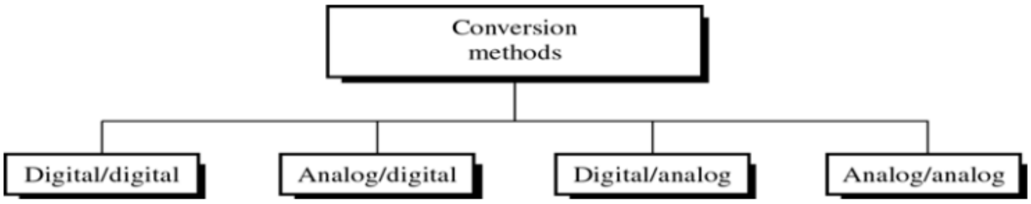
Conversions

Information must be transformed into signals before it can be transported across the communication media. There are the following types of conversions.



Digital to Digital Conversion

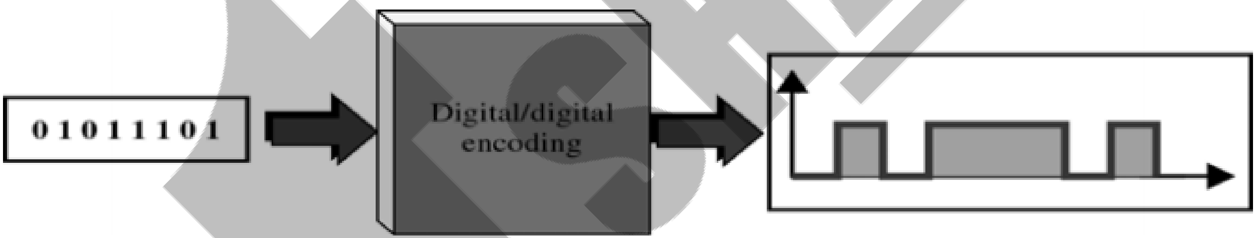
Digital to Digital conversion is the process of digital data to digital signals. There are three techniques to convert digital data to digital signals, are as follows:

1. Line Coding
2. Block Coding
3. Scrambling

Their details are as follows. Line coding is necessary.

1. Line Coding

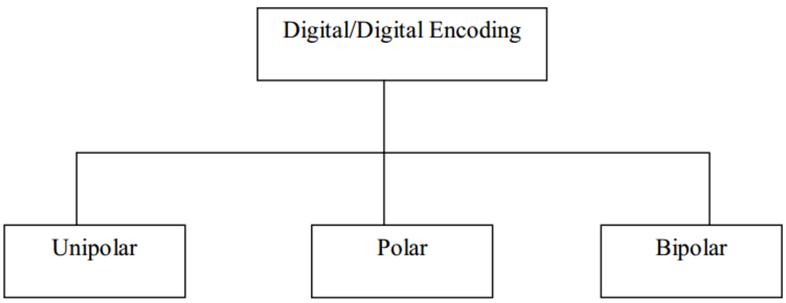
Line coding is the process of converting digital data to digital signals. Line coding converts a sequence of bits to a digital signal. For Example when you transmit data from Computer to the Printer, both original and transmitted data have to be digital.



Properties/Characteristics of Line Coding

- ✓ As the coding is done to make more bits transmit on a single signal, the bandwidth used is much reduced.
- ✓ For a given bandwidth, the power is efficiently used.
- ✓ The probability of error is much reduced.
- ✓ Error detection is done and the bipolar too has a correction capability.
- ✓ Power density is much favorable.
- ✓ The timing content is adequate.
- ✓ Long strings of 1s and 0s is avoided to maintain transparency.

Types of Line Coding

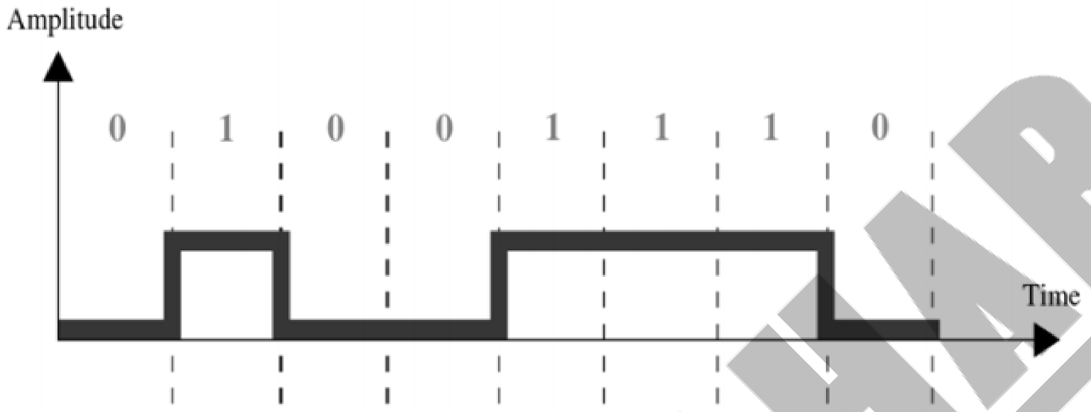


➢ Unipolar

Unipolar signaling is also called as On-Off Keying or simply OOK. The presence of pulse represents a 1 and the absence of pulse represents a 0. In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.

- **NRZ (Non-Return-to-Zero)**

A High in data is represented by a positive pulse and A Low in data input has no pulse. It is called NRZ because the signal does not return to zero at the middle of the bit. This scheme is very costly. For this reason, this scheme is normally not used in data communications today.



Advantages

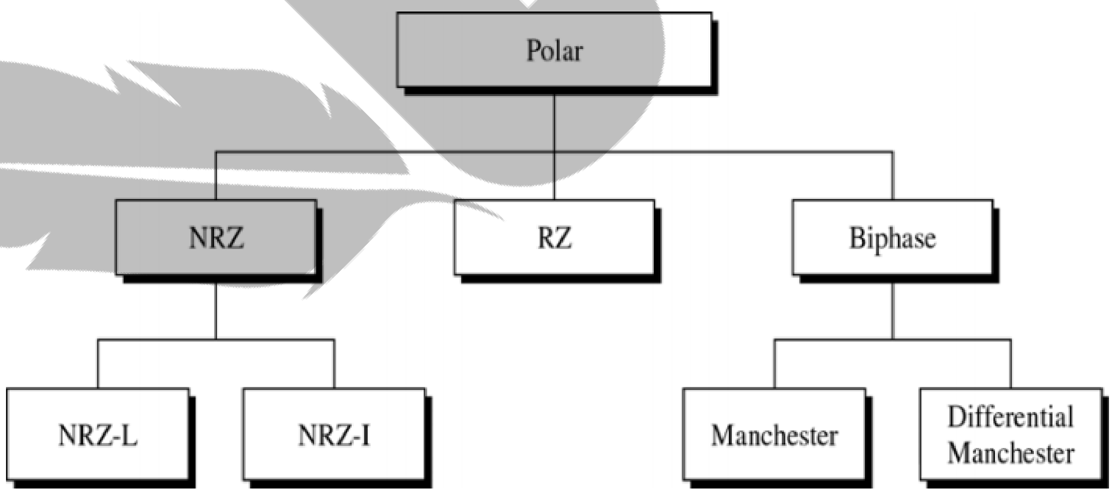
- It is simple.
- A lesser bandwidth is required.

Disadvantages

- No error correction done.
- Presence of low frequency components may cause the signal droop.
- No clock is present.
- Loss of synchronization is likely to occur (especially for long strings of 1s and 0s).

➢ Polar Schemes

In polar schemes, the voltages are on both sides of the time axis. It has three sub categories. Non Return to Zero (NRZ), Return to Zero (RZ) and Bi phase.

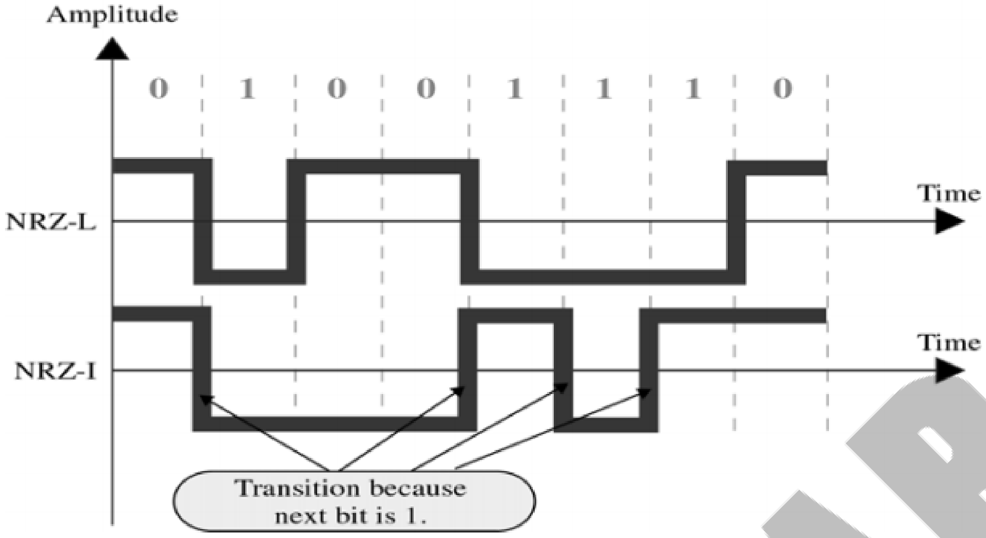


- **NRZ (Non Return-to-Zero)**

In NRZ Encoding, the level of signal is either positive or negative. It has two types NRZ-L and NRZ-I.

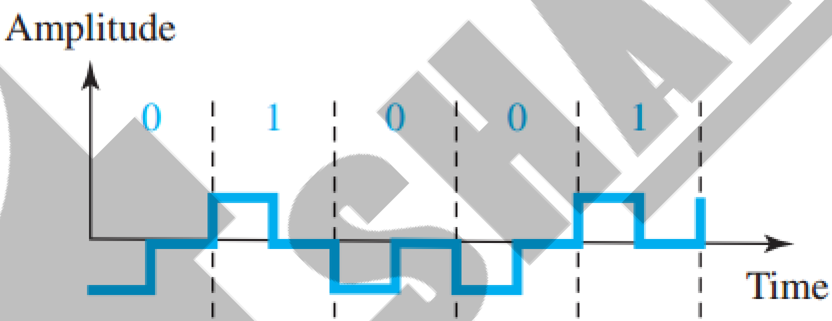
NRZ-L: A +ve voltage usually means the bit is a 1 and a –ve voltage means the bit is a 0 (vice versa)

NRZ-I: The inversion of the level represents a 1 bit, A bit 0 is represented by no change. NRZ-I is superior to NRZ-L due to synchronization provided by signal change each time a 1 bit is encountered.



- **RZ (Return to Zero)**

In this type of Polar signaling, a High in data, though represented by +ve signal. Half of the bit duration remains high but it immediately returns to zero and shows the absence of pulse during the remaining half of the bit duration. However, for a Low input, a negative pulse represents the data, and the zero level remains same for the other half of the bit duration.

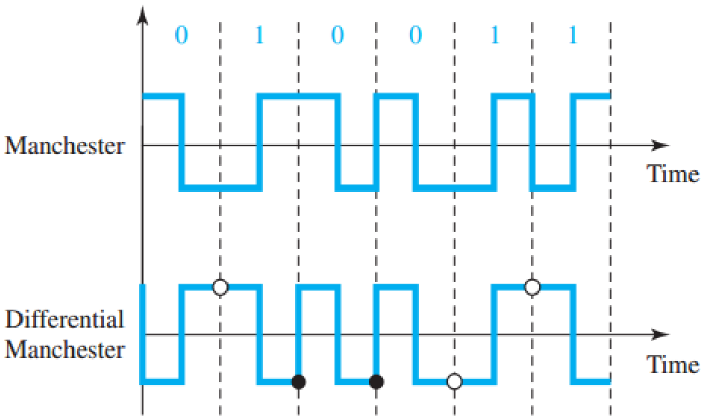


- **Bi-phase Encoding**

In bi-phase Signal changes at the middle of bit interval but does not stop at zero instead it continues to the opposite pole. It has two subcategories Manchester and Differential Manchester. The Manchester scheme overcomes several problems associated with NRZ-L, and differential Manchester overcomes several problems associated with NRZ-I.

Manchester: The idea of RZ (transition at the middle of the bit) and the idea of NRZ-L are combined into the Manchester scheme. Negative-to-Positive Transition= 1, Positive-to-Negative Transition = 0.

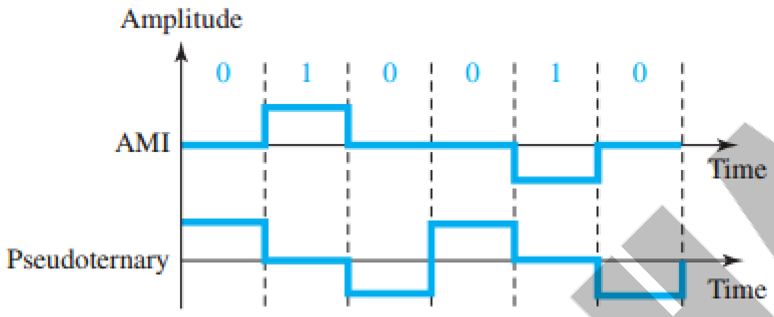
Differential Manchester: It combines the ideas of RZ and NRZ-I. There is always a transition at the middle of the bit, but the bit values are determined at the beginning of the bit. If the next bit is 0, there is a transition; if the next bit is 1, there is none.



- **Bipolar**

In bipolar encoding (sometimes called multilevel binary), there are three voltage levels: positive, negative, and zero. The voltage level for one data element is at zero, while the voltage level for the other element alternates between positive and negative. It has two subcategories:

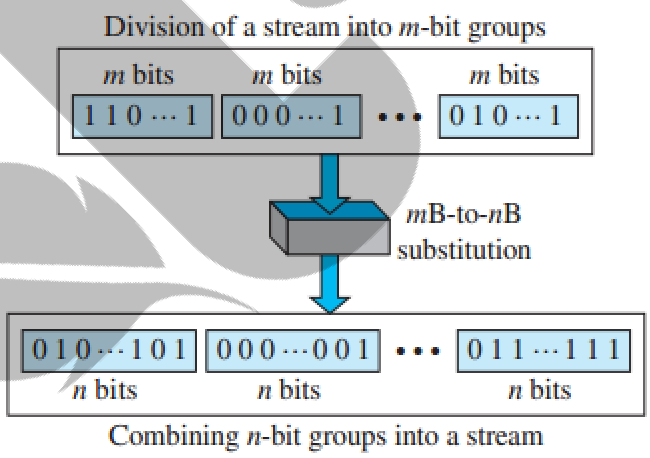
AMI (Alternate Mark Inversion): In the term alternate mark inversion, the word mark comes from telegraphy and means 1. So AMI means alternate 1 inversion. A neutral zero voltage represents binary 0. Binary 1s are represented by alternating positive and negative voltages. AMI is commonly used for long-distance communication.
Pseudo Ternary: In this type 1 bit is encoded as a zero voltage and the 0 bit is encoded as alternating positive and negative voltages.



2. Block Coding

Block coding helps in error detection and re-transmission of the signal. It is normally referred to as mB/nB coding as it replaces each m-bit data group with an n-bit data group (where n>m). Thus, its adds extra bits (redundancy bits) which helps in synchronization at receiver's and sender's end and also providing some kind of error detecting capability.

It normally involves three steps: division, substitution, and combination. In the division step,a sequence of bits is divided into groups of m-bits. In the substitution step, we substitute an m-bit group for an n-bit group. Finally, the n-bit groups are combined together to form a stream which has more bits than the original bits.

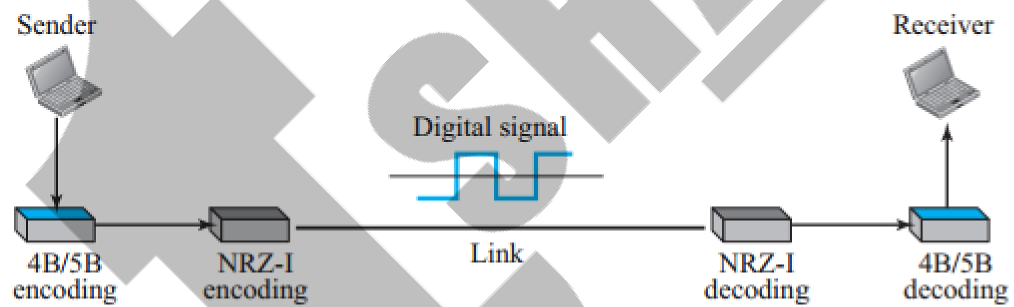


- **4B/5B (four binary/five binary)**

This coding scheme is used in combination with NRZ-I. The problem with NRZ-I was that it has a synchronization problem for long sequences of zeros. So, to overcome it we substitute the bit stream from 4-bit to 5-bit data group before encoding it with NRZ-I. So that it does not have a long stream of zeros. The block-coded stream does not have more than three consecutive zeros (see encoding table).

Data Sequence	Encoded Sequence	Control Sequence	Encoded Sequence
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

At the receiver, the NRZ-I encoded digital signal is first decoded into a stream of bits and then decoded again to remove the redundancy bits.

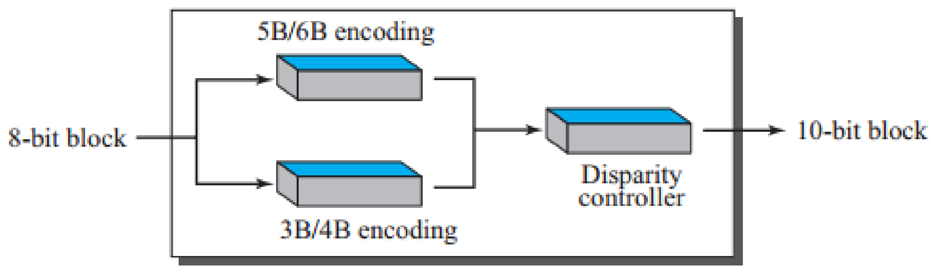


Drawback though 4B/5B encoding solves the problem of synchronization, it increases the signal rate of NRZ-L. Moreover, it does not solve the DC component problem of NRZ-L.

- **8B/10B (eight binary/ten binary)**

This encoding is similar to 4B/5B encoding except that a group of 8 bits of data is now substituted by a 10-bit code and it provides greater error detection capability than 4B/5B. It is actually a combination of 5B/6B and 3B/4B encoding. The most five significant bits of a 10-bit block is fed into the 5B/6B encoder; the least 3 significant bits is fed into a 3B/4B encoder. The split is done to simplify the mapping table.

A group of 8 bits can have 2^8 different combinations while a group of 10 bits can have 2^10 different combinations. This means that there are 2^10-2^8=768 redundant groups that are not used for 8B/10B encoding and can be used for error detection and disparity check. Thus, this technique is better than 4B/5B because of better error-checking capability and better synchronization.



8B/10B encoder

3. Scrambling

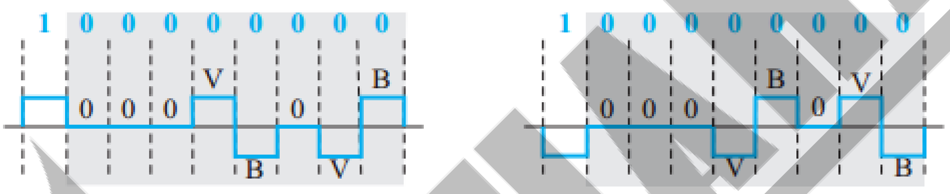
Scrambling is a technique that does not increase the number of bits and does provide synchronization. Problem with technique like Bipolar AMI(Alternate Mark Inversion) is that continuous sequence of zero's create synchronization problems one solution to this is Scrambling. There are two common scrambling techniques:

1. B8ZS(Bipolar with 8-zero substitution)
2. HDB3(High-density bipolar3-zero)

- **B8ZS**

Bipolar with 8-zero substitution (B8ZS) is commonly used in North America. In this technique, eight consecutive zero-level voltages are replaced by the sequence 000VB0VB. The V in the sequence denotes violation; this is a nonzero voltage that breaks an AMI rule of encoding (opposite polarity from the previous). The B in the sequence denotes bipolar, which means a nonzero level voltage in accordance with the AMI rule.

- ✓ V (Violation), is a non-zero voltage which means signal have same polarity as the previous non-zero voltage. Thus it is violation of general AMI technique.
- ✓ B (Bipolar), also non-zero voltage level which is in accordance with the AMI rule (i.e., opposite polarity from the previous non-zero voltage).



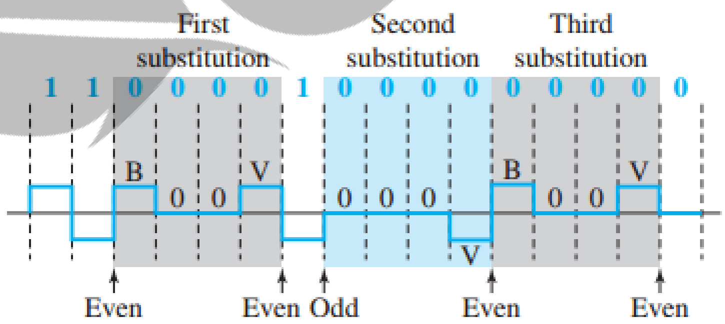
a. Previous level is positive. b. Previous level is negative.

Note – Both figures (left and right one) are correct, depending upon last non-zero voltage signal of previous data sequence (i.e., sequence before current data sequence "100000000"). In this technique four consecutive zero-level voltages are replaced with a sequence "000V" or "B00V".

Rules for using these sequences:

- ✓ If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be "000V", this helps maintaining total number of nonzero pulses even.
- ✓ If the number of nonzero pulses after the last substitution is even, the substitution pattern will be "B00V". Hence even number of nonzero pulses is maintained again.

Example: Data = 1100001000000000



Explanation – After representing first two 1's of data we encounter four consecutive zeros. Since our last substitutions were two 1's (thus number of non-zero pulses is even).So, we substitute four zeros with "B00V".
Note – Zero non-zero pulses are also even.

Analog to Digital Conversion

There are following two techniques we use to convert analog data to digital signals.

- Pulse Code Modulation
- Delta Modulation

A. Pulse Code Modulation

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

1. **Sampling**
2. **Quantization**
3. **Encoding**

Low pass filter:

The low pass filter eliminates the high frequency components present in the input analog signal to ensure that the input signal to sampler is free from the unwanted frequency components. This is done to avoid aliasing of the message signal.

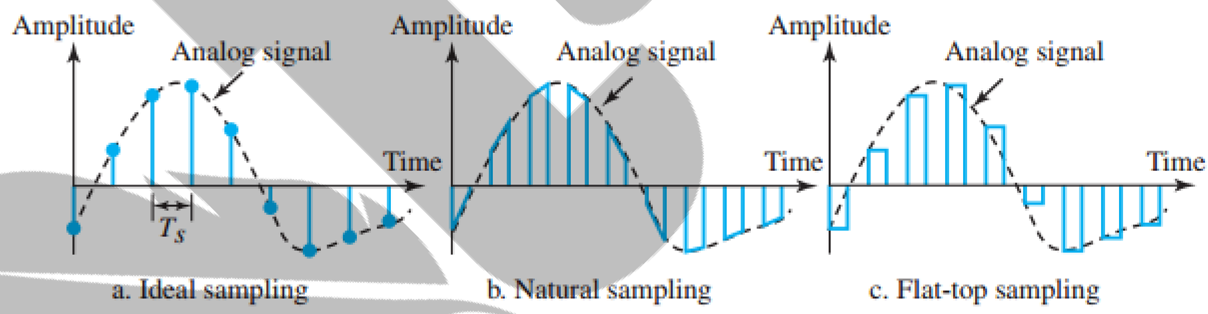
1. Sampling

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 pulse 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 pulse amplitude modulation (PAM).

Sampling Rate: Also called a sample rate. Typically expressed in samples per second, or hertz (Hz), the rate at which samples of an analog signal are taken in order to be converted into digital form.

Nyquist Theorem:

One important consideration is the sampling rate or frequency. 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 and given by:

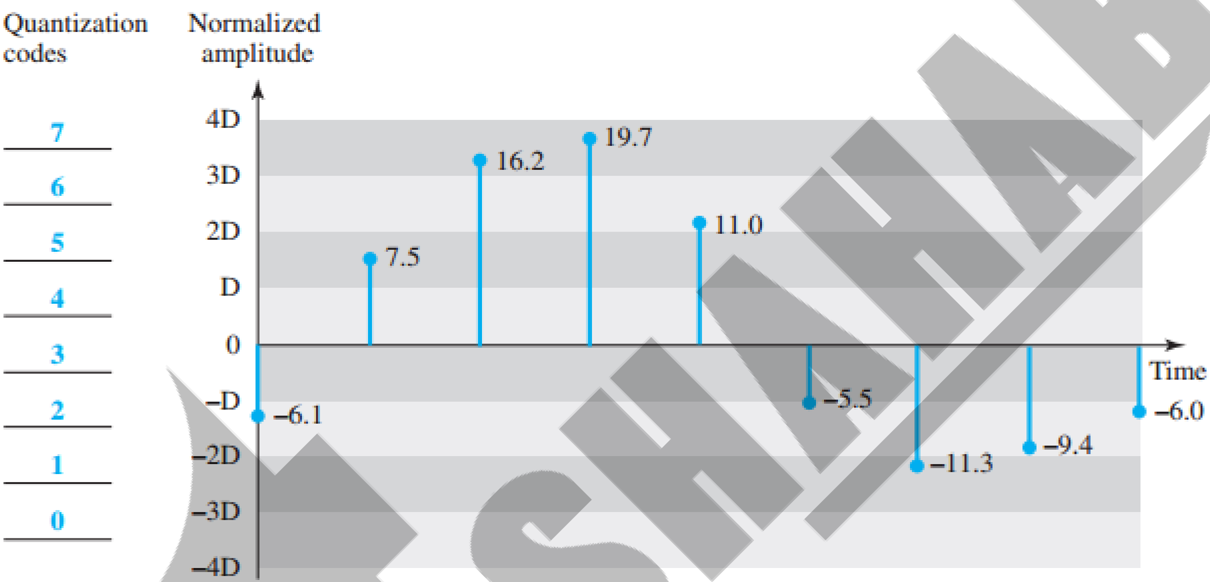
Fs =2*fh

2. Quantization

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:

i. We assume that the signal has amplitudes between Vmax and Vmin
ii. We divide it into L zones each of height d where, d= (Vmax- Vmin)/ L
iii. The value at the top of each sample in the graph shows the actual amplitude.
iv. The normalized pulse amplitude modulation (PAM) value is calculated using the formula amplitude/d.
v. After this we calculate the quantized value which the process selects from the middle of each zone.
vi. The Quantized error is given by the difference between quantized value and normalized PAM value.
vii. The Quantization code for each sample based on quantization levels at the left of the graph.



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

3. Encoding

The digitization of 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.

B. Delta Modulation

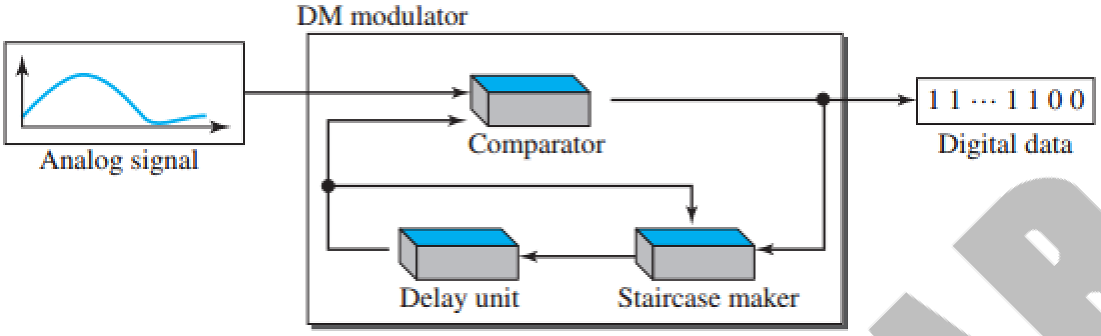
Since PCM is a very complex technique, other techniques have been developed to reduce the complexity of PCM. The simplest is delta Modulation. Delta Modulation finds the change from the previous value.

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. If the delta is positive, the process records a 1 else 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.

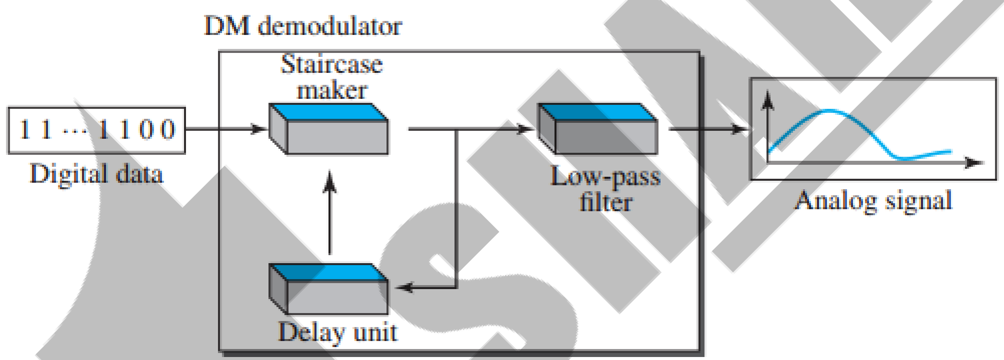
We have the following rules for output:

- ✓ 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. The created analog signal, however, needs to pass through a low-pass filter for smoothing.



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).

Quantization Error

It is obvious that DM is not perfect. Quantization error is always introduced in the process. The quantization error of DM, however, is much less than that for PCM.