6.3 How Digital Data is Encoded Using Signal Elements

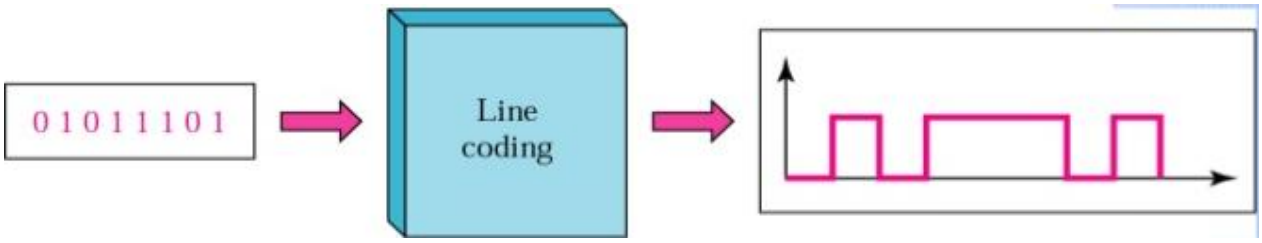
What is encoding?

Encoding is the process of converting a sequence of symbols, characters, alphabets or the data into a specific format for sending the data securely. On the other hand, Decoding is quite opposite to Encoding which is extracting information from the converted format.

What is data encoding?

Data Encoding is the process of **using** various patterns of **voltage** or current **levels** to represent 1s and 0s of the **digital** signals on the transmission link.

The common types of line **encoding** are Unipolar, Polar, Bipolar, and Manchester.



Encoding Techniques

Below are the data encoding techniques based on the type of data conversion.

- **Analog data to Analog signals** – Techniques such as Frequency Modulation, Amplitude Modulation and Phase Modulation of analog signals come under this category.

- **Analog data to Digital signals** – Pulse Code Modulation (PCM) does the digitization process also called as digital modulation. Key factors in PCM are sampling and quantization. Better output can be obtained from Delta Modulation than PCM.

- **Digital data to Digital signals** - Non-return to Zero Level (NRZ-L), Non-return to Zero Invented (NRZ-I), Manchester Encoding are few techniques.

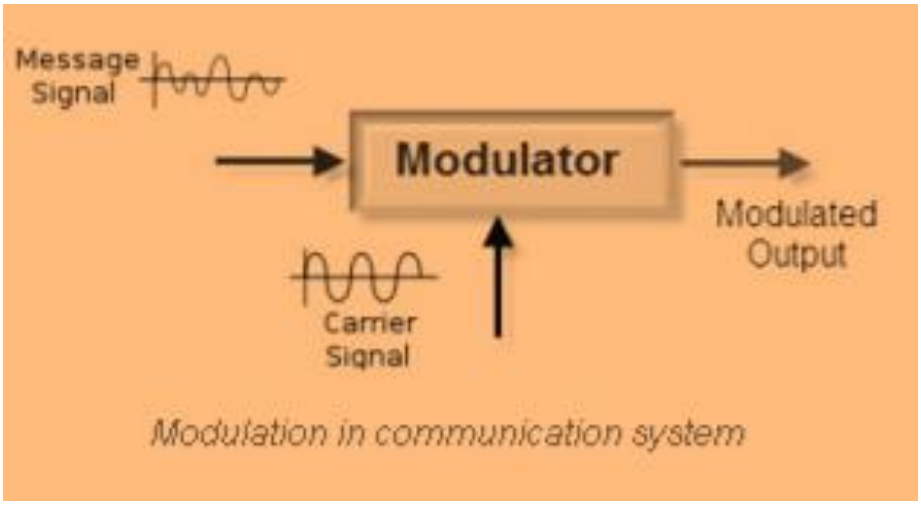
A signal can be anything like a sound wave which comes out when you shout. This shout can be heard only up to a certain distance. But for the same wave to travel over a long distance, you'll need a technique which adds strength to this signal, without disturbing the parameters of the original signal.

What is Signal Modulation?

- A message carrying signal has to get transmitted over a distance and for it to establish a reliable communication, it needs to take the help of a high frequency signal which should not affect the original characteristics of the message signal.
- The characteristics of the message signal, if changed, the message contained in it also alters. Hence it is a must to take care of the message signal.
- A high frequency signal can travel up to a longer distance, without getting affected by external disturbances. We take the help of such high frequency signal which is called as a **carrier signal** to transmit our message signal. Such a process is simply called as Modulation.

Modulation is the technique used to send information by modifying the basic characteristics such as frequency, amplitude and phase, of an electromagnetic signal (modulating signal) by attaching it to a higher frequency signal (carrier signal), producing a modulated signal. The most commonly used method is the Pulse Code Modulation (PCM).

In **digital modulation**, the modulation technique used is **Pulse Code Modulation (PCM)** where the analog signal is converted into digital form of 1s and 0s. As the resultant is a coded pulse train, this is called as PCM.



Why we need modulation?

Electronic devices produce messages like analog baseband signals in the form of audio, video or even messages can be in the form of digital bits from computer.

To send these messages we must have some communication channel like wires, co-axial cable, even wireless radio waves, microwaves or infrared.

We can easily transmit messages through wires or cables.

Voice, Video, bit streams from computer are having lower frequency band and can travel few distance with wires but cannot be sent through wireless media.

Voice signal has lower Bandwidth therefore it will not propagate through space and will be attenuated.

To transmit voice signal a large size antenna is required as antenna length is proportional to half of wavelength.

The size of the antenna will be more than the distance between transmitter and receiver.

Again when more than one transmitter is involved all station will overlap in one frequency band.

For those above reasons we choose a carrier, which is a high frequency radio wave, can travel long distance without attenuation and as the frequency is high smaller antenna is required.

Selecting different carrier frequency for different transmitting stations can eliminate overlapping of frequency band.

Advantages of Modulation

The antenna used for transmission, had to be very large, if modulation was not introduced. The range of communication gets limited as the wave cannot travel to a distance without getting distorted.

Following are some of the advantages for implementing modulation in the communication systems.

- Antenna size gets reduced.
- No signal mixing occurs.
- Communication range increases.
- Adjustments in the bandwidth is allowed.

Signals in the Modulation Process

Following are the **three types** of signals in the modulation process.

Message or Modulating Signal

The signal which contains a message to be transmitted, is called as a **message signal**. It is a baseband signal, which has to undergo the process of modulation, to get transmitted. Hence, it is also called as the **modulating signal**.

Carrier Signal

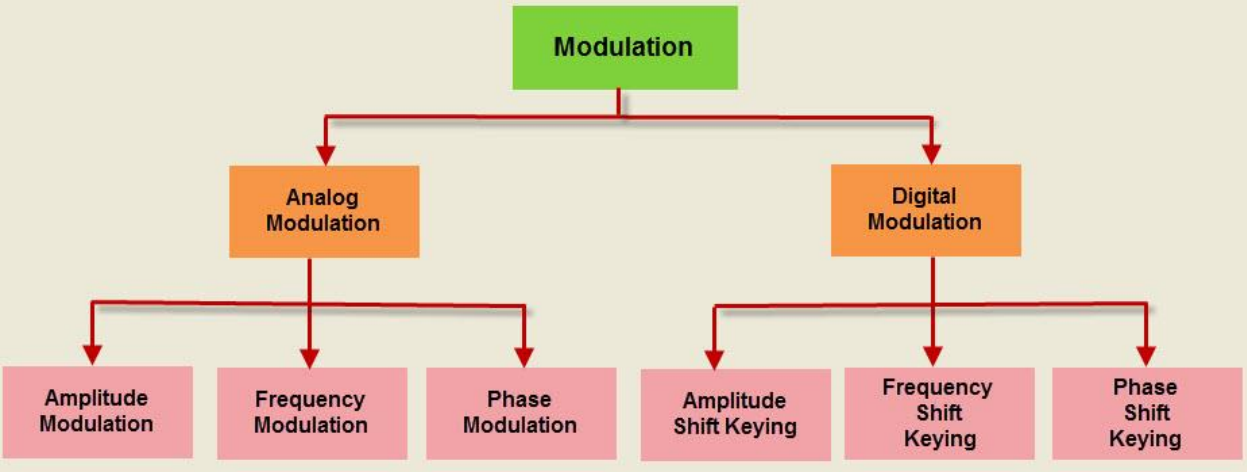
The high frequency signal which has a certain phase, frequency, and amplitude but contains no information, is called a **carrier signal**. It is an empty signal. It is just used to carry the signal to the receiver after modulation.

Modulated Signal

The resulting signal after the process of modulation, is called as the **modulated signal**. This signal is a combination of the modulating signal and the carrier signal.

Types of Modulation

There are many types of modulations. Depending upon the modulation techniques used, they are classified as shown in the following figure.



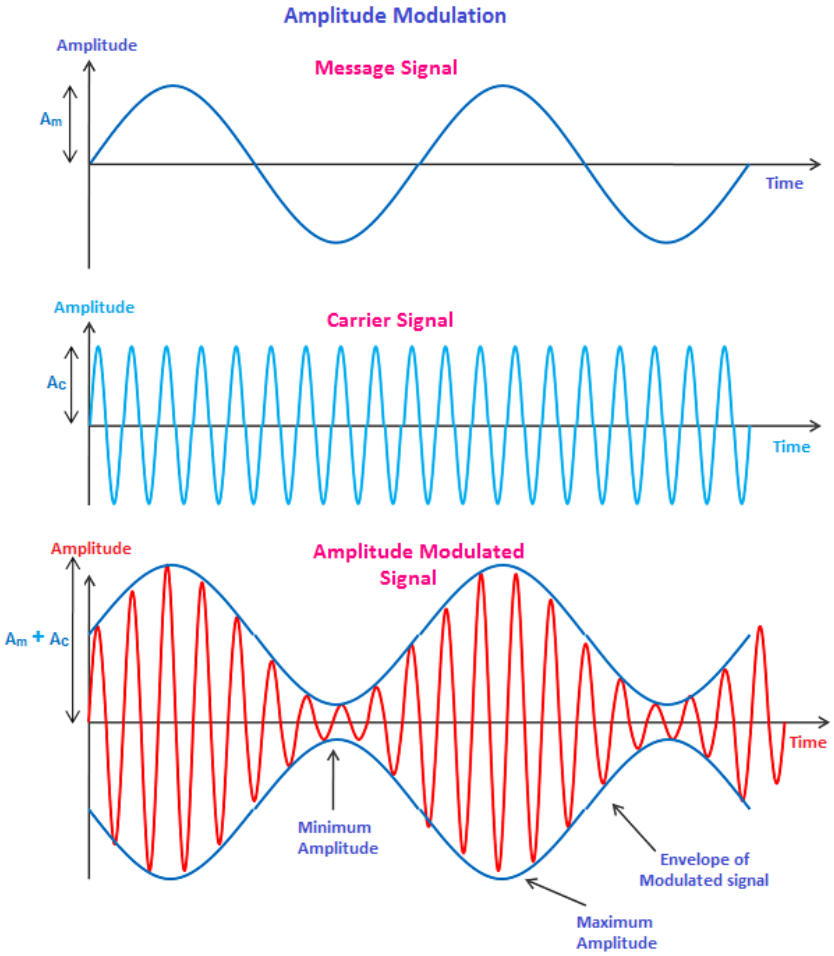
Analog Modulation

In this modulation, a continuously varying sine wave is used as a carrier wave that modulates the message signal or data signal. Three parameters of Sinusoidal wave can be altered to get modulation – they are amplitude, frequency and phase, so the types of analog modulation are:

1. Amplitude Modulation
2. Frequency Modulation
3. Phase Modulation

Amplitude Modulation (AM)

Amplitude modulation is a type of modulation where the amplitude (signal strength) of the carrier signal is varied in accordance with the amplitude (signal strength) of the message signal. The frequency or phase of the carrier signal remains unchanged.



AM Advantage

AM is the simplest type of modulation. Hardware design of both transmitter and receiver is very simple and less cost effective.

AM Disadvange:

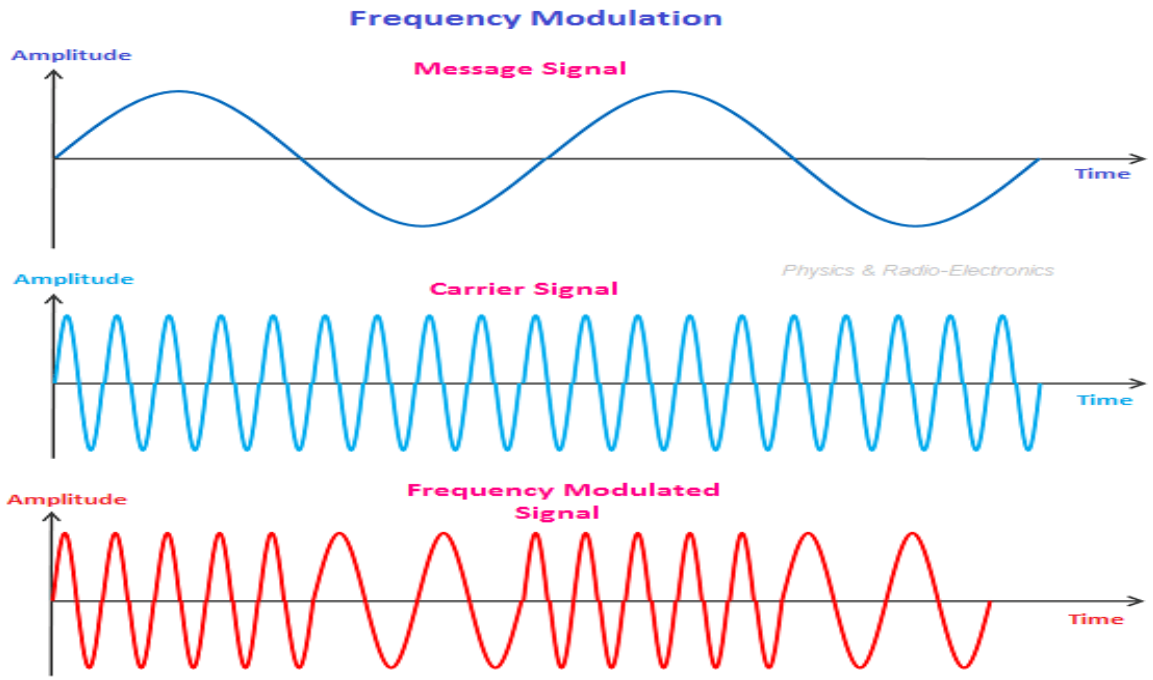
AM is very susceptible to noise.

Application:

AM radio broadcast

Frequency Modulation (FM)

Frequency modulation is a type of modulation where the frequency of the carrier signal varies as per variations of the message signal.



FM Advantage

Modulation and demodulation do not catch any channel noise.

FM Disadvantage:

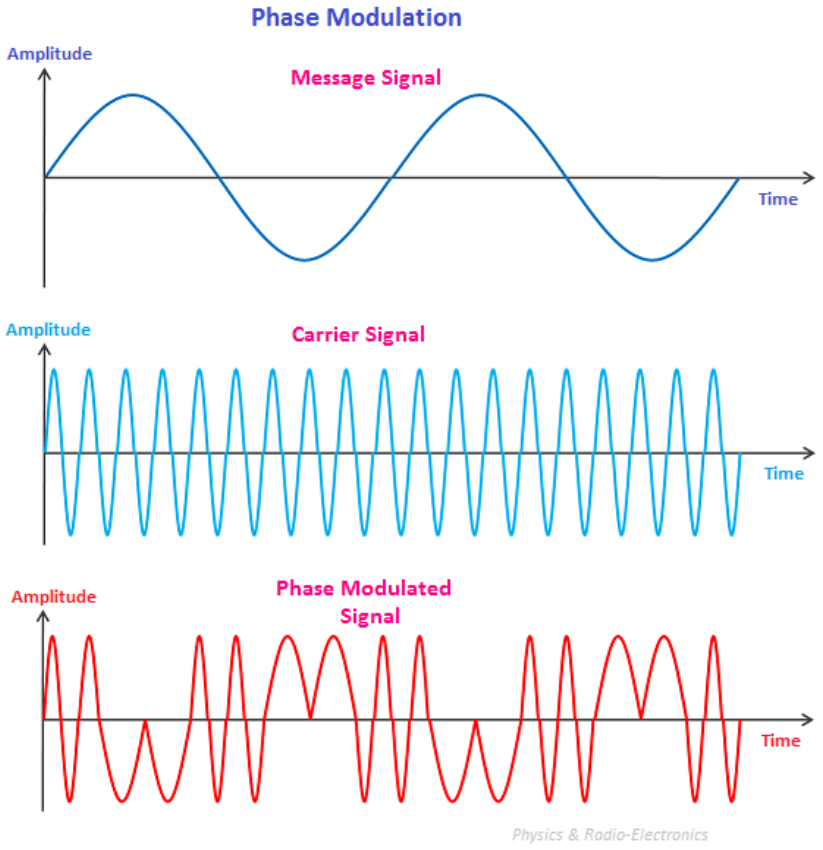
Circuit needed for FM modulation and demodulation is bit complicated than AM

Application:

FM radio broadcast is an example

Phase Modulation (PM)

Phase modulation is a type of modulation where the phase of the carrier signal varies as per variations of the data signal/message signal.



PM Advantage

Modulation and demodulation does not catch any channel noise.

PM Disadvantage:

Circuit needed for PM modulation and demodulation is bit complicated than AM and FM

Application:

Satellite communication.

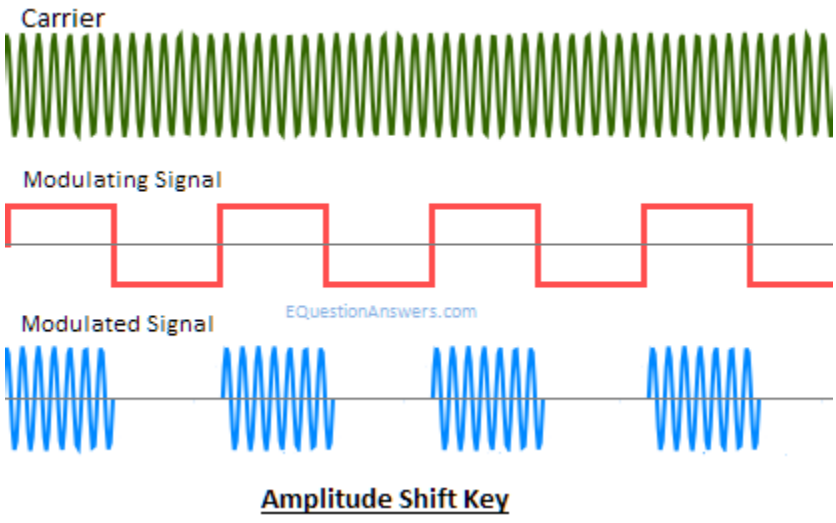
Digital Modulation

Analog modulation refers to the process of transferring digital low frequency baseband signal, like digital bit stream from computers over a higher frequency carrier signal such as a radio frequency band. Digital modulation in somewhat similar to the analog modulation except base band signal is of discrete amplitude level. For binary signal it has only two level, either high or logic 1 or low or logic 0. The modulation scheme is mainly three types.

1. Amplitude shift Key (ASK)
2. Frequency shift key (FSK)
3. Phase shift key (PSK)

Amplitude shift Key (ASK)

In this conversion technique, the amplitude of an analog carrier signal is modified to reflect binary data. When binary data represents digit 1, the amplitude is held at 1, otherwise it is set to 0. Both frequency and phase remain same as in the original carrier signal

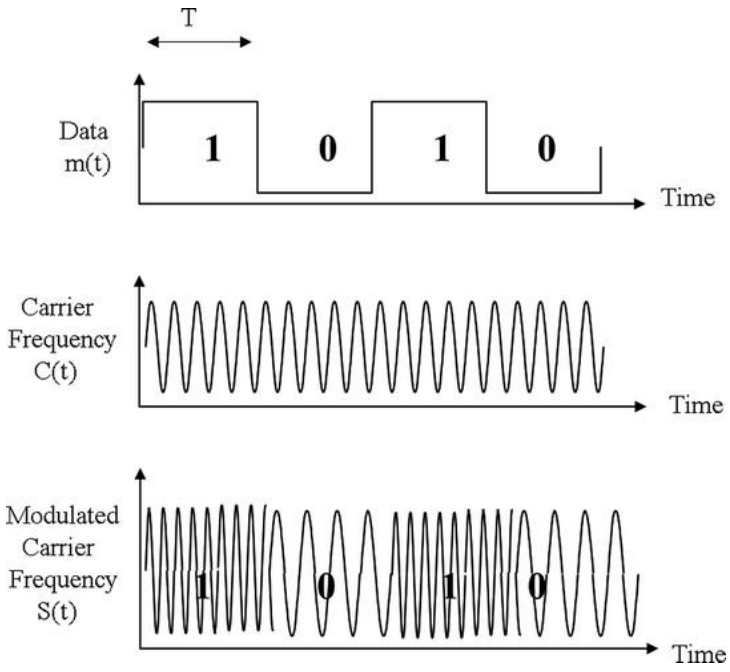


Application:

1. Used in our infrared remote controls
2. Used in fiber optical transmitter and receiver.

Frequency shift key (FSK)

In this conversion technique, the frequency of the analog carrier signal is modified to reflect Binary data.

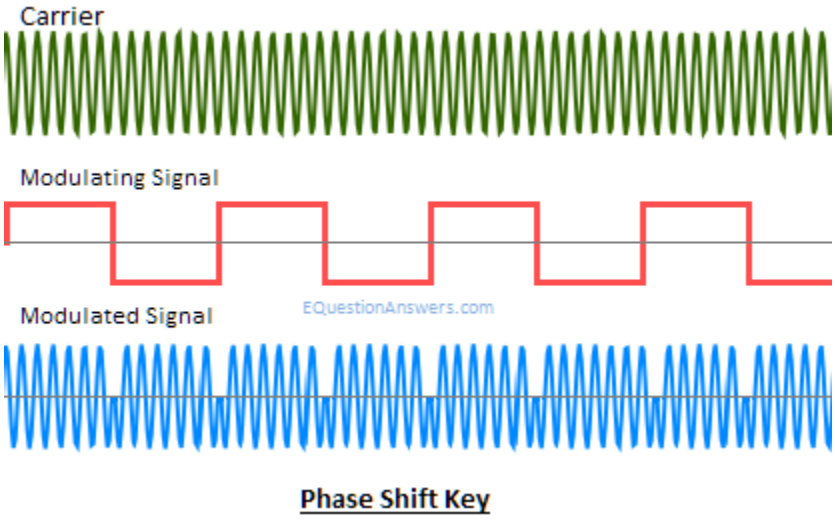


Application:

Many modems used FSK in telemetry systems

Phase shift key (PSK)

In this conversion scheme, the phase of the original carrier signal is altered to reflect the binary data.



Phase Shift Key

Application:

1. Used in our ADSL broadband modem
2. Used in satellite communication
3. Used in our mobile phones

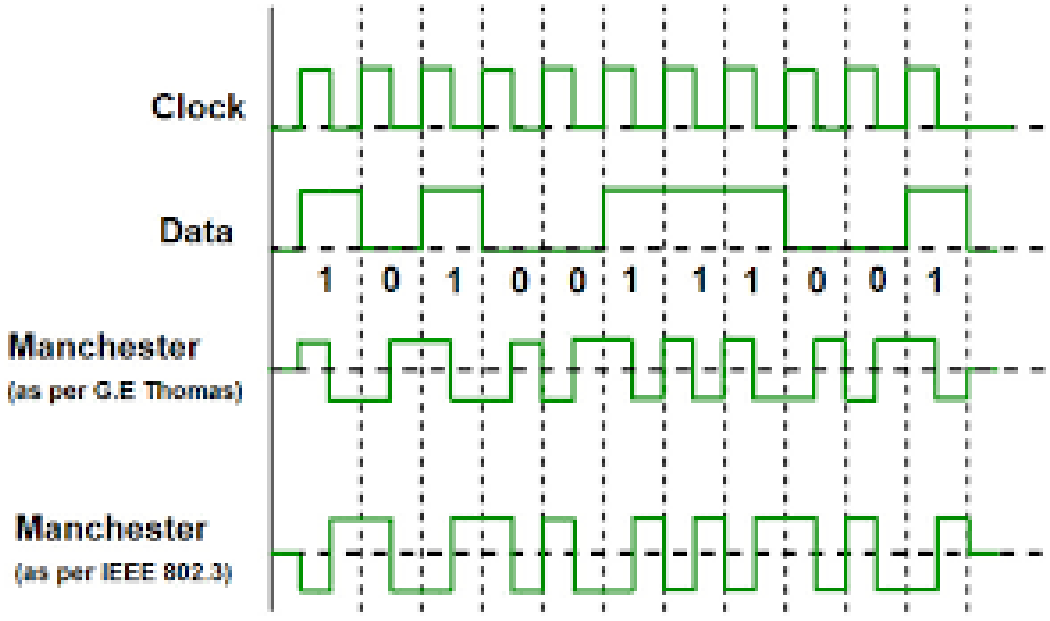
Below are the data encoding techniques based on the conversion of **Digital data to Digital signals**.

- Non-return to Zero Level (NRZ-L)
- Non-return to Zero Invented (NRZ-I)
- Manchester Encoding

Non-return to Zero Level (NRZ-L) - is an encoding scheme in which two different voltages for 0 and 1 bits are used to represent data and remain constant during a bit interval.

Non-return to Zero Invented (NRZ-I) - in this encoding scheme, in which a "1" is represented by a transition of the physical level, while a "0" has no transition.

Manchester Encoding - in Manchester encoding voltage changes from low to high or high to low in the middle of the signal.



Need for Synchronization

Synchronization

Synchronization is used to ensure that the data streams are received and transmitted correctly between two devices. Usually, a clock signal is transmitted in sequence with a data stream to maintain proper signal timing.

Synchronous transmission is a data transfer method which is characterized by a continuous stream of data in the form of signals which are accompanied by regular timing signals which are generated by some external clocking mechanism meant to ensure that both the sender and receiver are synchronized with each other.

Synchronous transmission modes are used when large amounts of data must be transferred very quickly from one location to the other. The speed of the synchronous connection is attained by transferring data in large blocks instead of individual characters.

Data are sent as frames or packets in fixed intervals.

Handling Errors (Error Control)

The purpose of error control is to ensure that the information received by the receiver is exactly the information transmitted by the sender. As the communication channel is highly unreliable, the receiver must be able to deal with the received data, if it contains error. **The term *error control* is defined as the process of identification or correction of error occurred in the transmitted data.**

Error detection - there are different error detection schemes used. The type of detection scheme depends on the type of error and the type of transmission (synchronous or asynchronous) also. There are random single bit errors in asynchronous or synchronous mode of transmission and burst error occurs in a group of continuous bits. The most widely used error-detecting codes are the parity, block sum check, and the cyclic redundancy check (CRC) codes.

Parity - The most common method of detecting the errors is the use of parity. With this method, the bits of a character to be transmitted are inspected and an extra bit is added before the transmission. This bit is known as the **parity bit.**

The bit is chosen to be a '0' or a '1', in order to keep the total number of '1' s '1' bits in the character odd or even respectively. To compute the parity bit, the number of bits in the character is added first, using modulo-2 addition, the result may be a '0' or a '1'. If the parity is chosen as odd, then the additional bit added must make the result into a '1' if the parity chosen is even, then the additional bit must make the result into a '0'. Following is an example for the parity generation.

At the receiving end, after the reception of the character, the parity bit is removed from the received character. The remaining bits are added using the modulo-2 addition and the result is checked with the received parity bit. If these two values differ, then the received character contains an error. Hence the use of parity bit is to detect single bit errors.

Schema	Character Bits	Parity Bit
Parity Odd	1101101 1000100 1111111	0 1 0
Parity Even	1101101 1000100 1111111	1 0 1

Simple parity Generation

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