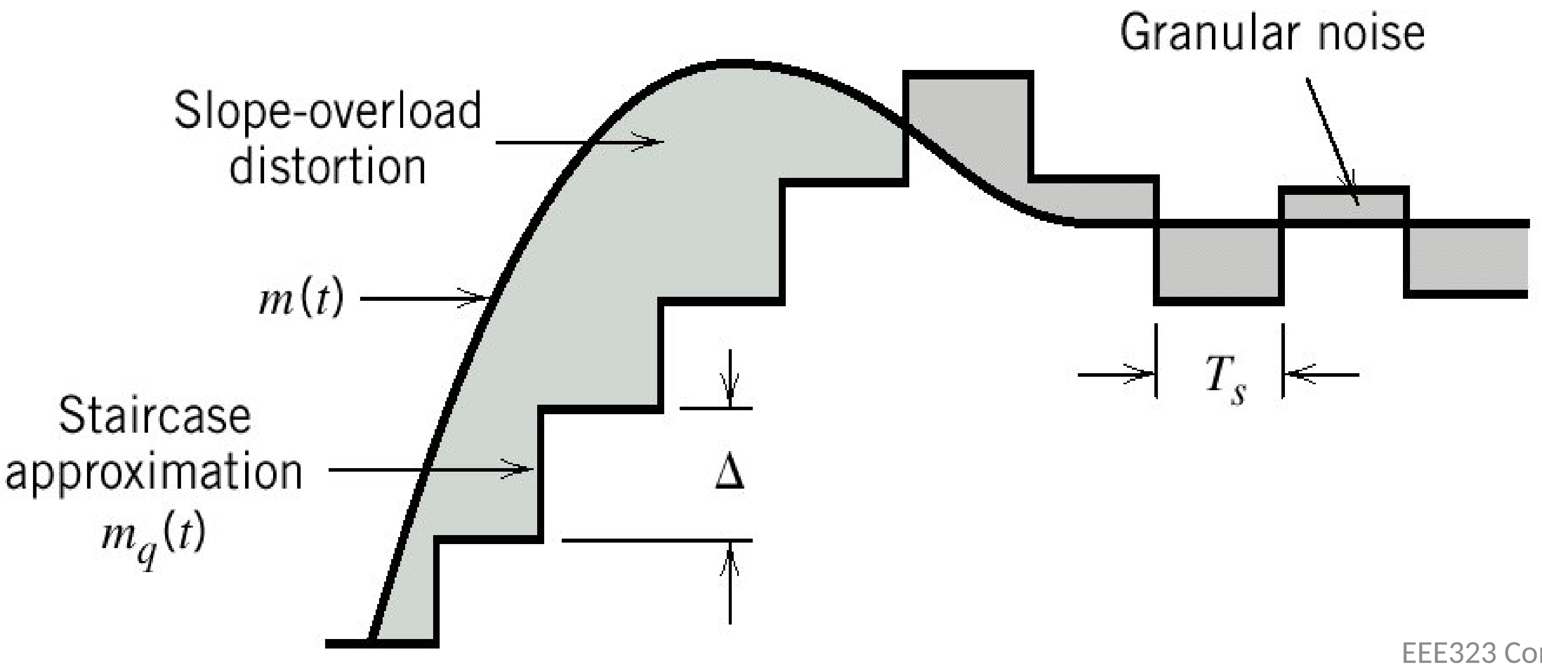
Delta Modulation Problems

•**Slope overload distortion** is due to the fact that the staircase approximation $m_q(t)$ can't follow closely the actual curve of the message signal $m(t)$. In contrast to slope-overload distortion, **granular noise** occurs when Δ is too large relative to the local slope characteristics of $m(t)$. granular noise is similar to quantization noise in PCM.

•**It seems that a large Δ is needed for rapid variations of $m(t)$ to reduce the slope-overload distortion and a small Δ is needed for slowly varying $m(t)$ to reduce the granular noise. The optimum Δ can only be a compromise between the two cases.**

•To satisfy both cases, an adaptive DM is needed, where the step size Δ can be adjusted in accordance with the input signal $m(t)$.



Slope overload

Due to the input analog signal amplitude changes faster than the speed of the modulator. If the input signal **is rising or falling with a slope larger than Δ/Ts**, where ***Ts*** is the sampling time, we say that the sampler is suffering from Slope Overload.

- To minimize : the product of the sampling step size and the sampling rate must be equal to or larger than the rate of change of the amplitude of the input analog signal. Thus, the condition to avoid slop overload in DM is

$$\frac{\boldsymbol{\Delta}}{\mathbf{Ts}} \geq \left|\frac{d\,m(t)}{dt}\right|_{max}$$

From above equation we observe that if step size is increased, slope overload distortion can be avoided. Also note that the sampling rate is $\boldsymbol{f_s} = \frac{\mathbf{1}}{\mathbf{Ts}}$.

Granular noise

A problem with DM is that the output signal must always either increase by a step, or decrease by a step, and cannot stay at a single value. Due to the difference between step size and sampled voltage.

Granular noise power for a sinusoidal signal is given by

$$N_g = \frac{\Delta^2}{3} \times \frac{f_m}{f_s}$$

To minimize Granular noise : increase the sampling rate, decrease the step size of modulator. The SNR for DM can be written as

$$SNR = \frac{S}{N_g}$$

Granular noise similar to that of PCM system, but Slope Overload is a new idea because it is a differential signal being encoded. This is a trade-off and there should be an optimal value

Example: In a single integration DM scheme, a tone signal is sampled at a rate of 64 kHz.

$$m(t) = Cos(2\pi \times 3500\, t)$$

1- Determine the minimum value of step size to avoid slope overload and the granular noise power and SNR

Solution : Given : f_s = 64 kHz; $m(t) = A_m \cos(2\pi f_m t)$; $A_m = 1$ Volt

$$\frac{\Delta}{Ts} \geq \left|\frac{d\,m(t)}{dt}\right|_{max} ; \qquad \left|\frac{d\,m(t)}{dt}\right|_{max} = A_m \times 2\pi f_m$$

Minimum step size to avoid slope overload is

$$\Delta \geq \frac{A_m \times 2\pi f_m)}{fs} \geq \frac{1 \times 2\pi \times 3.5)}{64} \geq \mathbf{0.3436\ V;}$$

Granular noise power $N_g = \frac{\Delta^2}{3} \times \frac{f_m}{f_s} ==$ 2.15 ◊ 10– 3 W

As the signal is sinusoidal, the normalized output signal power is given by S$=\frac{A^2}{2} = \mathbf{0.5}$

$$SNR = \frac{S}{N_g} = \frac{0.5}{2.15 \times 10^{-3}} = 232.3 \text{ or } 23.66 \text{ dB}$$

Delta Modulation

Example: Find the maximum amplitude of a 1 KHz sinusoidal signal input to a delta modulator that will prevent slope overload, when the sampling rate is 10,000 samples/sec and the step size is $\Delta = 0.1$.

Solution : Given : f_s = 10, 000; f_m = **1** 000 Hz and $\Delta = 0.1$.

$$f_s = \frac{1}{\mathbf{Ts}}$$

$$\frac{\Delta}{\mathbf{Ts}} \geq \left|\frac{d\ m(t)}{dt}\right|_{max} ; \qquad \left|\frac{d\ m(t)}{dt}\right|_{max} = A_m \times 2\ \pi\ f_m$$

$$\Delta \times f_s \geq A_m \times 2\ \pi\ f_m$$

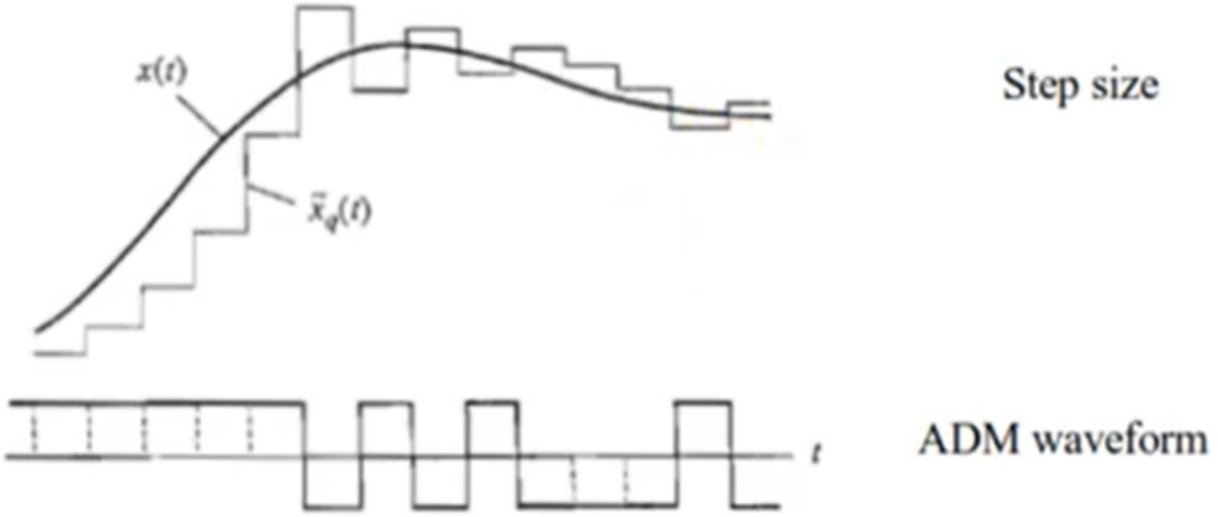
$$0.1 \times 10{,}000 \geq A_m \times 2\ \pi \times 1000$$

$$A_{m(max)} = \frac{1000}{2\pi \times 1000} = \frac{1}{2\pi}$$

Adaptive Delta Modulation (ADM)

The DM discussed so far suffers from one serious disadvantage. The dynamic range of amplitudes is too small because of the threshold and overload effects discussed earlier. To address this problem, some type of signal compression is necessary. In DM, a suitable method appears to be the adaptation of the step value according to the level of the input signal derivative.

This is called Adaptive Delta Modulation (ADM) in which the step size is automatically varied, depending on the level of the derivative of the input analog signal. The receiver must be able to adapt step sizes in the same manner as the transmitter.



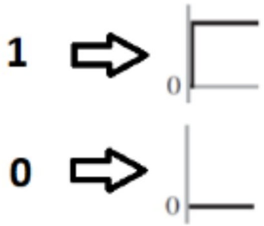
Comparison of PCM and DM Techniques

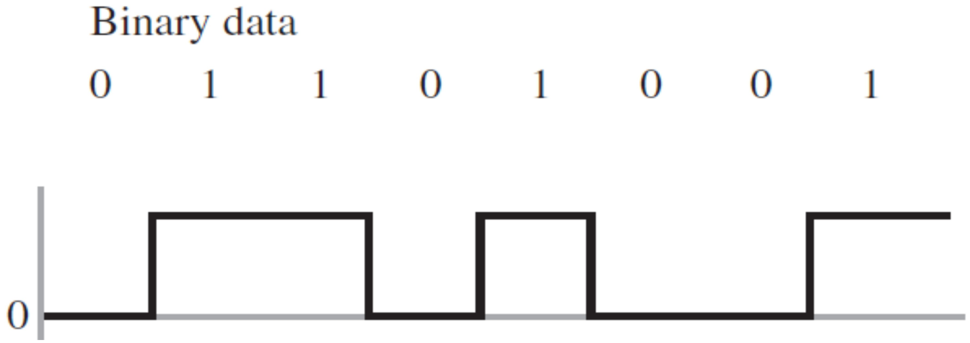
S. No.	Parameter	PCM	DPCM	DM	ADM
1.	Number of bits per sample	4/8/16 bits	More than one bit but less than PCM	One bit	One bit
2.	Number of levels	Depends on number of bits	Fixed number of levels	Two levels	Two levels
3.	Step size	Fixed or variable	Fixed or variable	Fixed	Variable
4.	Transmission bandwidth	More bandwidth needed	Lesser than PCM	Lowest	Lowest
5.	Feedback	Does not exist	Exists	Exists	Exists
6.	Quantization noise/distortion	Quantization noise depends on number of bits	Quantization noise & slope overload	slope overload & granular noise	Quantization noise only
7.	Complexity of implementation	Complex	Simple	Simple	Simple

Line Codes

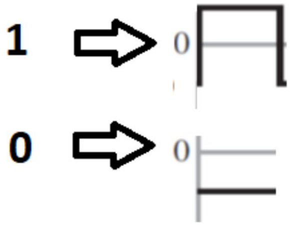
In reality, PCM, DM, and DPCM represent different strategies for source encoding, whereby an analog signal is converted into digital form. However, all above methods share a common feature: once a binary sequence of 1s and 0s is produced, a ***line code*** is needed for electrical representation of that binary sequence.
There are several line codes that can be used for this representation, as summarized here: The waveforms shown are drawn for the binary data stream **01101001.**

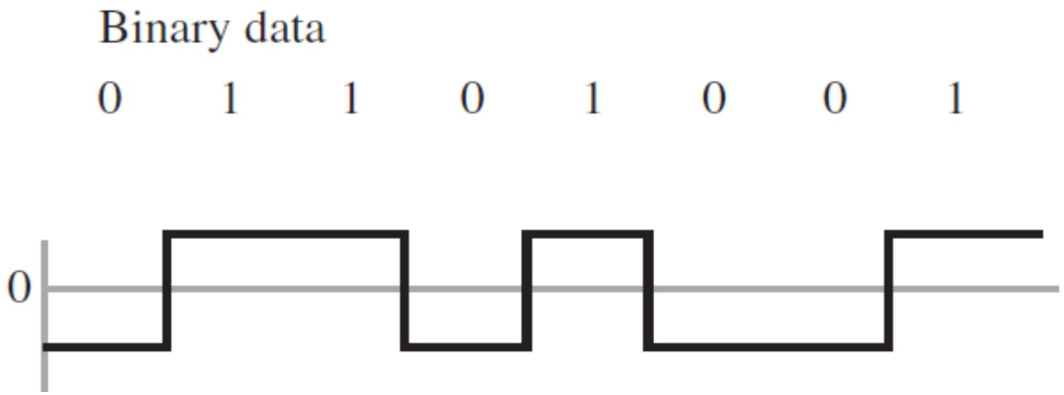
1. *On–off signaling*, in which symbol 1 is represented by transmitting a pulse of constant amplitude for the duration of the symbol, and symbol 0 is represented by switching off the pulse, as in Fig below.



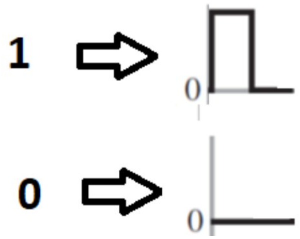


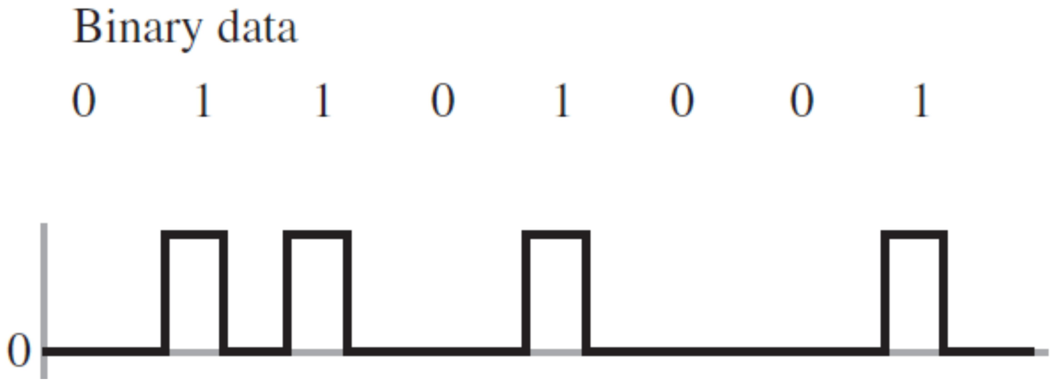
2. *Nonreturn-to-zero (NRZ) signaling*, in which symbols 1 and 0 are represented by pulses of equal positive and negative amplitudes, as shown in Fig. below.



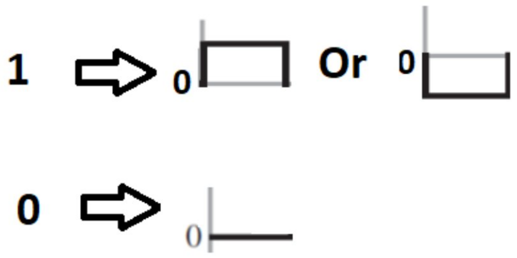


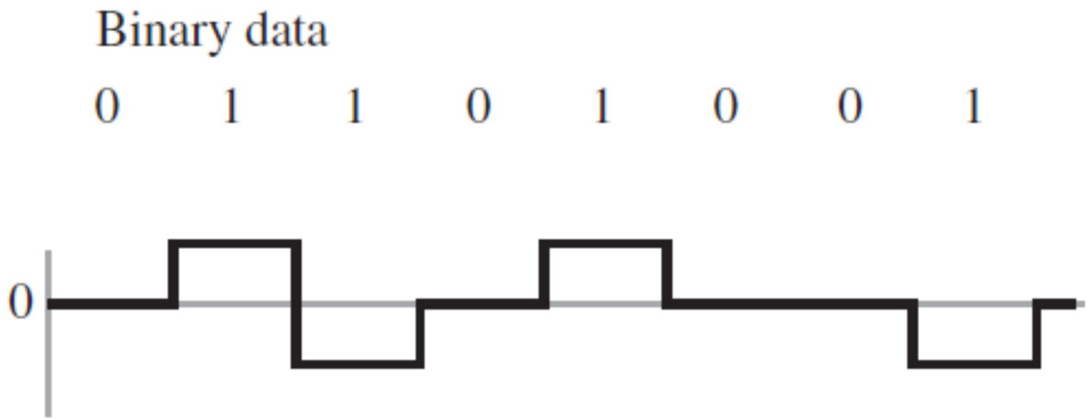
3. *Return-to-zero (RZ) signaling*, in which symbol 1 is represented by a positive rectangular pulse of half-symbol width, and symbol 0 is represented by transmitting *no* pulse, as illustrated in Fig hereunder.



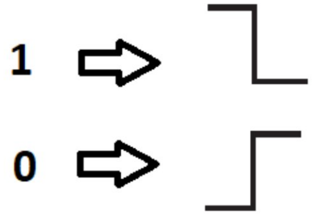


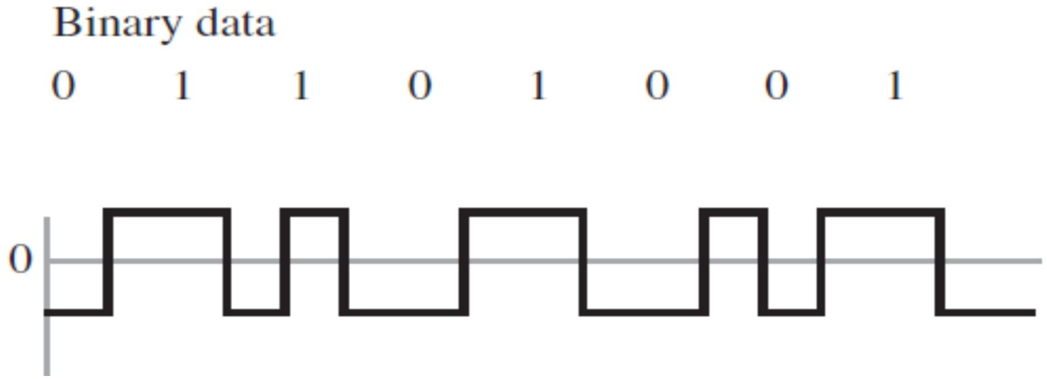
4. *Bipolar return-to-zero (BRZ) signaling*, which uses three amplitude levels as indicated in figure below . Specifically, positive and negative pulses of equal amplitude are used alternately for symbol 1, and no pulse is always used for symbol 0. A useful property of BRZ signaling is that the power spectrum of the transmitted signal has no dc component and relatively insignificant low-frequency components for the case when symbols 1 and 0 occur with equal probability.





5. *Split-phase (Manchester code)*, which is illustrated in below Fig. In this method of signaling, symbol 1 is represented by a positive pulse followed by a negative pulse, with both pulses being of equal amplitude and half-symbol width. For symbol 0, the polarities of these two pulses are reversed. The Manchester code suppresses the dc component and has relatively insignificant low-frequency components, regardless of the signal statistics.





6. *Differential encoding*, in which the information is encoded in terms of signal transitions, as illustrated in Fig. In the example of the binary PCM signal shown in the figure, a transition is used to designate symbol 0, whereas no transition is used to designate symbol 1. It is apparent that a differentially encoded signal may be inverted without affecting its interpretation. The original binary information is recovered by comparing the polarity of adjacent symbols to establish whether or not a transition has occurred. Note that differential encoding requires the use of a *reference bit*.