Multimedia Systems

Part 18

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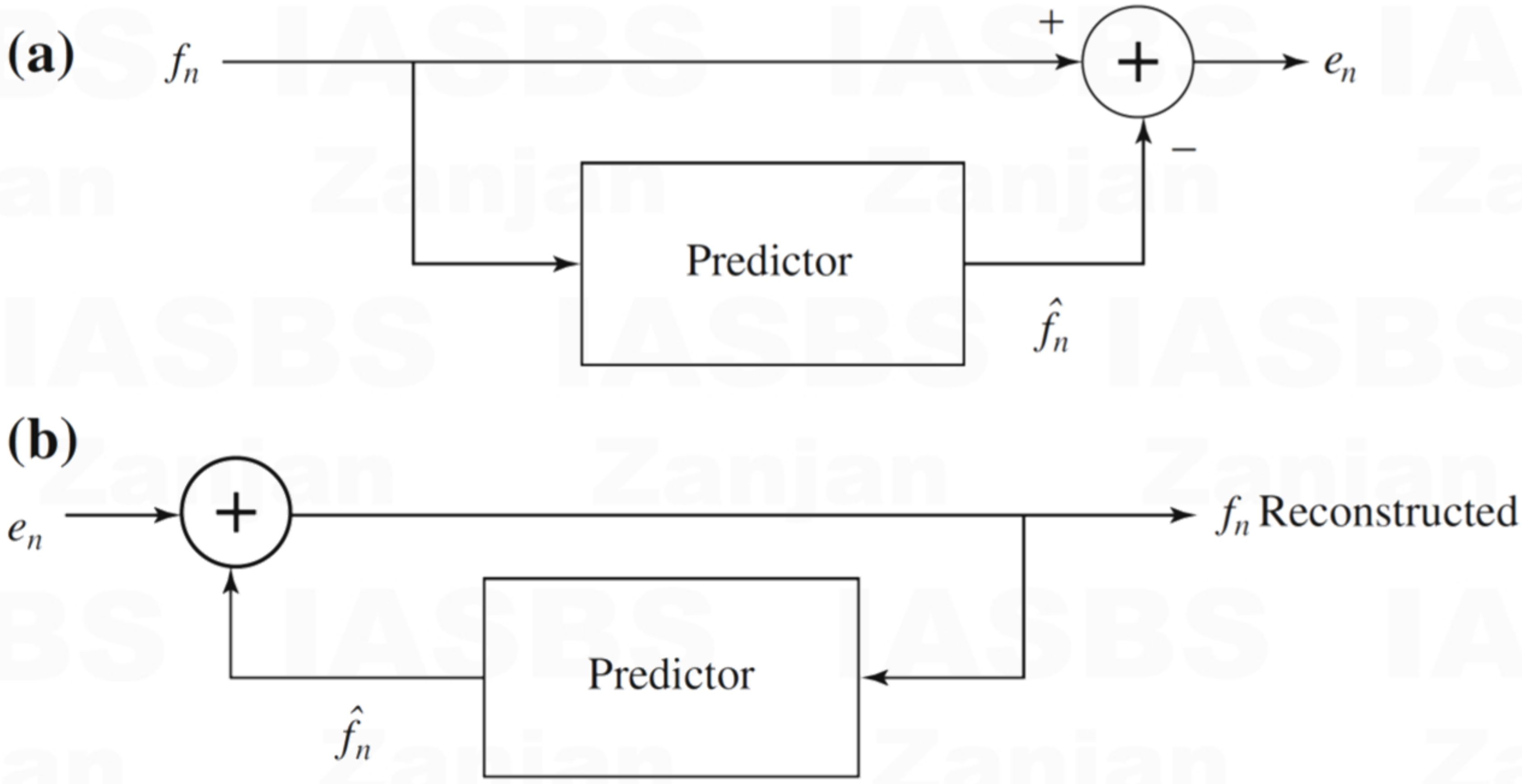
Lossless Predictive Coding

the predictor is based on f_{n-1}, f_{n-2}, … . Therefore, the predictor must involve a memory.



Differential Pulse Code Modulation

Differential Pulse Code Modulation (DPCM) is exactly the same as Predictive Coding, except that it incorporates a quantizer step.

- can be uniform or no-nuniform

- The original signal f_n,
- the predicted signal $\hat{f}_n$,
- the quantized, reconstructed signal $\tilde{f}_n$.

Differential Pulse Code Modulation

How DPCM operates is to form the prediction $\hat{f}_n$, form an error e_n by subtracting the $\hat{f}_n$ from the actual signal f_n, then quantize the error to a quantized version, $\tilde{e}_n$.

$$
\begin{aligned}
\hat{f}_{\mathrm{n}} &= \text{function\_of}\ (\tilde{f}_{\mathrm{n}-1}, \tilde{f}_{\mathrm{n}-2}, \tilde{f}_{\mathrm{n}-3}, \ldots) \\
e_{\mathrm{n}} &= f_{\mathrm{n}} - \hat{f}_{\mathrm{n}} \\
\tilde{e}_{\mathrm{n}} &= Q[e_{\mathrm{n}}] \\
&\quad \text{transmit codeword}(\tilde{e}_{\mathrm{n}})
\end{aligned}
$$

The main effect of the coder–decoder process is to produce reconstructed, quantized signal values

$$\tilde{f}_n = \hat{f}_n + \tilde{e}_n$$

Differential Pulse Code Modulation

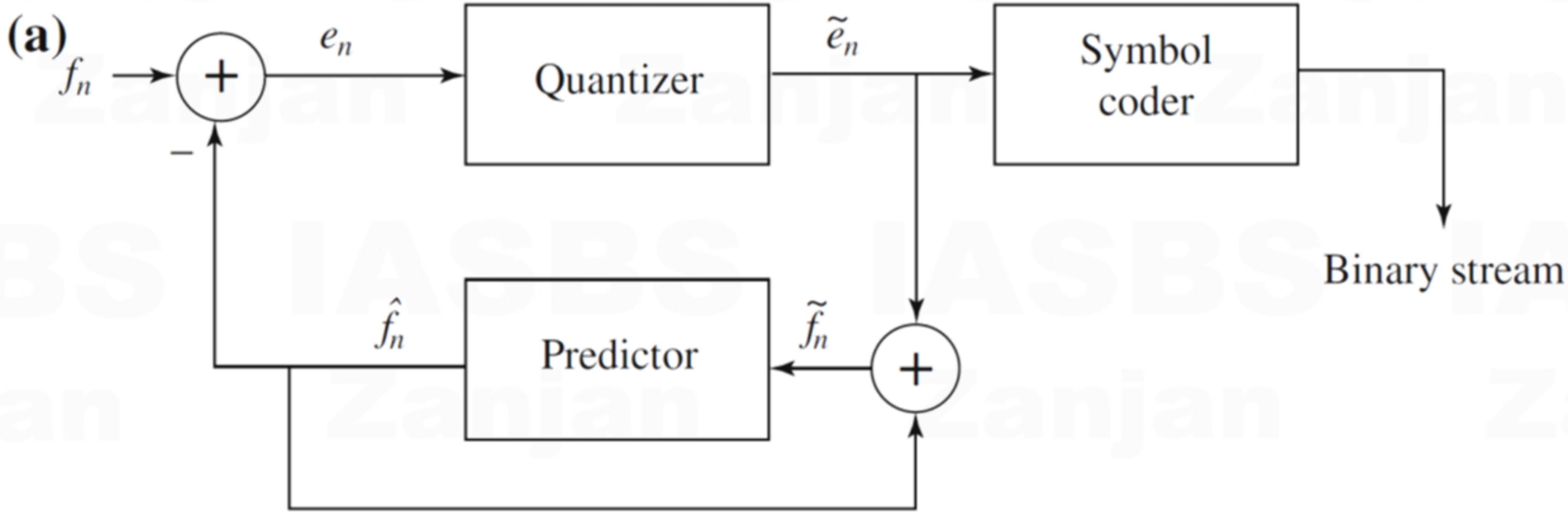
The “distortion” is the average squared error and calculated as follows:

$$distorsion = \frac{\sum_{n=1}^{N}(\tilde{f}_n - f_n)^2}{N}$$

One often sees diagrams of distortion versus the number of bit levels used.

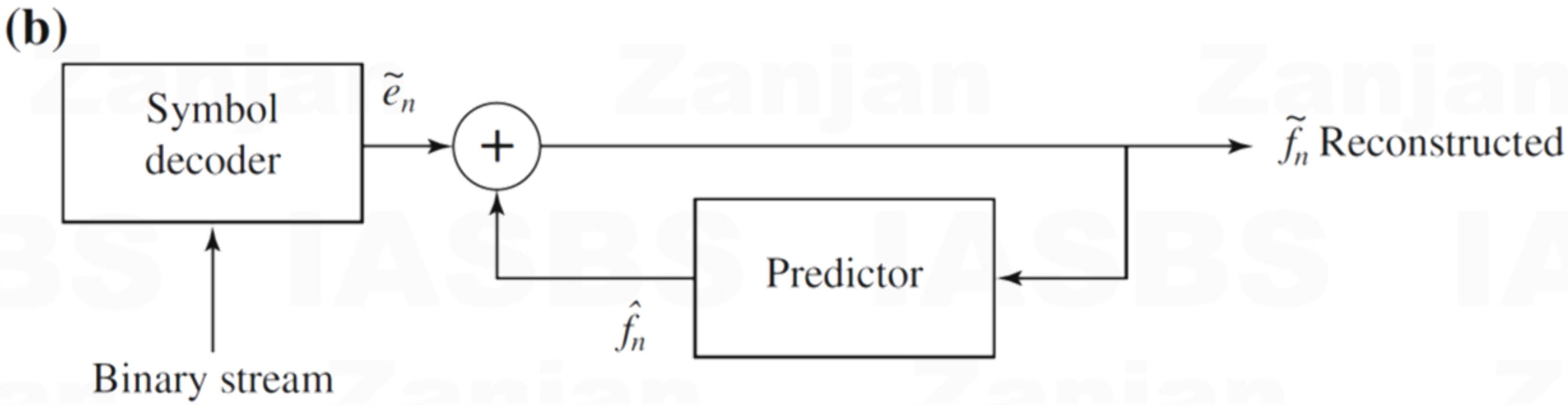
$$\min \sum_{n=i}^{i+N-1} (f_n - Q[f_n])^2 \qquad \min \sum_{n=i}^{i+N-1} (d_n - Q[d_n])^2\, l(d_n)$$

Differential Pulse Code Modulation



- The predictor is always based on the reconstructed, quantized version of the signal
- The box labeled "Symbol coder" in the block diagram simply means a Huffman Coder
- we need to buffer previous values of f˜ to form the prediction

Differential Pulse Code Modulation



- The predictor is always based on the reconstructed, quantized version of the signal
- The box labeled "Symbol coder" in the block diagram simply means a Huffman Coder
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Differential Pulse Code Modulation

It helps us explicitly to understand the process of coding to look at actual numbers.
Suppose we adopt a particular predictor as follows:

$$\hat{f}_n = trunc[(\tilde{f}_{n-1} + \tilde{f}_{n-2})/2]$$

$$e_n = f_n - \hat{f}_n$$

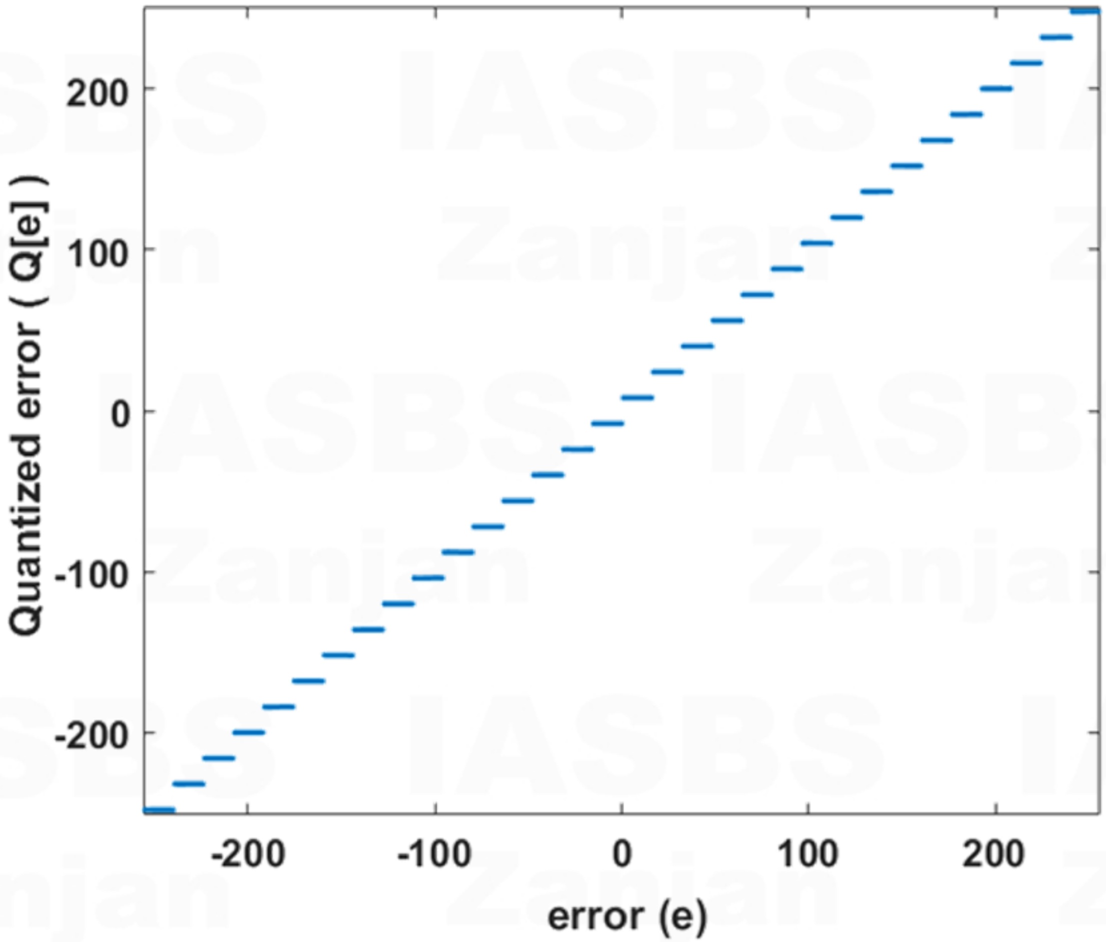
$$\hat{e}_n = Q[e_n]$$

Let us use the particular quantization scheme

$$\tilde{e}_n = Q[e_n] = 16 \times \text{floor}\,[(255 + e_n)/16] - 256 + 8$$

Differential Pulse Code Modulation

$$\tilde{e}_n = Q[e_n] = 16 \times \mathrm{fix}[(255 + e_n)/16] - 256 + 8$$



e_n in range	Quantized to value
−255 .. −240	−248
−239 .. −224	−232
⋮	⋮
−31 .. −16	−24
−15 .. 0	−8
1 .. 16	8
17 .. 32	24
⋮	⋮
225 .. 240	232
241 .. 255	248

Differential Pulse Code Modulation

As an example stream of signal values, consider the set of values:

f1	f2	f3	f4	f5
130	150	140	200	230

$$\hat{f}_n = trunc[(\tilde{f}_{n-1} + \tilde{f}_{n-2})/2]$$

$$e_n = f_n - \hat{f}_n$$

$$\hat{f} = \boxed{130},\ 130,\ 142,\ 144,\ 167$$

$$e = \boxed{0},\ 20,\ -2,\ 56,\ 63$$

$$\tilde{e} = \boxed{0},\ 24,\ -8,\ 56,\ 56$$

$$\tilde{f} = \boxed{130},\ 154,\ 134,\ 200,\ 223$$

e_n in range	Quantized to value
−255 .. −240	−248
−239 .. −224	−232
⋮	⋮
−31 .. −16	−24
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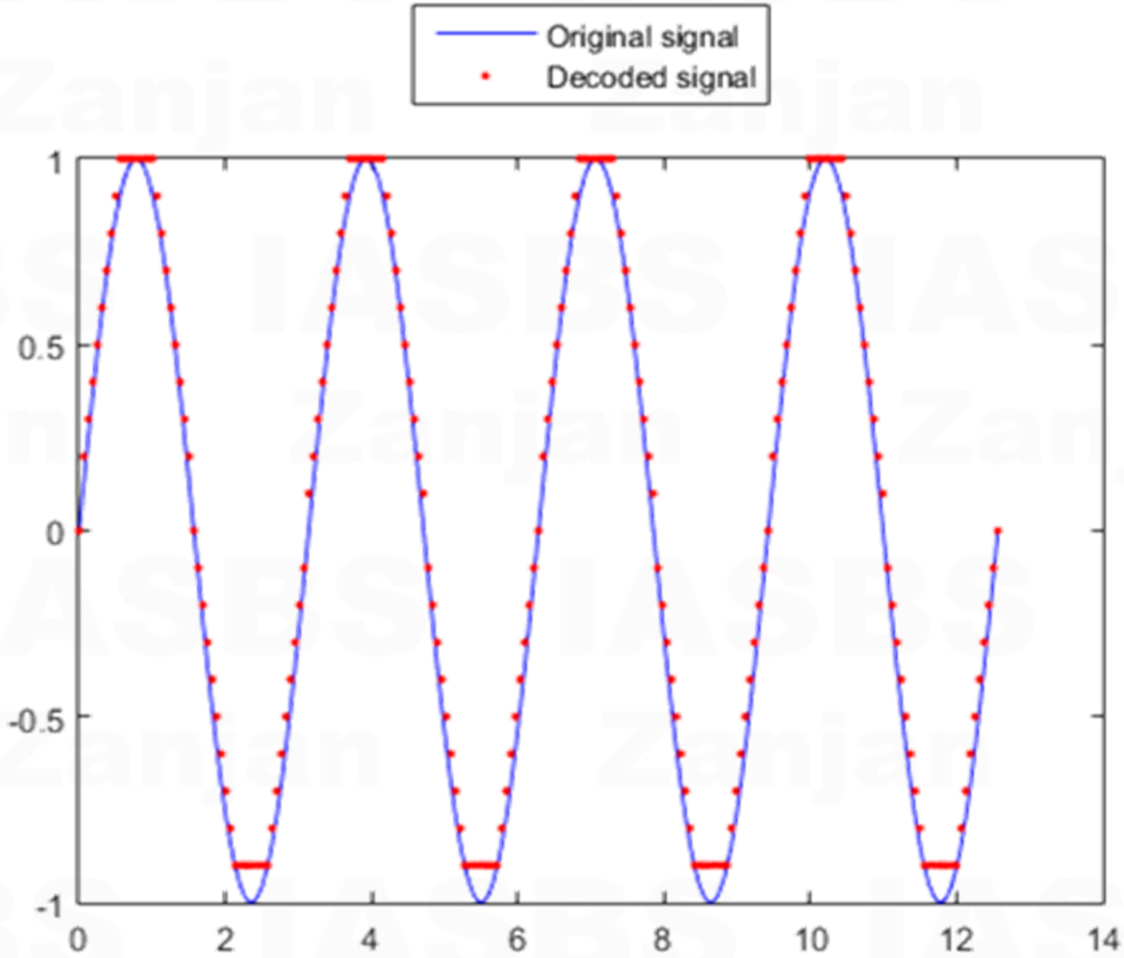
Differential Pulse Code Modulation




```
predictor = [0 1];
partition = [-1:.1:.9];
codebook  = [-1:.1:1];

t = [0:pi/50:4*pi];
x = sin(2*t);

encodedx=dpcmenco(x,codebook,partition,predictor);
decodedx=dpcmdeco(encodedx,codebook,predictor);
```

Delta Modulation

Delta Modulation (DM), a much-simplified version of DPCM often used as a quick analog-to-digital converter.

The idea in DM is to use only a single quantized error value, either positive or negative. (1-bit coder)

$$\hat{f}_n = \tilde{f}_{n-1}$$

$$e_n = f_n - \hat{f}_n = f_n - \tilde{f}_{n-1}$$

$$\tilde{e}_n = \begin{cases} +k \text{ if } e_n > 0, & \text{where } k \text{ is a constant} \\ -k \text{ otherwise,} & \end{cases}$$

$$\tilde{f}_n = \hat{f}_n + \tilde{e}_n$$

prediction simply involves a delay.

Delta Modulation

let's consider actual numbers. Suppose signal values are as follows:

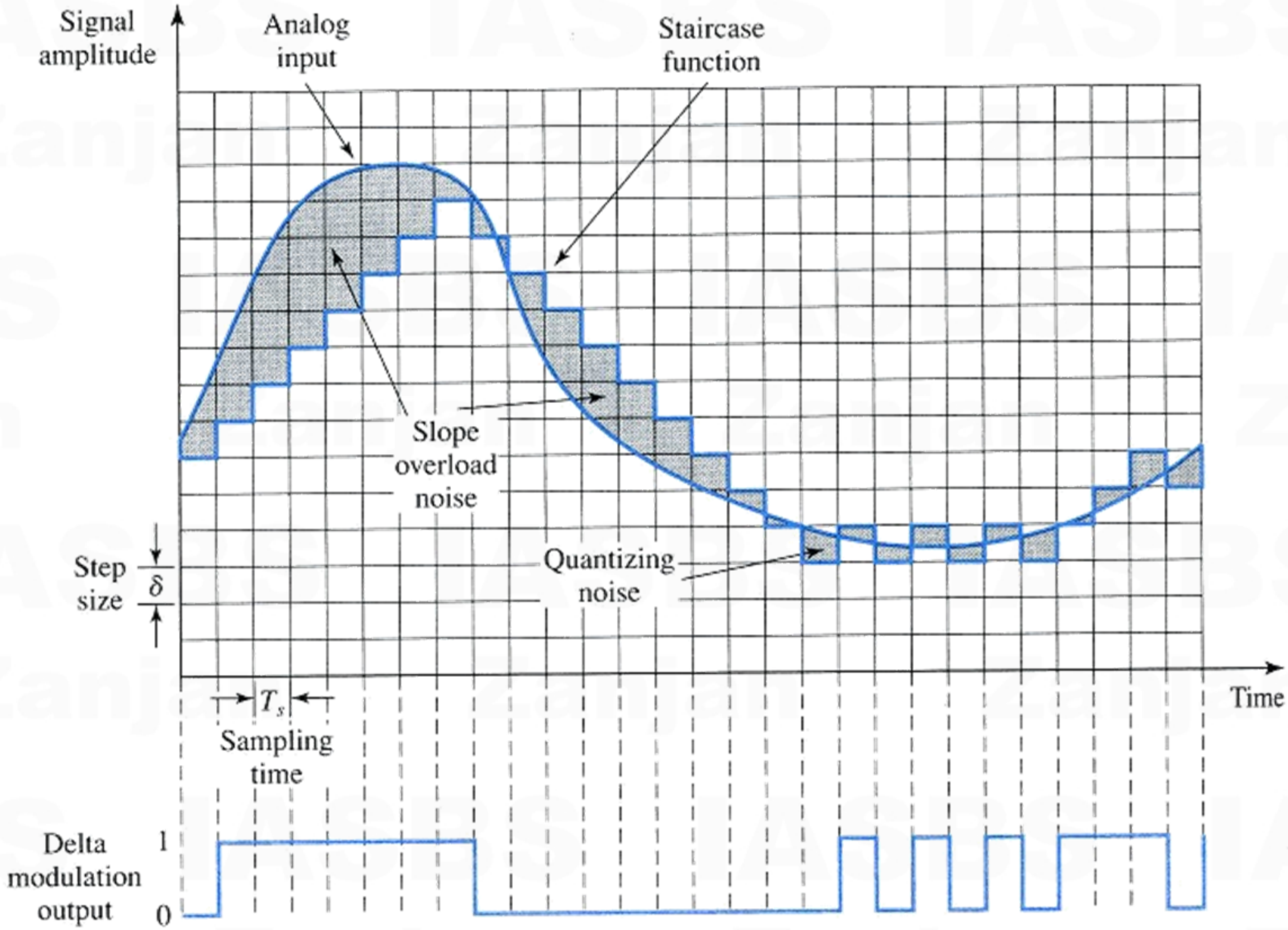
$$\hat{f}_n = \tilde{f}_{n-1}$$
$$e_n = f_n - \hat{f}_n = f_n - \tilde{f}_{n-1}$$
$$\tilde{e}_n = \begin{cases} +k \text{ if } e_n > 0, & \text{where } k \text{ is a constant} \\ -k \text{ otherwise,} \end{cases}$$
$$\tilde{f}_n = \hat{f}_n + \tilde{e}_n$$

f1	f2	f3	f4
10	11	13	15

We also define an exact reconstructed value $\tilde{f}_1 = f_1 = 10$. using a step value k = 4

$$\hat{f}_2 = 10,\ e_2 = 11 - 10 = 1,\quad \tilde{e}_2 = 4,\quad \tilde{f}_2 = 10 + 4 = 14$$
$$\hat{f}_3 = 14,\ e_3 = 13 - 14 = -1,\ \tilde{e}_3 = -4,\ \tilde{f}_3 = 14 - 4 = 10$$
$$\hat{f}_4 = 10,\ e_4 = 15 - 10 = 5,\quad \tilde{e}_4 = 4,\quad \tilde{f}_4 = 10 + 4 = 14$$

Delta Modulation



Delta Modulation