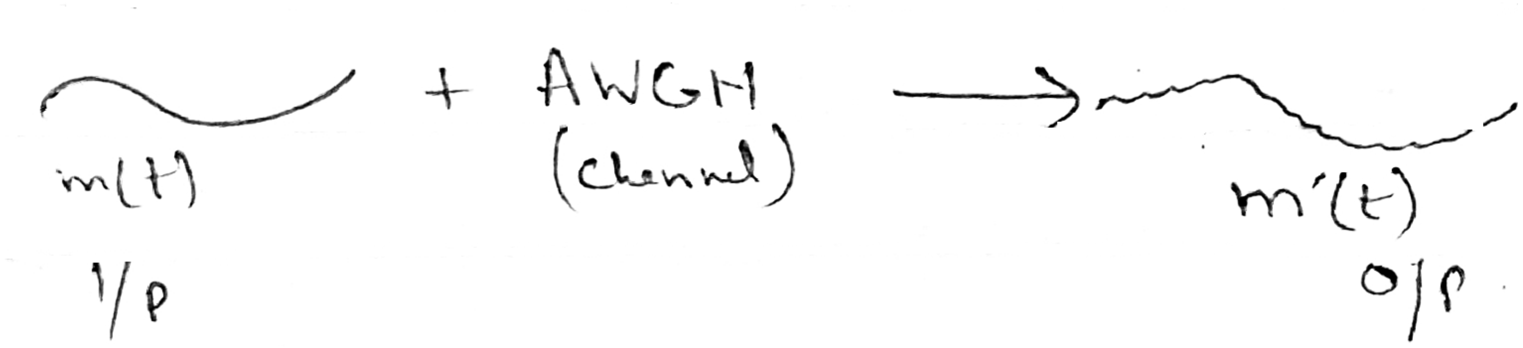
Communication Systems
EE-351

Lectures 31 to 33

Digital Transmission:

- Transmission of digital signals through channel.

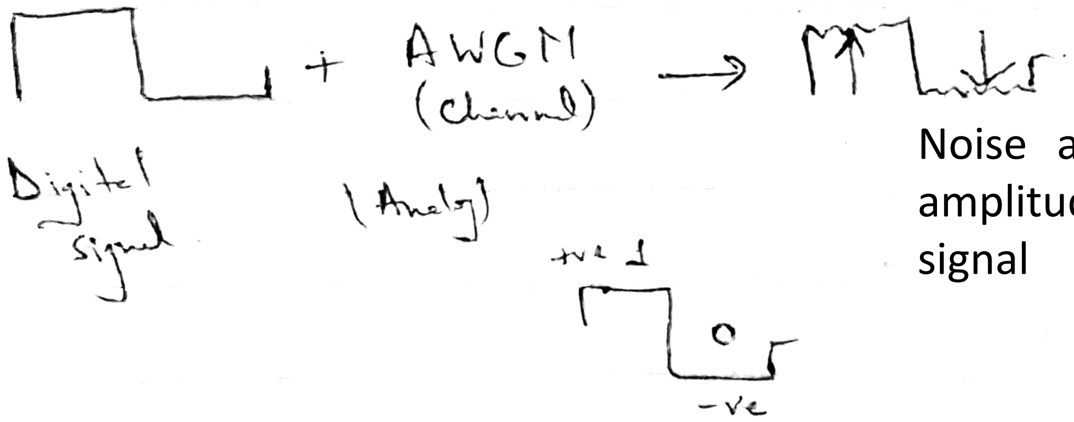


Need to know exact value at each point for reconstruction

- Signal can be easily added with noise in the channel since both are analog in nature.

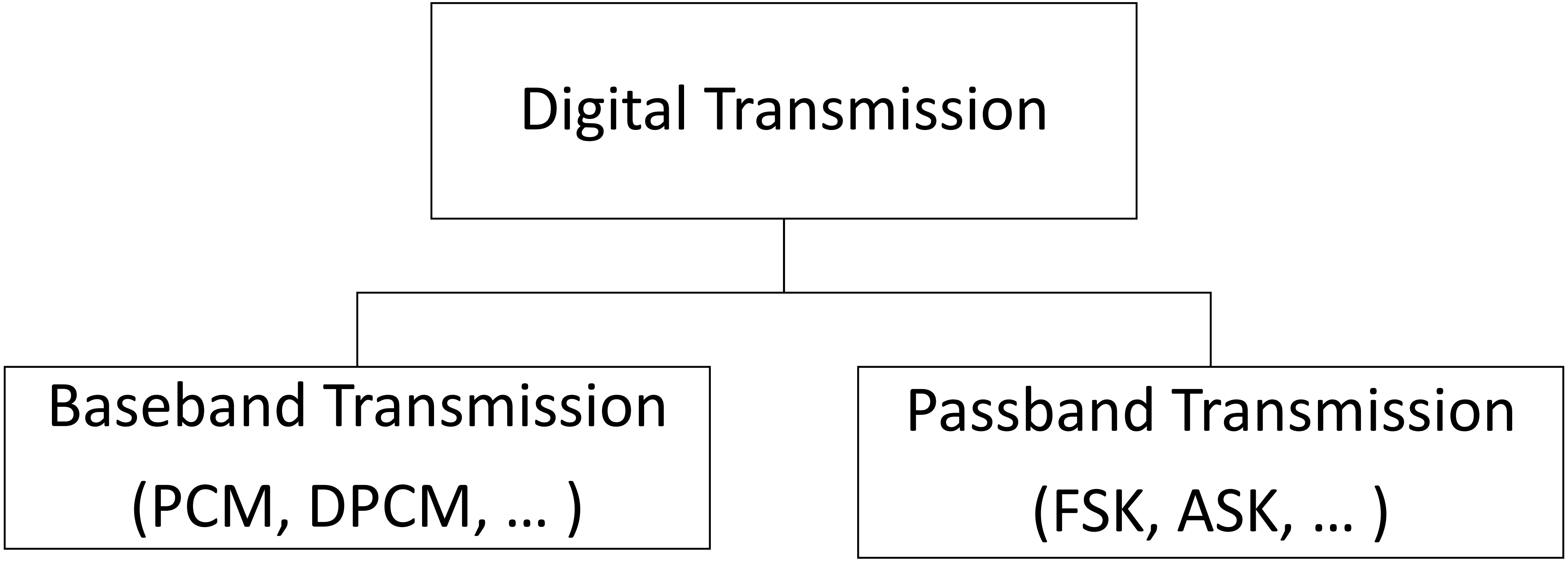
Digital Transmission:

- Exact signal can be generated even if it is tampered by Gaussian noise.

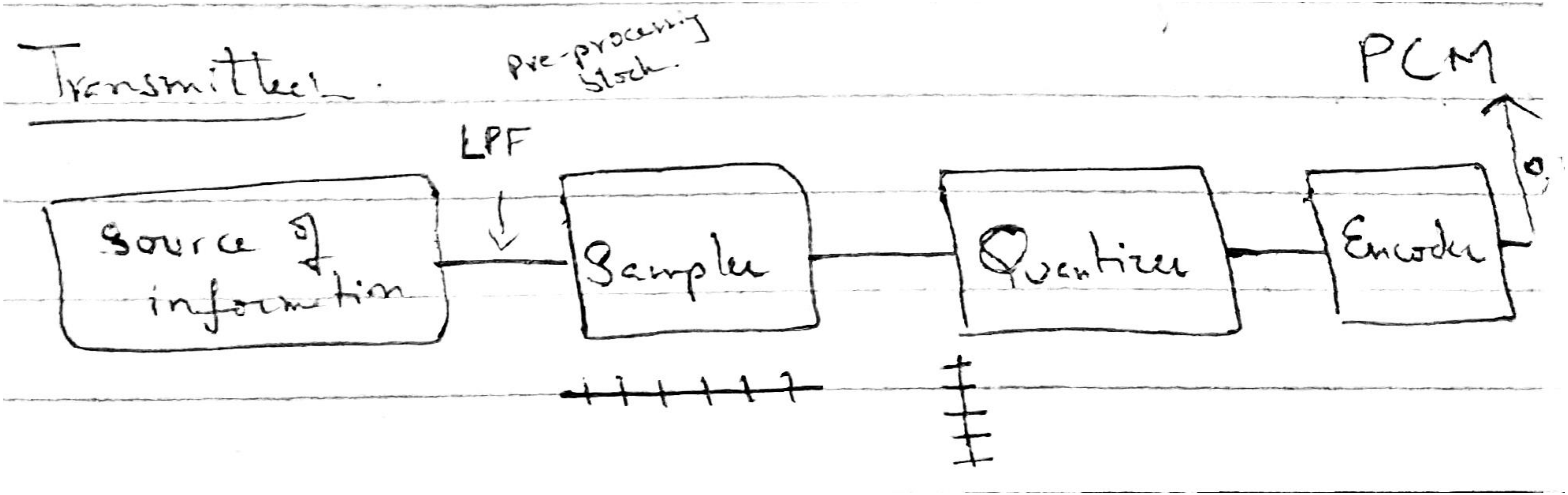


Noise affects the amplitude of the signal

Types of digital transmission:

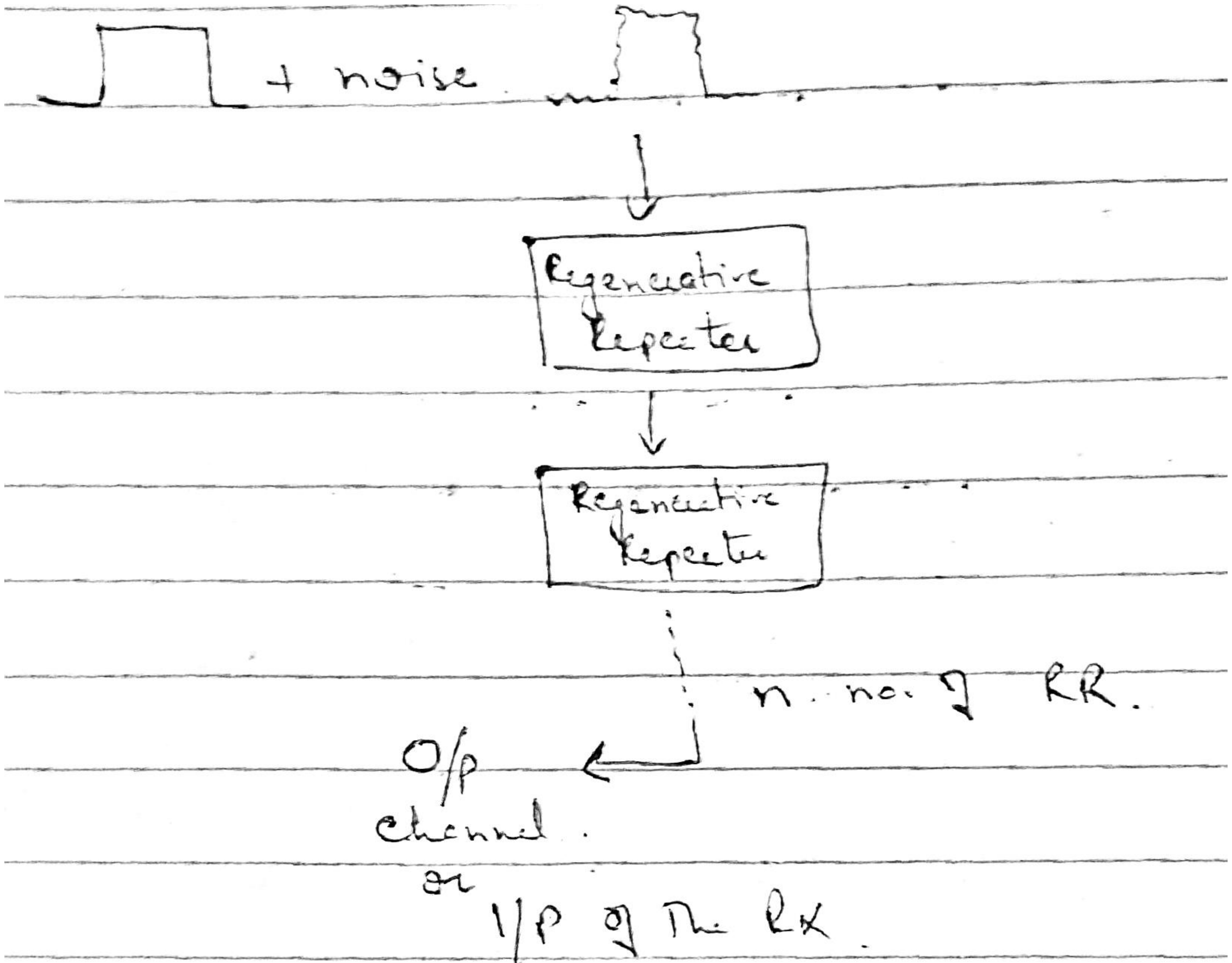


Pulse Code Modulation (PCM):



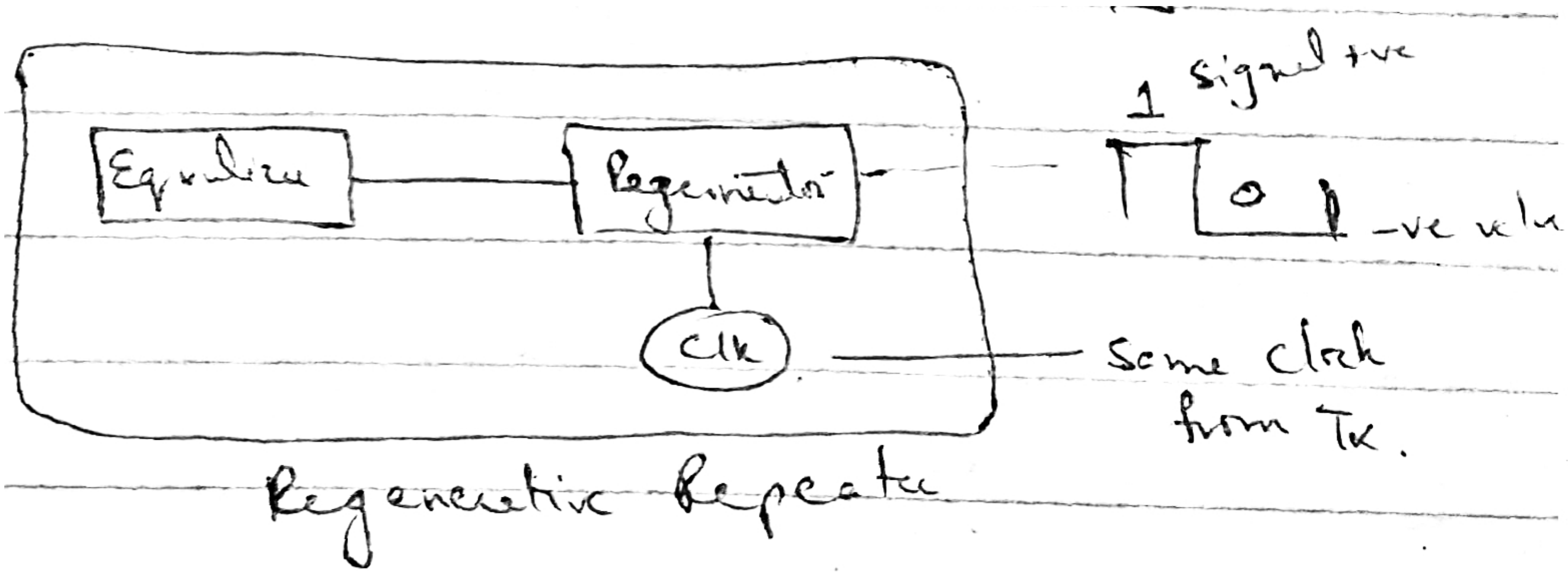
Pulse Code Modulation (PCM):

Channel:



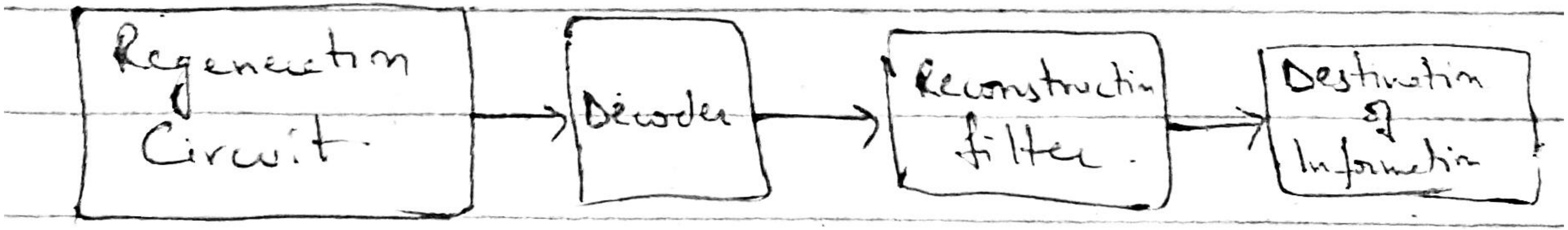
Pulse Code Modulation (PCM):

Channel:



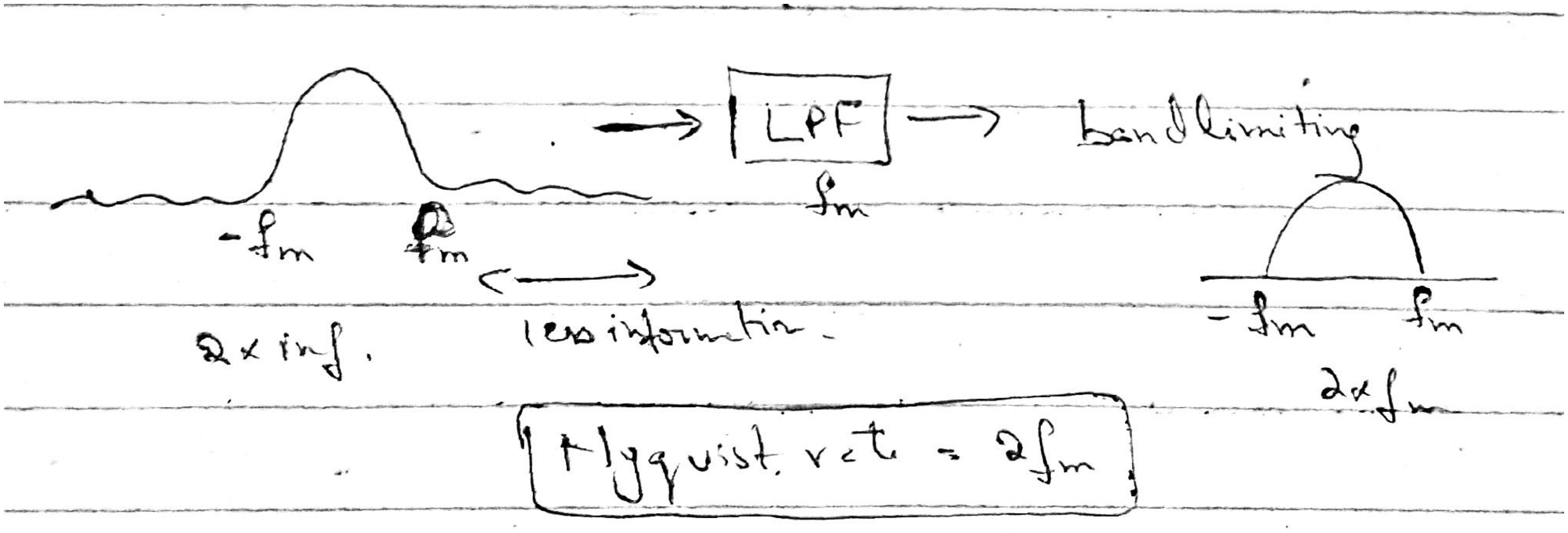
Pulse Code Modulation (PCM):

Receiver:



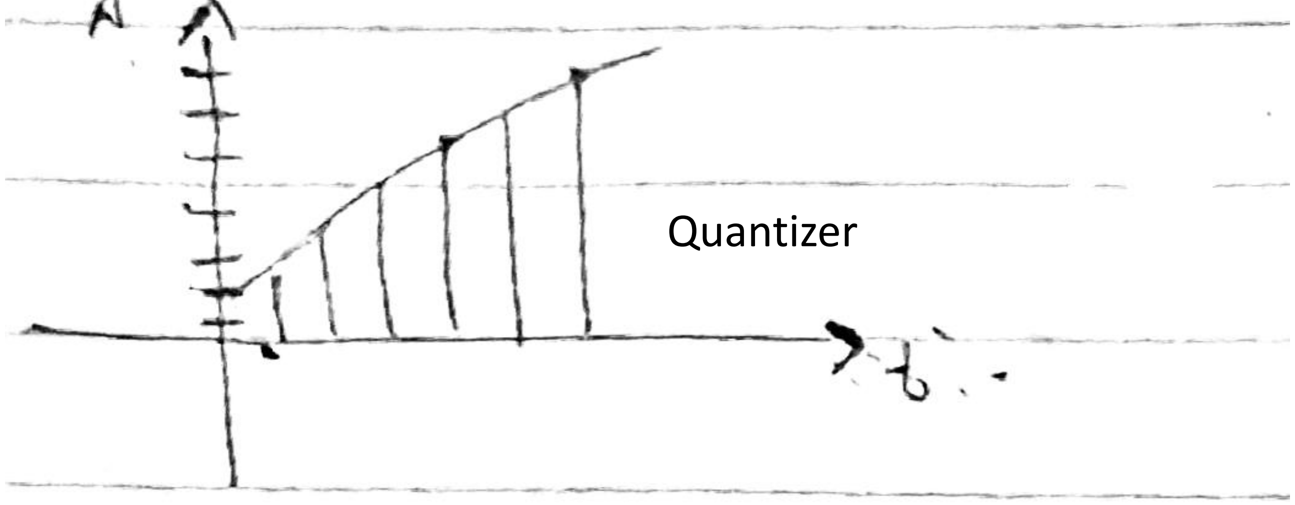
Pulse Code Modulation (PCM):

Source of information:



Pulse Code Modulation (PCM):

- Sampler + Quantizer:
  - $m(t) \rightarrow m(nT_s)$

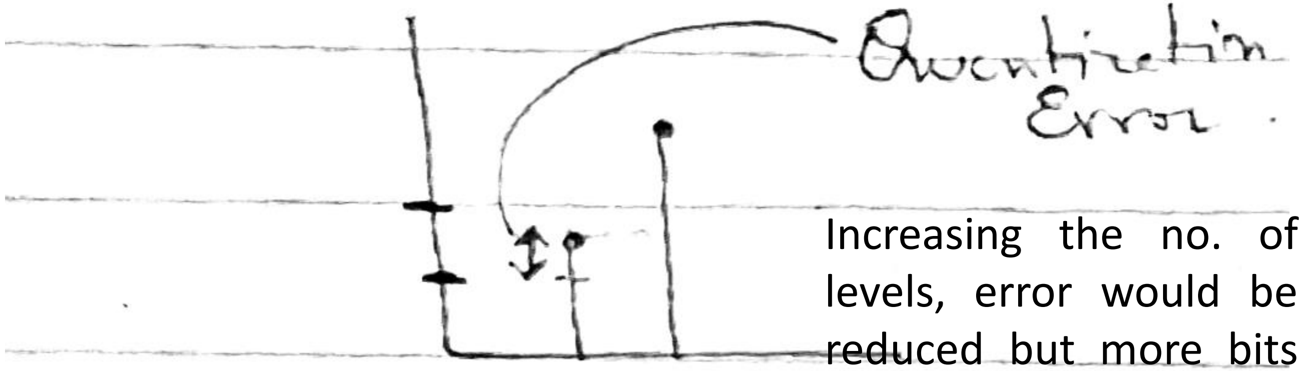


Quantizer

  - 8 levels → 3 bits
  - 4 levels → 2 bits

↓

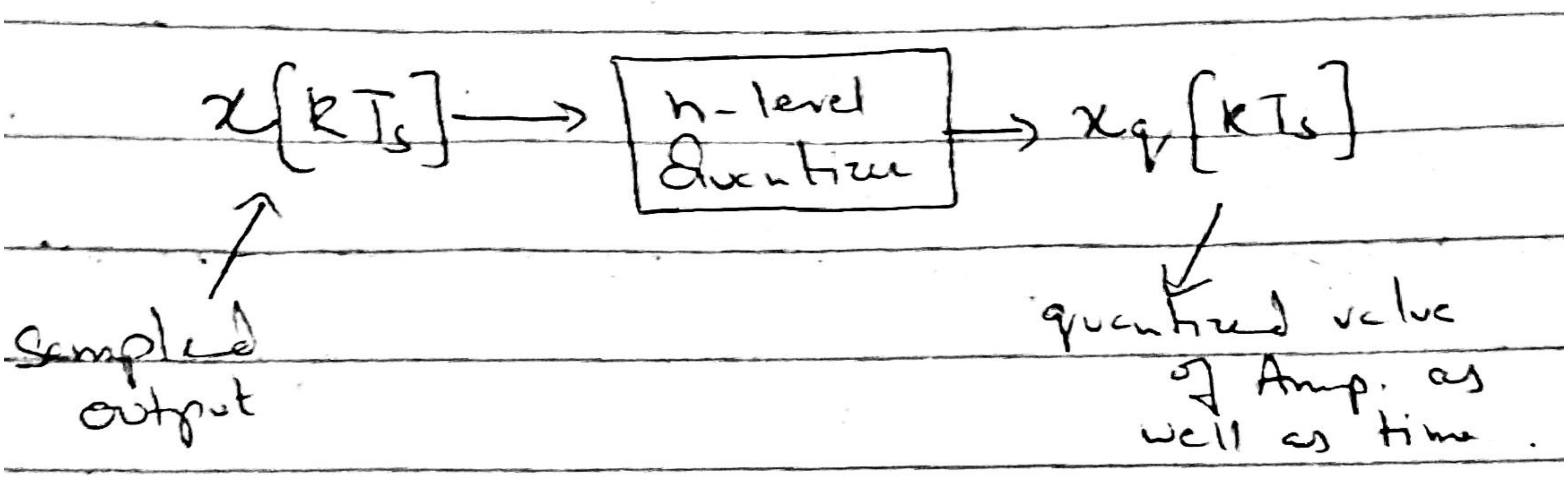
Transmission freq. would be increased	→	Process becomes costly



Increasing the no. of levels, error would be reduced but more bits are required

Quantization:

- N-levels of amplitude



- Levels are dependent on the number of bits that encoder can encode.

Quantization:

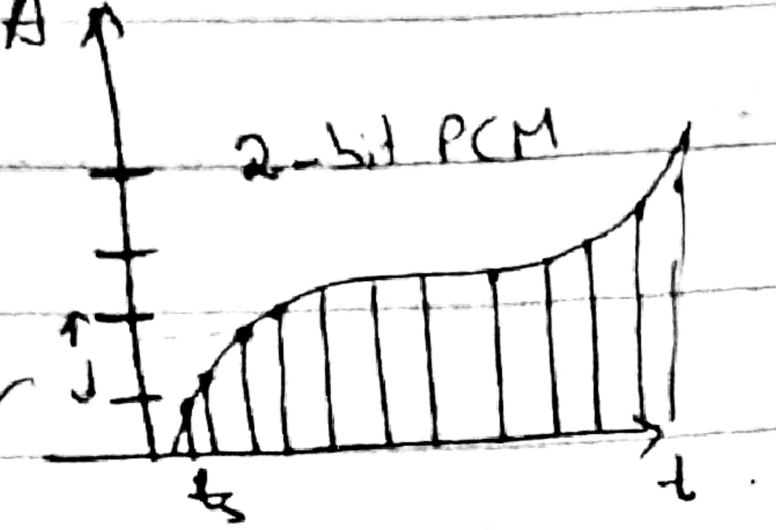
$n = 2$. $2^n \rightarrow$ levels.

2-bit encoder

$2^2 = 4$ levels

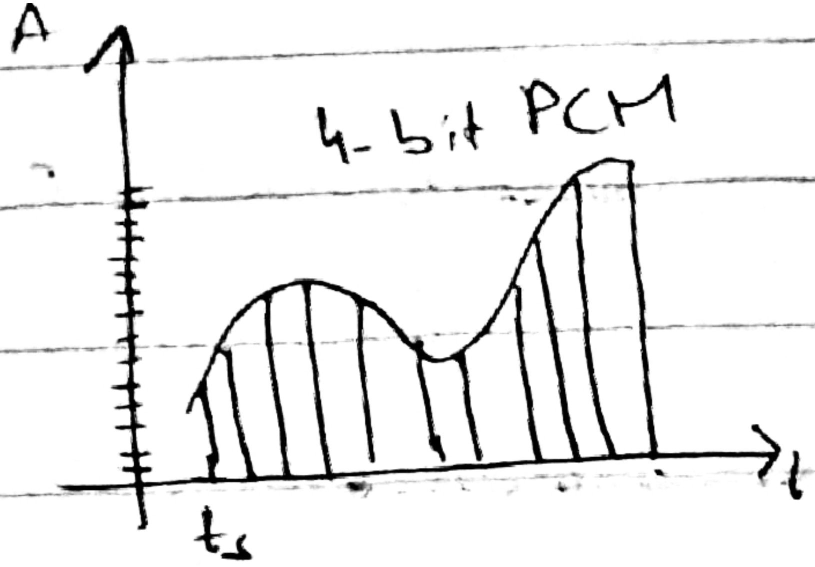
$n = 4$, $2^4 = 16$ levels

Quantization Error will be less



Sampling instant $= t_s$

error in the signal.



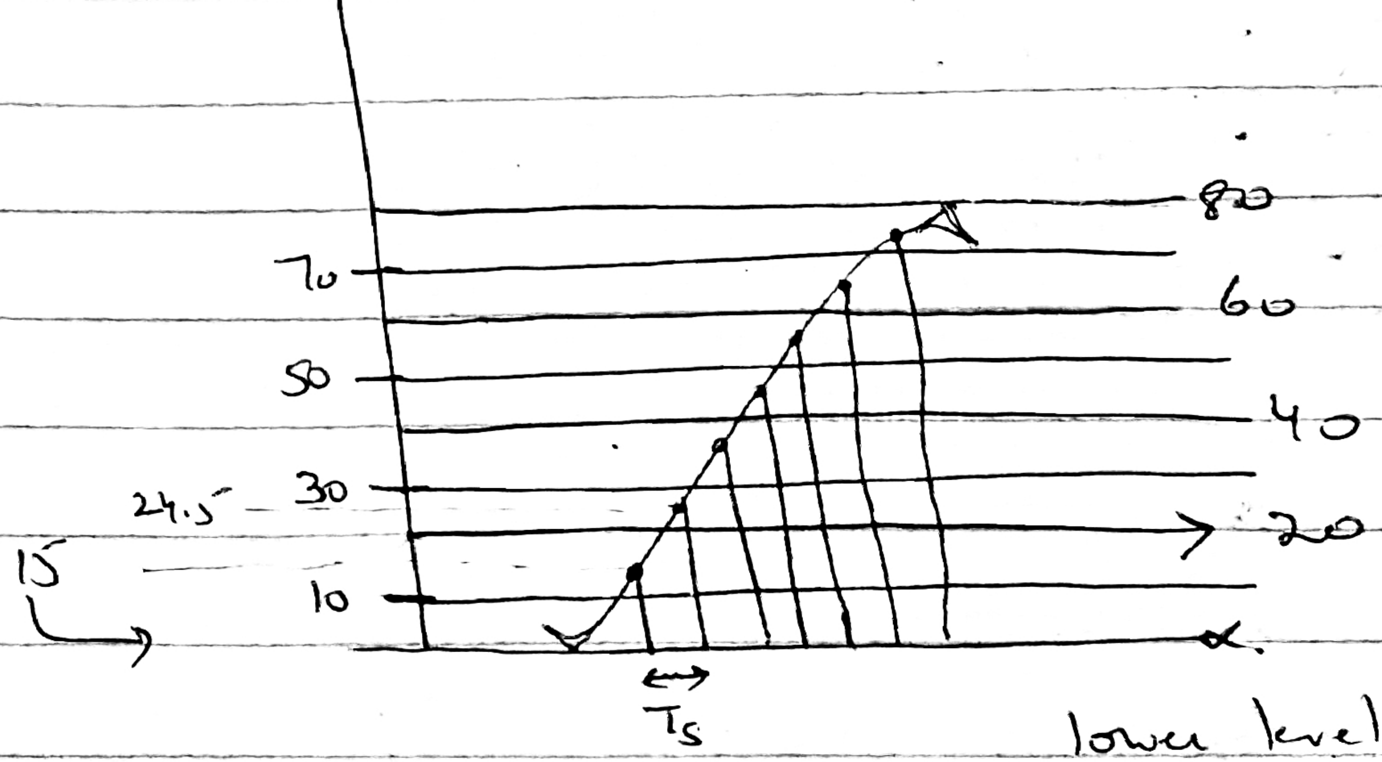
→ 16 diff. levels.

→ More precise.

no. of bits increase.

↓

precision would increase.



lower level or upper level ??

Step size ?

Δ diff b/w two levels

$$= \frac{V_{max} - V_{min}}{L}$$

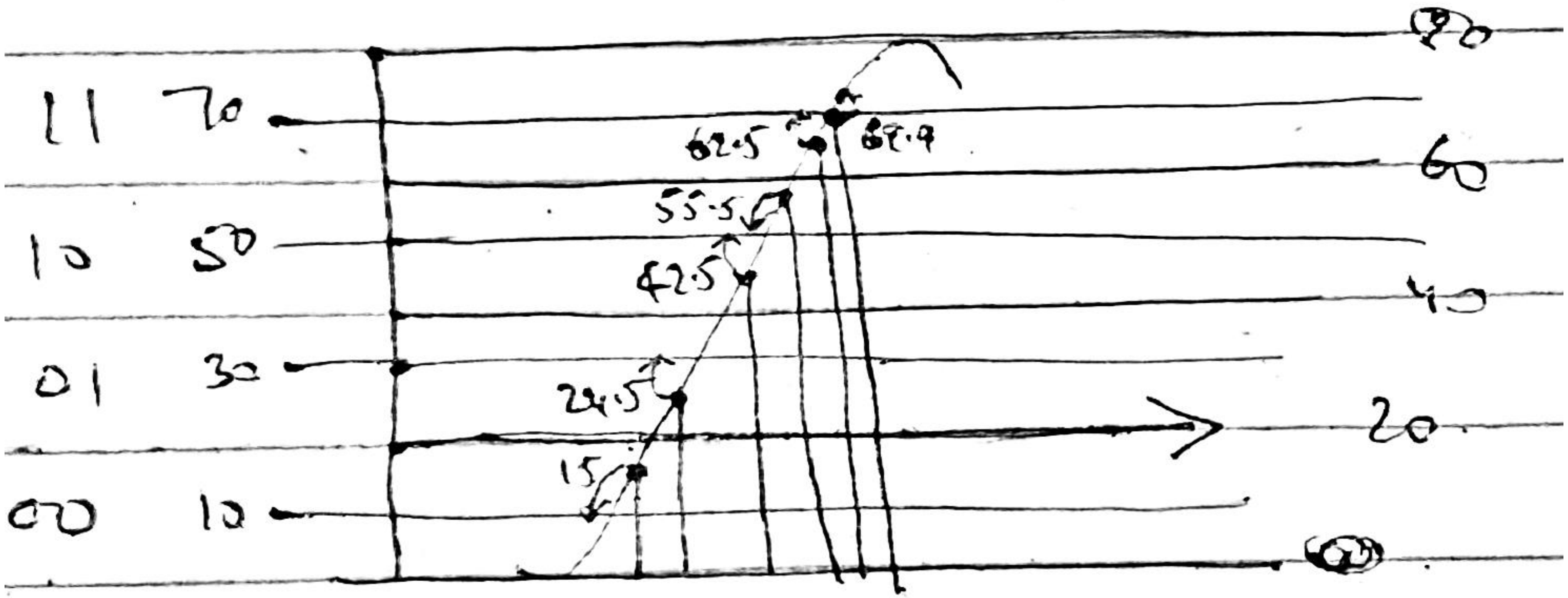
$$= \frac{80 - 0}{4} = 20.$$

Quantization:

$\boldsymbol{x(kT_s)}$	15	24.5	42.5	55.5	69.5	69.9
$\boldsymbol{x_q(kT_s)}$	10	30	50	50	70	70
$\boldsymbol{Q_e}$	-5	5.5	7.5	-4.5	1.5	0.1
bit	00	01	10	10	11	11

$$Q_e = x_q(kT_s) - x(kT_s)$$

Quantization:



Quantization:

bit	level
$0^+ \longrightarrow$	10
$20^- \longrightarrow$	10.
$20^+ \longrightarrow$	30

$20.00001 \leftarrow 20^+$

$30^+ \longrightarrow 30.$

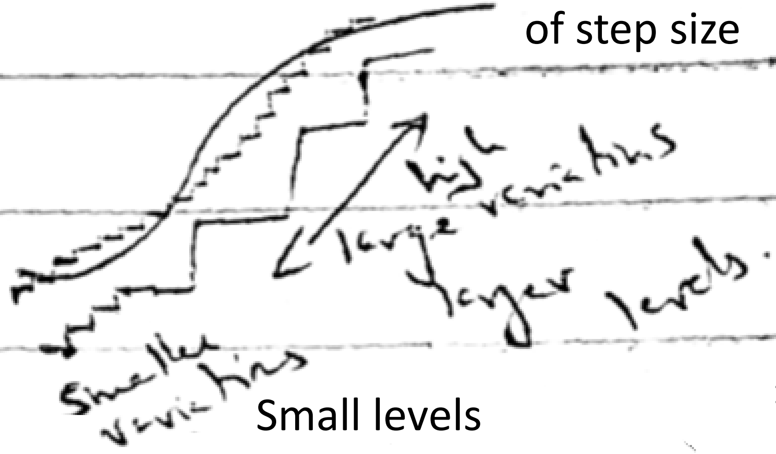
$35 \longrightarrow 30$

$35 \longrightarrow 5.$

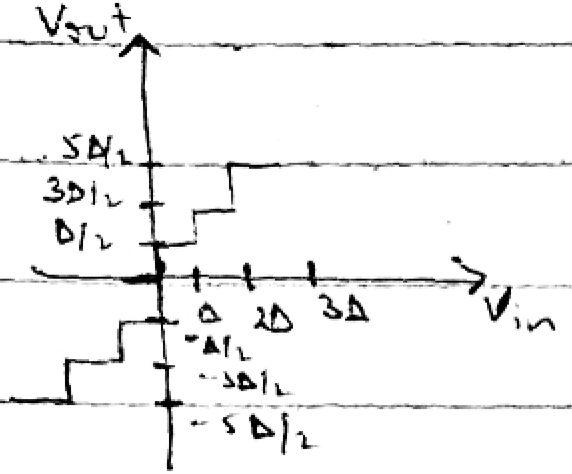
$$|Q_e|_{max} = \frac{\text{step size}}{2} = \frac{\Delta}{2}$$

Types of Quantization

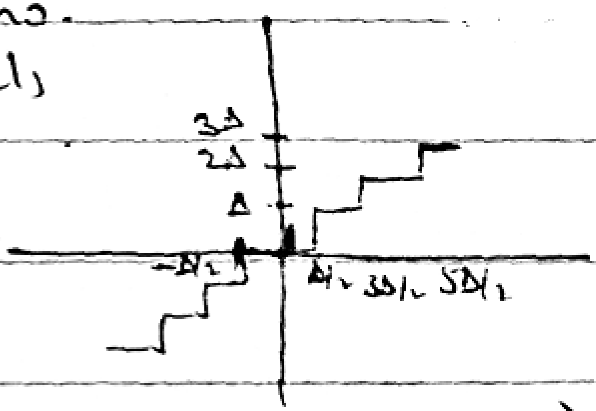
- Uniform Quantization
  - Step size → fixed
    - Mid rise Quantization (even no. of levels)
    - Mid tread Quantization (odd no. of levels)
- Non-uniform Quantization
  - step size ↓ variable.



→ even no. of levels



→ odd no. of levels



$V_{in}(-\Delta/2 \leftrightarrow \Delta/2)$ $V_{out}(0)$ ↑

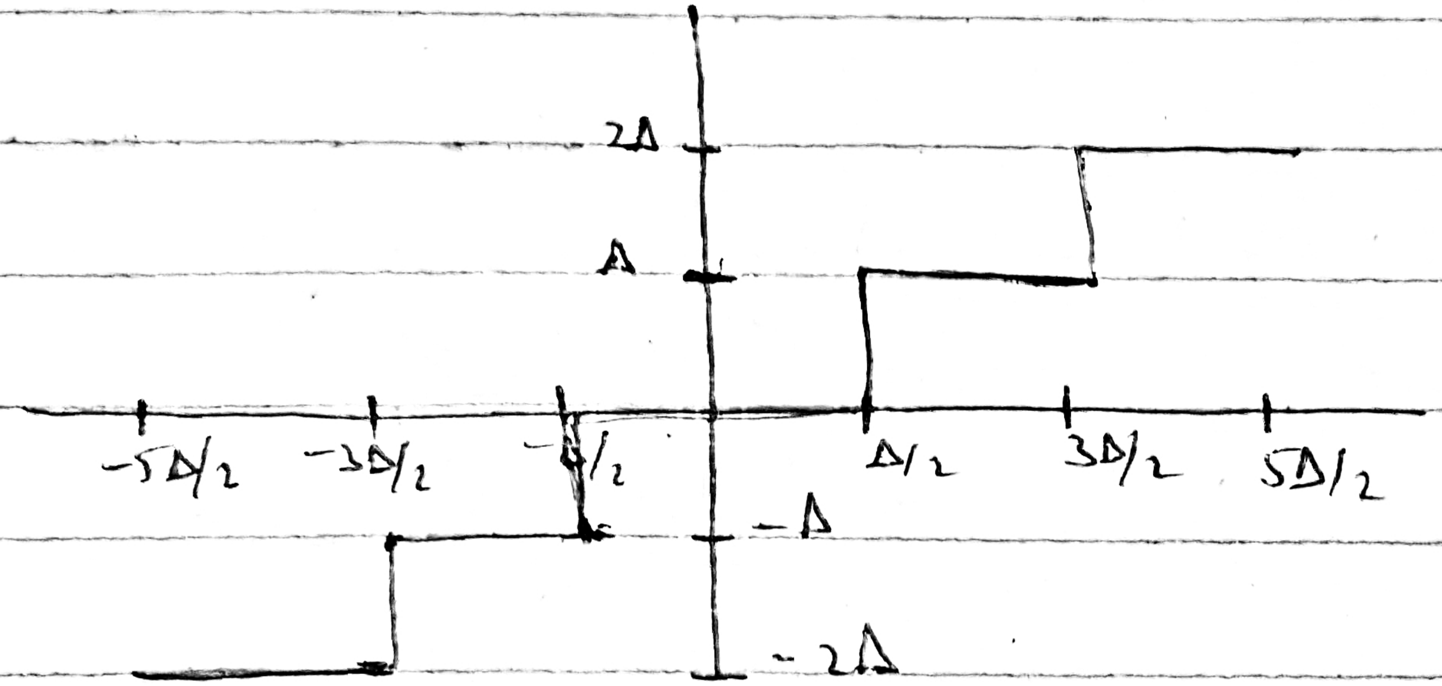
$V_{in}\,(0 - \Delta) \rightarrow V_{out}\,(\Delta/2)$

$V_{in}\,(\Delta - 2\Delta) \rightarrow V_{out}\,(3\Delta/2)$

rising at 0.

No level, denoted at 0.

5-level Quantizer:



$$\left\{ \begin{array}{l} \left(-5\Delta/2, -3\Delta/2\right); \left(-3\Delta/2, -\Delta/2\right); \left(-\frac{\Delta}{2}, \frac{\Delta}{2}\right); \\ \left(\Delta/2, 3\Delta/2\right); \left(3\Delta/2, 5\Delta/2\right) \end{array} \right.$$

5 Quantization intervals.

each of width Δ $\rightarrow$ uniform quantizer

$$V = g(m)$$

O|P ← sample

Quantization function

if $\frac{3\Delta}{2} \leq m < \frac{5\Delta}{2}$, $g(m) = 2\Delta$ ← midpoint

if $\Delta/2 \leq m < 3\Delta/2$, $g(m) = \Delta$

if $-\Delta/2 \leq m < \Delta/2$, $g(m) = 0$

if $-3\Delta/2 \leq m < -\Delta/2$, $g(m) = -\Delta$

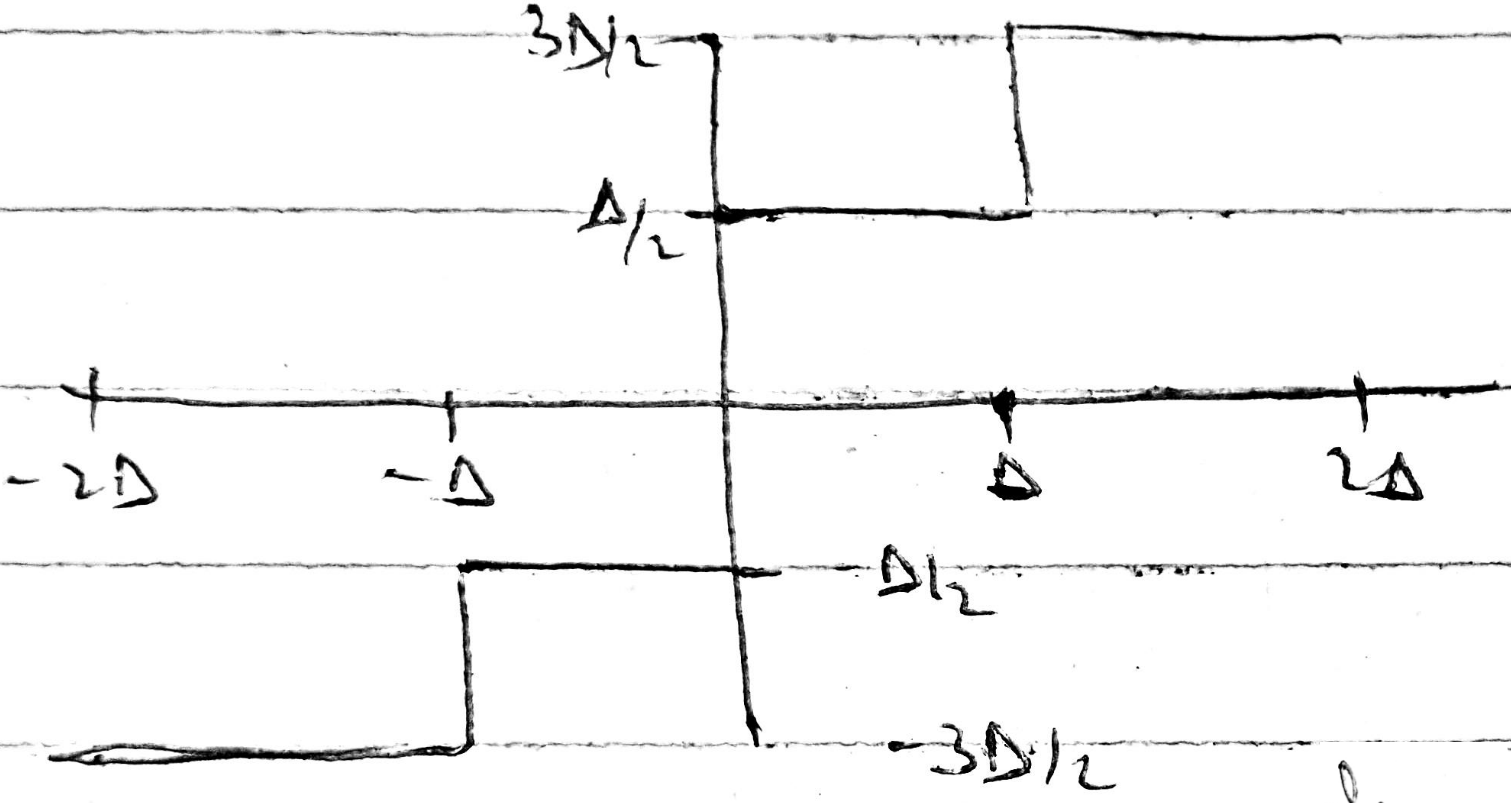
if $-5\Delta/2 \leq m < -\frac{3\Delta}{2}$, $g(m) = -2D$

All values in $\left(\frac{3\Delta}{2}, \frac{5\Delta}{2}\right)$ are mapped to 2Δ

dynamic range = $-5\Delta/2$ to $5\Delta/2$

At midpoint Quantization characteristic is flat.

mid-tread Quantizer



dynamic range $-2\Delta \rightarrow 2\Delta$

Quantizer characteristic rising at 0 from $-\Delta/2$ to $\Delta/2$, midrise quantizer

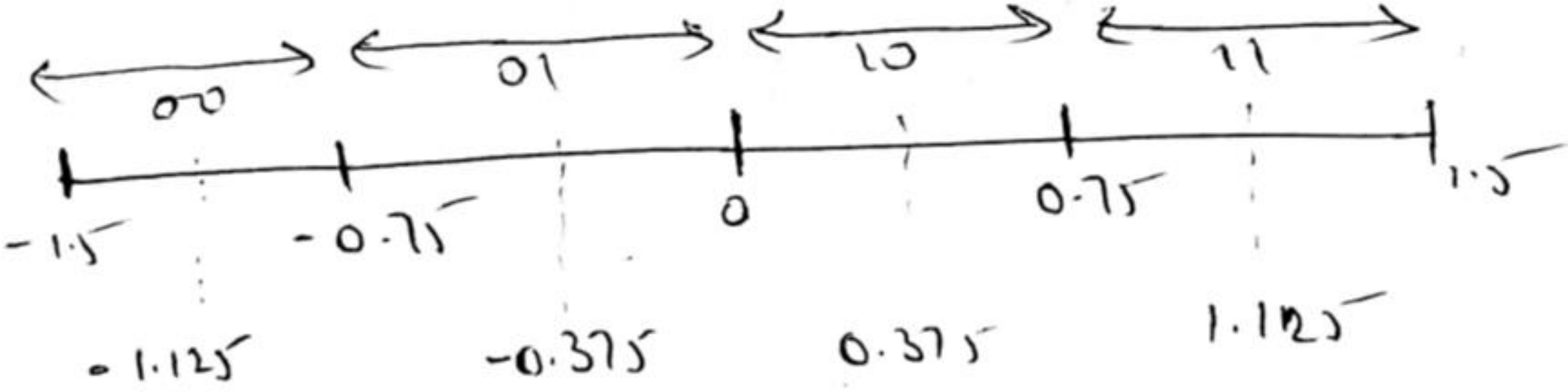
Example:

- For the following sequence {1.2, -0.2, -0.5, 0.4, 0.89, 1.3, …, }, Quantize it using a uniform quantizer in the range (-1.5,1.5) with 4 levels and write the quantized sequence and the corresponding binary stream.

Solution:

$$\Delta = \frac{1.5 - (-1.5)}{4} = 0.75.$$

$$n = \log_2 L = 2 \text{ bits}.$$



Solution:

Quantized sequence is :

{1.125, -0.375, -0.375, 0.375, 1.125, 1.125}

Binary stream is:

{11, 01, 01, 10, 11, 11}