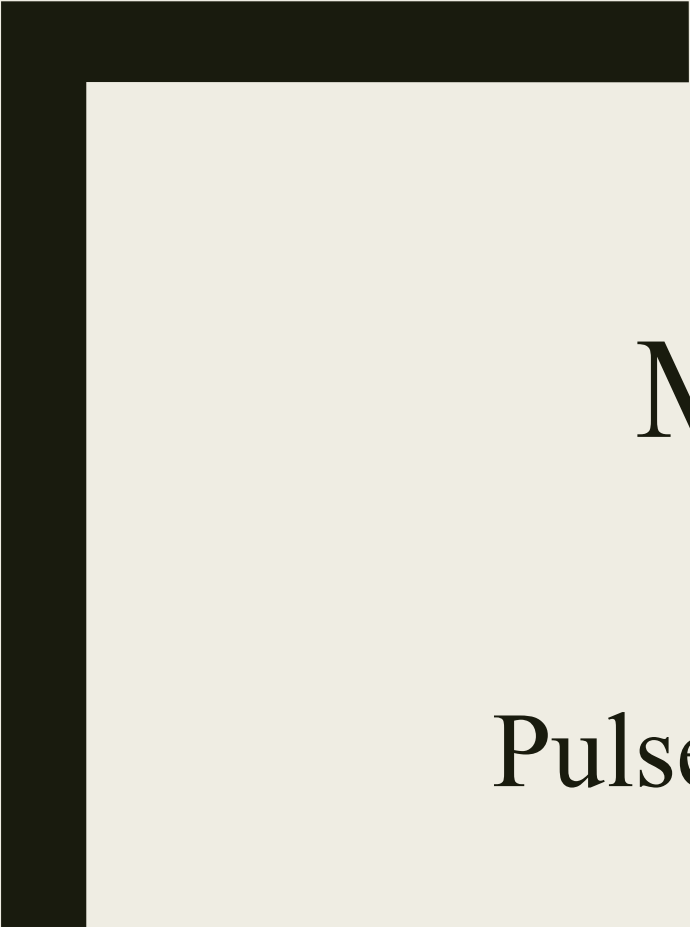




PULSE CODE MODULATION

Pulse code generator/receiver



PCM generator

- In PCM generator the signal $x(t)$ is bandlimited to 'W', the sample and hold circuit then samples the signal at rate $F_s \geq 2W$
- The output of this circuit is called $x(nT_s)$ which are discrete in time analog (continuous) in amplitude
- A q- level quantizer compares input $x(nT_s)$ with its fixed digital levels, it then assigns any one of the digital level to $x(nT_s)$ which results in minimum distortion or error.
- The error is called *quantization* error
- The quantizer output is digital level and called $X_q(nT_s)$

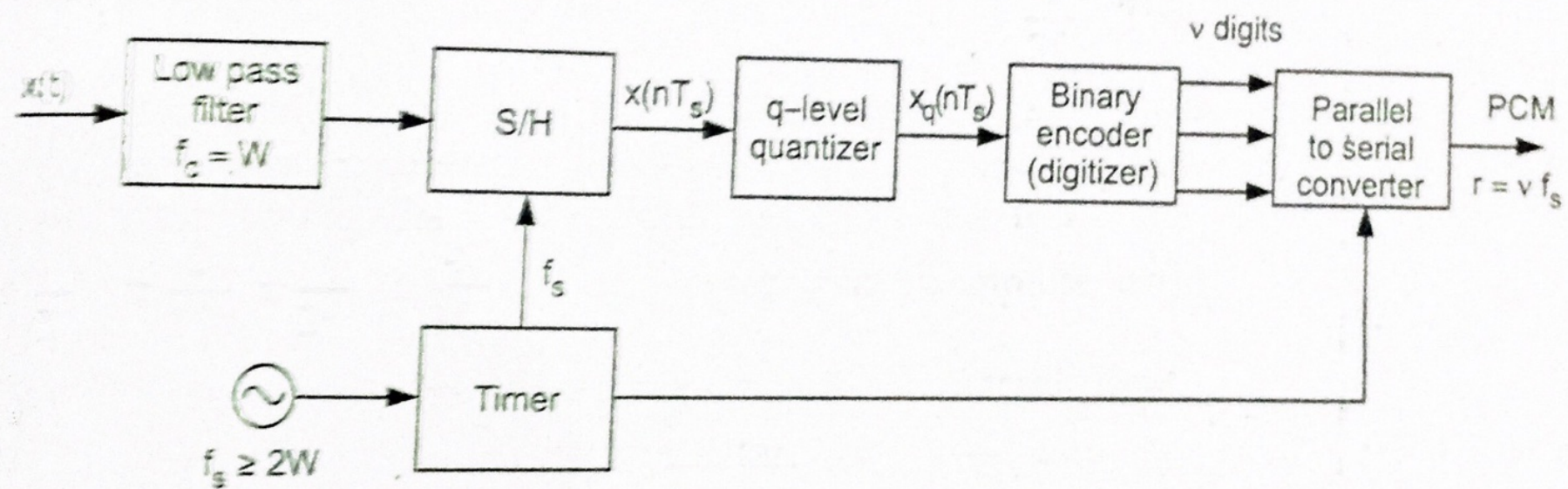


Fig. 6.1.1 PCM generator

? How quantization take place

- If δ is the step size i.e. the distance in amplitude between level and another ■
- If the input to quantizer $x(nT_s)$ varies from -4δ to $+4\delta$, i.e. it can take any value between -4δ to $+4\delta$
- Hence the fixed digital levels available at : $\pm \frac{\delta}{2}$, $\pm 3 \frac{\delta}{2}$, $\pm 5 \frac{\delta}{2}$, and $\pm 7 \frac{\delta}{2}$
- If $x(nT_s) = 4\delta$ then $x_q(nT_s) = 7 \frac{\delta}{2}$
- If $x(nT_s) = -4\delta$ then $x_q(nT_s) = -7 \frac{\delta}{2}$
- It can see that the maximum quantization error ε will be $\pm \frac{\delta}{2}$

Transfer characteristic of a quantizer and variation of quantization error with input

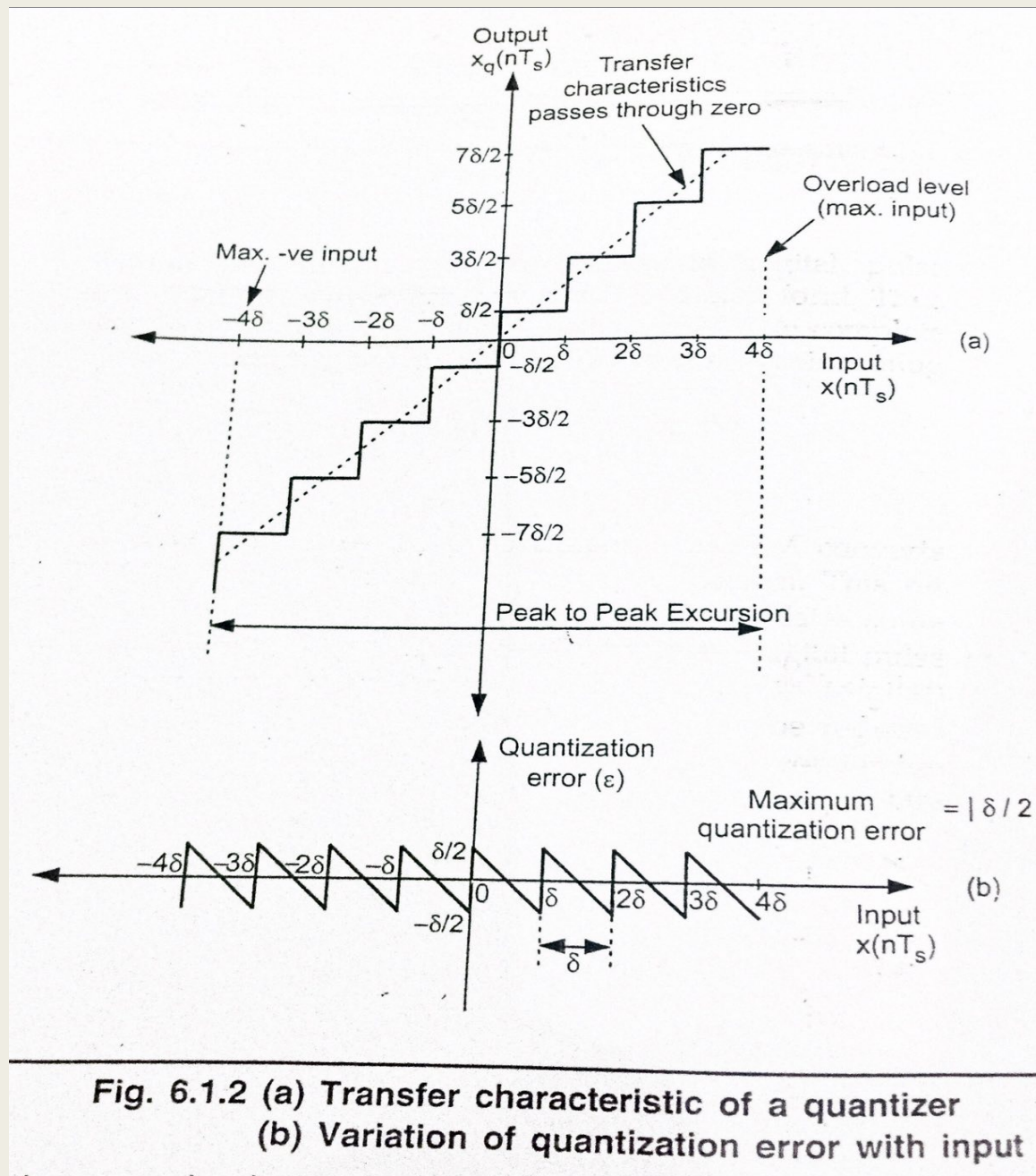


Fig. 6.1.2 (a) Transfer characteristic of a quantizer
(b) Variation of quantization error with input

continue

- Quantization error is given as $\epsilon = X_q(nT_s) - X(nT_s)$ ■
- When $X_q(nT_s) = 0$, quantizer will assign any one of the nearest binary levels i.e. either $\frac{\delta}{2}$ or $-\frac{\delta}{2}$ is assigned, then the quantization error will be,

$$\epsilon = X_q(nT_s) - X(nT_s) = \frac{\delta}{2} - 0 = \frac{\delta}{2}$$

$$\text{for } \delta < x(nT_s) < 2\delta ; X_q(nT_s) = 3\frac{\delta}{2}$$

$$\text{or } -\delta < x(nT_s) < -2\delta ; X_q(nT_s) = -3\frac{\delta}{2}$$

Hence the maximum quantization error is : $\pm \frac{\delta}{2}$ or

$$\text{Maximum quantization error} = \epsilon_{\max} = \left\lceil \frac{\delta}{2} \right\rceil$$

Signaling rate r

- Let the quantizer use ' v ' number of binary digits to represent each quantization level, then the number of levels ' q ' permissible for such number of binary ' v '

- $$q = 2^v$$

- here q represents total number of digital levels of q - levels quantizer

- and each sample is converted to ' v ' bits

- The total number of samples per second equal to sampling frequency= F_s

- Hence the number of bits per second= signaling rate r

- = number of samples per second (F_s) x number of bits per sample(v)

- Signaling rate in PCM: $r = v F_s$

Transmission Bandwidth B_T

- Sampling theorem impose $F_s \geq 2W$
- Bandwidth needed for PCM transmission will be given by half of the signaling rate
- Transmission Bandwidth of PCM,
$$B_T \geq \frac{1}{2} r$$
$$\geq \frac{1}{2} (v F_s)$$
$$\geq 2 W$$

PCM Receiver

- The receiver block diagram show that the first unit is the regenerator unit which reshapes the received signal and removes the noise.
- The second unit is to convert the serial digits to parallel digital words for each sample.
- Then the signal is converted to its analog value $X_q(nT_s)$ by sample and hold unit
- Then the signal is passed through lowpass reconstruction filter to get the original signal.
- It is impossible to reconstruct original signal $x(t)$ because of permanent quantization error introduced during quantization at the transmitter.
- The quantization error can be reduced by increasing the binary comparison levels which leads to increase binary digits(bits) per sample v .
- But increasing bits v increases the signaling rate r as well as transmission bandwidth
- Therefore the choice of these parameters is made, such that noise due to quantization error is in tolerable limits.

PCM receiver and reconstruction waveform

