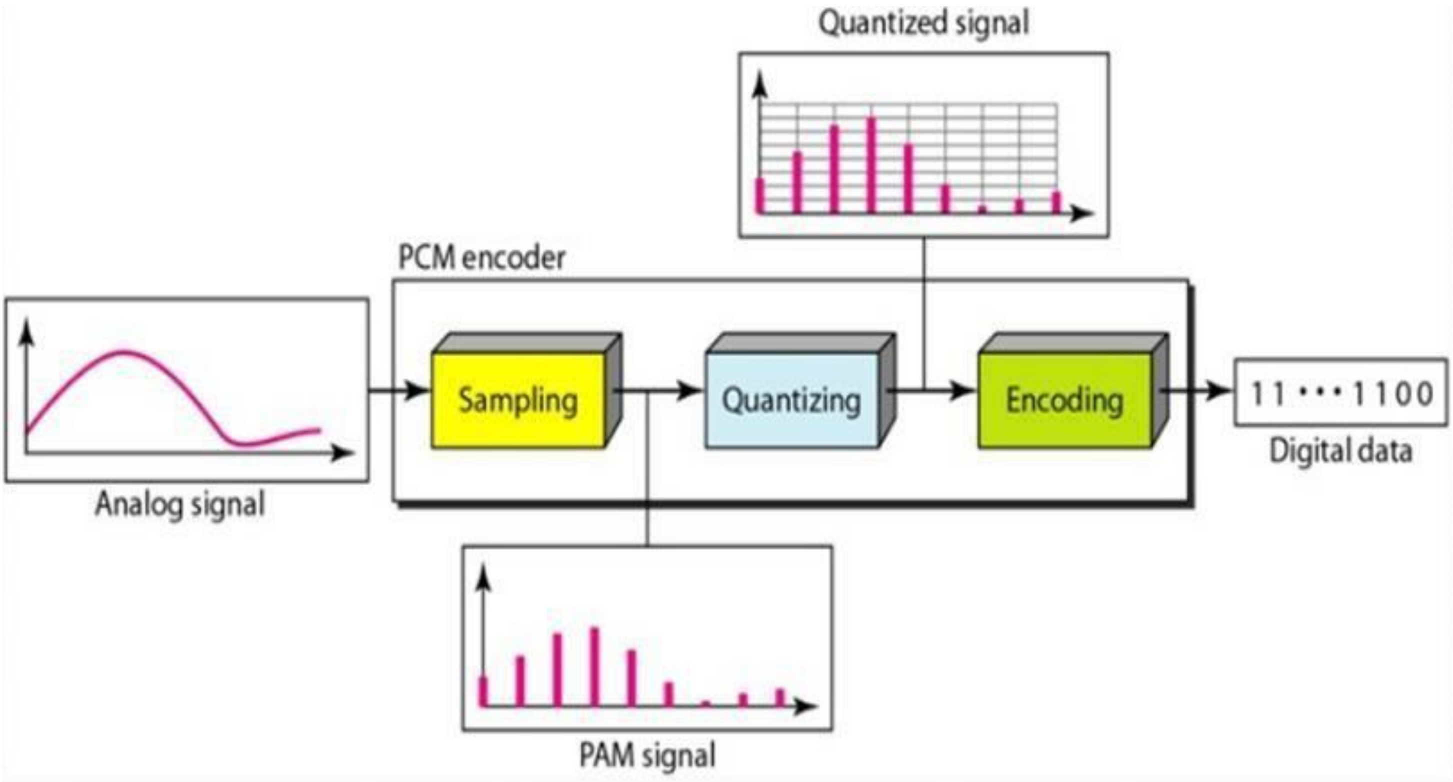
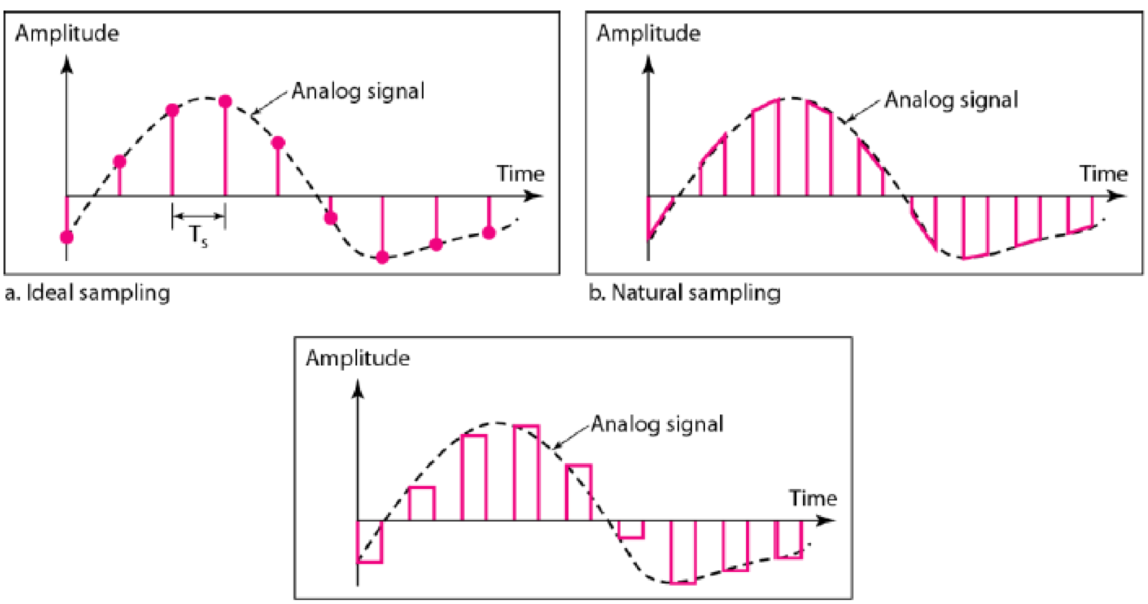


Fig.3 Representation of the Sampling Process



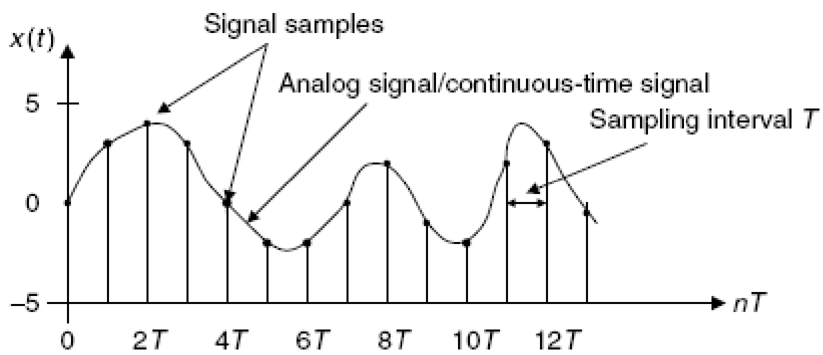
Sampling methods:

- Ideal – An impulse at each sampling instant.
- Natural – A pulse of Short width with varying amplitude.
- Flat Top – Uses sample and hold, like natural but with single amplitude value.



a. Ideal sampling b. Natural sampling

c. Flat-top sampling



The sampling rate:

$$f_s = \frac{1}{T_s} \quad \text{Samples per second (Hz)}$$

$$T_s \leq \frac{1}{2 f_m} \quad \textbf{or} \quad T_s \leq \frac{1}{2 f_{max}}$$

The relationship between the frequency of signal and sampling rate is:

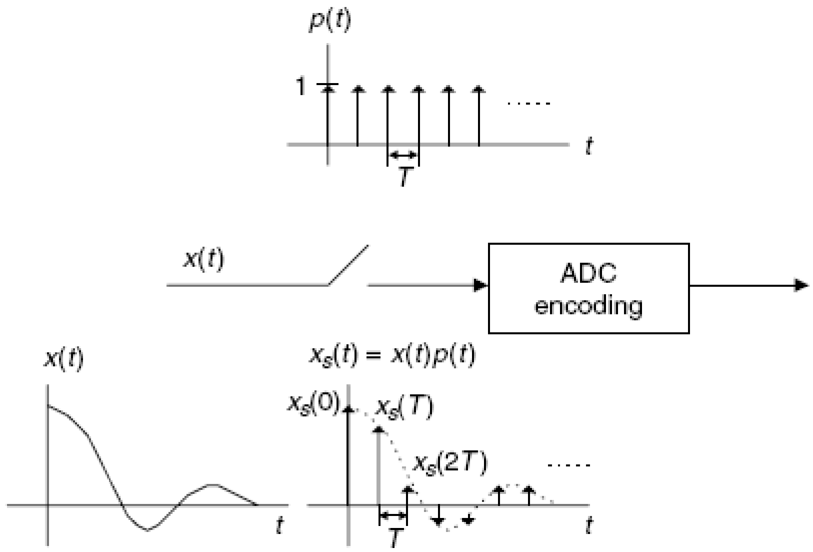
$f_s \geq 2 f_{max}$ Where, f_{max} is the maximum-frequency component of the analog signal to be sampled

The Nyquist rate or frequency is the minimum rate at which a finite bandwidth signal needs to be sampled to retain all of the information.

The sampling rate ($f_s = 2f_m$) also called ***Nyquist rate***.

The Nyquist criterion is a theoretically sufficient condition to allow an analog signal to be reconstructed completely from a set of uniformly spaced discrete time samples.

Other concept of the sampling process is shown below and called **Natural Sampling**:



The sampling process can be written as the product of the continuous signal and the sampling pulses (pulse train):

$$\boldsymbol{x_s(t) = x\,(t)P(t)}$$

Each pulse in P(t) has width T and amplitude 1/T.

Ex: determine the sampling rate for the speech signal with 4 kHz?

Sol:

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

= 2 * 4000 = 8000 Hz minimum (8 kHz)

Ex: For the signal $g(t) = 5\cos(\,2\pi\, 7000\, t)$, find the sampling rate?

Sol:

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

= 2 * 7000 =14000 Hz min (14 kHz)

Ex: If the time interval of the sampled signal is $2\,\mu s$, find f_s ?

Sol:

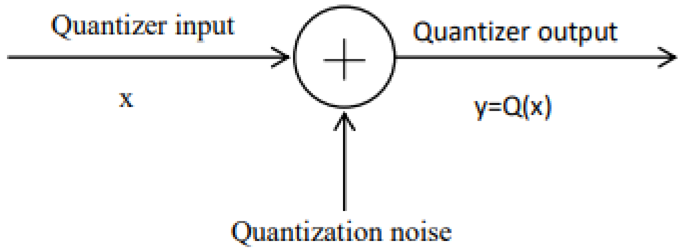
$f_s = 1/T_s$
$= 1/2\ \mu s = 0.5 \times 10^6$ Hz

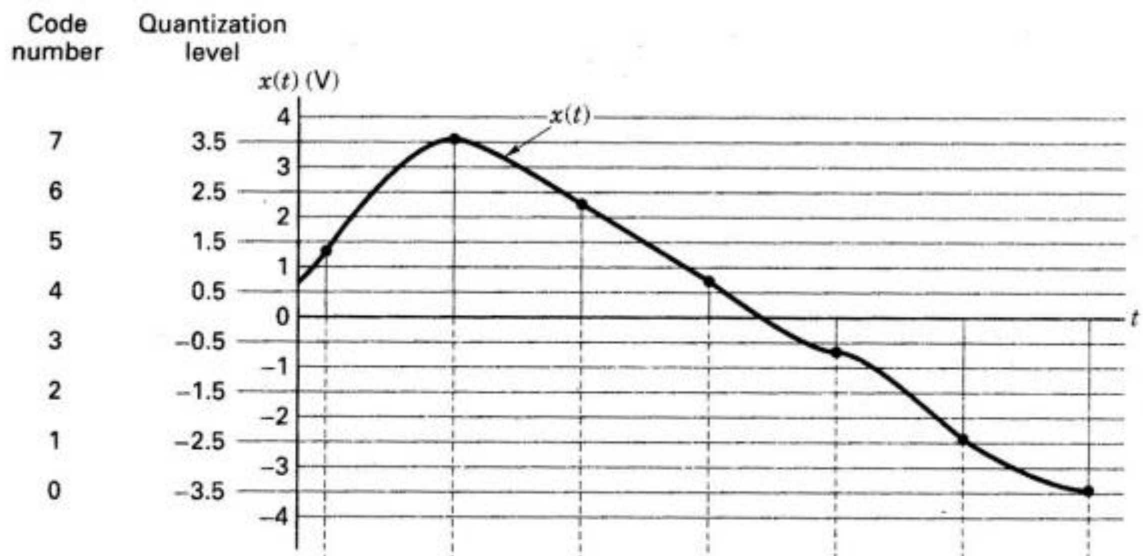
H.W.

- Ex: Channel 1 of two channels system handles 8 kHz signal. Channel 2 handles 10 kHz signals. The two channels are sampled at equal intervals of time using very narrow pulses at the lowest frequency that is theoretical adequate. Calculate the fs for the both?
- Find the frequency of the signal if the sampling rate is 23000 Hz.
- Determine the frequency of the signal of $3\sin(45 \times 10^7 t)$ and the time of sampling?
- Why the frequency of the sampling > the frequency of the message?

QUANTIZATION

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





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