Introduction to Digital Techniques

Signal

- A function that conveys information, generally about the state or behavior of a physical system.
- Eg: Speech as a function of time, Photographic image as brightness function of two spatial variables.
- There are two types of signal. Analog and Digital

Analog Signals

- Signals that vary in continuous fashion and take an infinite number of values in any given range.
- Directly measurable quantities in terms of some other quantity.
- Continuous time signals.

Examples:

- Thermometer – mercury height rises as temperature rises.
- Car Speedometer – Needle moves farther right as you accelerate.
- Stereo – Volume increases as you turn the knob.

Digital Signals

- Signals that vary in discrete steps and take only two possible values either 1 or 0 within any specified range
- Discrete time signals.
- have only two states. For digital computers, we refer to binary states, 0 and 1. "1" can be on, "0" can be off.
- Examples:
  - Light switch can be either on or off
  - Door to a room is either open or closed

Analog Signals	*Digital Signals*
Continuous	Discrete
Infinite range of values	Finite range of values
More exact values, but more difficult to work with	Not as exact as analog, but easier to work with
Shape of the signals is different. So, no common format.	Common format for the transmission of different kind of message signals (audio, video etc).
Less immunity to interference	High immunity to interference.
Bandwidth of Channel=Bandwidth of Signal.	Bandwidth of Channel > Bandwidth of Signal.

Analog Signals	*Digital Signals*
☐ Difficult to multiplex signals.	☐ Easier and efficient to multiplex several digital signals.
☐ Storage difficult and costly.	☐ Storage relatively easier and inexpensive.
☐ Inflexible operation as compared to Digital operations.	☐ Flexible operation of the system
☐ System is simple.	☐ Increased system complexity as every signal in nature is in analog form and has to be converted into digital using ADC converters.

Analog and Digital Signals

- Example:

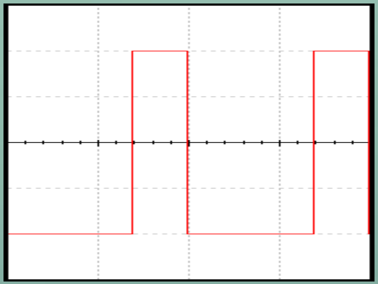
  A digital thermostat in a room displays a temperature of 72°. An analog thermometer measures the room temperature at 72.482°. The analog value is continuous and more accurate, but the digital value is more than adequate for the application and significantly easier to process electronically.

Example of Analog Signals

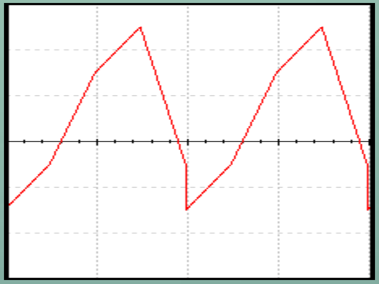
- An analog signal can be any time-varying signal.
- Minimum and maximum values can be either positive or negative.
- They can be periodic (repeating) or non-periodic.
- Sine waves and square waves are two common analog signals.
- Note that this square wave is not a digital signal because its minimum value is negative.

0 volts

Sine Wave

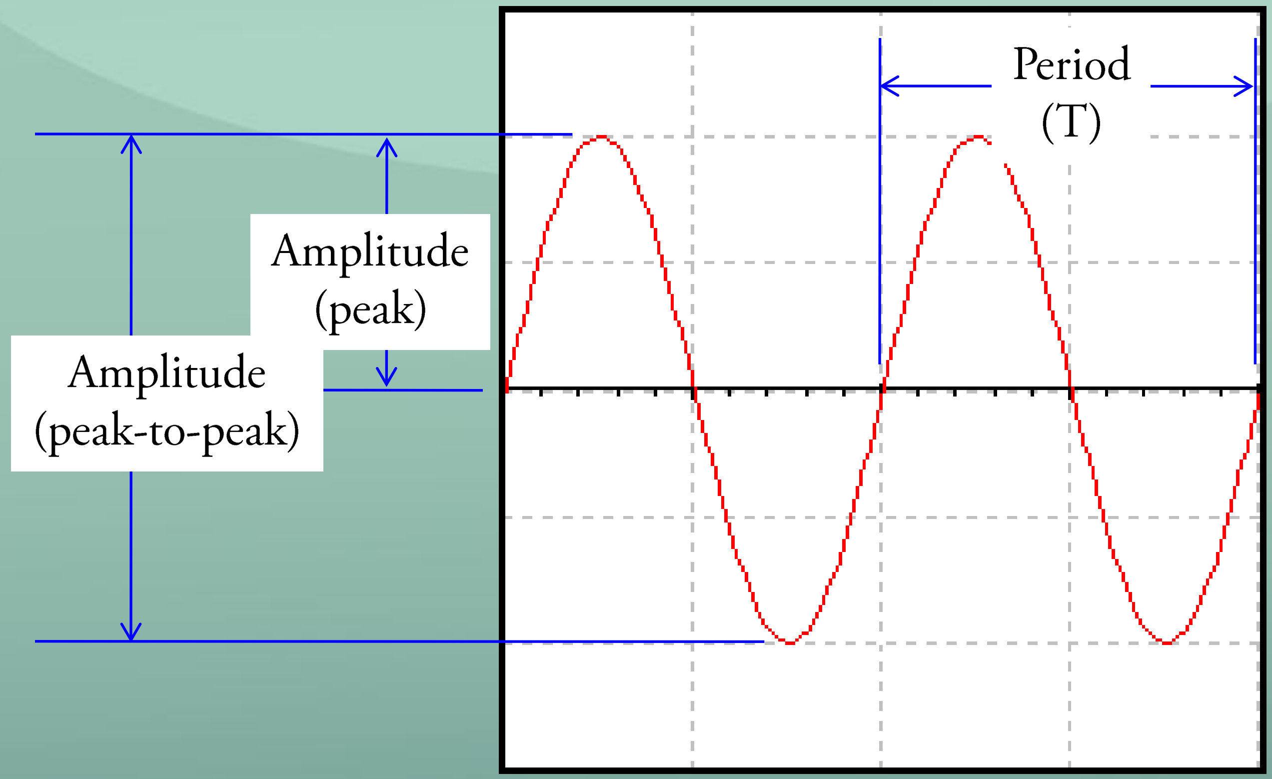


Square Wave
(not digital)



Random-Periodic

Parts of an Analog Signal

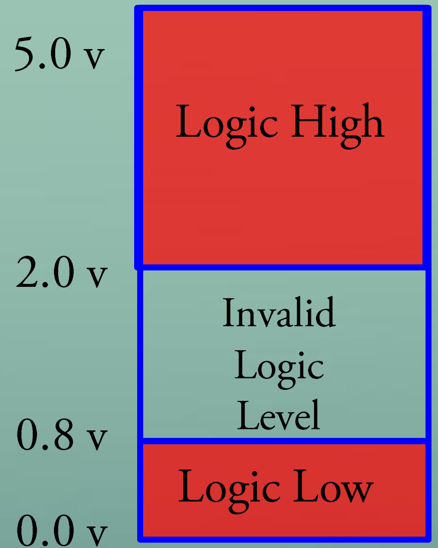


Frequency:

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

Logic Levels

- Before examining digital signals, we must define logic levels. A logic level is a voltage level that represents a defined digital state.
- Logic HIGH: The higher of two voltages, typically 5 volts
- Logic LOW: The lower of two voltages, typically 0 volts



Logic Level	Voltage	True/False	On/Off	0/1
HIGH	5 volts	True	On	1
LOW	0 volts	False	Off	0

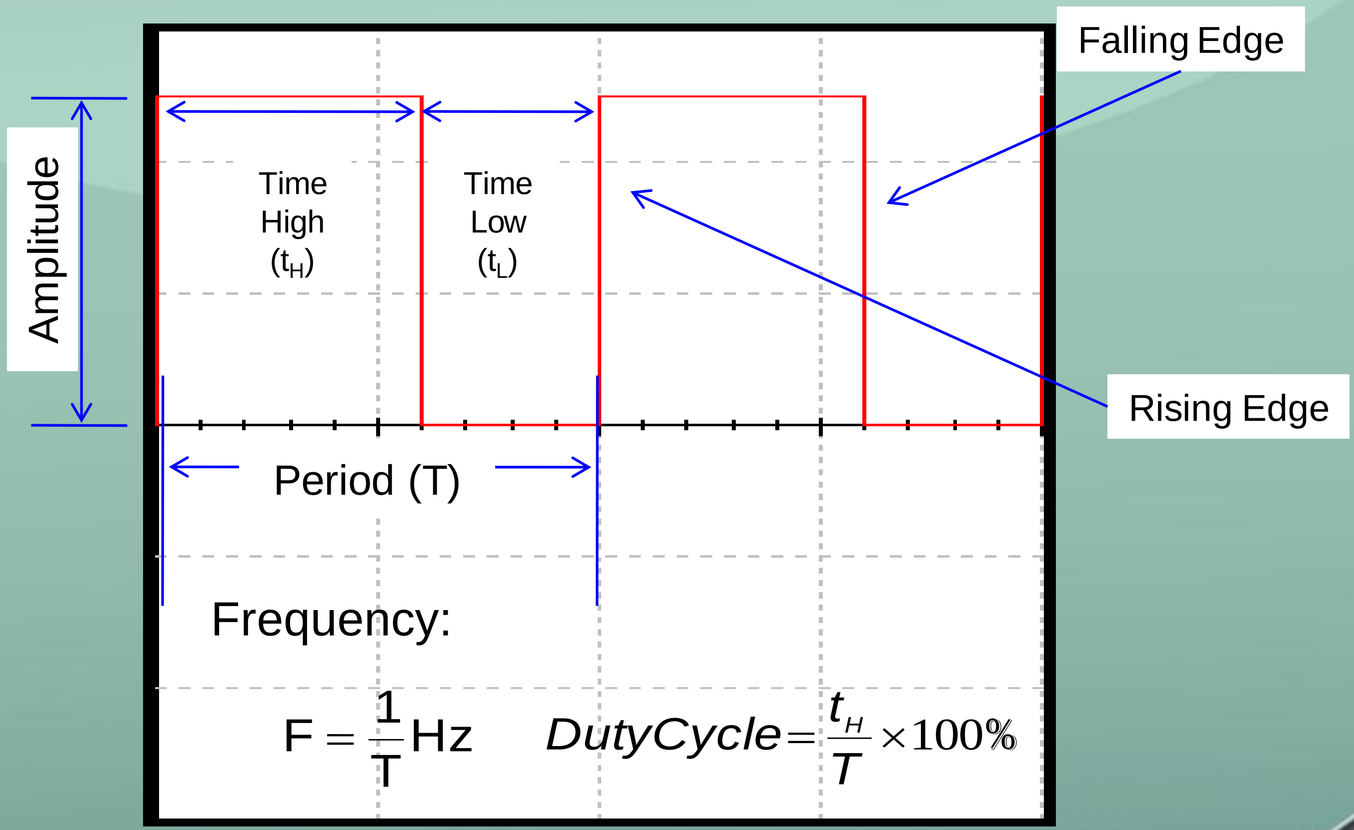
Example of Digital Signals

- Digital signal are commonly referred to as square waves or clock signals.
- Their minimum value must be 0 volts, and their maximum value must be 5 volts.
- They can be periodic (repeating) or non-periodic.
- The time the signal is high (tH) can vary anywhere from 1% of the period to 99% of the period

Parts of a Digital Signal

- **Amplitude:** For digital signals, this will ALWAYS be 5 volts.
- **Period:** The time it takes for a periodic signal to repeat. (seconds)
- **Frequency:** A measure of the number of occurrences of the signal per second. (Hertz, Hz)
- **Time High** (tH): The time the signal is at 5 v.
- **Time Low** (tL): The time the signal is at 0 v.
- **Duty Cycle:** The ratio of tH to the total period (T).
- **Rising Edge:** A 0-to-1 transition of the signal.
- **Falling Edge**: A 1-to-0 transition of the signal.

Parts of a Digital Signal



Disadvantages of Digital Signals

- Not Accurate
- Increased system complexity
- Increased functional bandwidth

Importance of Digital Electronics

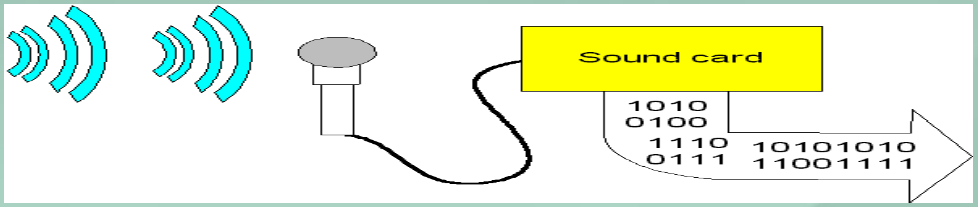
Because of the increasing use of digital computers in both data processing and automatic control system, digital electronics has a greater importance. Some of them are listed below:

- Used for wide variety of industrial and consumer products as in automated industrial machinery
- Computers used in different field
- Microprocessors, IC technology
- Calculators, Digital watches and clocks
- TV, games, Electronic systems etc

Application of Digital Signals

- Digital Speech Processing
- Digital Image Processing
- Consumer Electronics
- Communication field
- Engineering and Computer science

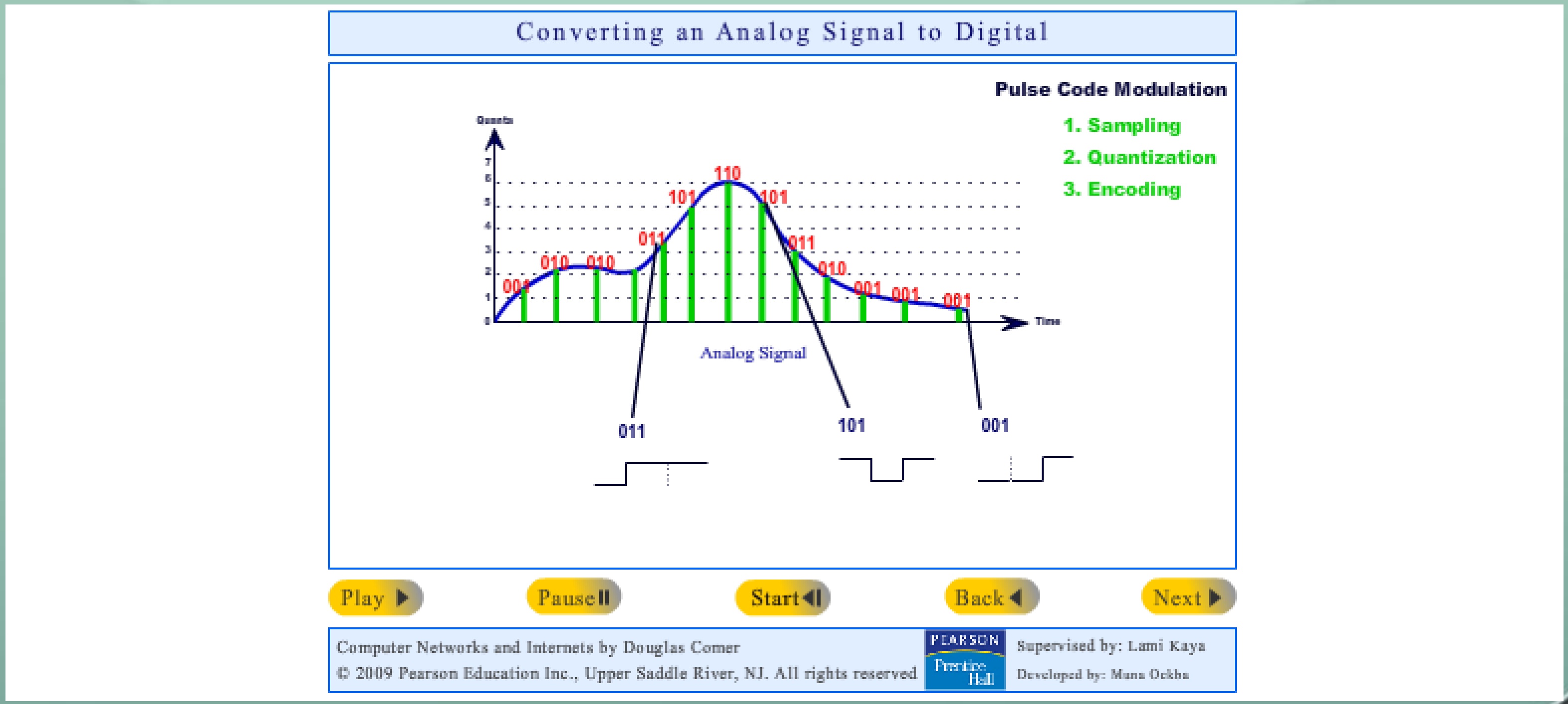
Analog to Digital Conversion



- Most signals of practical interest, such as speech, biological signals, seismic signals, sonar signals and various communications signals such as audio and video signals, are analog.
- To process analog signals by digital means, it is first necessary to convert them into digital form, that is, to convert them to a sequence of numbers having finite precision.
- This procedure is called analog-to-digital (A/D) conversion, and the corresponding devices are called A/D converters (ADCs).

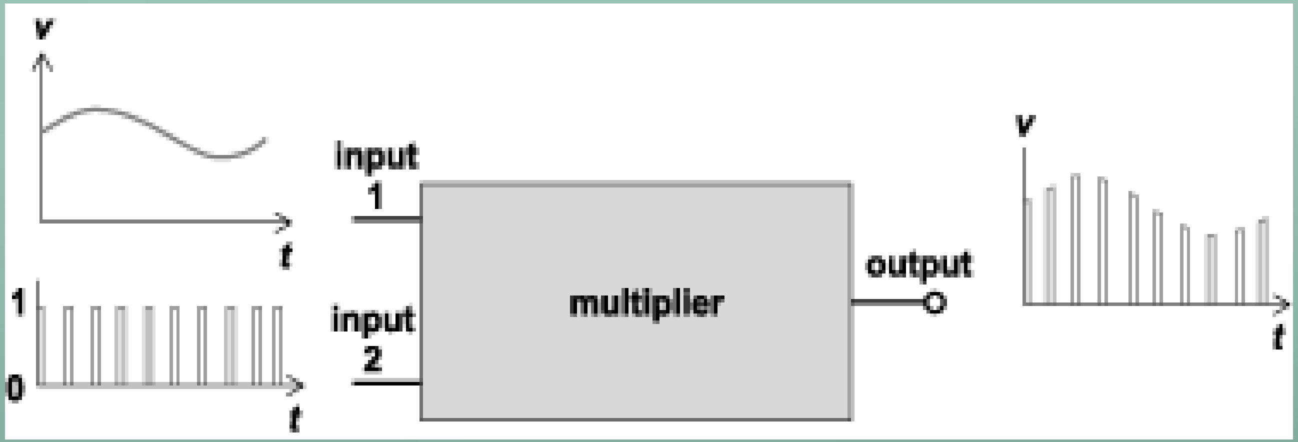
PCM- Pulse Code Modulation

- 3 Step process: Sampling, Quantization, coding

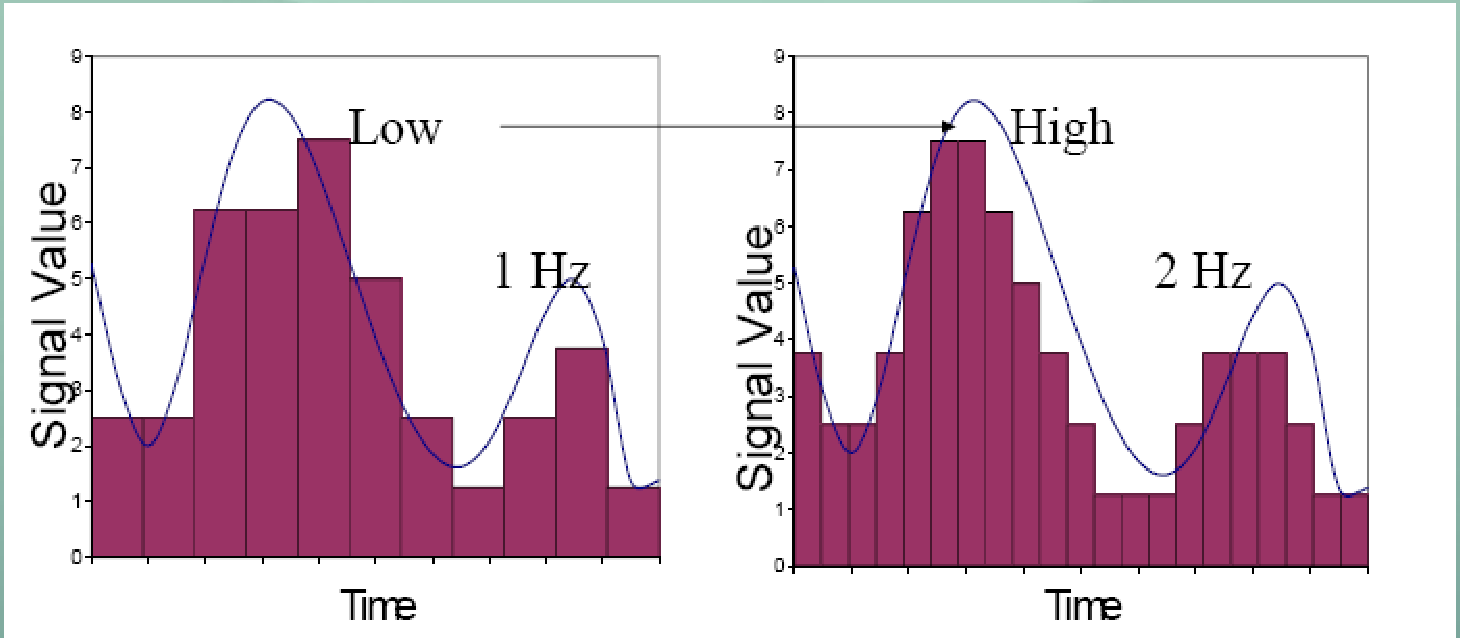


Sampling

- Conversion of a continuous-time signal into a discrete- time signal obtained by taking "samples" of the continuous-time signal at discrete-time instants. (Time discretization)



- Sampling rate is the frequency at which ADC evaluates analog signal. As we see in the second picture, evaluating the signal more often more accurately depicts the ADC signal. ie. Higher no. of sampling-----more accuracy

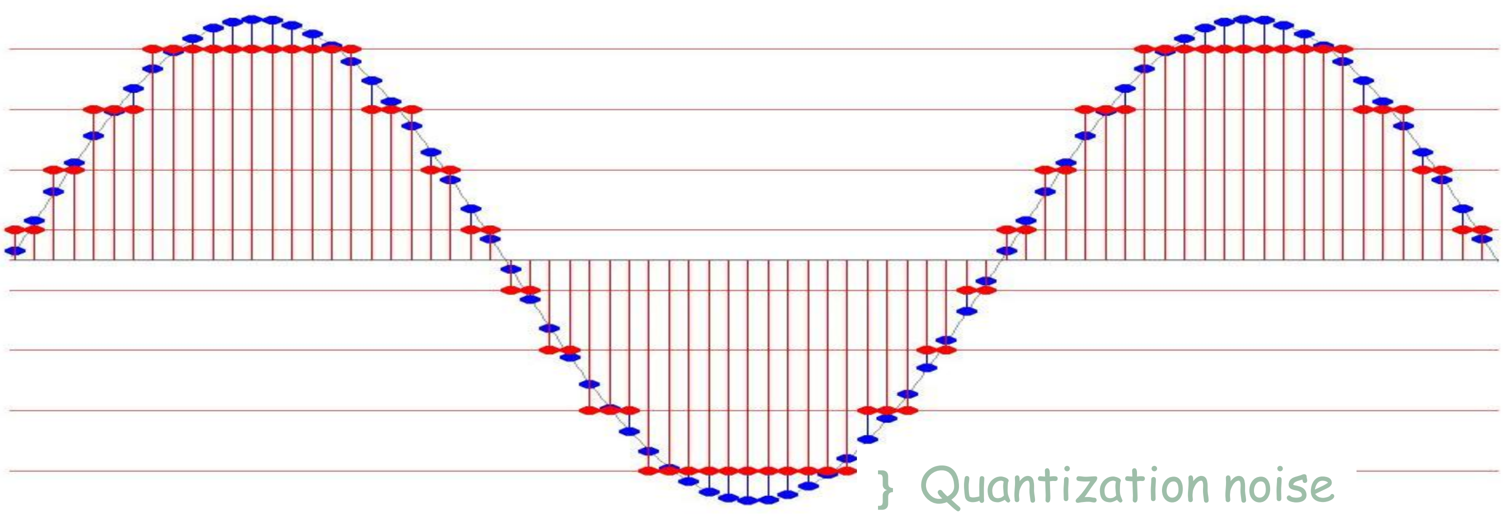


Quantization

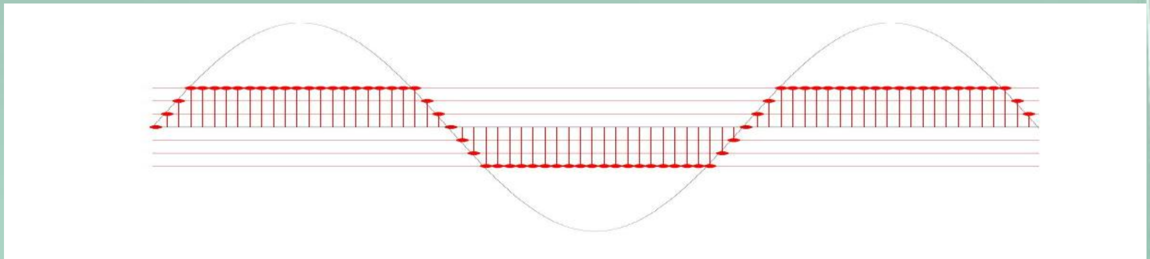
- Conversion of a discrete-time continuous-valued signal into a discrete-time, discrete-valued (digital) signal.
- The value of each signal sample is represented by a value selected from a finite set of possible values.
- The difference between the unquantized sample and the quantized output is called the quantization error.
- Is Amplitude discretization

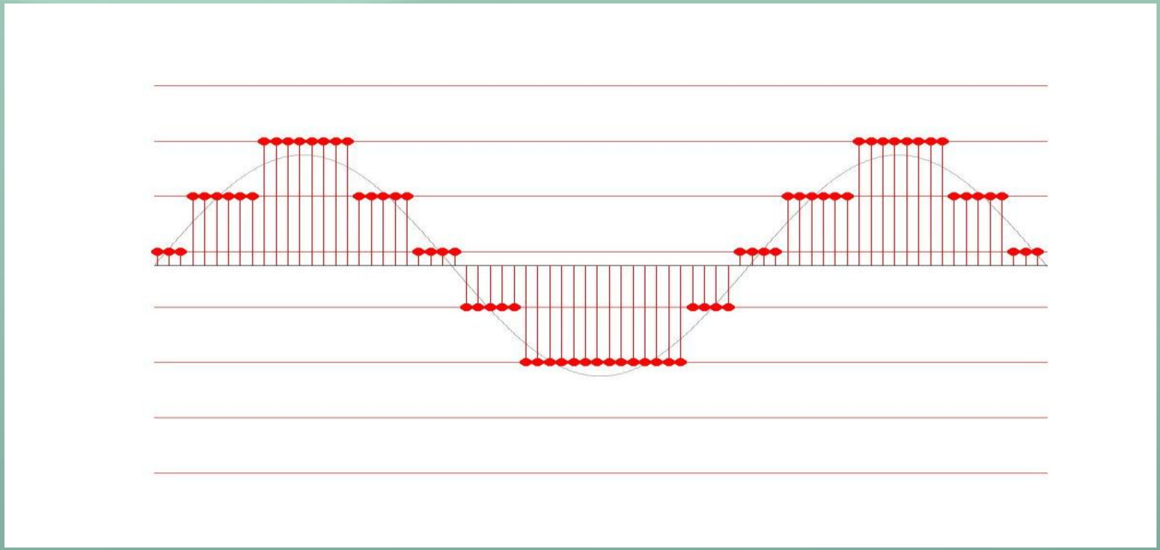
Quantization

- 1 bit → 2 possible values
- 2 bits → 4 possible values
- 8 bits → 256 possible values
- 16 bits → 65356 possible values



- If too low
  - Good resolution
  - Risk of saturation





- If too high
  - Poor resolution
  - No saturation

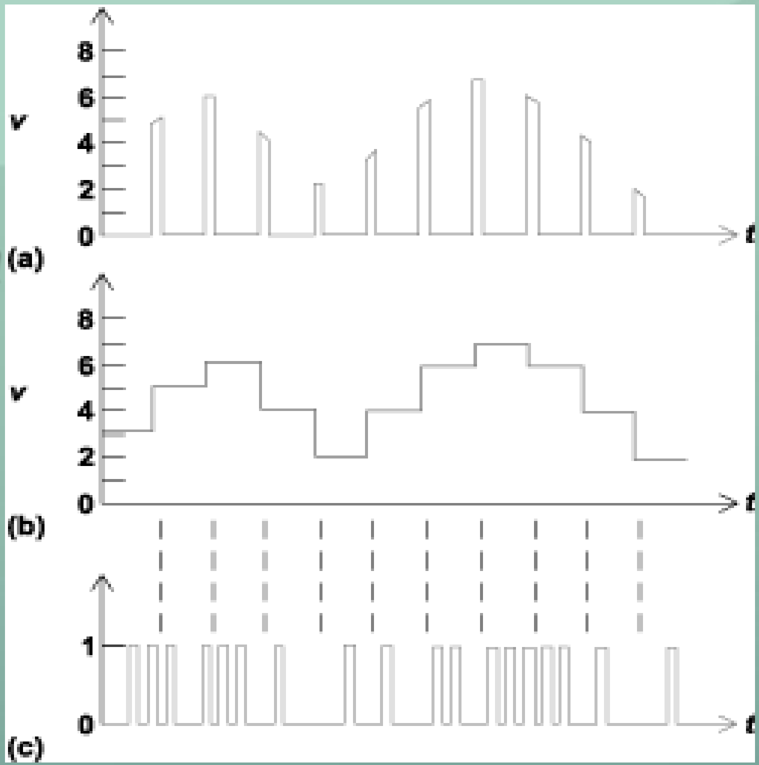
Coding

- Each discrete value in a quantization process is represented by a b-bit binary sequence
- Assigning a digital word or number to each state and matching it to the input signal

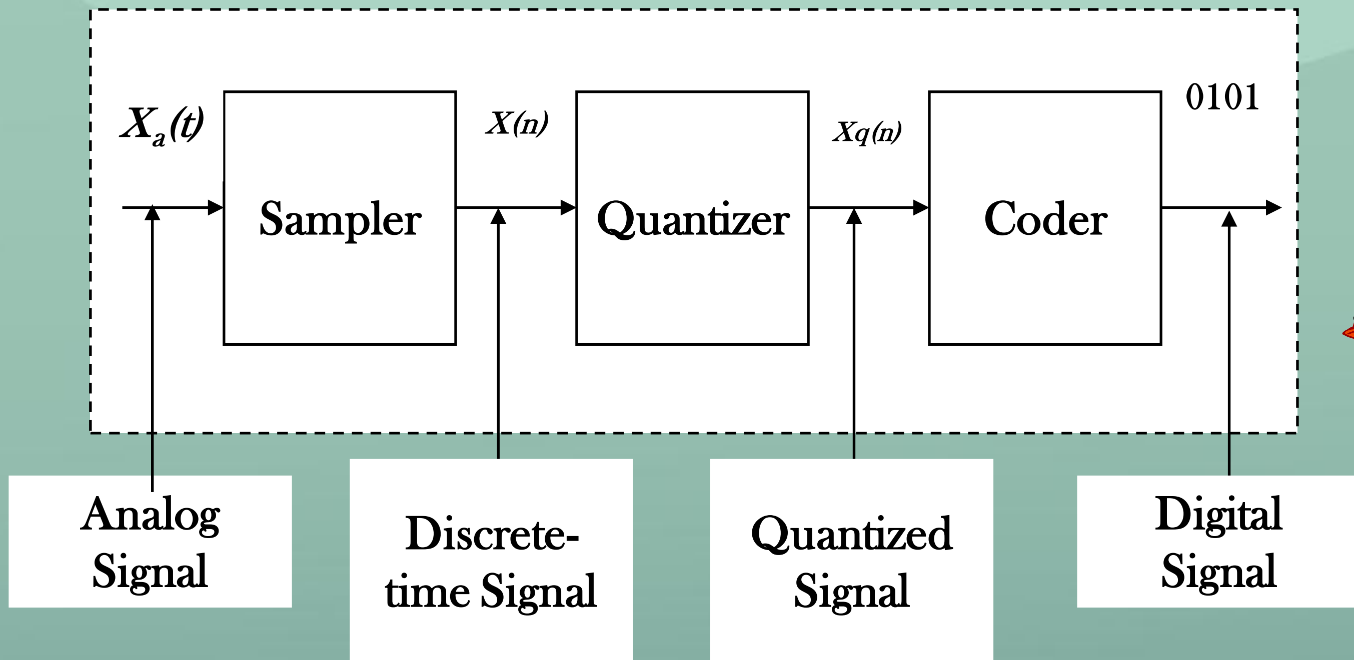
Output States	Output Binary Equivalent
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Analog to Digital Conversion

PCM- Pulse Code Modulation



Analog to Digital Conversion



Examples of A/D Applications

- Microphones - take your voice varying pressure waves in the air and convert them into varying electrical signals
- Strain Gages - determines the amount of strain (change in dimensions) when a stress is applied
- Thermocouple – temperature measuring device converts thermal energy to electric energy
- Voltmeters
- Digital Multimeters

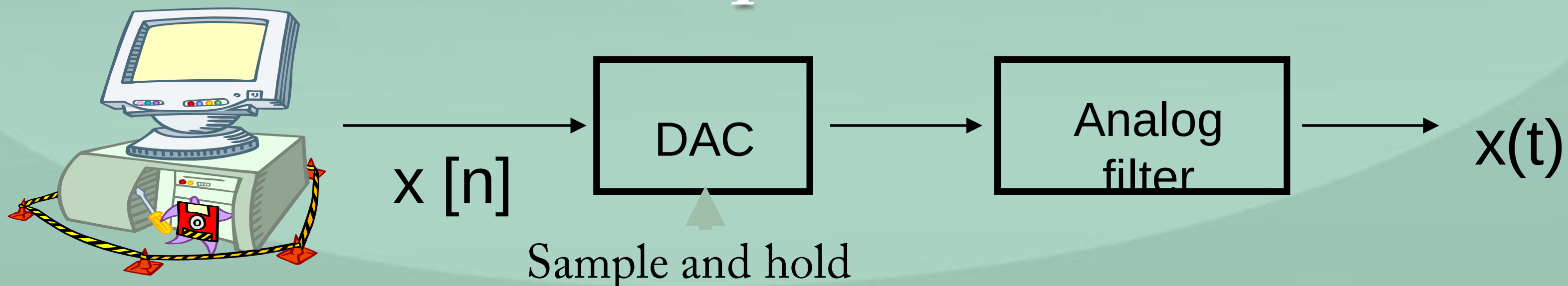
Accuracy of A/D Conversion

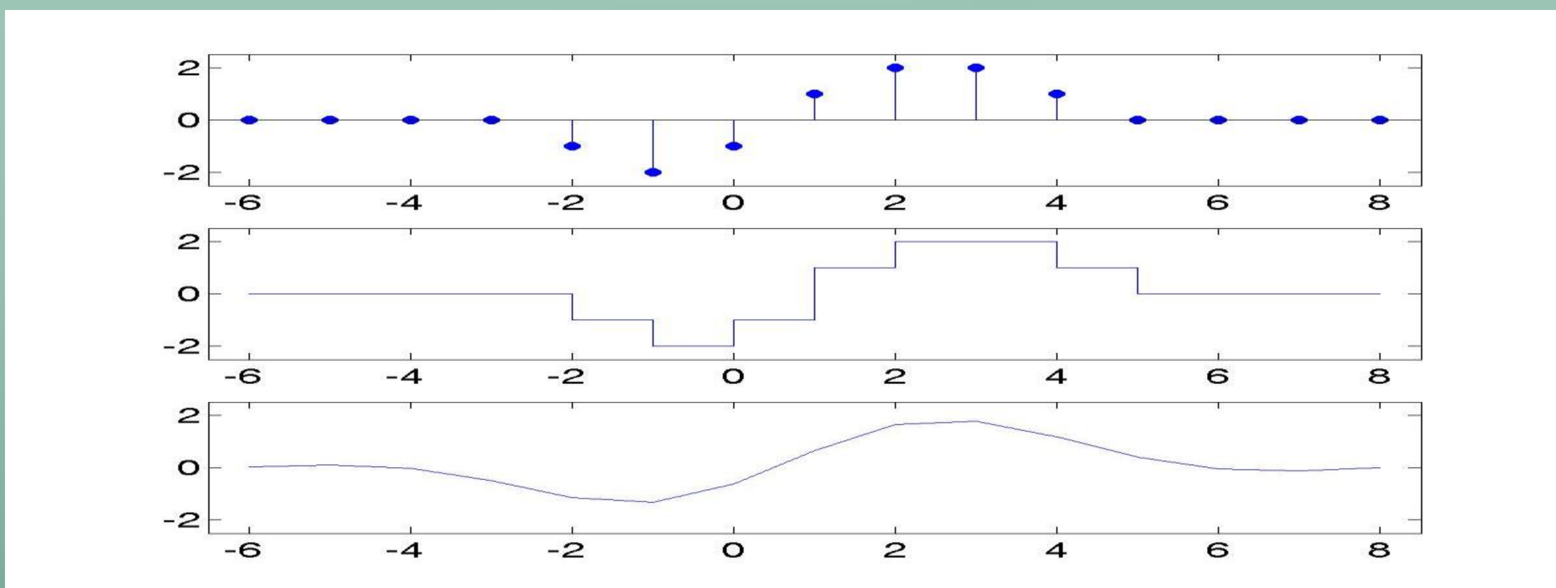
- There are two ways to best improve accuracy of A/D conversion:

- Increasing the sampling rate which increases the maximum frequency that can be measured.

- Increasing the resolution which improves the accuracy in measuring the amplitude of the analog signal. (many levels assignment in quantization process)

DAC process





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Questions????
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