

ADAPTIVE DELTA MODULATION (ADM)

INTRODUCTION

ADM

- To overcome the quantization errors due to slope overload and granular noise,

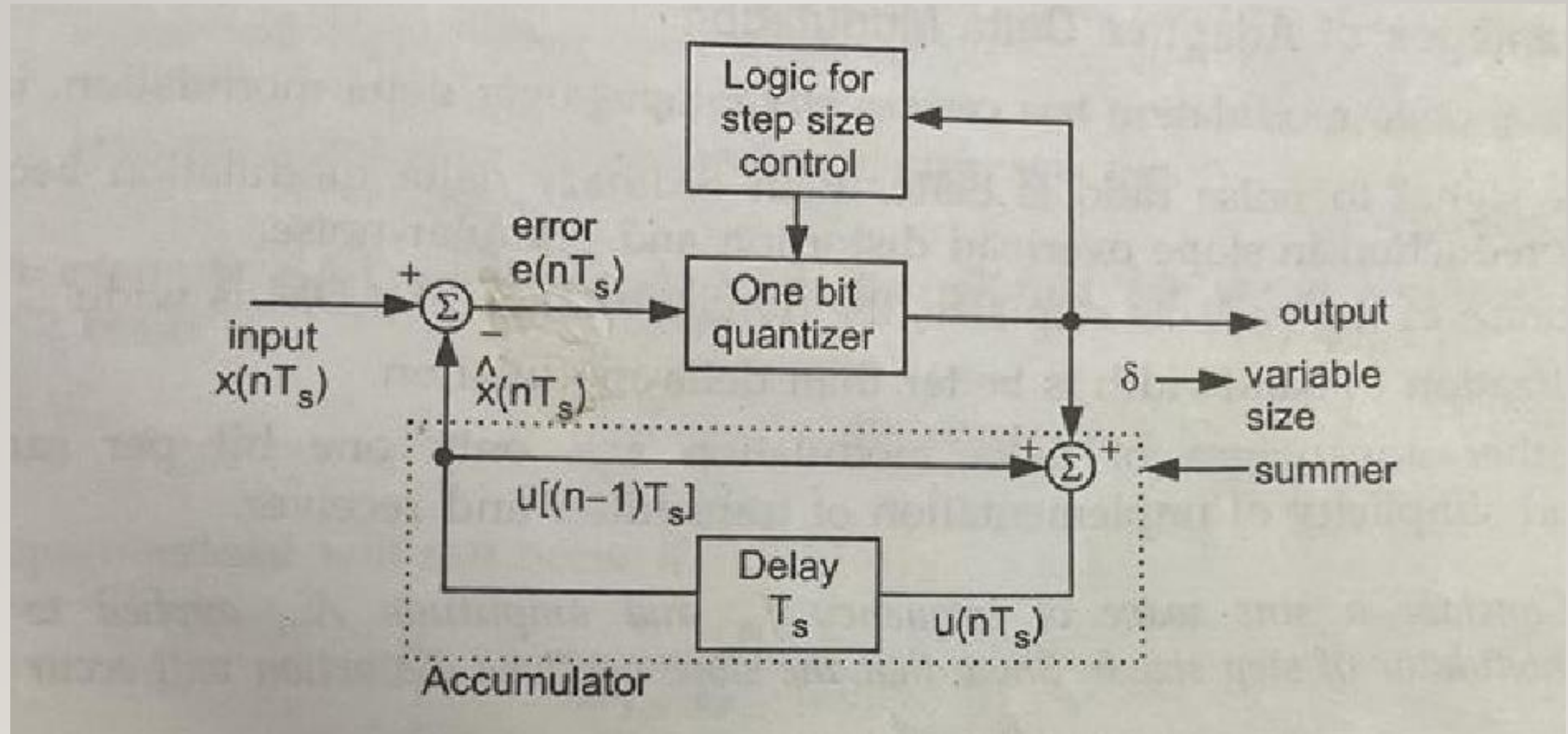
The step size is δ is made adaptive to variations in the input signal $x(t)$.

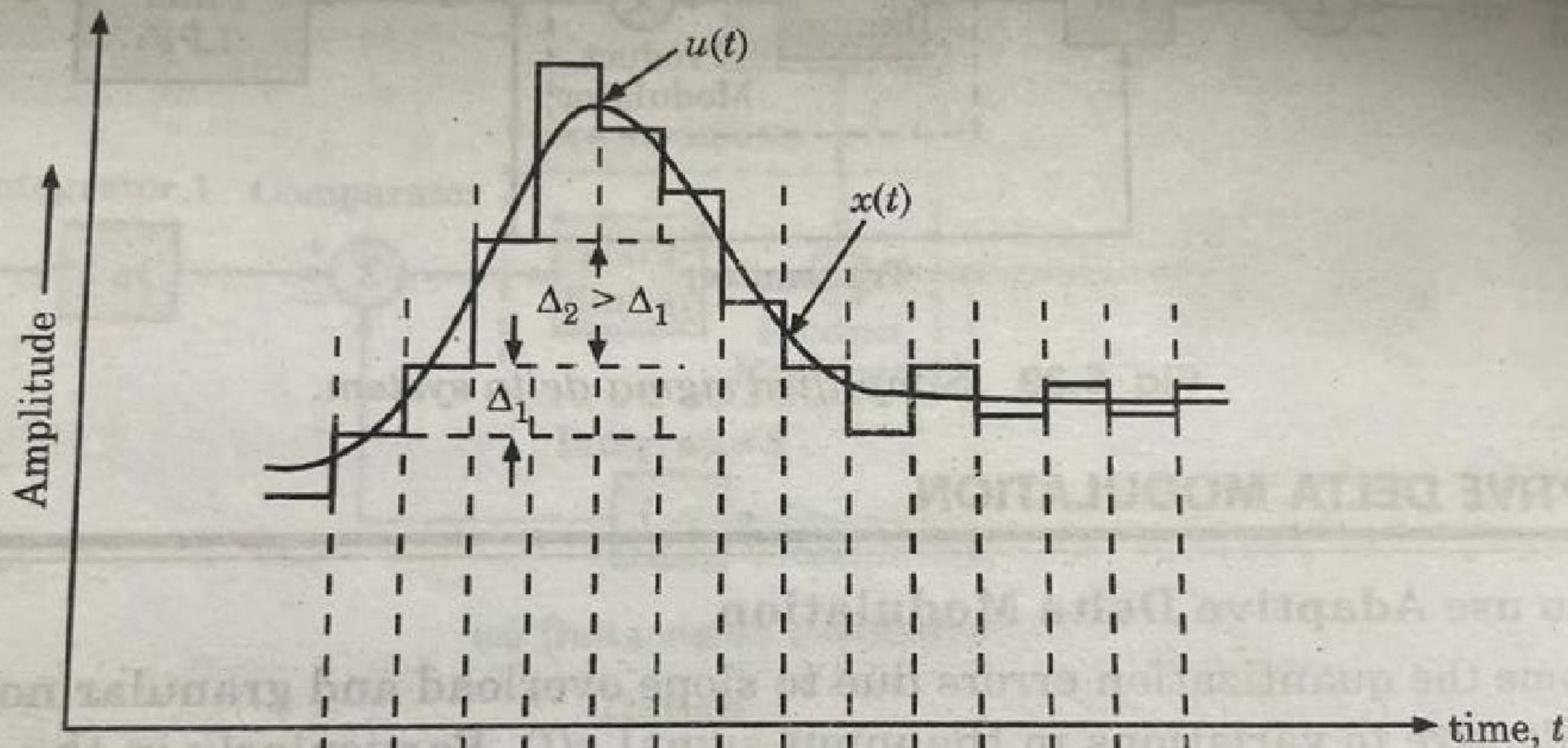
- ❑ Practically in the steep segment of the signal $x(t)$, the step size is increased.
- ❑ While, when the input signal is varying slowly, the step size is reduced.
- ❑ Then the method is called Adaptive Delta Modulation (ADM)
- ❑ The adaptive delta modulators can take continuous changes in step size or discrete changes in step size.

ADM TRANSMITTER

- The logic for step size control(**in the transmitter**) is added and it used to increases or decreases step size according to certain rule depending one one bit quantizer output.
- For example if one bit quantizer output is high(1), then step size may be doubled for next sample. If one bit quantizer output is low, then step size may be reduced by one step
- Fig.in next slide, shows waveforms of adaptive delta modulator and sequence of bits transmitted.

ADAPTIVE DELTA MODULATION - TRANSMITTER





Binary one bit
quantized signal

1 1 1 1 0 0 0 0 0 1 0 1 0

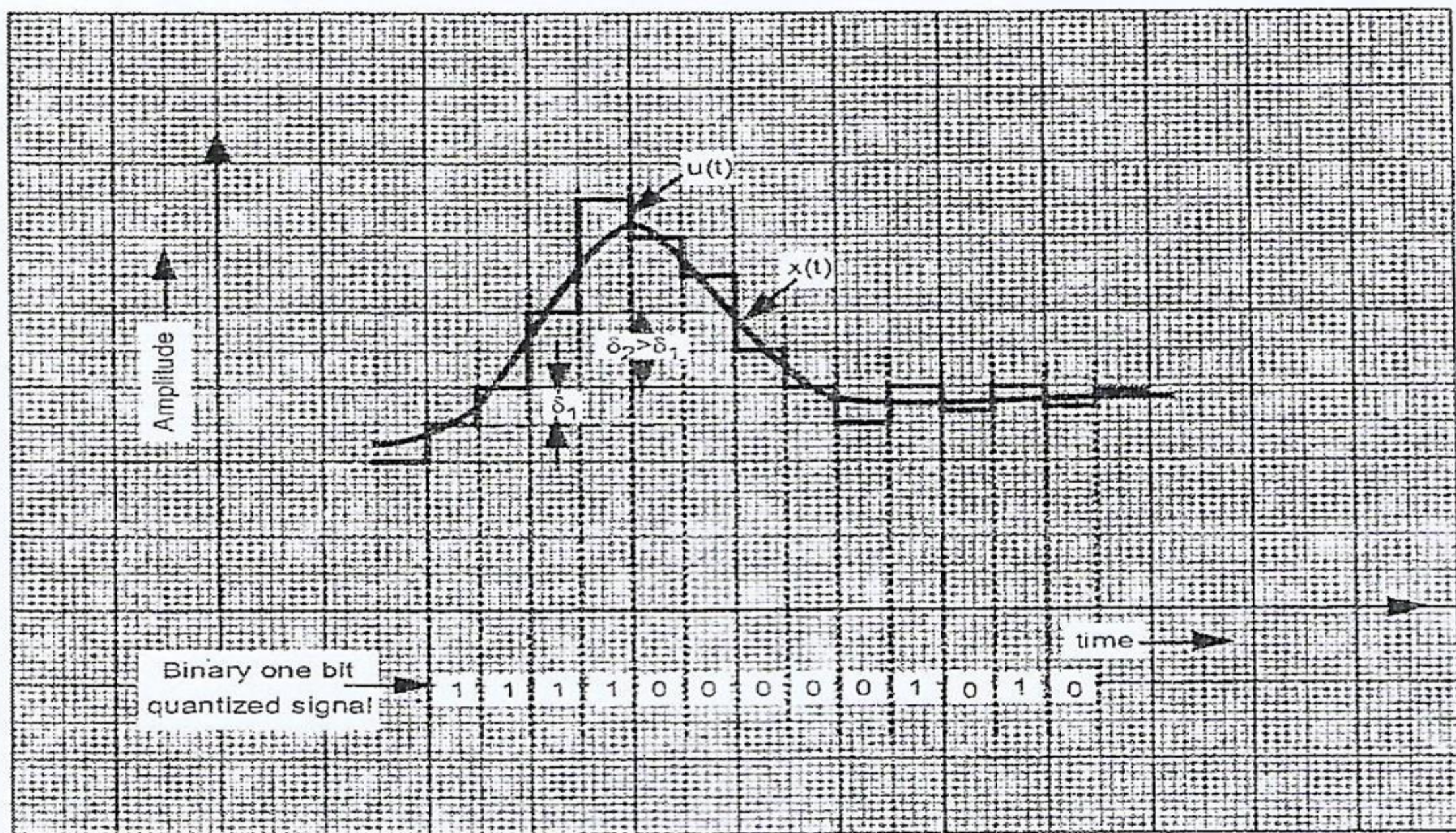


Fig. 6.3.2 Waveforms of adaptive delta modulation

ADM RECEIVER

- In the receiver of Adaptive Delta Modulator, the first part ~~generates the step size from each incoming bit.~~
- Exactly the same process is followed as that in transmitter. The previous input and present input decides the step size.
- It is then given to an accumulator which builds up staircase waveform.
- The low-pass filter then smoothens output staircase waveform to reconstruct the smooth signal.

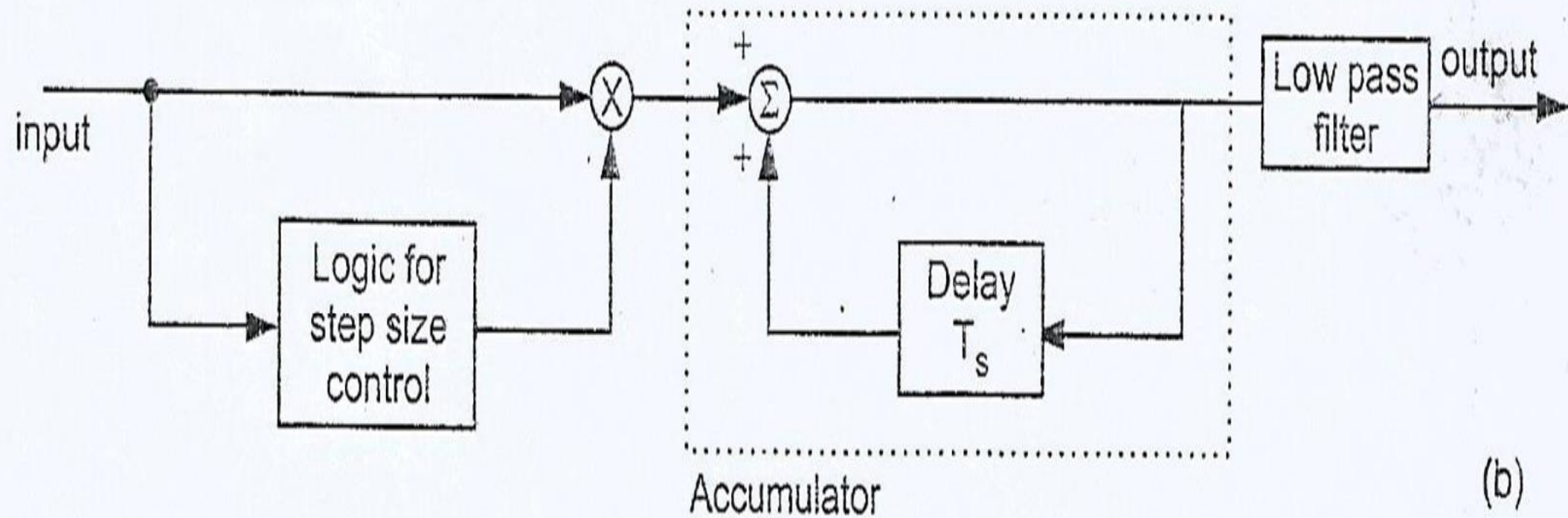


Fig. 6.3.1 Adaptive delta modulator (a) Transmitter (b) Receiver

ADVANTAGES OF ADAPTIVE DELTA MODULATOR

- ❑ The signal to noise ratio is better than ordinary Delta Modulator because of the reduction in Slope overload distortion and Granular noise.
- ❑ Because of the variable step size, the dynamic range of ADM is wide
- ❑ Utilization of bandwidth is better than Delta Modulation
- ❑ Only one bit per sample is required (same as in DM)
- ❑ Simplicity of implementation of transmitter and receiver (same as in DM)

Ex.6.3.1 Consider a sine wave of frequency f_m and amplitude A_m applied to a delta modulator of step size δ . Show that the slope overload distortion will occur if

$$A_m > \frac{\delta}{2\pi f_m T_s}$$

where T_s is the sampling period.

SOLUTION

- The input signal $x(t)$ to the modulator is sinusoidal signal, i.e. $x(t) = A_m \sin(2\pi F_m t)$

The slope of any signal is its first derivative with respect to time, and the slope is maximum when the 1st derivative is maximum.

$$\therefore \text{slope of input signal } x(t) = \frac{d}{dt} x(t) = \frac{d}{dt} | A_m \sin(2\pi F_m t) | = A_m \cdot 2\pi F_m \cdot \cos(\pi F_m t)$$

and this slope is maximum when $(A_m \cdot 2\pi F_m \cdot \cos(\pi F_m t))$ is maximum ,

this happens when the term $(\cos(2\pi F_m t))$ is equal to its maximum value, i.e. = 1

$$\therefore \text{slope maximum of } x(t) = A_m \cdot 2\pi F_m$$

$$\text{the slope maximum of Delta Modulator} = \frac{\text{Step size } \delta}{\text{sampling period}} = \frac{\delta}{T_s}$$

Slope overload distortion will take place if slope of input signal is greater than slope of Delta

$$\text{Modulator, i.e. } A_m \cdot 2\pi F_m > \frac{\delta}{T_s} \quad \text{or} \quad A_m > \frac{\delta}{2\pi F_m T_s}$$

Ex.6.3.2 A delta modulator system is designed to operate at five times the Nyquist rate for a signal with 3 kHz bandwidth. Determine the maximum amplitude of a 2 kHz input sinusoid for which the delta modulator does not have slope over load. Quantizing step size is 250 mV. Derive the formula that you use.

[Dec-95, 6-Marks]

Sol. : In example 6.3.1 we have derived the relation for slope overload distortion which will occur if,

$$A_m > \frac{\delta}{2\pi f_m T_s} \quad \text{By equation 6.3.1} \quad \dots (6.3.3)$$

$\therefore$ Slope overload will not occur if,

$$A_m \leq \frac{\delta}{2\pi f_m T_s} \quad \dots (6.3.4)$$

The maximum frequency in the signal is,

$$W = 3 \text{ kHz}$$

$$\therefore \text{Nyquist rate} = 2W = 2 \times 3 \text{ kHz} = 6 \text{ kHz}$$

$$\text{Sampling frequency} = 5 \text{ times Nyquist rate}$$

$$f_s = 5 \times 6 \text{ kHz}$$

$$= 30 \text{ kHz}$$

$$\therefore \text{Sampling interval } T_s = \frac{1}{f_s} = \frac{1}{30 \times 10^3}$$

$$\text{Step size } \delta = 250 \text{ mV} = 250 \times 10^{-3}$$

EE

Activate Windows

Go to Settings to activate Windows.

$$= 0.25 \text{ V}$$

Given that

$$f_m = 2 \text{ kHz} = 2 \times 10^3 \text{ Hz}$$

$\therefore$ Putting these values in equation 6.3.4

$$A_m \leq \frac{0.25}{2\pi \times 2 \times 10^3 \times \frac{1}{30 \times 10^3}}$$

$\therefore$

$$A_m \leq 0.6 \text{ volts}$$

Ex. 6.3.4 Find the signal amplitude for minimum quantization error in a delta modulation system if step size is 1 volts having repetition period 1 ms. The information signal operates at 100 Hz.

Sol. : The quantization error is minimum when slope overload distortion is absent. Then the quantization error is due to granular noise only. We know that the slope overload distortion is absent if,

$$A_m \leq \frac{\delta}{2\pi f_m T_s}$$

Here

A_m is the signal amplitude

δ is step size. Given 1V

f_m is signal frequency. Given 100 Hz

T_s is sampling duration. Given 1 ms.

Hence signal amplitude becomes,

$$A_m \leq \frac{1}{2\pi \times 100 \times 1 \times 10^{-3}}$$

i.e.

$$A_m \leq 1.6 \text{ V}$$

That is, the signal amplitude should be less than 1.6 volts to have minimum quantization error.

Ex. 6.3.5 Derive an expression for signal to quantization noise power ratio for delta modulation. Assume that no slope overload distortion exists.

Sol. : (i) To obtain signal power :

In example 6.3.1 we have derived that slope overload distortion will not occur if

$$A_m \leq \frac{\delta}{2\pi f_m T_s}$$

Here A_m is peak amplitude of sinusoidal signal

δ is the step size

f_m is the signal frequency and

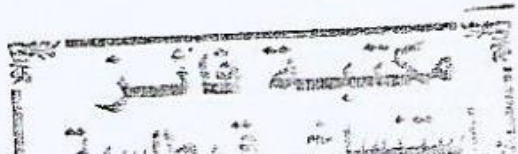
T_s is the sampling period.

From above equation, the maximum signal amplitude will be,

$$A_m = \frac{\delta}{2\pi f_m T_s} \quad \dots (6.3.6)$$

Signal power is given as,

$$P = \frac{V^2}{R}$$



Here V is the rms value of the signal. Here $V = \frac{A_m}{\sqrt{2}}$. Hence above equation

becomes,

$$P = \left(\frac{A_m}{\sqrt{2}} \right)^2 / R$$

Normalized signal power is obtained by taking $R = 1$. Hence,

$$P = \frac{A_m^2}{2}$$

Putting for A_m from equation 6.3.6,

$$P = \frac{\delta^2}{8\pi^2 f_m^2 T_s^2} \quad \dots (6.3.7)$$

Ex. 6.3.7 A DM system is tested with a 10 kHz sinusoidal signal with 1V peak to peak at the input. It is sampled at 10 times the Nyquist rate.

(i) What is the step size required to prevent slope overload ?

(ii) What is the corresponding SNR ?

Sol. : Given data

$$\text{Signal frequency, } f_m = 10 \text{ kHz}$$

$$\text{Signal amplitude, } A_m = \frac{1V}{2} = 0.5V$$

$$\text{Nyquist rate} = 2 \times f_m = 2 \times 10 \text{ kHz} = 20 \text{ kHz}$$

$$\begin{aligned} \text{Sampling frequency, } f_s &= 10 \times \text{Nyquist rate} \\ &= 10 \times 20 \text{ kHz} = 200 \text{ kHz} \end{aligned}$$

$$\therefore T_s = \frac{1}{f_s} = \frac{1}{200 \times 10^3} \text{ sec}$$

(i) To obtain step size

From equation 6.3.4 we have,

$$A_m \leq \frac{\delta}{2\pi f_m T_s}$$

Under this condition slope overload will not occur. From above equation step size will be,

$$\delta \geq 2\pi f_m T_s A_m$$

Putting values in above equation,

$$\begin{aligned}\delta &\geq 2\pi \times 10,000 \times \frac{1}{200 \times 10^3} \times 0.5 \\ &\geq 0.157 \text{ V}\end{aligned}$$

Thus the step size greater than 157 mV will prevent the slope overload.

(ii) To obtain signal to noise ratio

Signal to noise ratio of delta modulation system is given by equation 6.3.12 as,

$$\frac{S}{N} = \frac{3}{8\pi^2 W f_m^2 T_s^3}$$

This is post filtered signal to noise ratio. In this example value of 'W' is not given. Hence we will calculate signal to noise ratio from equation 6.3.7 and equation 6.3.10 as,

$$\begin{aligned}\frac{S}{N} &= \frac{\frac{\delta^2}{8\pi^2 f_m^2 T_s^2}}{\frac{3}{8\pi^2 f_m^2 T_s^2}} \\ &= \frac{\delta^2}{3}\end{aligned}$$

Putting values in above equation.

$$\begin{aligned}\frac{S}{N} &= \frac{3}{8\pi^2 \times (10,000)^2 \times \frac{1}{(200 \times 10^3)^2}} \\ &= 15.2 = 11.8 \text{ dB.}\end{aligned}$$

- Ex. 6.3.10** In a single integration DM scheme, the voice signal is sampled at a rate of 64 kHz. The maximum signal amplitude is 1 volt, voice signal bandwidth is 3.5 kHz.
- Determine the minimum value of step size to avoid slope overload.
 - Determine granular noise N_o
 - Assuming signal to be sinusoidal, calculate signal power and signal to noise ratio.
 - Assuming that noise signal amplitude is uniformly distributed in the range $(-1, 1)$ determine the signal power and signal to noise ratio.

[Dec-2000, 8 Marks
Dec-98, 8 Marks]

Sol. : The given data is,

$$f_s = 64 \text{ kHz}, \quad A_m = 1 \text{ V}, \quad W = 3.5 \text{ kHz}.$$

i) To obtain step size

Slope overload will not occur if,

$$A_m < \frac{\delta}{2\pi f_m T_s}$$

Putting values in above equation with

$$T_s = \frac{1}{64 \times 10^3} \text{ and } f_m = 3.5 \text{ kHz}$$

$$1 \leq \frac{\delta}{2\pi \times 3500 \times \frac{1}{64 \times 10^3}}$$

$\therefore$

$$\delta \geq 0.3436 \text{ volts}$$

ii) To obtain granular noise power

Noise power is given by equation 6.3.11 as,

$$\begin{aligned} N_o &= \frac{W T_s \delta^2}{3} = \frac{W \delta^2}{3 f_s} \\ &= \frac{3.5 \times 10^3 \times (0.3436)^2}{3 \times 64 \times 10^3} \\ &= 2.15 \text{ mW} \end{aligned}$$

iii) To obtain S/N ratio

Amplitude of the signal is 1V. For sinusoidal signal, the signal power will be

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$$P = \frac{A_m^2}{2} = \frac{1}{2} \text{ W}$$

Hence signal to noise ratio will be,

$$\begin{aligned} \frac{S}{N} &= \frac{\text{Signal power}}{\text{Noise power}} \\ &= \frac{1/2}{2.15 \times 10^{-3}} = 232.3 \end{aligned}$$

$$\text{or } \left(\frac{S}{N} \right)_{dB} = 10 \log_{10} \frac{S}{N} = 23.66 \text{ dB}$$

COMPARISON BETWEEN PCM, DM, AND ADM

No	Parameter of comparison	PCM	DM	ADM
1	Number of bits	It can use 4,8,16 bit per sample	It uses only one bit for one sample	It uses only one bit for one sample
2	Levels and	The number of levels(q) depend on number of bits, Level size is kept fixed	Step size is kept fixed and can not be varied	According to the signal variation, step size varies (i.e. adapted)
3	Quantization error and distortion	Quantization error depends on number of levels used	Slope overload distortion and granular noise are present.	Quantization noise is present but other errors are absent.
4	Transmission bandwidth	Highest bandwidth is required since number of bits are high	Lowest bandwidth is required	Lowest bandwidth is required
5	feedback	There is no feedback in transmitter or receiver	Feedback exists in transmitter	Feedback exists
6	Complexity of implementation	System complex	Simple	Simple