# Real Time Systems Design

## Lecture (7): Analog To Digital Convertors

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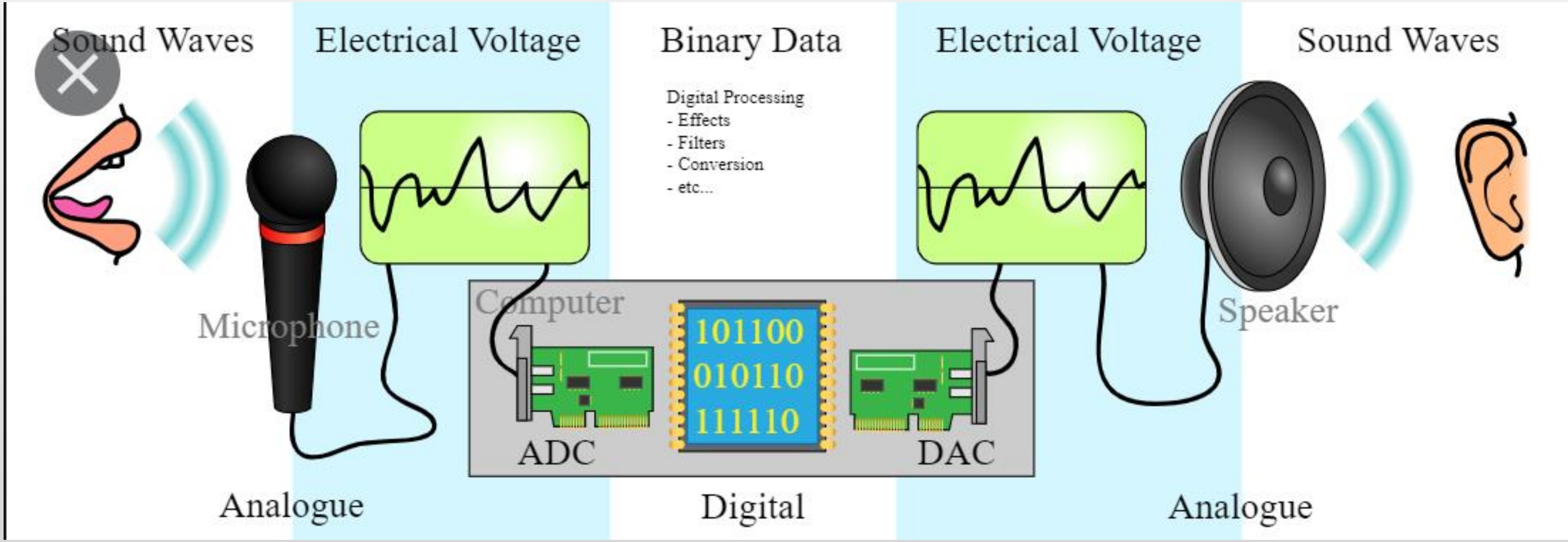
# Introduction to ADC and DAC




E-Lectures for Third Level
Real-Time systems design

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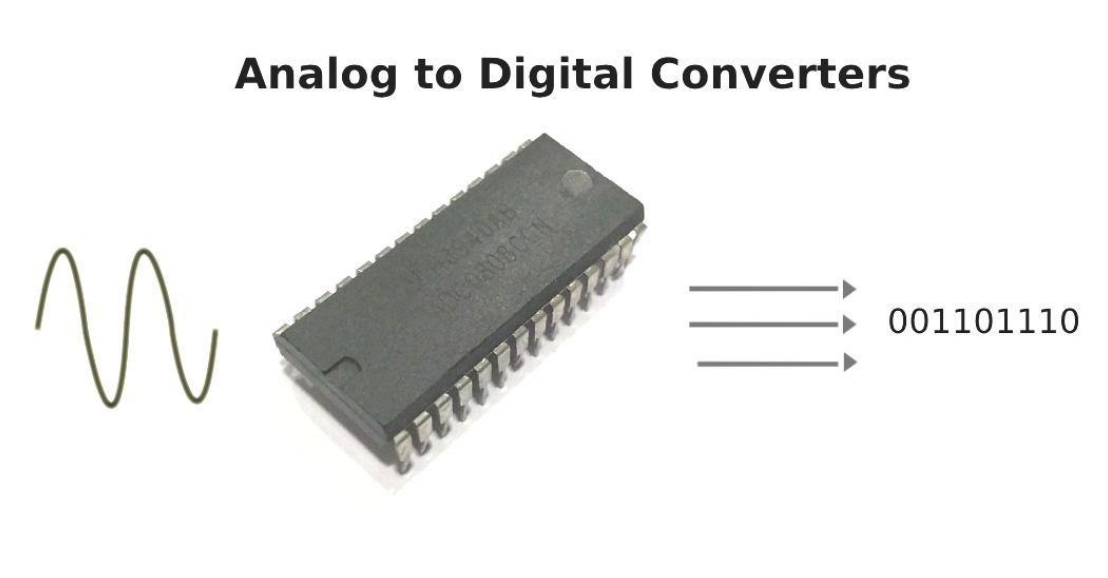
# Definition of Analog to Digital Convertor

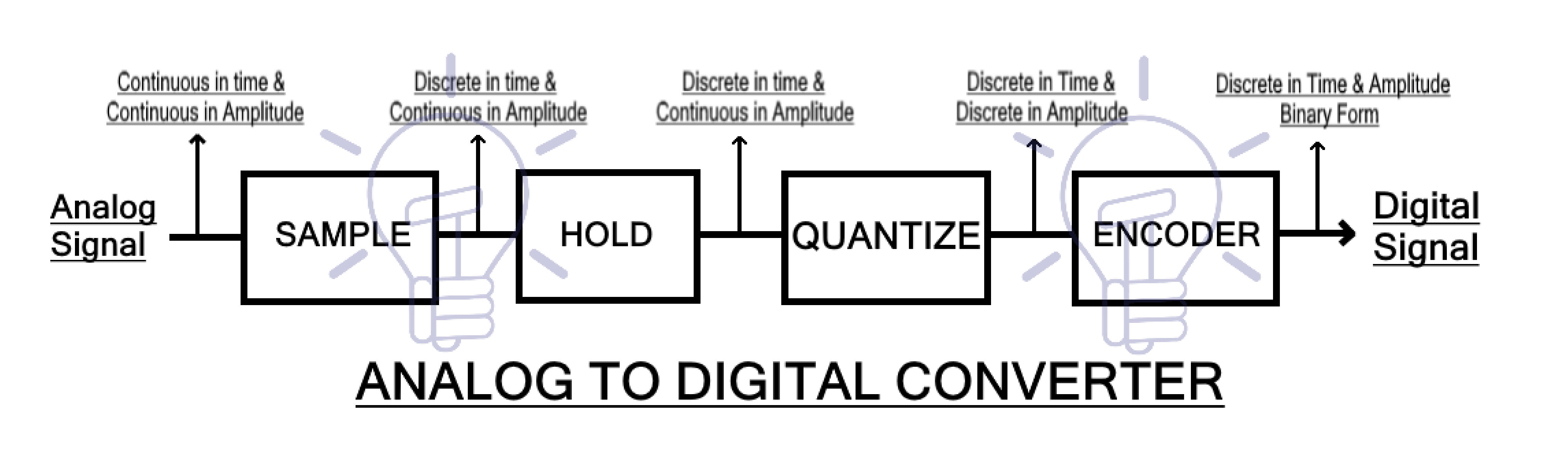
Analog to Digital Converter (ADC) is an electronic integrated circuit used to convert the analog signals such as voltages to digital or binary form consisting of 1s and 0s.

Most of the ADCs take a voltage input as 0 to 10V, -5V to +5V, etc. and correspondingly produces digital output as some sort of a binary number.

The analog-to-digital converter (ADC) accepts an analog input-a voltage or a current-and converts it to a digital value that can be read by a microprocessor.



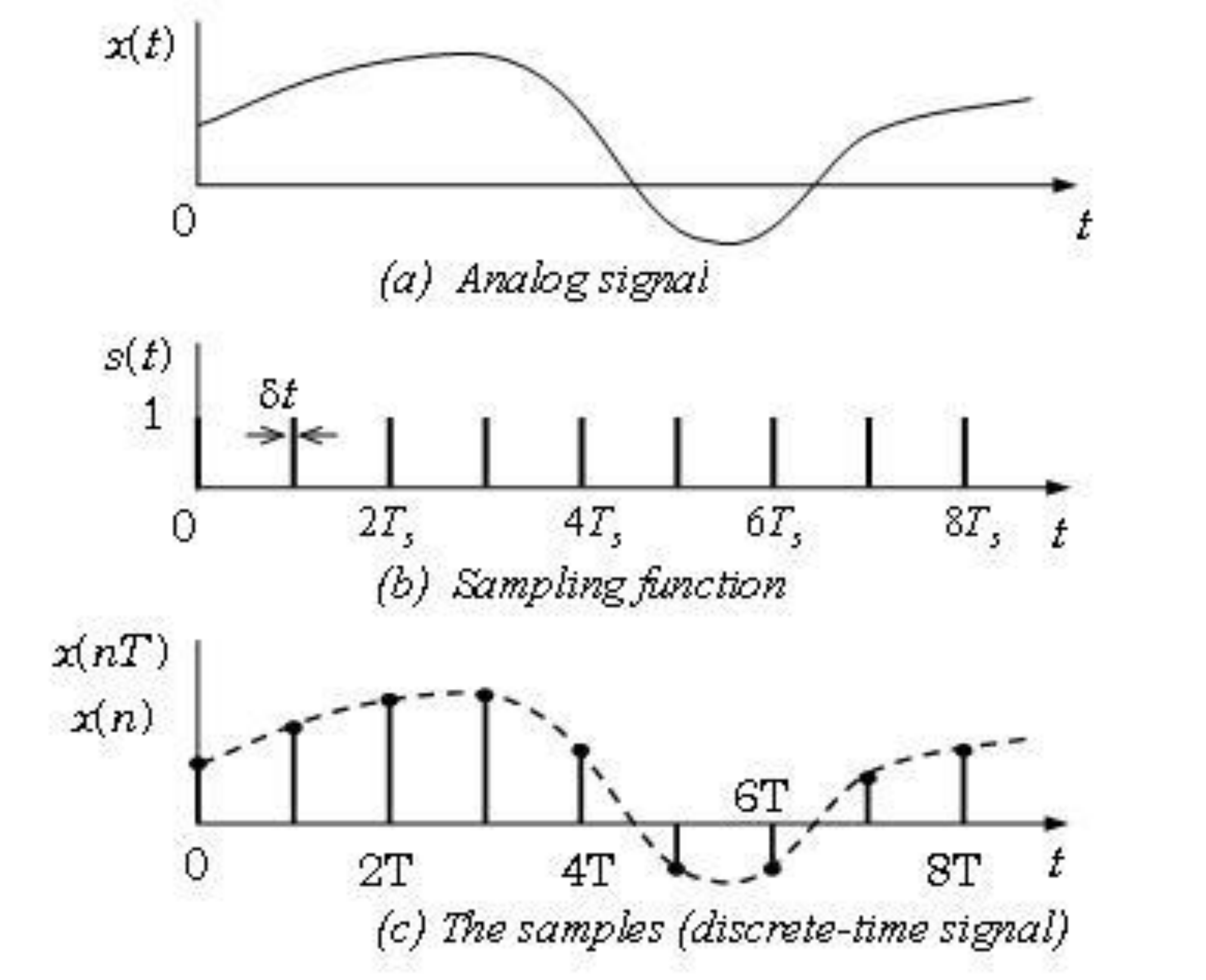
# ADC Basics



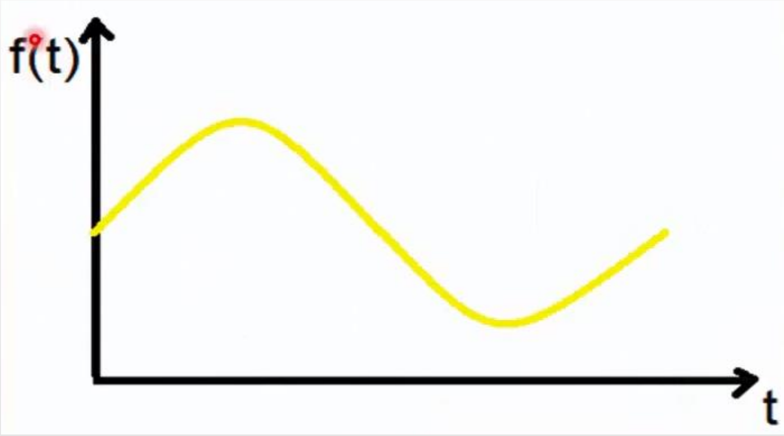
Continuous in time &
Continuous in Amplitude
Discrete in time &
Continuous in Amplitude
Discrete in time &
Continuous in Amplitude
Discrete in Time &
Discrete in Amplitude
Discrete in Time & Amplitude
Binary Form
Analog
Signal
SAMPLE
HOLD
QUANTIZE
ENCODER
Digital
Signal
ANALOG TO DIGITAL CONVERTER

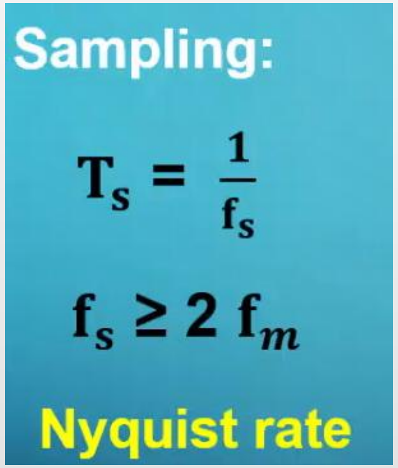
# Sampling

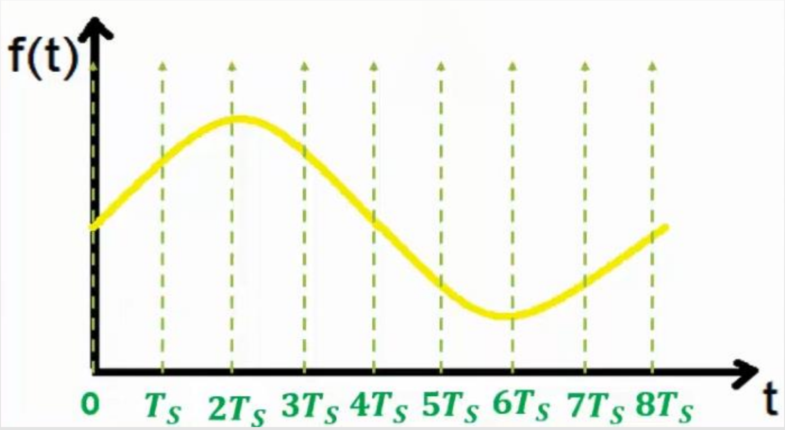
Sampling Frequency: By sampling we turn a continuous-time function which may take on infinitely many values at different times into a discretized function that may take on infinitely many values at different discrete indices. Sampling generally is done with a Sample-And-Hold circuit (simple experiments can be done using a capacitor and switch). To be able to reconstruct the signal we must consider the Sampling Theorem which says that a sampling frequency twice the highest frequency we're expecting is needed.
In a simple way sampling can be defined as the process of taking samples from the continuous time function x(t) and for the signal to reconstruct we must consider the sampling theorem which states that the sampling frequency must be always greater than or equal to twice the highest frequency.



# Sampling rate or frequency

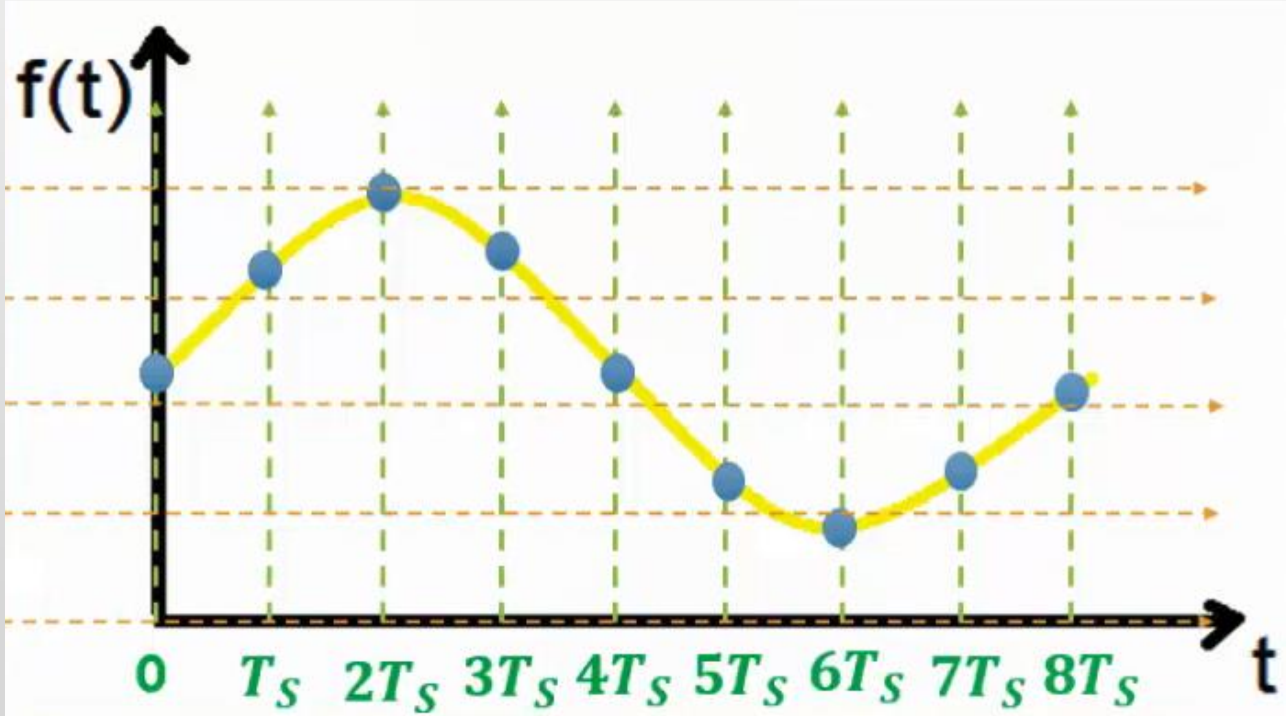


# Quantization

**Quantization:** is the process of taking a continuous voltage signal and mapping it to a discrete number of voltage levels, $N=2^n$ where n refers to the number of bits.

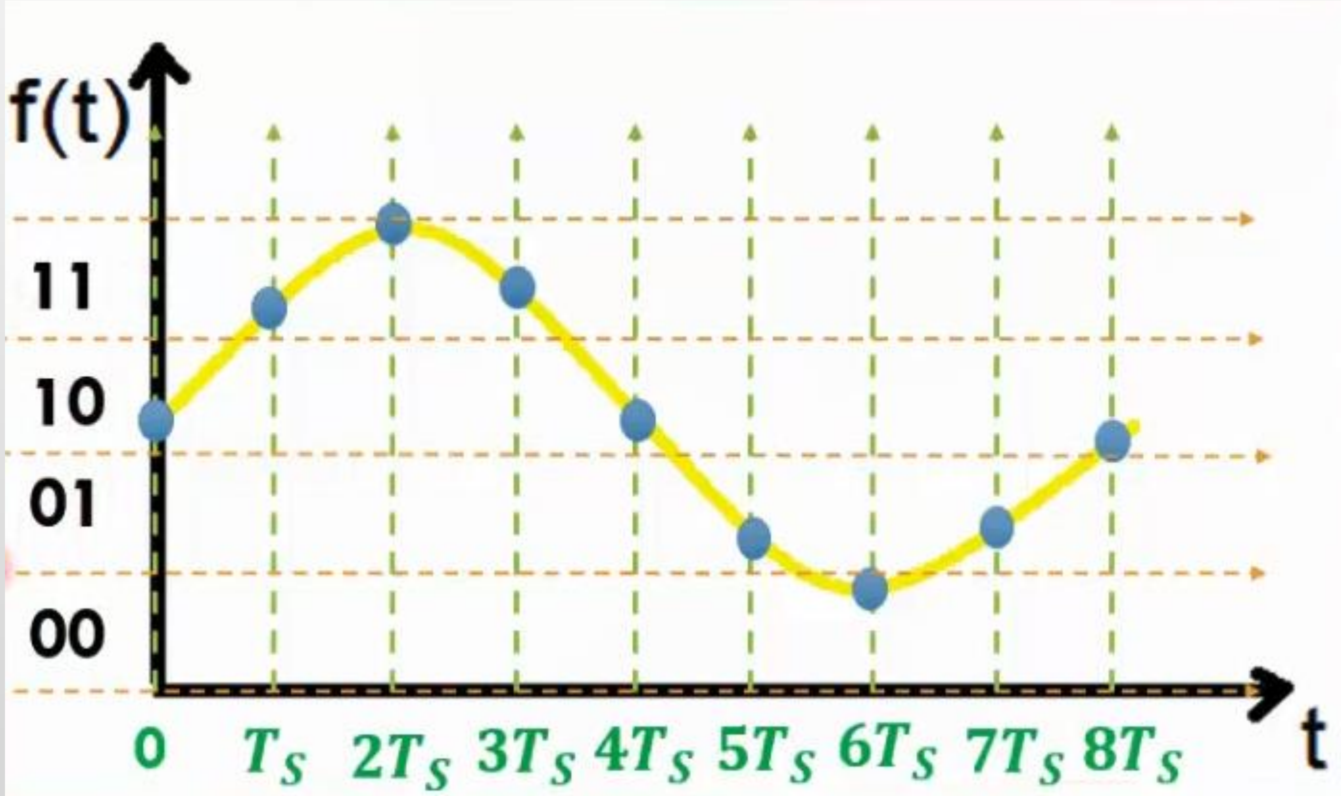



**Example:** Let the number of bits is 2 then the number of levels $N=2^2 = 4$ levels

# Coding

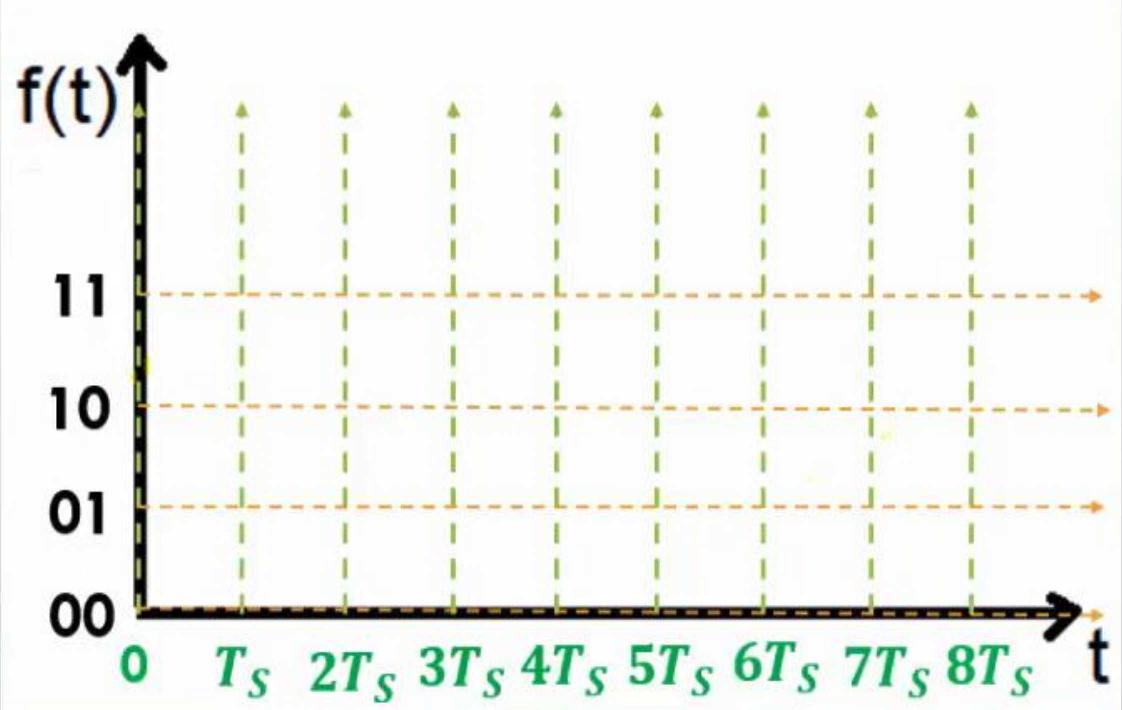
The output code can be obtained from the level of each sample

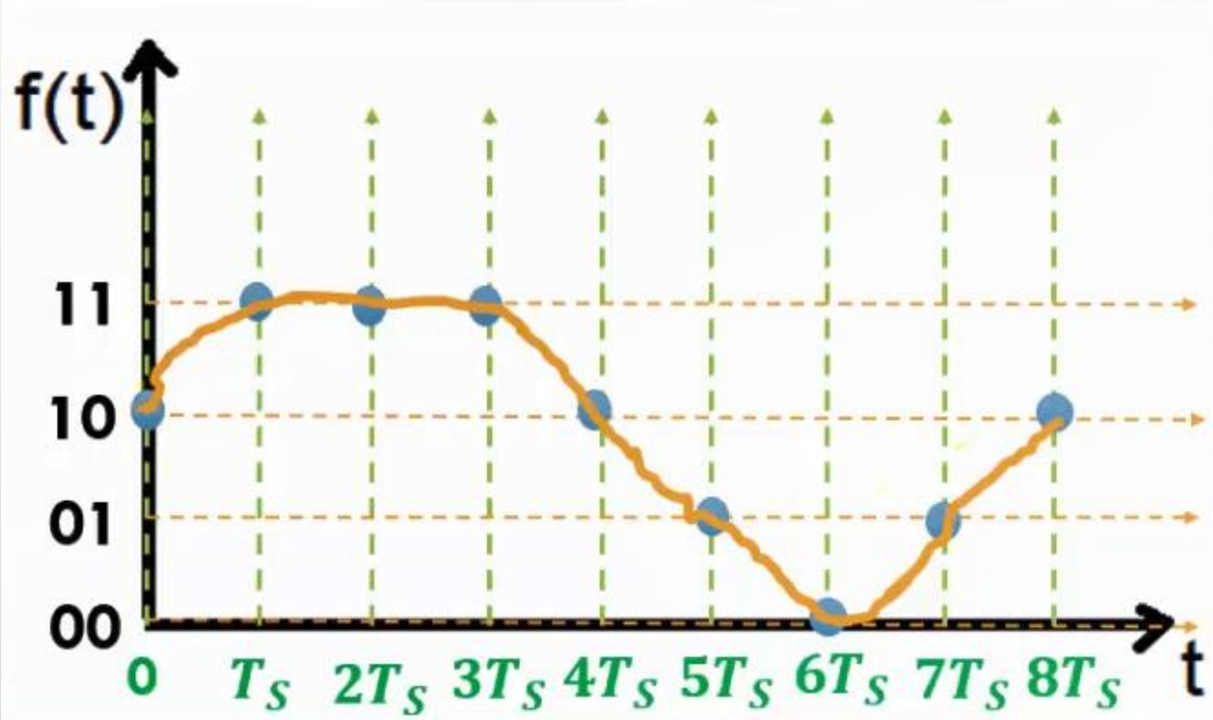
10 11 11 11 10 01 00 01 10




**Thus the analog signal has been converted to digital signal**

# Reconstruction




10 11 11 11 10 01 00 01 10

# Analog Reference For ADC

Analog To Digital Conversion process needs an extremely stable voltage reference $\mathbf{V_{ref}+}$ and $\mathbf{V_{ref}-}$ representing the maximum allowable voltage swing for the input in order to be correctly converted to digital value with respect to the limits which are set by the analog reference $\mathbf{V_{ref}}$.

The easiest way to guarantee a stable $V_{ref}$ is to use a resistor and a capacitor to resist any sudden drop in voltage and protect your system. You can also use a Zener diode as well to guarantee a stable voltage reference which immunes your system against any sudden changes in power supply increase/drop. The concept is indicated in the diagram below.

# The Reference voltage

The reference voltage is the maximum value that the ADC can convert. The ADC requires a reference voltage to which the analog input is compared to produce the digital output. The digital output is the ratio of the analog input with respect to this reference voltage.

Digital value = (Analog input voltage)/ VREF)

For example, for 12-bit ADC, VIN=1V, VREF=3.3 V

Digital value = (1 V/3.3 V)=0.303

# Resolution

Resolution: The step size of the converter defines the converter's resolution.

Resolution = reference voltage/$2^n$

Where n: no. of bit, if we want to convert voltage (0-10) and n=3,then

Resolution = $10/2^3=10/8=1.25$ volt

Meaning that we need 1.25 volt to represent each input step

# Summary

- ✓ Introduction to ADC and DAC
- ✓ Definition of Analog to Digital Convertor
- ✓ ADC Basics
- ✓ Sampling
- ✓ Sampling rate or frequency
- ✓ Quantization
- ✓ Coding
- ✓ Reconstruction
- ✓ Reference voltage and resolution