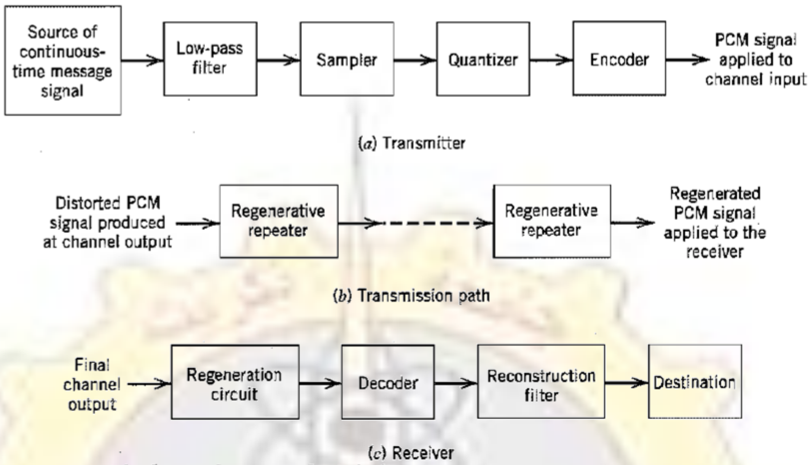
Pulse Code Modulation

In PCM, a message signal is represented by a sequence of coded pulses which is acomplished by representing the signal in discrete form in both time and amplitude. The basic operation performed in the transmitter of a PCM system are sampling, quantizing and encoding.

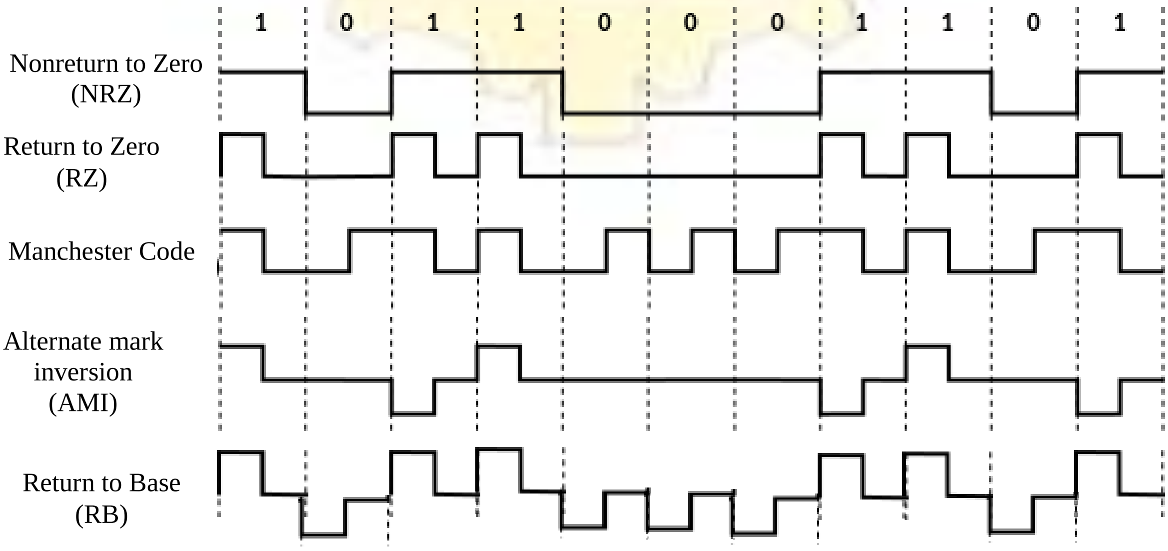


The basic elements of a PCM system.

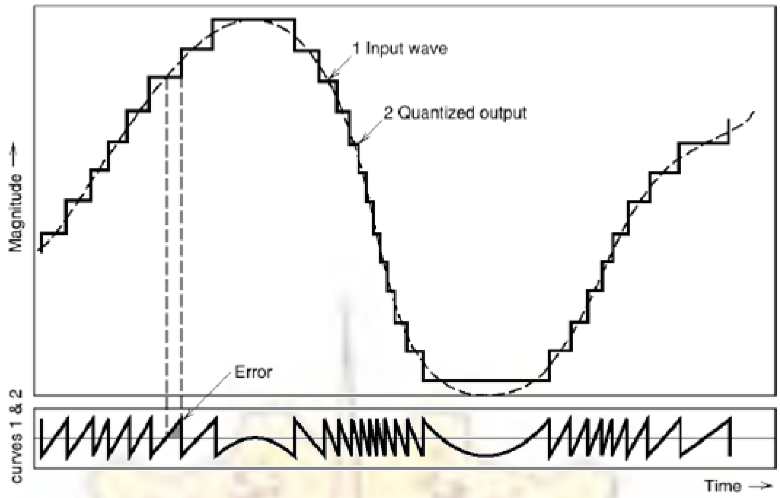
Pulse code modulation (PCM) performs the following

1- Sample the alalouge signal
2- Quantize the sampled signal into a number of discrete levels.
3- Use code to designate each quantized level.

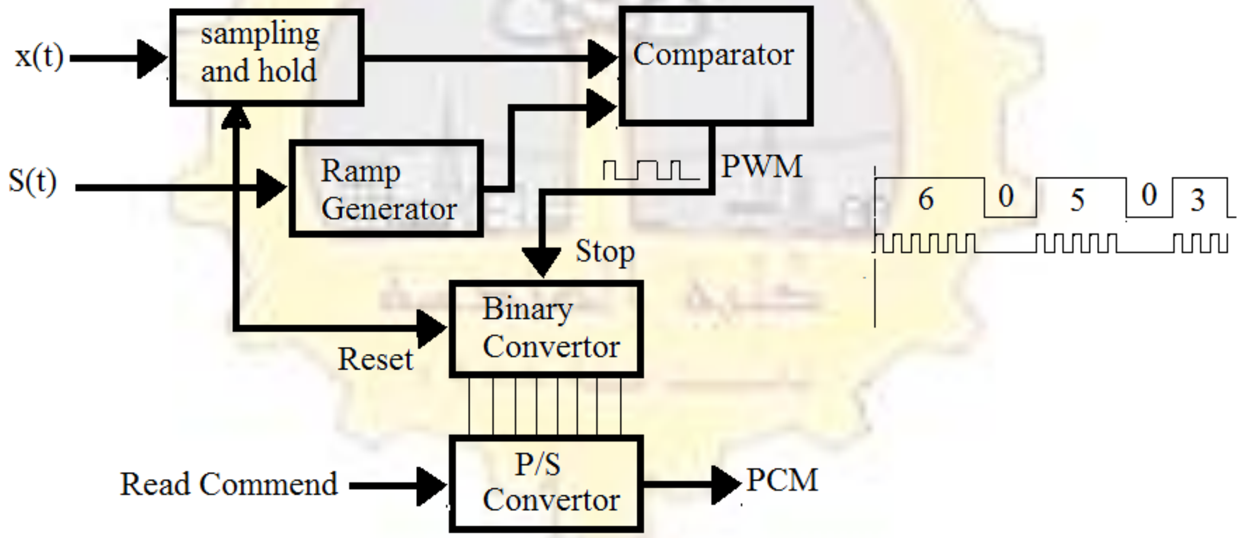
Line Coding



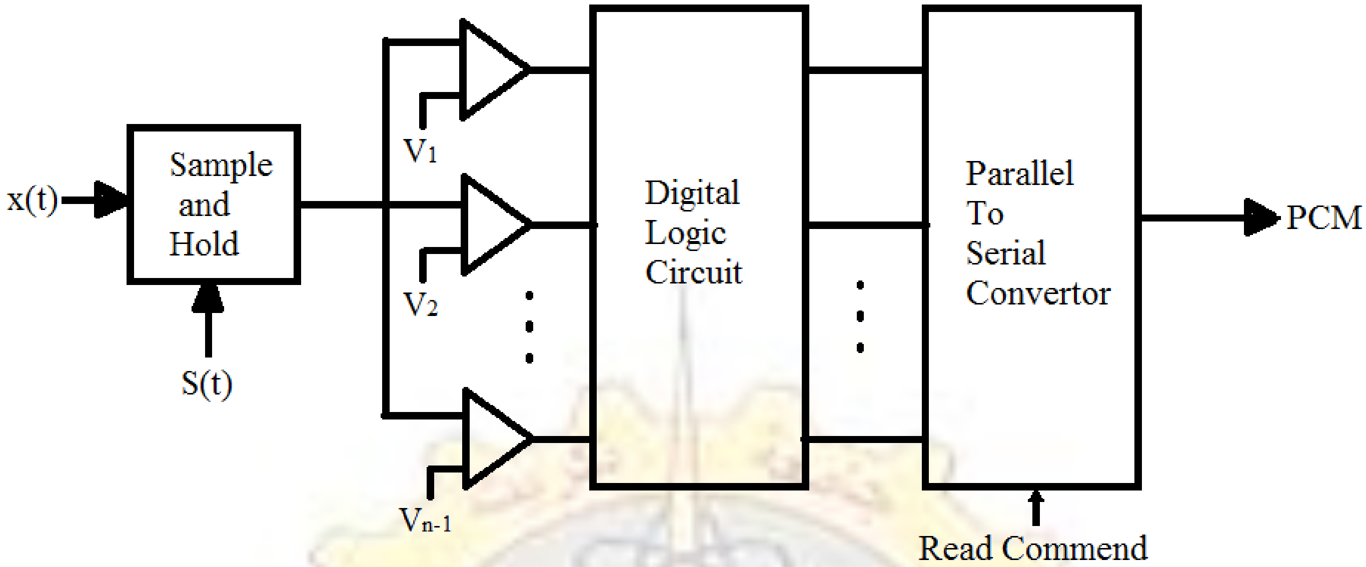
Quantization Noise



Generation of PCM
Using ramp encoder



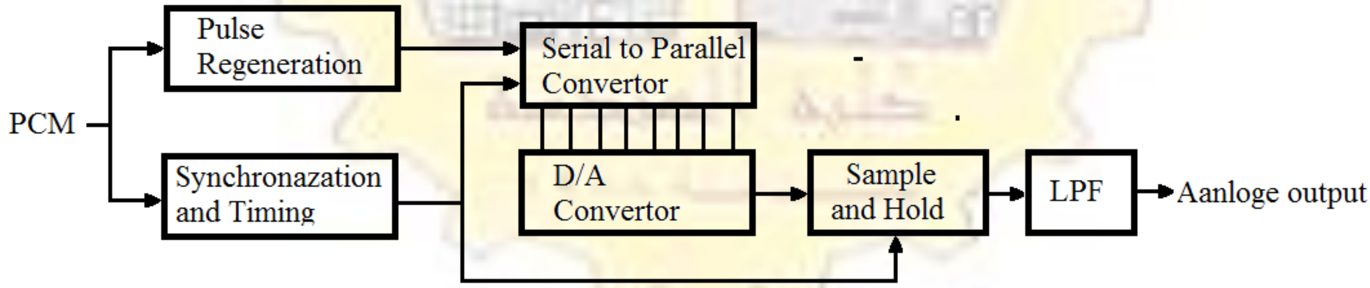
A parallel or flash encoder



Number of comparator equal to the number of quantization levels (L)

L= 2^n where n equal to the number of digital representing each encoded sample

Demodulation of PCM



Quantizing Noise:

Since the quantization process introduces some fluctuations about the true value, these fluctuations can be regarded as noise. As the number of quantization levels L increases, the quantization noise decreases.

$$N_q = \frac{V_q^2}{3L^2}$$

The output SNR:

$$\frac{S_o}{N_q} = \frac{\overline{V(t)^2}}{\frac{V_q^2}{3L^2}} = \frac{3L^2\,\overline{V(t)^2}}{V_q^2}$$

For tone modulation $\overline{V(t)^2} = \frac{A^2}{2}$, $V_q = A$

$$\frac{S_o}{N_q} = \frac{3L^2\,\frac{A^2}{2}}{A^2} = \frac{3L^2}{2}$$

$$\left(\frac{S_o}{N_q}\right)_{dB} = 10\log_{10}\frac{S_o}{N_q} = 10\log_{10}\frac{3L^2}{2} = 1.76 + 20\log_{10} L$$

Bandwidth requirement of PCM

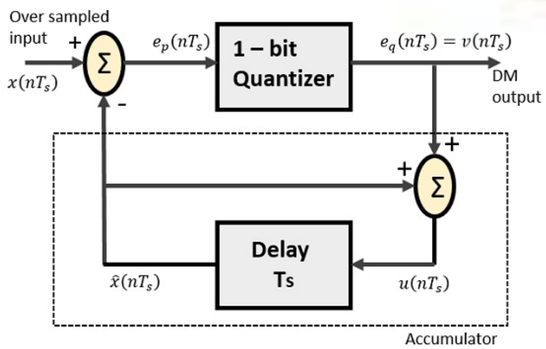
The information rate of PCM channel is nf_s bits/sec, if message bandwidth is f_{max} and the sampling rate is (≥ 2) then nf_s binary pulses must be transmitted per second.

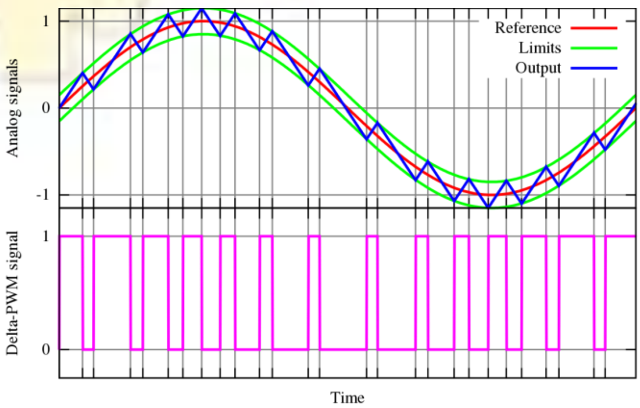
Assuming the PCM signal is is a low-pass signal of bandwidth , the required minimum sampling rate is $2BW_{PCM}$. Thus:

$BW_{PCM} = nf_s$

Delta modulation

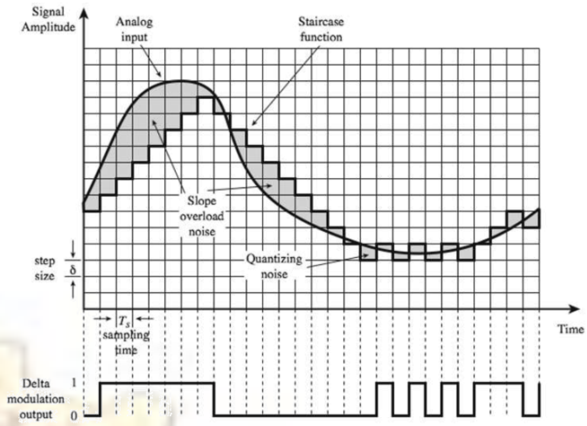
Delta modulation is a process mainly used in the transmission of voice information. It is a technique where analog-to-digital and digital-to-analog signal conversions are seen. Delta modulation (DM) is an easy way of DPCM. The delta demodulator comprises of a low pass filter, a summer, and a delay circuit. The predictor circuit is eliminated here and hence no assumed input is given to the demodulator.





Principle of the delta pulse-width modulation (PWM). The output signal (blue) is compared with the limits (green). The limits (green) correspond to the reference signal (red), offset by a given value. Every time the output signal reaches one of the limits, the PWM signal (purple) changes state.

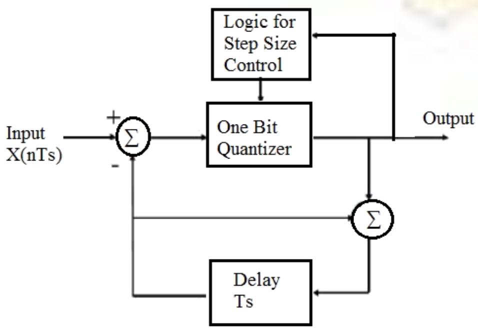
In the basic form, DM provides a stair case approximation to the over sampled version of the message signal, the difference between the input and the approximation is quantized into only two levels, nemely ±Δ, corresponding to positive and negative difference, respectively.

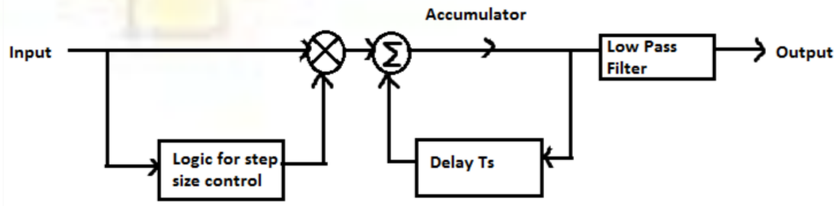


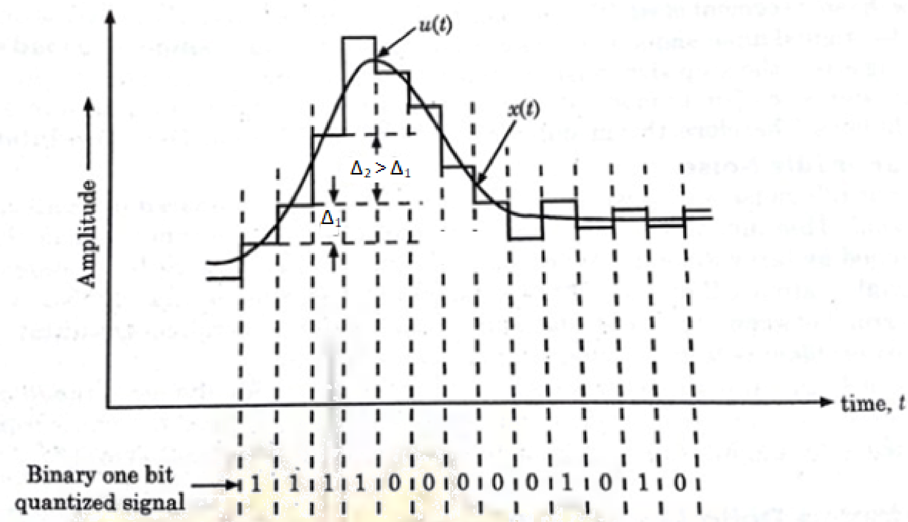
Adaptive Delta Modulation:

This modulation is the refined form of delta modulation. This method was introduced to solve the granular noise and slop overload error caused during delta modulation. This method is similar to DM except that the step size is variable according to the input signal in ADM whereas it is a fixed value in DM.

ADM, Modulation and demodulation:







Example:

Consider a PCM system, determine the maximum sampling period allowed to reconstructed the anolge signal from the digital sample without distrotion. Calculate the quantization noise due to the 4 bits A/D convertor. What happens to the quantization noise if the 5 bits A/D convertor where use? Compare the advantages and disadvantages of using a 5 bits A/D convertor or 4 bits A/D convertot in terms of the channel BW required.

Example:

Information signal is PCM using 8 levels quantization if the signal is given as 4cos(6πt) with sampling rate 12Hz. Sketch the sample signal and determine the binary representation (using NRZ) of each sample.

Example:

Information signal is PCM using 8 levels quantization if the signal is given as 16cos(4πt) with sampling rate 10Hz. Sketch the sample signal and determine the binary representation (using RZ) of each sample.

Example:

If the input message is [11100110100]. Represet the signal by return to zero (RZ), non-return to zero (NRZ), return to base (RB), alternate mark inversion (AMI) and manchester code.

Example:

A Three independent message signals of bandwidth 0.5KHz, 0.5KHz, 2KHz respectively. Each signal is sampled and quantized using PCM using q=8. The signals are to be transmitted using TDM scheme, determine: 1. Speed of the commutator. 2. BT of the TDM output.

Example:

In a binary PCM system, the output signal-to-quantization ratio is to be hold to a minimum of 40 dB. If the message is a single tone with f_m=4 kHz. Determine the number of required levels, and the corresponding output signal-to quantizing noise ratio and minimum required system bandwidth.

Delta modulation (DM) is a signal conversion method used for speech communication when quality is not a concern. In DM, the most basic kind of differential pulse-code modulation, the difference between two sequences is stored in n-bit data streams (DPCM).

Delta modulation reduces the delivered data to a 1-bit data stream. It has the following characteristics:

- To mimic the analog signal, a series of segments is employed.
- The next bits are determined by comparing the previous bits to each section of the expected signal.
- The change in information, i.e. an increase or decrease in signal amplitude from the previous sample, is sent.
- Whereas the no-change condition retains the modulated signal in the same 0 or 1 state as the sample provided.
- Delta modulation necessitates the use of resampling techniques to get a high signal-to-noise ratio, which implies that the analog signal is recorded at a rate many times faster than the Nyquist rate.

Advantages of Delta Modulation

Some of its main advantages are as follows:

- Delta modulation is a high-performance approach.
- This modulation technique is utilized when extreme circuit simplicity is critical and the usage of a high bit rate is permissible.
- This technology gets rid of the need for correcting circuits in radio design and error identification.
- The dynamic range is large because the different step size covers such a variation.
- Delta modulation is effective with narrower channel bandwidths.
- There is no indication of granular or slope overload.
- Slope error is reduced to a lesser degree.

Disadvantages of Delta Modulation

Some drawbacks include:

- Signals vary at a faster rate.
- Granular noise can be observed.

Adaptive Delta Modulation in Digital Communications

Adaptive delta modulation is a type of delta modulation that is more sophisticated. Because of the disadvantages of delta modulation, an adaptive delta modulation approach was devised. When the modulating signal has a steep slope, we need a more significant step size, and when the message has a moderate slope, we need a small step size. Delta Modulation approaches overlook this level of information. As a result, we must have control over the step size based on our needs to acquire the sample output promptly. This is the fundamental idea of adaptive Delta Modulation.

Block Diagram of Adaptive Delta Modulation

Summer, a quantizer, a delay circuit, and a logic circuit for adjusting step size comprise the transmitter circuit. The baseband signal X is delivered into the circuit (nTs). The feedback circuit in the transmitter is called an Integrator. The integrator creates the preceding sample's staircase estimate.

The difference e(nTs) between the current sample and the staircase approximation of the previous sample is determined in the summer circuit. This error signal is sent to the quantizer, which generates a quantized value. The step size control block determines whether the following approximation's step size is large or low based on the quantized value. As output, the quantized signal is provided.

Demodulation takes place at the receiver end. There are two pieces to the receiver. The first component is the control of the step size. The received signal is then transmitted via a logic step size control block, where the step size is calculated from each incoming bit. The size of the step is determined by the current and prior input. The accumulator circuit in the second half of the receiver recreates the staircase signal. This waveform is then sent through a low pass filter, which smoothes it out and recreates the original signal.

Advantages of Adaptive Delta Modulation

Some of the benefits of the adaptive modulation process are as follows:

- The slope error in delta modulation is reduced through adaptive delta modulation.

- It employs a low pass filter to reduce quantized noise during demodulation.
- This modulation solves the slope overload problem and granular error in delta modulation. As a result, the signal-to-noise ratio of this modulation is higher than that of delta modulation.
- This modulation enables resilient performance in the presence of bit mistakes. In radio design, it decreases the requirement for error detection and correction circuits.
- Adaptive delta modulation has a wide dynamic range since the changing step size covers a wide range of values.

Disadvantages of Adaptive Delta Modulation

- Quantization noise can be observed

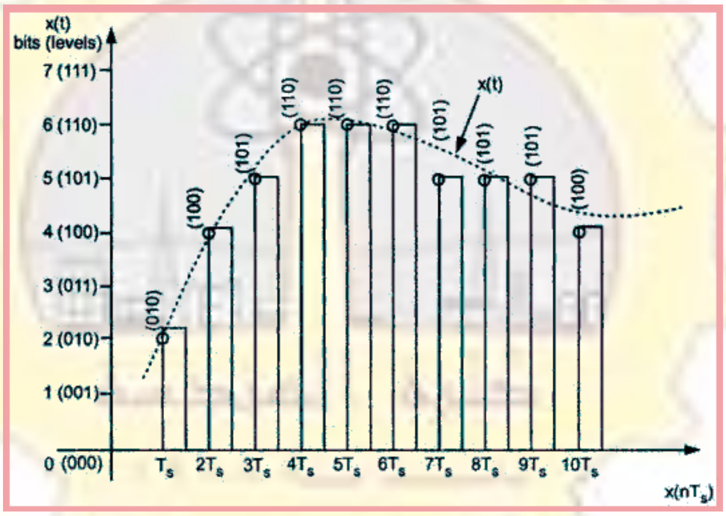
Practical Applications of Adaptive Delta Modulation

The following are some of the uses of the adaptive modulation method

- This modulation is utilized in systems that demand higher wireless voice quality as well as faster data transmission.
- This modulation method is utilized in television signal transmission.
- In speech coding, this modulation approach is utilized.
- NASA also uses this modulation as a standard for all communications between mission control and spacecraft.
- Motorola's SECURENET digital radio product line employs 12kbit/sec Adaptive Delta Modulation.
- The military use a 16 to 32 kbit/sec modulation technique in TRI-TAC digital telephones to deliver voice detection grade audio in deployed regions.

Differential Pulse Code Modulation Working and Application

Differential pulse code modulation is a technique of analog to digital signal conversion. This technique samples the analog signal and then quantizes the difference between the sampled value and its predicted value, then encodes the signal to form a digital value. Before going to discuss differential pulse code modulation, we have to know the demerits of PCM (Pulse Code Modulation). The samples of a signal are highly correlated with each other. The signal's value from the present sample to the next sample does not differ by a large amount. The adjacent samples of the signal carry the same information with a small difference. When these samples are encoded by the standard PCM system, the resulting encoded signal contains some redundant information bits. The below figure illustrates this.



The above figure shows a continuing time signal x(t) denoted by a dotted line. This signal is sampled by flat-top sampling at intervals Ts, 2Ts, 3Ts…nTs. The sampling frequency is selected to be higher than the Nyquist rate. These samples are encoded by using 3-bit (7 levels) PCM. The samples are quantized to the nearest digital level as shown by small circles in the above figure. The encoded binary value of each sample is written on the top of the samples. Just observe the above figure at samples taken at 4Ts, 5Ts, and 6Ts are encoded to the same value of (110). This information can be carried only by one sample value. But three samples are carrying the same information means redundant.

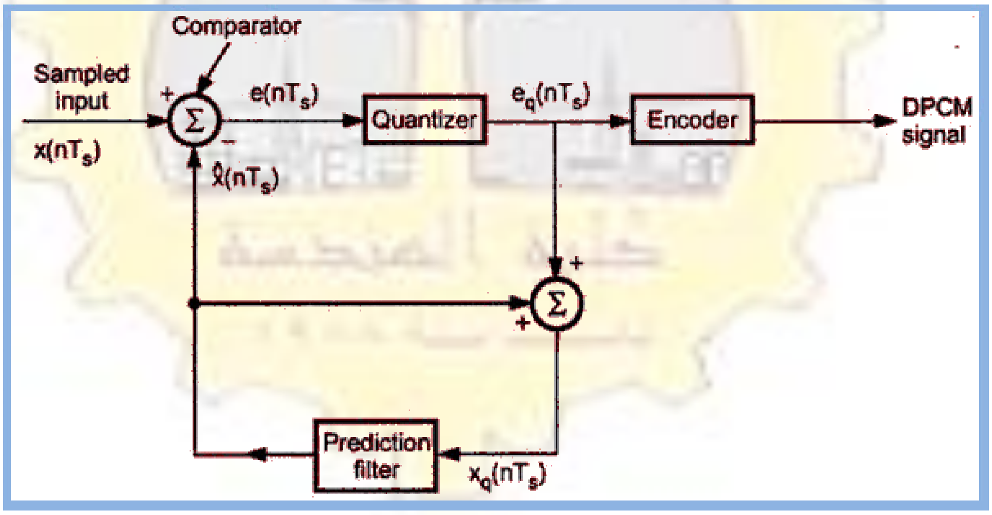
Now let consider the samples at 9Ts and 10Ts, the difference between these samples only due to the last bit and first two bits are redundant since they do not change. So in order to make the process this redundant information and to have a better output. It is an intelligent decision to take a predicted sampled value, assumed from its previous output and summarise them with the quantized values. Such a process is called a Differential PCM (DPCM) technique.

Principle of Differential Pulse Code Modulation

If the redundancy is reduced, then the overall bitrate will decrease and the number of bits required to transmit one sample will also reduce. This type of digital pulse modulation technique is called differential pulse code modulation. The DPCM works on the principle of prediction. The value of the present sample is predicted from the previous samples. The prediction may not be exact, but it is very close to the actual sample value.

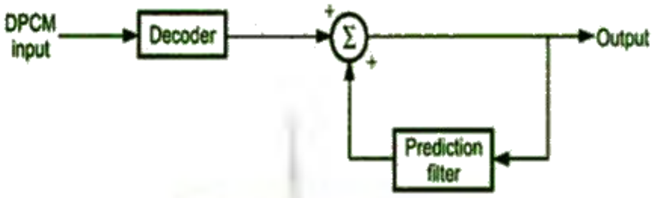
Differential Pulse Code Modulation Transmitter

The below figure shows the DPCM transmitter. The transmitter consists of a comparator, quantizer, prediction filter, and an encoder.



Differential Pulse Code Modulation Receiver

In order to reconstruct the received digital signal, the DPCM receiver (shown in the below figure) consists of a decoder and prediction filter. In the absenteeism of noise, the encoded receiver input will be the same as the encoded transmitter output.



As we discussed above, the predictor undertakes a value, based on the previous outputs. The input given to the decoder is processed and that output is summed up with the output of the predictor, to obtain better output. That means here first of all the decoder will reconstruct the quantized form of the original signal. Therefore the signal at the receiver differs from the actual signal by quantization error q(nTs), which is introduced permanently in the reconstructed signal.