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Physical Layer

Analog to Digital Conversion

ANALOG-TO-DIGITAL CONVERSION

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The tendency today is to change an analog signal to digital data.

Two techniques for analog to digital conversion

- *Pulse code modulation*
- *Delta modulation*.

Pulse Code Modulation (PCM)

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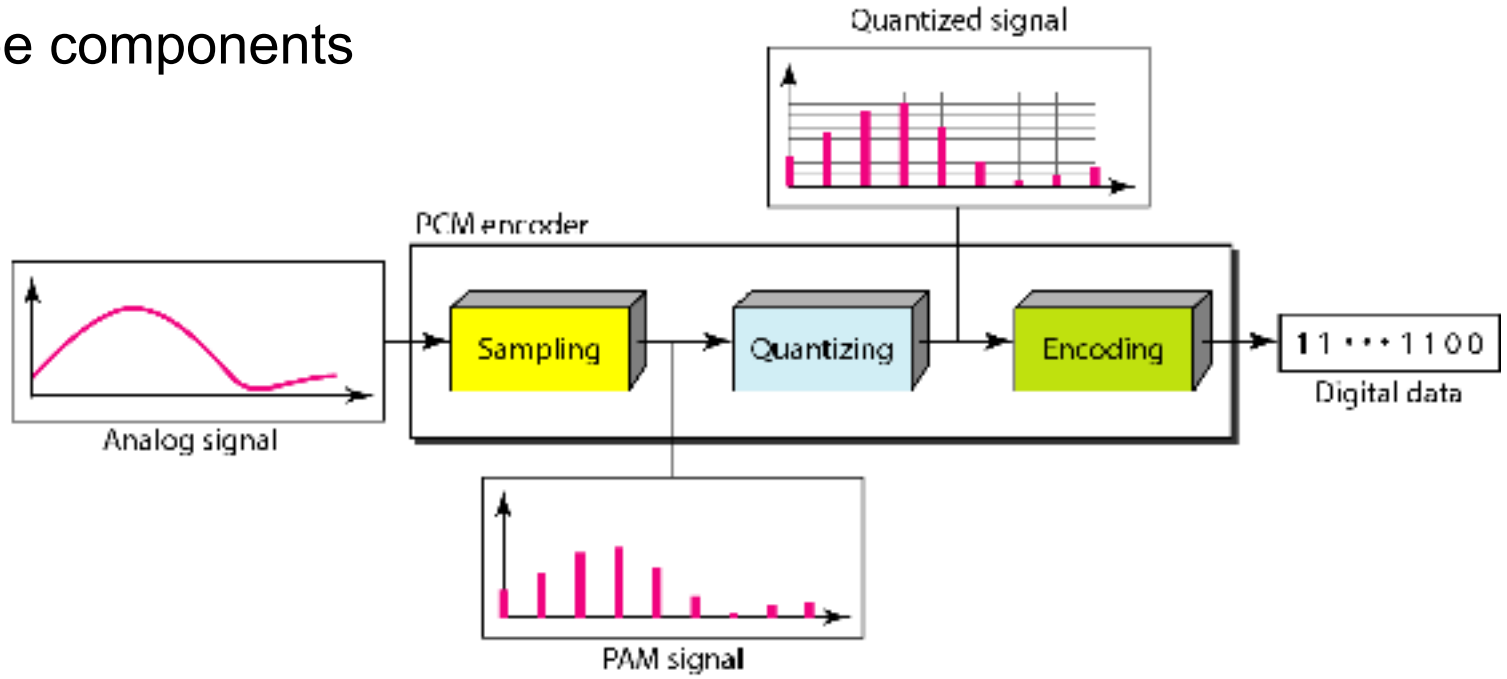
PCM:- The most common technique to change an analog signal to digital data

1. The analog signal is sampled. 2. The sampled signal is quantized. 3. The quantized values are encoded as streams of bits.

A PCM encoder has three components

- **Sampling**
- **Quantizing**
- **Encoding**



Three different sampling methods for PCM

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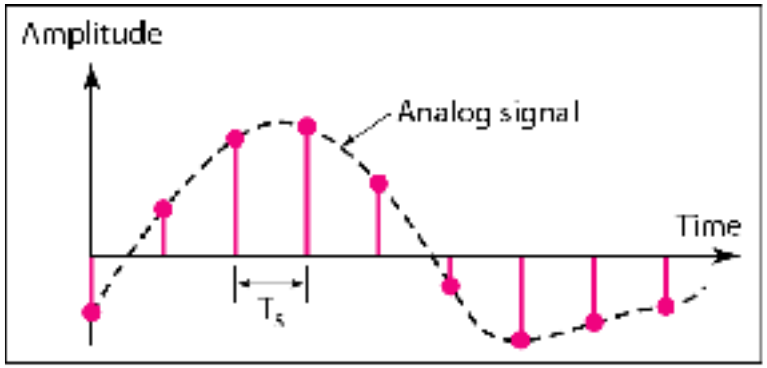
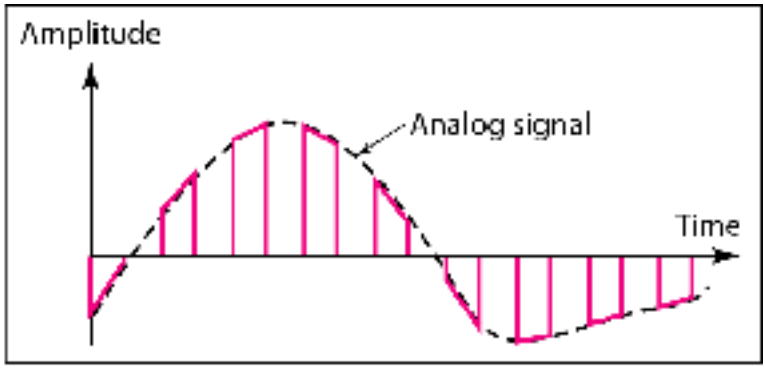
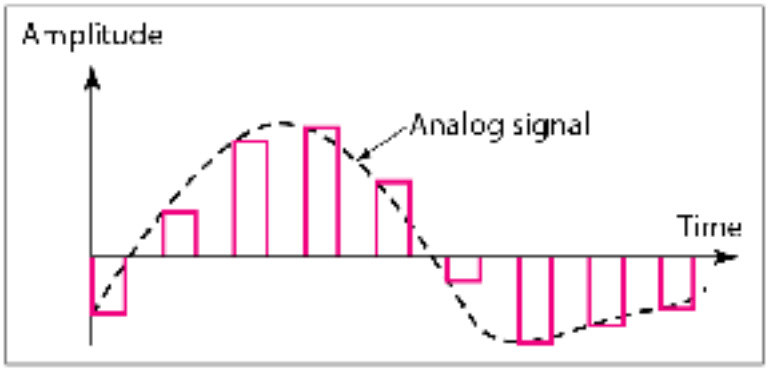
- Sample interval or period: The time interval at which analog signal is sampled (e.g.- every T_S sec)
- Sampling rate or sampling frequency:- Inverse of the sampling interval
- Types of sampling methods:-
  - Ideal,
  - Natural,
  - Flat-top-



a. Ideal sampling



b. Natural sampling



c. Flat-top sampling

Nyquist theorem

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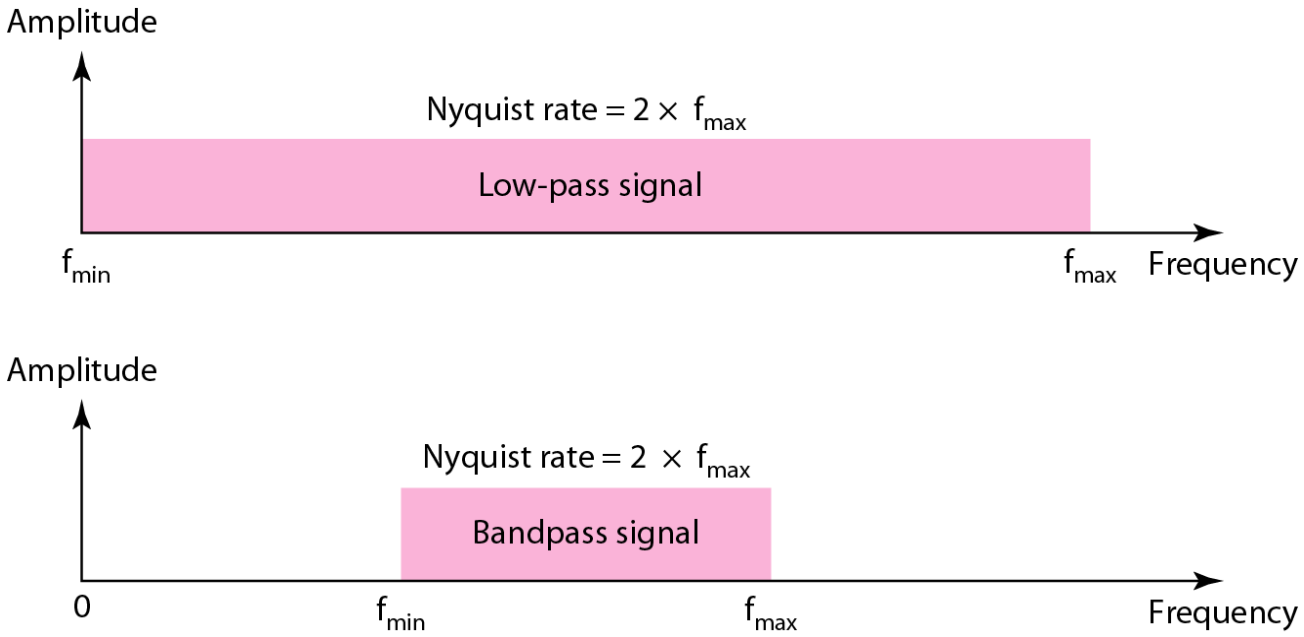
According to the Nyquist theorem, the sampling rate must be at least 2 times the highest frequency contained in the signal.



Question

We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample? Assuming that human voice contains frequencies from 0 to 4000 Hz

Solution

The human voice normally contains frequencies from 0 to 4000 Hz. So the sampling rate and bit rate are calculated as follows:

$$\text{Sampling rate} = 4000 \times 2 = 8000 \text{ samples/s}$$
$$\text{Bit rate} = 8000 \times 8 = 64{,}000 \text{ bps} = 64 \text{ kbps}$$

Quantization and encoding of a sampled signal

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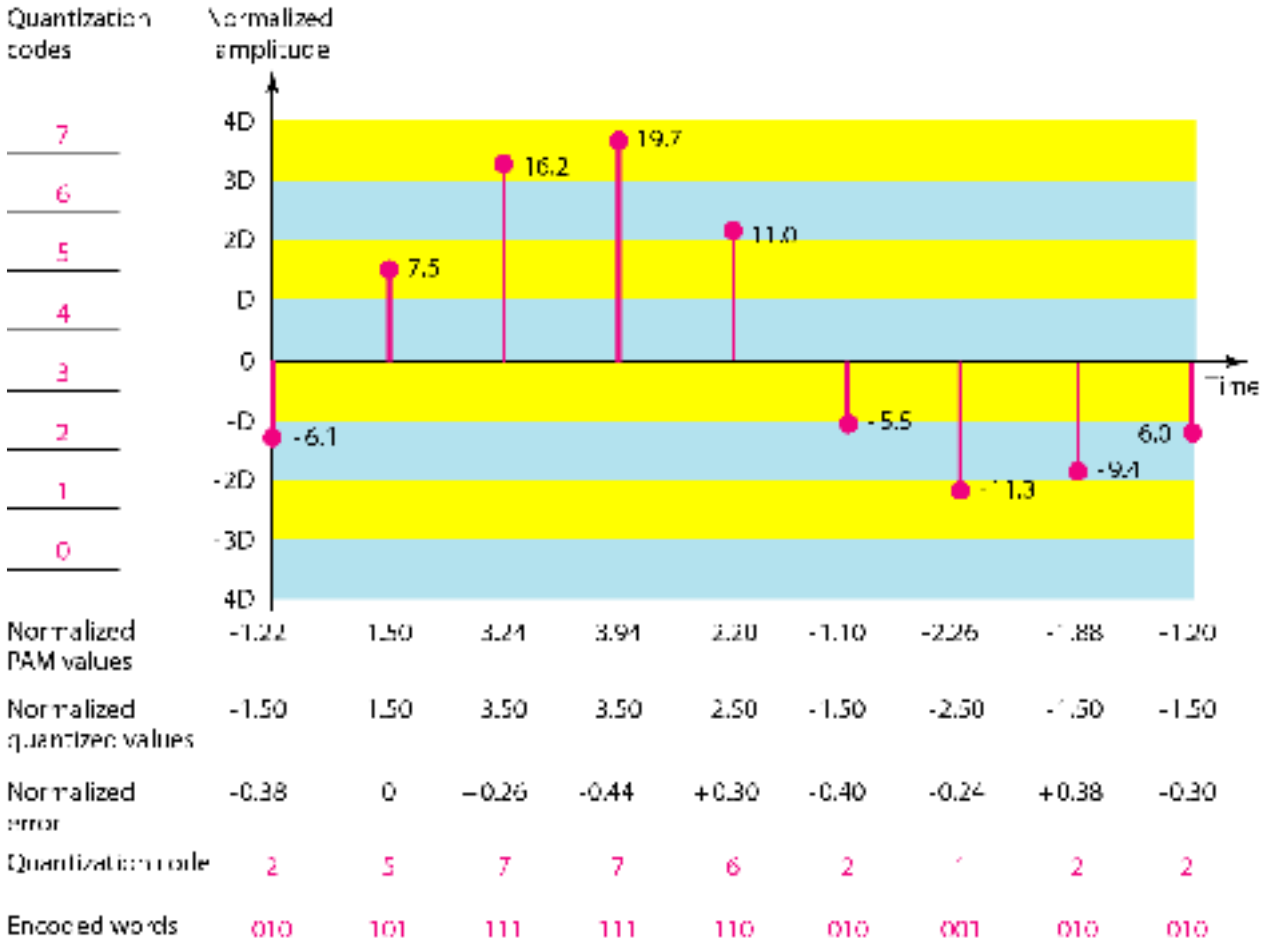
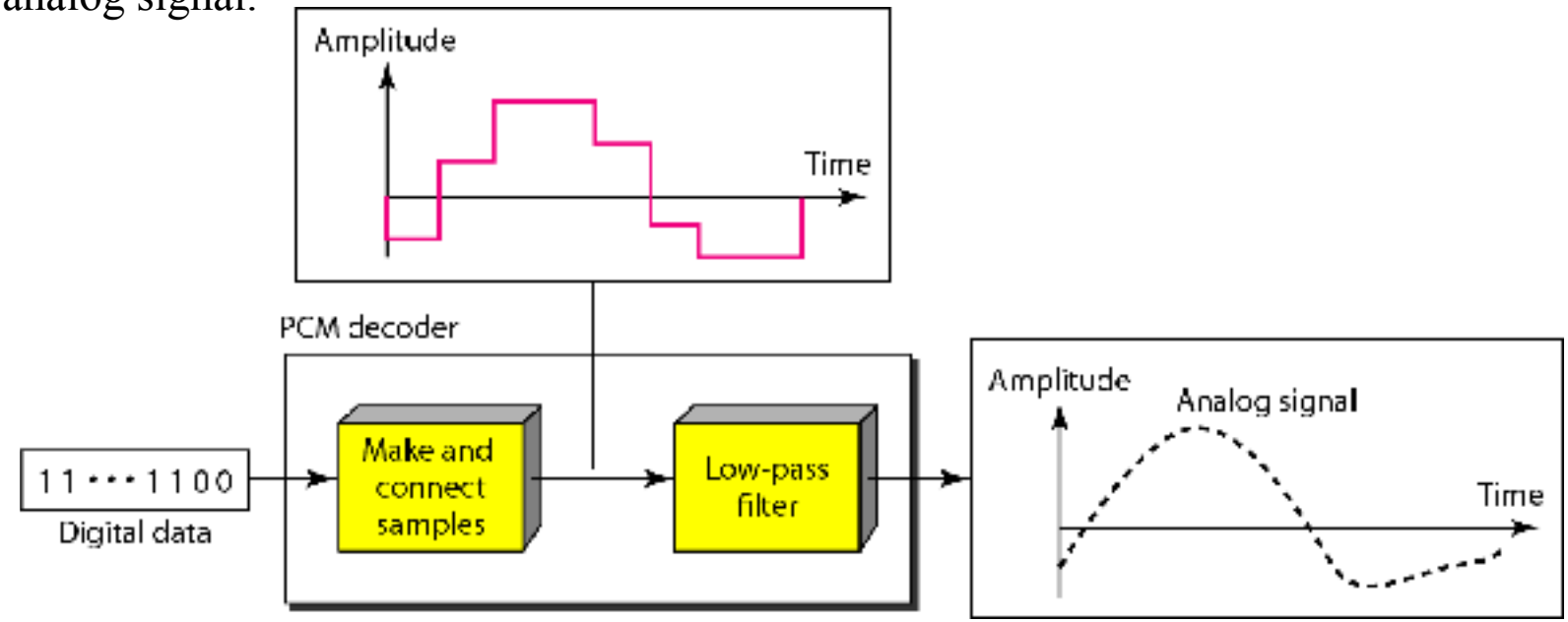
- **Quantization:** provides fixed pre-defined quantized levels (L)
- The choice *of* number of levels, depends on the range of the amplitudes of the analog signal.
- If the amplitude of a signal fluctuates between two values only, we need only two levels; if the signal, like voice, has many amplitude values, we need more quantization levels.
- **Encoding:-** Process of converting the quantized values as streams of bits.
- After quantization, number of bits per sample is decided, each sample can be changed to an llb-bit code word



Normalized PAM values	-1.22	1.50	3.21	3.91	2.20	-1.10	-2.26	-1.88	-1.20
Normalized quantizer values	-1.50	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	-0.38	0	−0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

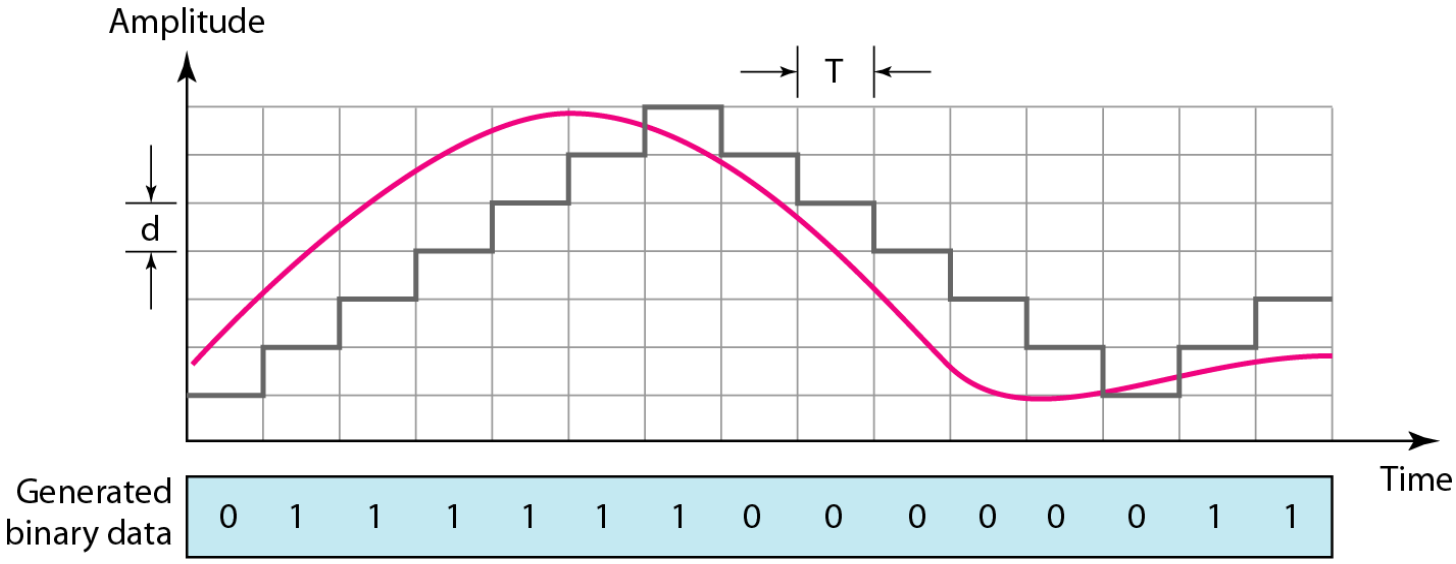
Components of a PCM decoder

- The recovery of the original signal requires the PCM decoder.
- The decoder first uses circuitry to convert the code words into a pulse that holds the amplitude until the next pulse.
- After the staircase signal is completed, it is passed through a low-pass filter to smooth the staircase signal into an analog signal.



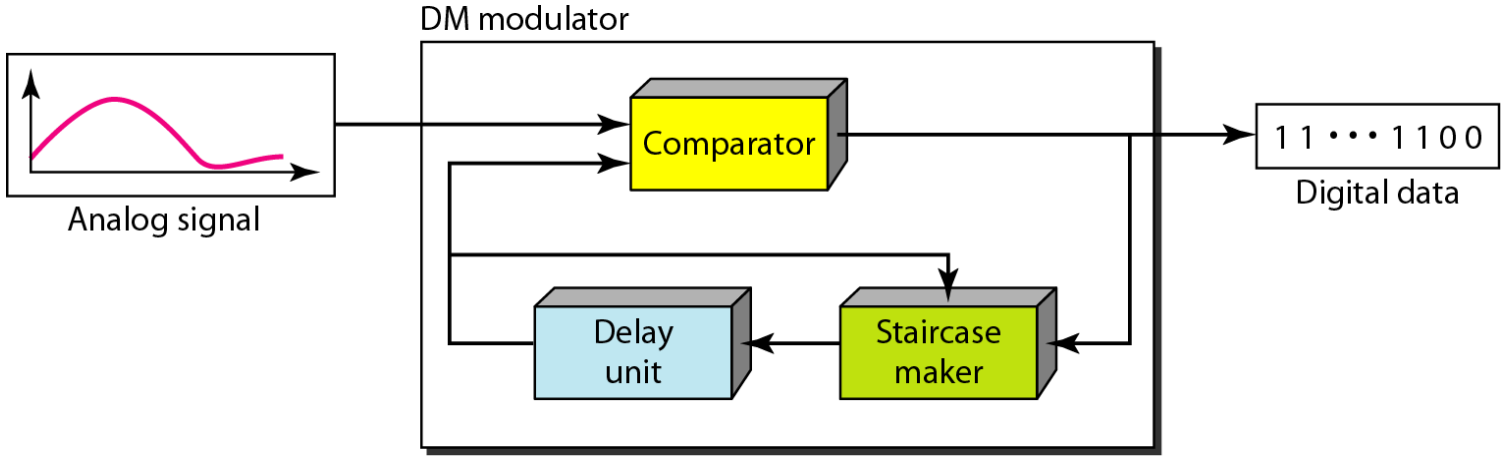
Delta Modulation

- *Delta Modulation (DM)* have been developed to reduce the complexity of PCM.
- PCM finds the value of the signal amplitude for each sample.
- DM finds the change from the previous sample.



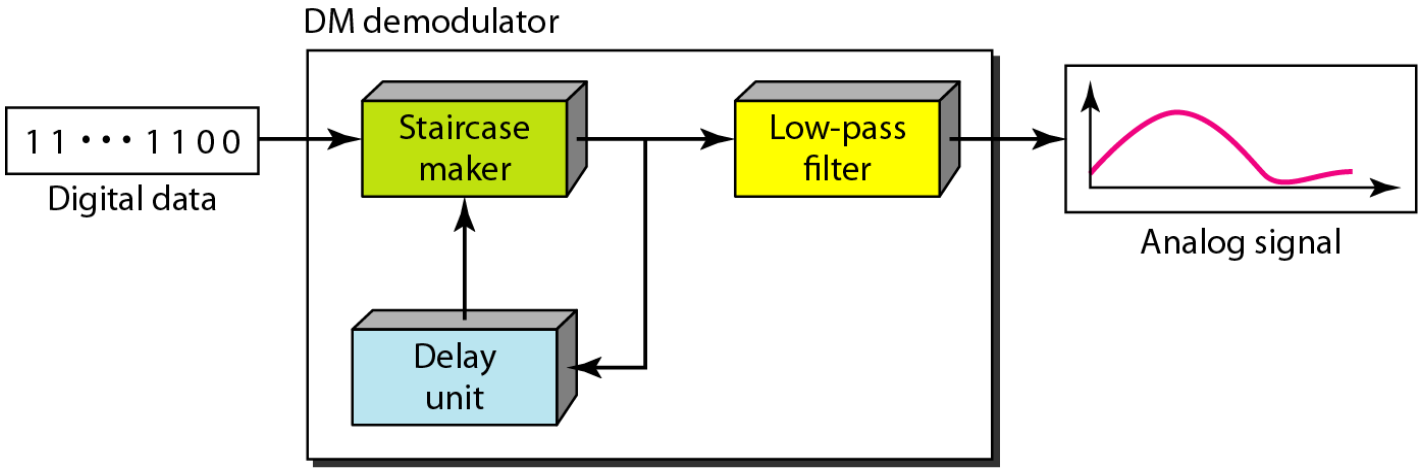
Delta modulation components

- Modulator is used at the sender site to create a stream of bits from an analog signal.
- The process records the small positive or negative changes, called delta.
- Positive delta--→ recorded as 1; negative delta--→ recorded as 0
- The modulator builds a second signal that resembles a staircase.
- Finding the change is then reduced to comparing the input signal with the gradually made staircase signal
- Delay unit is used to hold the staircase function for a period between two comparisons



Delta demodulation components

- The demodulator takes the digital data and, using the staircase maker and the delay unit, creates the analog signal.
- The created analog signal, however, needs to pass through a low-pass filter for smoothing



TRANSMISSION MODES

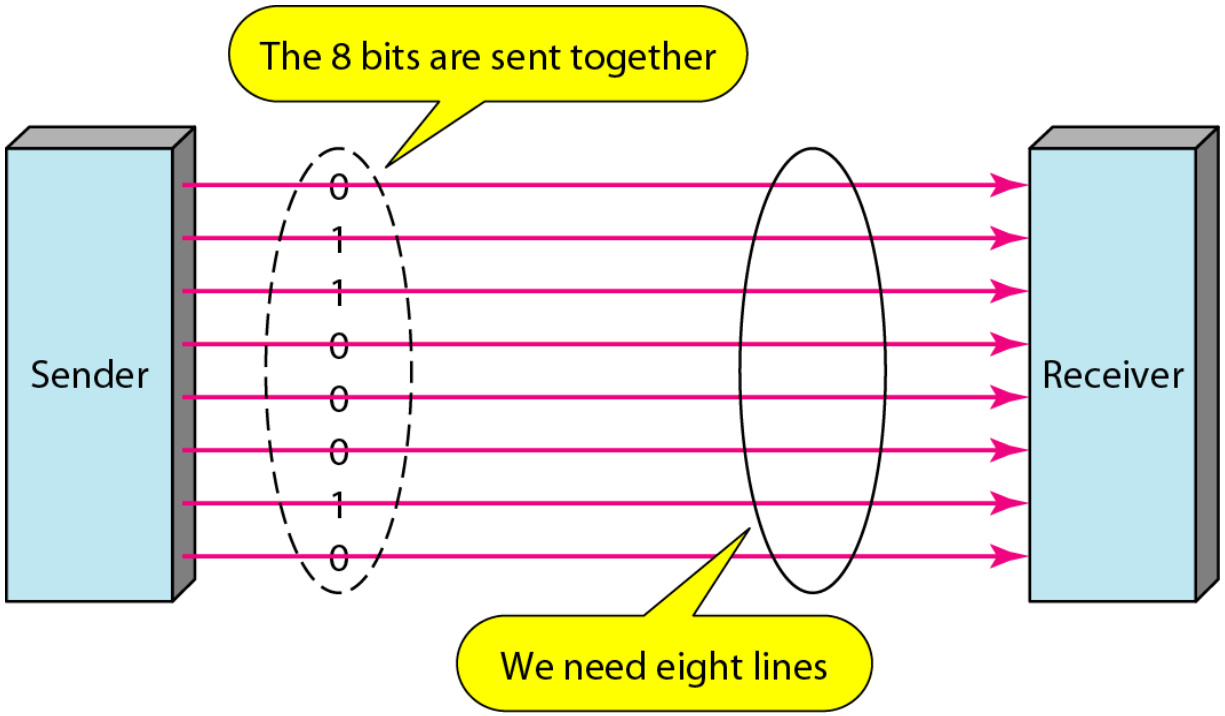
The transmission of binary data across a link can be accomplished in either parallel or serial mode.

Parallel Transmission:- *In parallel mode, multiple bits are sent with each clock tick.*

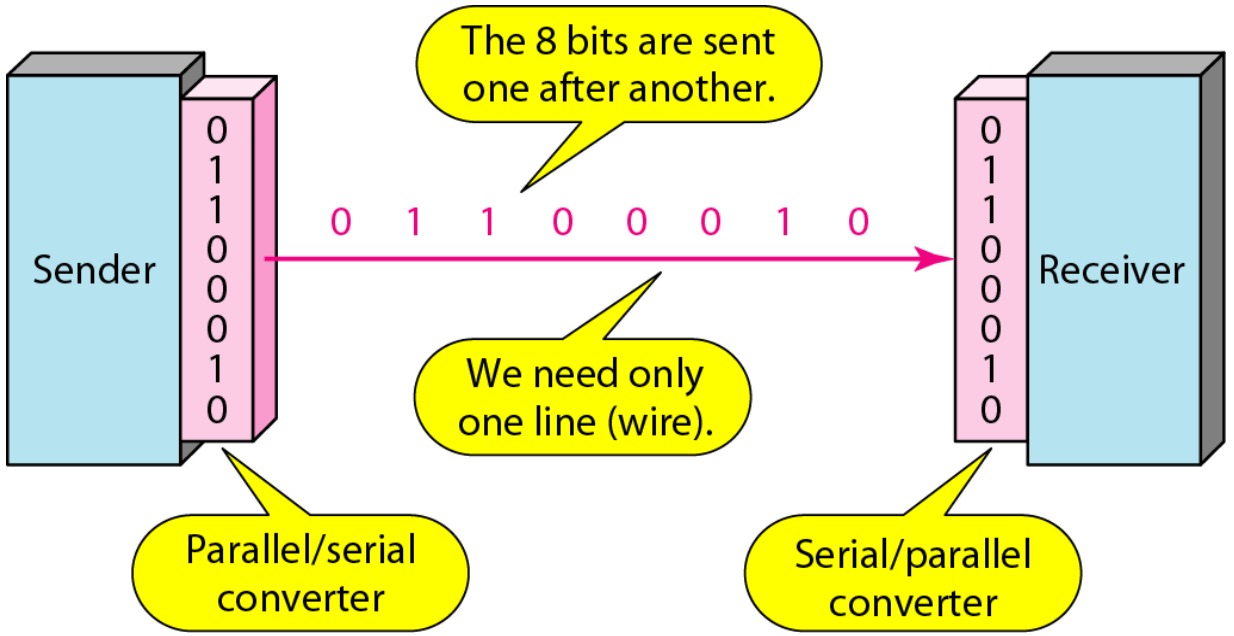
Serial Transmission:- *In serial mode, 1 bit is sent with each clock tick. there are three subclasses of serial transmission:*

- *asynchronous*
- *synchronous*
- *isochronous*

Parallel transmission



Serial transmission



Asynchronous transmission

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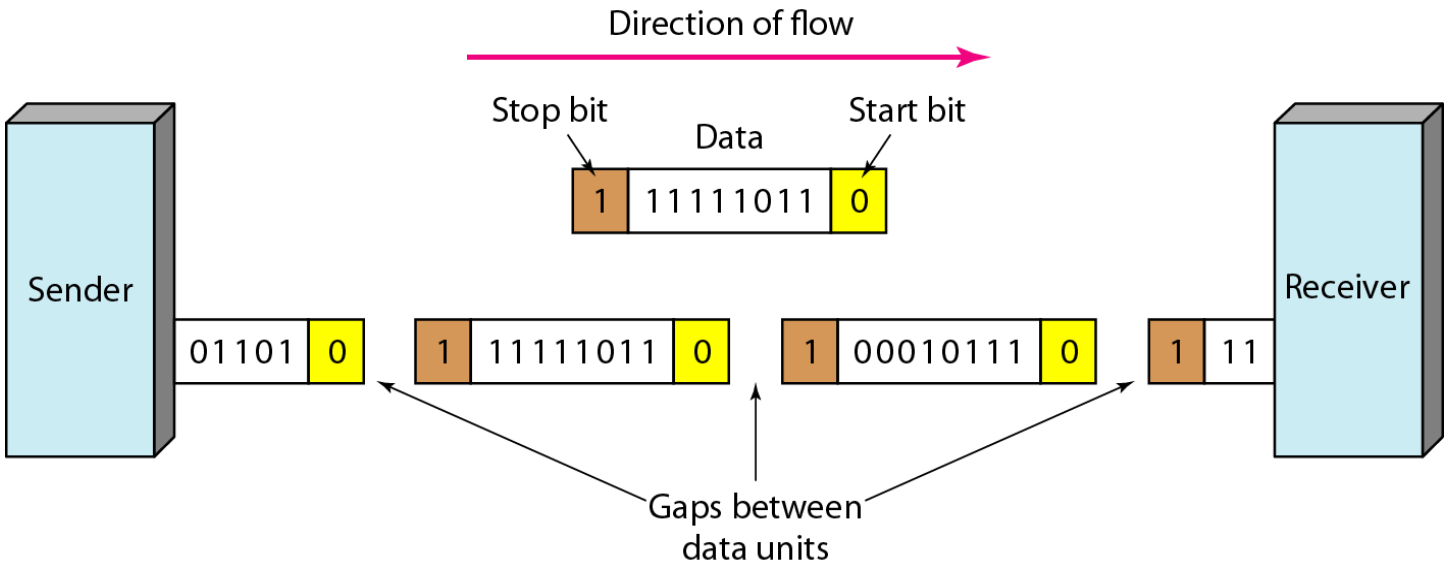
In asynchronous transmission, we send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte. There may be a gap between each byte



Synchronous transmission

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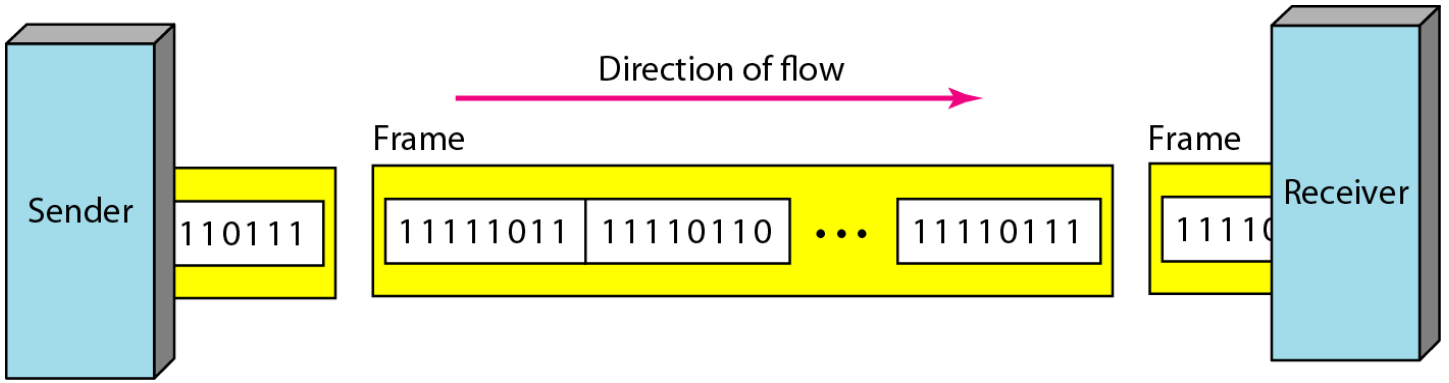
In synchronous transmission, we send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits.



Isochronous transmission

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- Synchronization between characters is not enough; the entire stream of bits must be synchronized in case of isochronous transmission.
- The isochronous transmission guarantees that the data arrive at a fixed rate.