Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Syatems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & Dr. Mayasah Razzaq Abd-Ali
Lecture:6

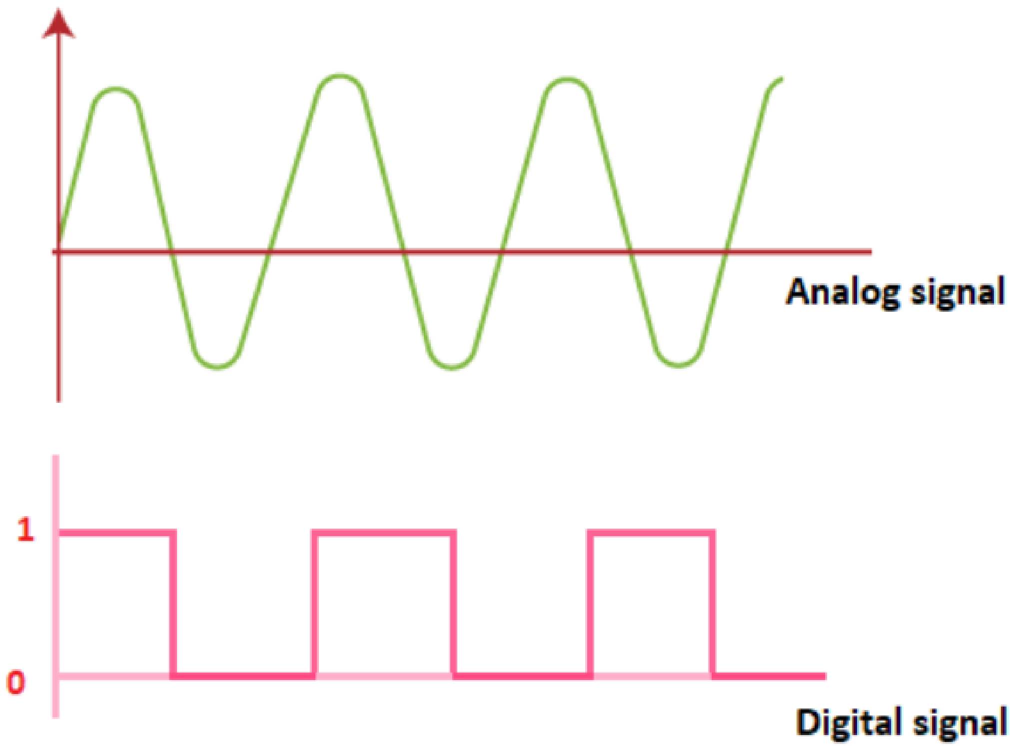
Lecture 6

Sampling

Sampling is defined as a method to select a subset from the large data. In digital communication, it is defined as a process of measuring the instantaneous value of an analog signal in the discrete form.

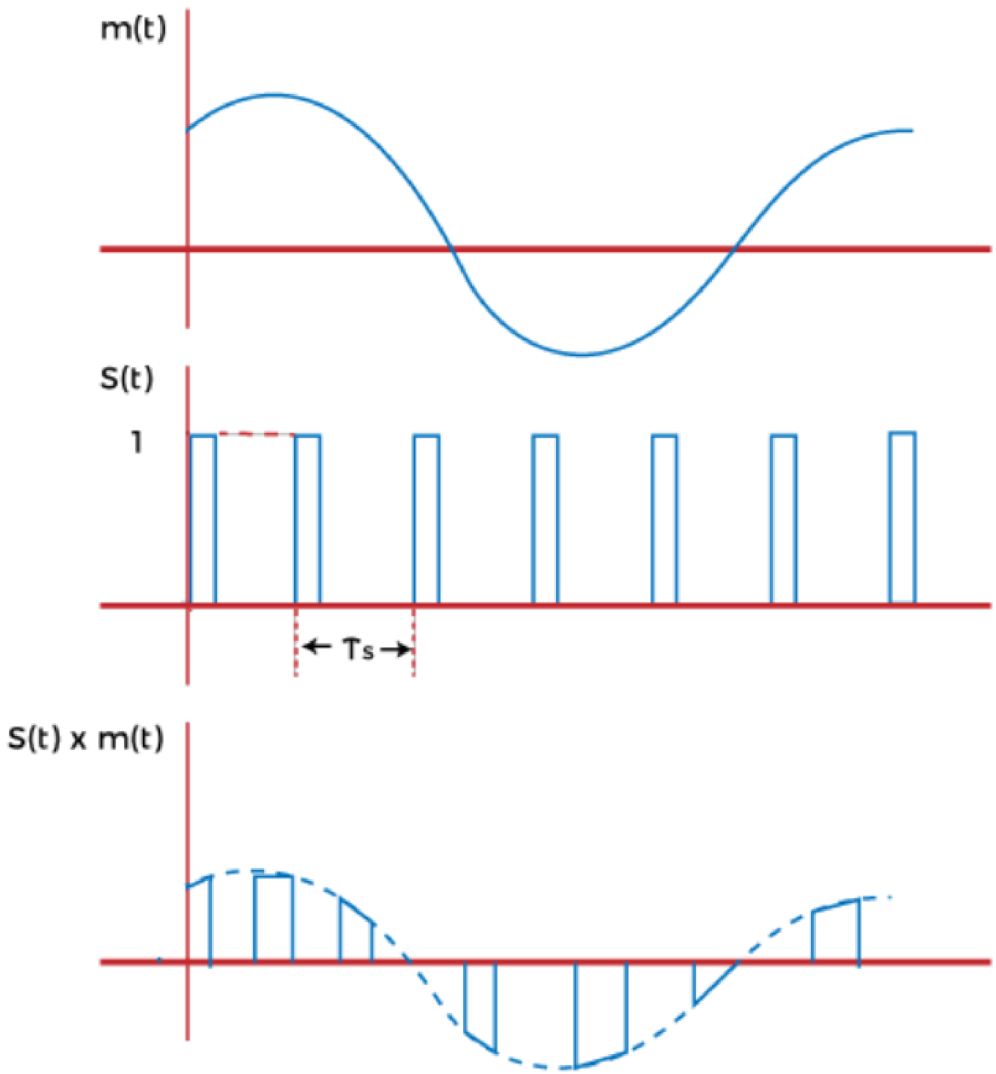
Sampling is a process performed by a sampler. It is present in almost every type of digital communication system that helps in converting an analog signal to the digital signal. An analog signal is a continuous time-varying signal, while digital signal is a signal in the discrete form. The function of a sampler is to measure the samples of the instantaneous value of the continuous signal and convert it into the discrete values.

The combination of quantizer and sampler in digital communications works as an A/D (Analog to Digital) converter. It converts an incoming analog signal to the digital signal. The sampler converts the analog signal to the discrete values and the quantizer represent each level to the fixed discrete finite set of values. Thus, we can define the analog to digital conversion as a two-step process. The first step is performed by the sampler and the second step is performed by the quantizer. The waveforms of a continuous analog signal and digital signal are shown below:



When the continuous signal is sampled at regular intervals and multiplied by a periodic pulse train, the produced signal is the sampled signal, as shown below:

Email: mayasah.razzaq@uomus.edu.iq



Here, we will discuss the sampling theorem, sampling rate, Nyquist rate, methods of sampling, anti-aliasing filter, advantages of sampling, disadvantages of sampling, and applications of sampling.

Sampling theorem

Sampling theorem is based on the fixed sampling rate, called Nyquist rate. Hence, sampling theorem is also known as Nyquist theorem. It is based on the theory of the bandlimited signals. Let's discuss the sampling theorem of the bandpass signals and baseband signals.

According to the sampling theory of the signals, a signal can be successfully reconstructed if its sampling rate is not greater than the maximum frequency W. The samples are spaced at sampling time 'T_s' seconds apart without zero mean square error:

$$T_s = \frac{1}{2\omega}$$

According to the sampling theory of the baseband signals, a signal can be successfully reconstructed if the samples are separated with a uniform interval less than or equal to $1/2F_m$. It can be represented as:

$$T_s \leq 1/2F_m$$

Sampling rate

Sampling rate is defined as the number of samples taken per second from a continuous signal for a finite set of values. We can also define it as a sampling frequency, which is the reciprocal of the sampling time.

$$F_s = \frac{1}{T_s}$$

Where,

- F_s is the sampling frequency
- T_s is the sampling time

As discussed, sampling rate is an essential period for the sampler to perform sampling process. It helps in the successful recovery of the digital signal at the

Email: mayasah.razzaq@uomus.edu.iq

receiving end. Hence, a fixed parameter was defined for the sampling rate, known as Nyquist rate.

Nyquist rate

Suppose H is the highest selected frequency. A bandlimited signal is transmitted at the frequency components lower than W Hz. Thus, for the replication of the original signal, the sampling rate should be twice the highest frequency. It is given by:

$$F_s = 2\omega$$

Where,

• Fs is the sampling rate

• W is the highest frequency

Such rate of sampling is known as Nyquist rate. The sampling at the Nyquist rate does not introduce any distortion. Nyquist rate is also known as the minimum sampling rate and is represented by the condition:

$$F_s = 2F_m$$

Where,

• Fs is the sampling frequency or sampling rate • Fm is the maximum frequency of the input signal or the message signal

Nyquist Interval

Nyquist interval is the reciprocal of the Nyquist rate. It is given by:

$$\mathbf{TS = 1/2W}$$

Where,

• TS is the Nyquist Interval

• W is the highest frequency

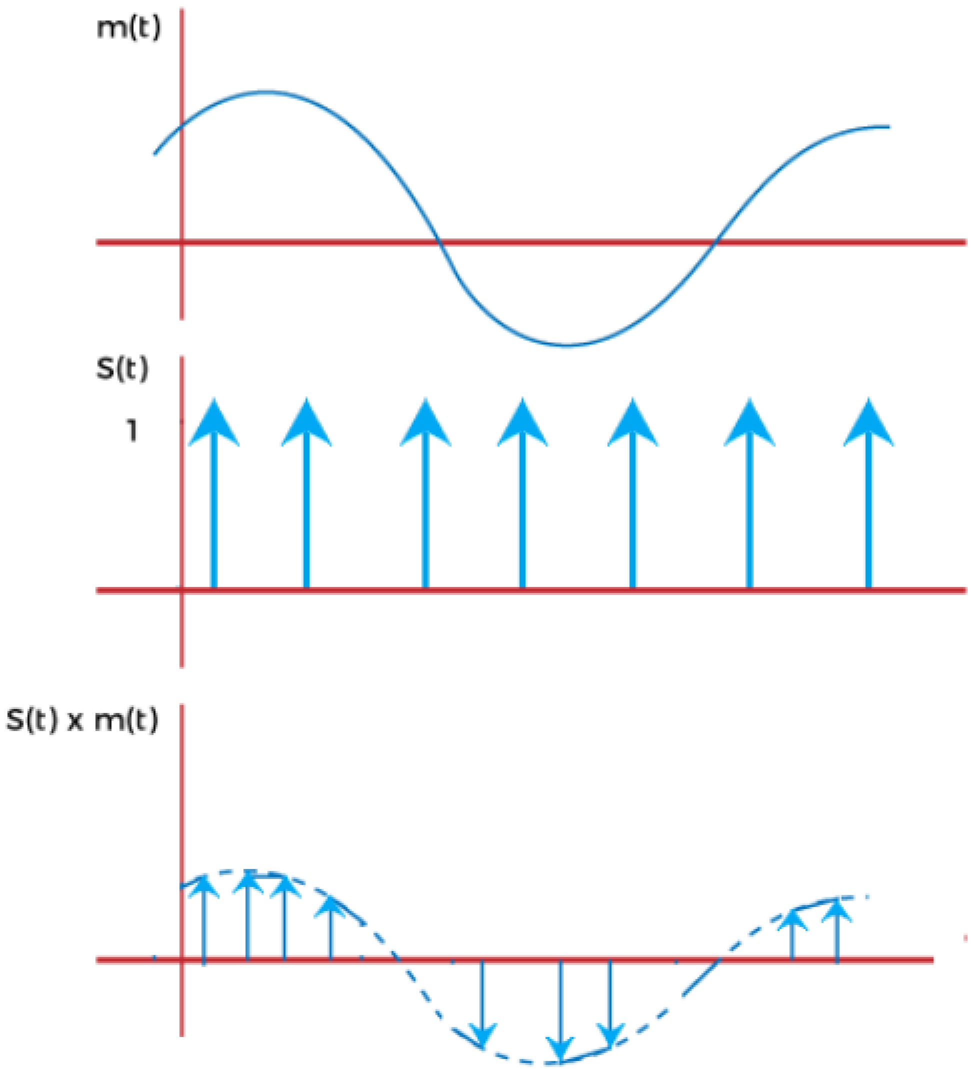
Methods of sampling

The methods of sampling are classified as follows:

1. Ideal Sampling
2. Natural Sampling
3. Flat-top sampling

1. Ideal Sampling

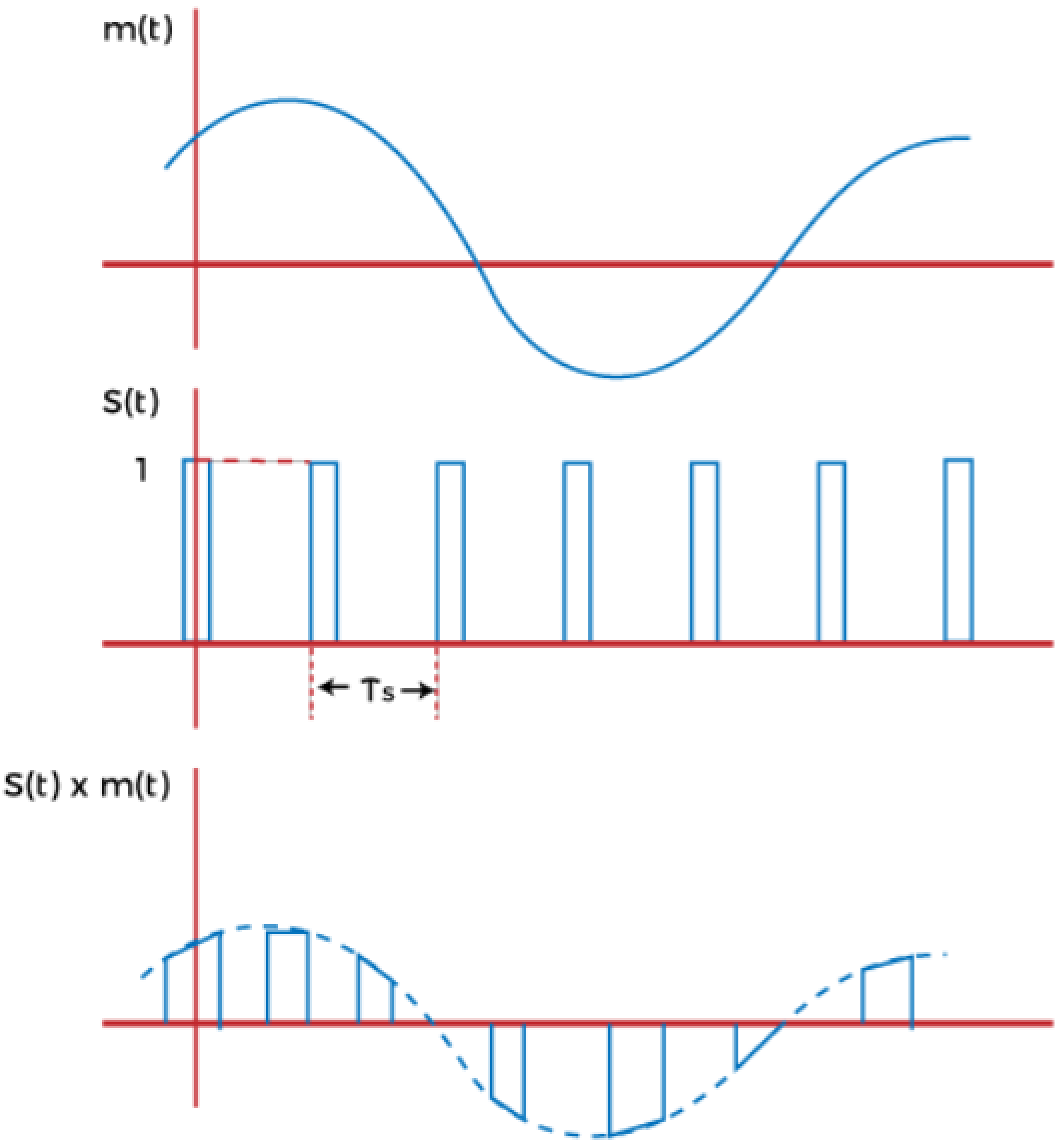
Ideal sampling is also known as instantaneous sampling or impulse sampling. The sampling process multiplies the input signal and the carrier signal, which is present in the form of train of pulses.



The above diagram shows the waveforms of the message signal, sampling signal in the form of train of pulses, and the sampled signal. The working principle that multiples the input signal and the sampling signal is known as multiplication principle.

2. Natural Sampling

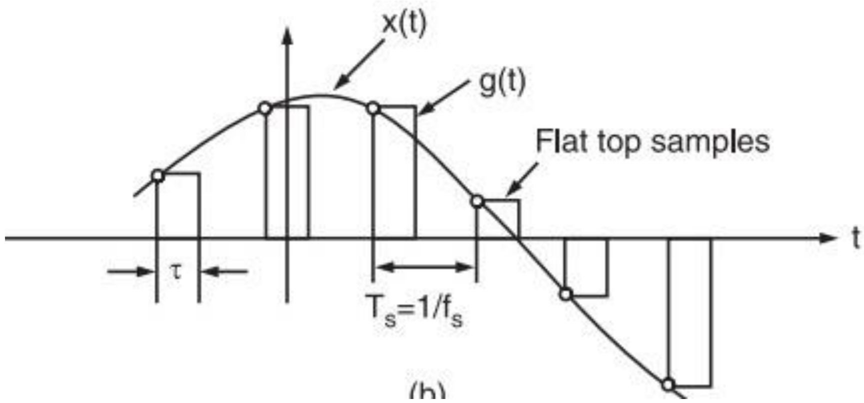
Natural Sampling is considered an efficient multiplexing method in Pulse Amplitude Modulation. Here, the analog signal is multiplied by the uniformly spaced rectangular pulses.



The above diagram shows the waveforms of the message signal, sampling signal, and the sampled signal.

3. Flat-top sampling

The design and reconstruction of flat-top sampling is easy than the natural sampling process. The pulses in the flat-top sampling method are in the flat shape at the top and are held at a constant height. It means that the samples are flat and have constant amplitude.



Why sampling is required?

We know that the sampling process helps in the conversion of an analog signal to the digital signal. The data transmission in the form of digital signal offers various advantages, such as high efficiency, fast speed, low cost, low interference, low distortion, and high security. Hence, sampling is essential to improve the quality and transmission ability of the signals over the communication channel.

Advantages of sampling

The major advantages of the sampling process are due to the conversion of the transmission to the digital form, which has various advantages as discussed above. It converts an analog signal to the discrete values. The advantages of sampling are as follows:

- Low cost
- High accuracy
- Easy to implement
- Less time consuming
- Low signal loss
- High scope

It prevents the signal loss or any information loss by converting the incoming data to the suitable rate for transmission. For example, if a signal contains high frequency components, the sampling process will convert it into high rates for effective transmission. Generally, the input signal is sampled at the frequency rate twice that the incoming signal. It is done to preserve the full information in the signal.

Applications of sampling

Sampling describes the number of possible digital values that are used to represent a sample. Sampling is essential because it prevents any information loss during the transmission loss. It also increases the accuracy of the system. Sampling is used in various processes, such as PAM, PCM, and TDM