UNIT- 3 DIGITAL TRANSMISSION

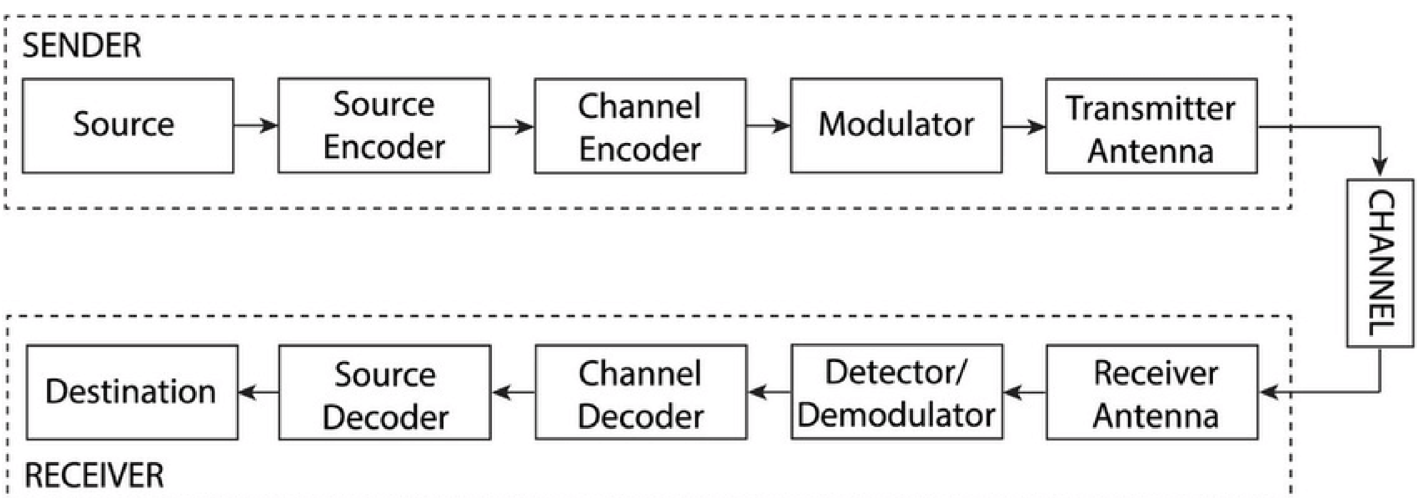
Unit III:

Digital Transmission , Analog to Digital Conversion : Block Diagram of Digital Communication System. Parallel and serial ports Pulse Code Modulation(PCM), Sampling, Sampling Rate, Quantization, Delta modulation, Adaptive Delta Modulation, Transmission modes, Parallel Transmission, Serial Transmission, Asynchronous Transmission, Synchronous Transmission.

Digital communication system is a system through which we can **share different types of data worldwide.** Digital communication sends the data via **different frequency signals**. It has a very important role in our modern society.

We can tweet anything in seconds and that is worldwide available to read. the beautiful or funny posts you have uploaded on social media and the comments of your friends, that late chats and video calls with your friends and family, this blog that you are reading, that all are possible because of digitalization in communication system.We are going to see what the science behind this very speedy communication system is. Firstly, we are going to see the technology and main devices required in it.

BLOCK DIAGRAM OF DIGITAL COMMUNICATION SYSTEM



SENDER:

Transducer: The diagram starts with the sender, which transmits the data and receiver receives the information at the end. so, the data can be audio, video, image, text or any other type. Now, this information may be analog or may be digital. If the information signal is in an electric signal then it is okay. But, if the information is not in the electrical signal form, (for example audio, video, image or text) then we need to convert them into an electric signal. However, the transducer converts the **non-electric signal into an electric signal.** So, after the first block the information is in the form of an electrical signal.

Source Encoding: The main task of source encoding is to reduce redundancy so we can use bandwidth effectively. At this stage the digital data gets compromised and there are multiple ways to compress the digital data like **Huffman coding** and **Shannon Fano coding.** For analog redundancy we go for **adaptive delta modulation** and **Pulse-code modulation.** So, after this block the signal will be digital.

Channel Encoding: It is used to provide noise immunity by adding redundancy in it. There are many techniques available for it like **Block code, Cyclic code, Convolutional code** and many more techniques are available. After this block the signal will still be a digital signal.

Digital Modulator and Antenna: To transmit information at longer distances we need to convert the low frequency digital signal into high frequency analog signal. Digital Modulator multiplies the digital signal we converted in last stage with **high frequency carrier signal** and convert it in high frequency analog signal so we can easily send it by antenna.There are various techniques available for converting signal like **Amplitude-shift keying (ASK), frequency-shift keying (FSK), phase-shift keying (PSK)** and **Quadrature Phase Shift Keying (QPSK).** After this block the signal is converted into a high frequency modulated signal which the antenna will get and transmit further.

Antennas: Antennas are widely used in the field of digital communication. They receive an electromagnetic wave and convert it into an electric signal or receive an electric signal and convert it into an electromagnetic wave.

RECEIVER:

Digital Demodulator and Antenna: By its name that it will demodulate the signal that is received by the receiver antenna. And again convert the high frequency analog signal to digital signal.

Channel Decoding: **[***We transmitted a signal, It converted into an electrical signal(digital or analog). After it we source encoded that signal and convert it into a digital signal.Suppose that the source code we get from that is **[010101]**. After doing channel encoding we get signal channel code **011010101**(suppose).Now the digital modulator will transmit the signal but before reaching to the receiver the signal may get disturbed because of noise. So the information may not remain the same, it will change. The wrong information will get at the other end. And this thing is dangerous. This is why channel decoding is important at the receiver side.]*

At channel decoding, it checks if the received signal is the same as transmitted.For example if it's **011010100** (transmitted was **011010101**). There is one bit error. So, the channel decoder will correct the signal. And if the received signal is not changed so the channel decoder will do nothing with it. It will only remove the redundancy so as per our example the code will be **[010101]** (the front 011 will removed which was added by channel decoder at the transmitter side)

Source Decoding: Source decoder will convert the digital signal into the analog signal. And that will again be converted into an information signal by the speaker, television or any other device.

Advantages and Disadvantages of the digital communication system

Advantages:

- It is simpler and cheaper because integrated circuits became smaller, speedy and chep.
- More privacy and security through the use of encryption because we can rearrange digital data.
- Data correction, error detection and error correction is possible
- Flexible hardware implementation because, if hardware will change we can change the programming language.
- Easier and sufficient multiplexing by TDMA(Time-division multiple access) & CDMA(Code-Division Multiple Access)

Disadvantages:

- High power consumption due to multiple stages and complex circuits as we show in the Digital Communication Block Diagram.
- Bandwidth per channel is very high.
- Synchronization is compulsory, if we don't synchronize the data so there will be many errors in information.

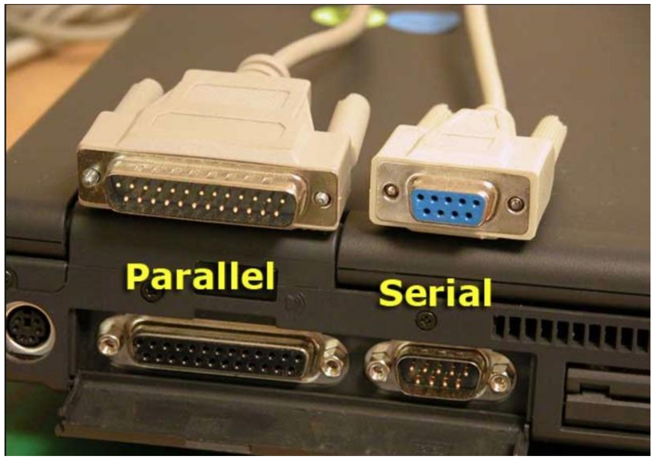
PARALLEL AND SERIAL PORTS

Serial Ports

Serial Ports provide an interface to connect serial lines to prepare a serial communication. Serial ports are typically used in modem, mouse, security cameras etc. A Serial port uses DB-9 connector, a 9 pin D-Shaped Connector which connects to the transmission line. A serial port provides a serial communication using one line and thus has no dependency on other wire's speed and its length can be extended as per the need.

Parallel Ports

Parallel ports provide an interface to connect multiple lines to prepare a parallel communication to send large data at a time. Parallel ports are used in connecting printers, hard-drives, CD-drives etc. All lines speed should be the same to avoid error and cross-talk issues. To avoid such issues, the wires are kept small in length. A parallel port uses a D-25 connector, a 25 pin D-Shaped connector which connects to the transmission wires.



Following are the important differences between Serial Ports and Parallel Ports.

Sr.No.	Key	Serial Ports	Parallel Ports
1	Purpose	Serial Port is used for serial data transmission.	Parallel Port is used for parallel data transmission.
2	Transmission Speed	Transmission speed of a serial port is slow as compared to a parallel port.	Transmission speed of a parallel port is quite high as compared to a serial port.
3	Redundancy	Bottom-Up model is better suited as it ensures minimum data redundancy and focus is on re-usability.	Top-down model has a high ratio of redundancy as the size of the project increases.

4	No. Of Wires	Wire connections to the serial port are quite less as compared to parallel ports.	No. of wires that are connected to parallel ports are quite high as compared to serial ports.
5	Capability	A serial port is able to transmit a single stream of data at a time.	A parallel port is able to transmit multiple data streams at a time.
6	Data Sending Mechanism	A serial port sends data bit by bit after sending a bit at a time.	A parallel port sends data by sending multiple bits in parallel fashion.
7	Port Type	A serial port uses Male ports.	A parallel port uses Female ports.
8	Applications	Modems,security cameras, device controllers use serial ports.	Printers, Hard Drives, CD drives use parallel ports.

ANALOG TO DIGITAL CONVERSION

The tendency today is to change an analog signal to digital data. The following techniques can be used for Analog to Digital Conversion:

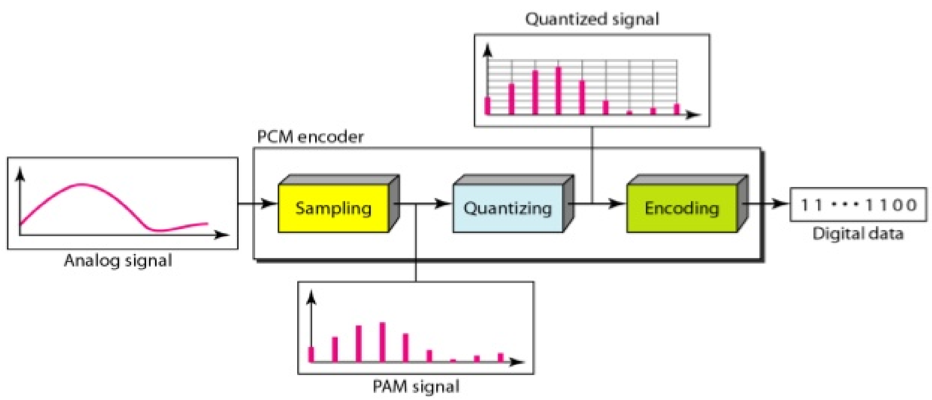
- **Pulse Code Modulation**
- **Delta Modulation**

I. PULSE CODE MODULATION (PCM):

The most common technique to change an analog signal to digital data (digitization) is called pulse code modulation (PCM). A PCM encoder has the following three processes:

1. Sampling (The analog signal is sampled)
2. Quantization (The sampled signal is quantised)
3. Encoding (The quantised values are encoded as streams of bits)

Figure 4.21 *Components of PCM encoder*



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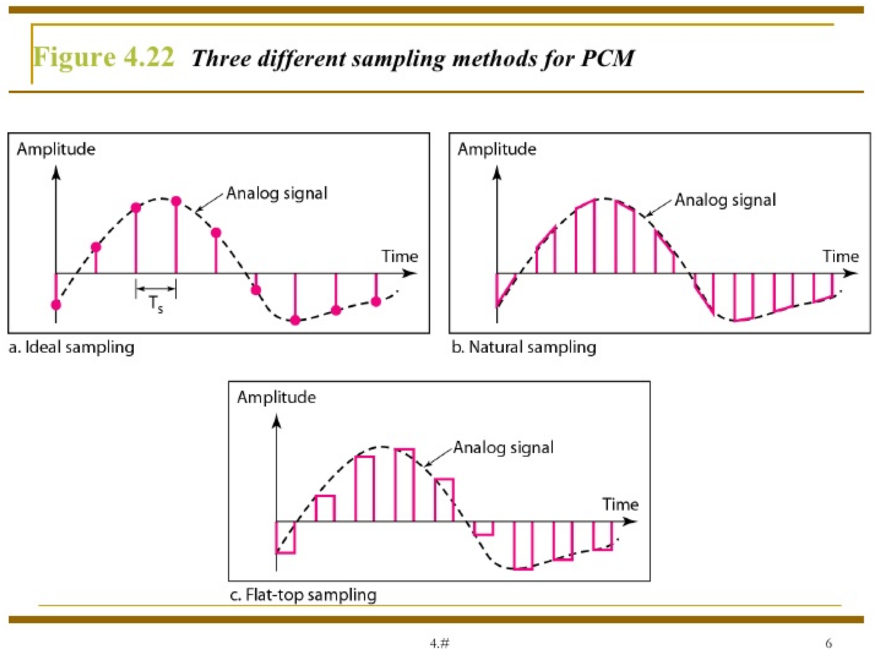
Sampling – The first step in PCM is sampling. Sampling is a process of measuring the amplitude of a continuous-time signal at discrete instants, converting the continuous signal into a discrete signal. There are three sampling methods:

(i) Ideal Sampling: In ideal Sampling also known as Instantaneous sampling pulses from the analog signal are sampled. This is an ideal sampling method and cannot be easily implemented.

(ii) Natural Sampling: Natural Sampling is a practical method of sampling in which pulses have finite width equal to T.The result is a sequence of samples that retain the shape of the analog signal.

(iii) Flat top sampling: In comparison to natural sampling flat top sampling can be easily obtained. In this sampling technique, the top of the samples remains constant by using a circuit. This is the most common sampling method used.



The sampling process is sometimes referred to as <u>Pulse Amplitude Modulation (PAM).</u>

<u>Sampling rate</u> : According to the Nyquist theorem, the sampling rate must be at least 2 times the highest frequency contained in the signal. It is also known as the minimum sampling rate

<u>Quantization –</u> The result of sampling is a series of pulses with amplitude values between the maximum and minimum amplitudes of the signal. The set of amplitudes can be infinite with non-integral values between two limits.

The following are the steps in Quantization:

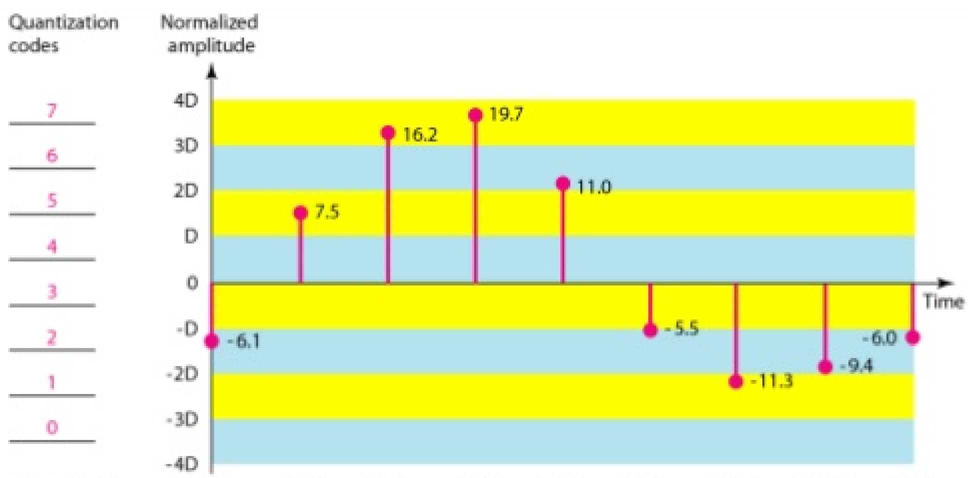
- We assume that the signal has amplitudes between V_{max} and V_{min}
- We divide the range into L zones each of height d where, d= (Vmax- Vmin)/ L.

  Eg: assume that we have a sampled signal and the sample amplitudes are between -20V and +20V. We decide to have eight levels(L=8).

  therefore , d= 20 -(-20) /8 =5V

- We assign quantized values of 0 to (L-1) to the midpoint of each zone.
- The value at the top of each sample in the graph shows the actual amplitude.
- The first row is the normalized pulse amplitude modulation(PAM) value for each sample.The normalized value is calculated using the formula (actual amplitude/d)
- After this we calculate the quantized value which the process selects from the middle of each zone.
- The Quantized error is given by the difference between quantised value and normalised PAM value.
- The Quantization code for each sample based on quantization levels at the left of the graph.

Figure 4.26 ***Quantization and encoding of a sampled signal***



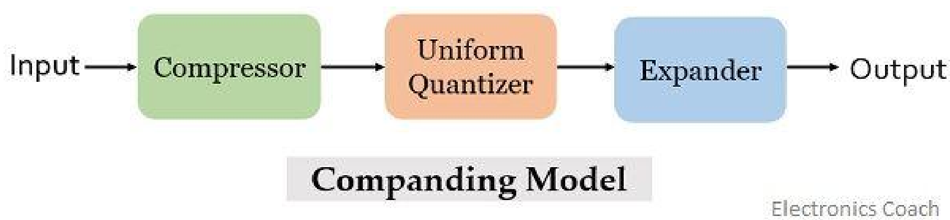
Normalized PAM values	-1.22	1.50	3.24	3.94	2.20	-1.10	-2.26	-1.88	-1.20
Normalized quantized values	-1.50	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	-0.38	0	+0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

4.21

Quantization level: The choice of L, the number of levels, depends on the range of the amplitude of the signal and how accurately we need to recover the signal. [*If the amplitude of a signal fluctuates between two values only, we need two levels. In audio* *digitizing, L is chosen to 256. In the video it is 1000.]* Choosing lower values of L increases the quantization error.

Quantization Error: Quantization is an approximation process. The input values to the quantizer are real values; the output values are the approximate values. The output values are chosen to be the middle value in the zone. If the input value is also at the middle of the zone, there is no quantization error, otherwise there is an error. [*In the previous example the normalised PAM value of the third sample is 3.24, but the normalised quantized value is 3.50. This means that there is an error of +0.26].*The value of the error for any sample is less than d/2.

Companding - Companding is a technique of achieving non-uniform quantization in PCM. It is a word formed by the combination of words **com**pression and exp**anding**. Companding is done in order to improve SNR of weak signals.
In many applications, the distribution of the instantaneous amplitude in analog signals is not uniform. Nonuniform quantization can be achieved by using a process called companding**.**
The signal companded at the sender before conversion and it is expanded at the receiver after conversion.



<u>Encoding –</u> The digitization of the analog signal is done by the encoder. After each sample is quantized and the number of bits per sample is decided, each sample can be changed to an n bit code. Encoding also minimizes the bandwidth used.
The number of bits for each sample is determined from the number of quantization levels. If the number of quantization levels is L , the number of bits is $n_b = \log_2 L$. The bit rate can be found from the formula

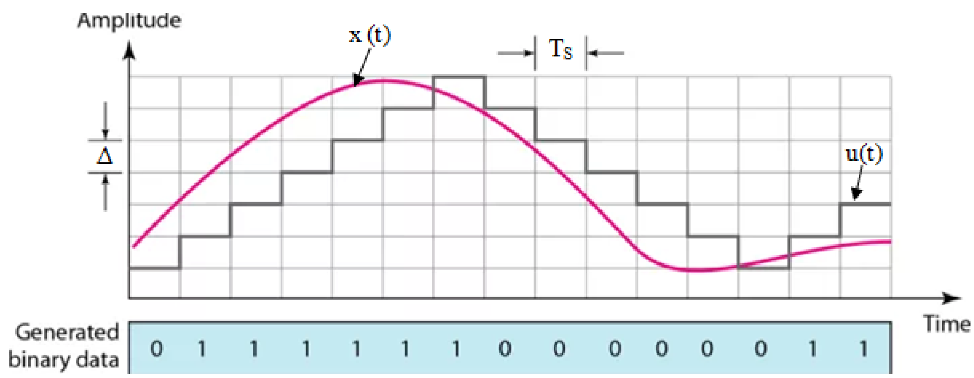
Bit rate = sampling rate x number of bits per sample

$$= f_s \times n_b$$

In our example, L is 8 and n_b is therefore 3.

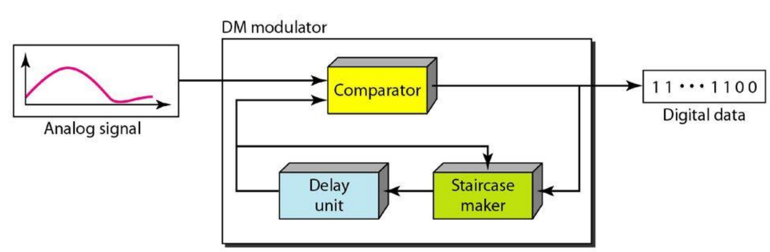
II. DELTA MODULATION (DM):

PCM is a very complex technique. Other techniques have been developed to reduce the complexity of PCM. The simplest is **delta modulation**. Delta Modulation finds the change from the previous value.



Modulator – The modulator is used at the sender site to create a stream of bits from an analog signal. The process records a small positive change called delta(σ). If the delta is positive, the process records a 1; if it is negative, the process records a 0. The modulator builds a second signal that resembles a staircase. The input signal is then compared with this gradually made staircase signal.

Figure 4.29 *Delta modulation components*

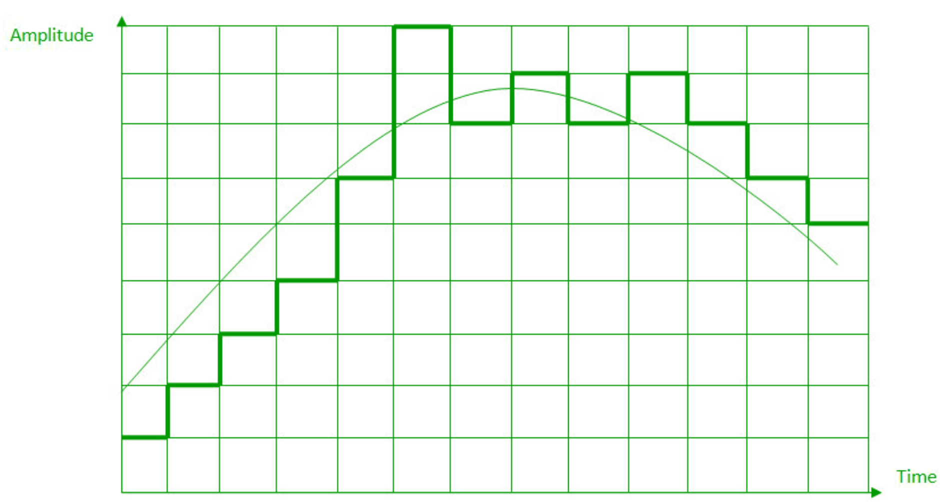


We have the following rules for output:

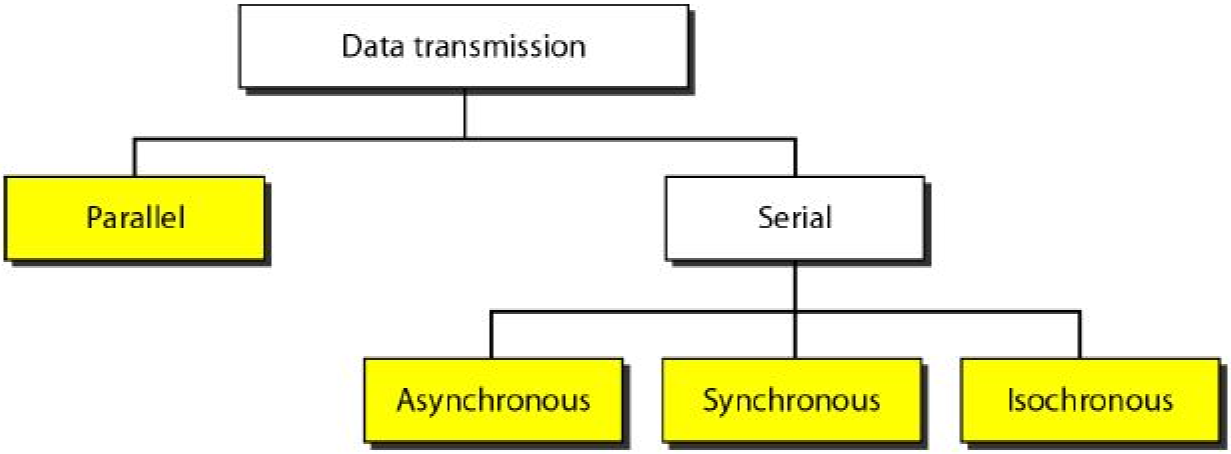
- At each sampling interval, compare the value of the analog signal with the last value of the staircase signal.
- If the input analog signal is higher than the last value of the staircase signal, increase delta by 1, and the bit in the digital data is 1.
- If the input analog signal is lower than the last value of the staircase signal, decrease delta by 1, and the bit in the digital data is 0.

Demodulator- The demodulator takes the digital data and using the staircase maker and the delay unit , creates the analog signal.

ADAPTIVE DELTA MODULATION:
The performance of a delta modulator can be improved significantly by making the step size of the modulator assume a time-varying form. A larger step-size is needed where the message has a steep slope of modulating signal and a smaller step-size is needed where the message has a small slope. The size is adapted according to the level of the input signal. This method is known as adaptive delta modulation (ADM).



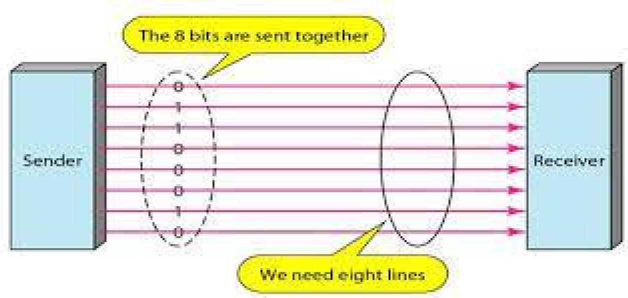
TRANSMISSION MODES



Data is transferred in the form of bits between two or more digital devices. There are two methods used to transmit data between digital devices: Parallel transmission and Serial transmission.

Parallel Transmission:

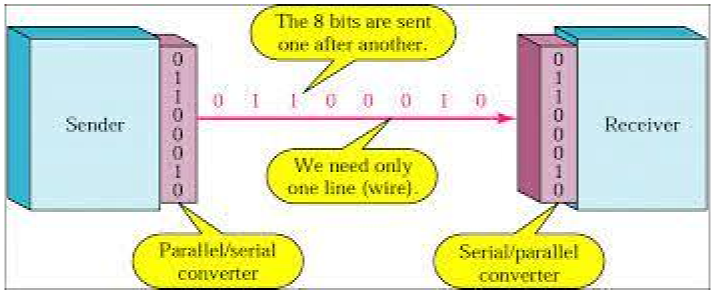
In Parallel Transmission, many bits flow together simultaneously from one computer to another computer. When data is sent using parallel transmission, multiple data bits are transmitted over multiple channels at the same time. Parallel Transmission is faster than serial transmission to transmit the bits.



The main advantages of parallel transmission are it is easier to program and data sent fast.
Disadvantage is cost: it requires n communication lines just to transmit the data stream and it is usually limited to short distances.
Parallel Transmission is used when a large amount of data is sent, the data being sent is time sensitive and the data needs to be sent quickly.

Serial Transmission:

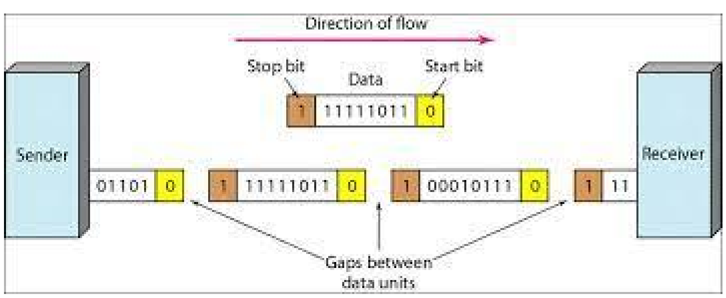
In Serial Transmission, one bit flows another, so we need only one communication channel. When data is sent or received using serial data transmission, the data bits are organised in a specific order,since they can only be sent one after another. The order of the data bit is important. It is a reliable data transmission method because a data bit is only sent if the previous data bit has already been received. In this transmission, one bit flows at one clock pulse.



Serial transmission is normally used for long distance data transfer. It is used in cases where the amount of data being sent is relatively small.
The advantage of serial over parallel transmission is that with only one communication channel, it reduces the cost of transmission.

Serial transmission occurs in three ways: Asynchronous, Synchronous and Isochronous.

Asynchronous Serial Transmission :-
Data bits can be sent at any point time, because timing of a signal is unimportant. Instead, information is received and translated by agreed upon patterns. Patterns are based on grouping the bit stream into bytes. Each group is usually 8 bits. Without synchronisation,the receiver cannot use timing to predict when the next group will arrive. To alert the receiver,we send one start bit(0) at the beginning and one or more Stop bits(1s) at the end of each byte.The time between sending and receiving data is not constant,the transmission of each byte may then be followed by a gap of varying duration.

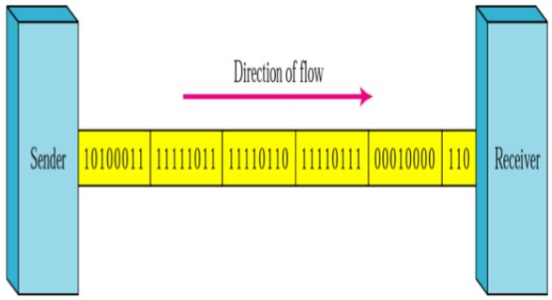


The advantage of using an asynchronous method is that no synchronisation is required between the transmitter and receiver devices. It is cheap and cost effective.

A disadvantage is that data transmission can be slower.

Synchronous Serial Transmission:-

In synchronous transmission, the bit stream is combined into longer frames,which may contain multiple bytes. We send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits. Ie, Data bits are transmitted as a continuous stream in the time master clock. The data transmitter and receiver both operate using a synchronized clock frequency.



The above figure gives the schematic illustration of synchronous transmission. We have drawn in the division between bytes. In reality, that division does not exist;the sender puts its data into the line as one long string.

Without gaps and start and stop bits,there is no built-in mechanism to help the receiving device adjust its bits. Timing becomes very important, therefore, because the accuracy of the received information is completely dependent on the ability of the receiving device to keep an accurate count of the bits as they come in.

The advantages of synchronous transmission is speed.