جامعة المستقبل
AL MUSTAQBAL UNIVERSITY

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قسم الانظمة الطبية الذكية

Lecture 9- Quantization Stage

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Quantization theory

- Analog to digital conversion is a two-step process, which changes a sampled analog voltage into digital form. These processes are quantization and coding.
- Quantization is the transformation of a continuous analog input into a set of data represented by discrete output states. Coding is the assignment of a digital code word or number to each output state
- The number of possible states N is equal to the number of bit combinations:

$$N = 2^n,$$

where n is the number of bits.

The analog quantization size (or resolution) Q is defined as the full scale range of the ADC divided by the number of output states:

$$Q = \frac{(V_{\max} - V_{\min})}{2^n - 1}.$$

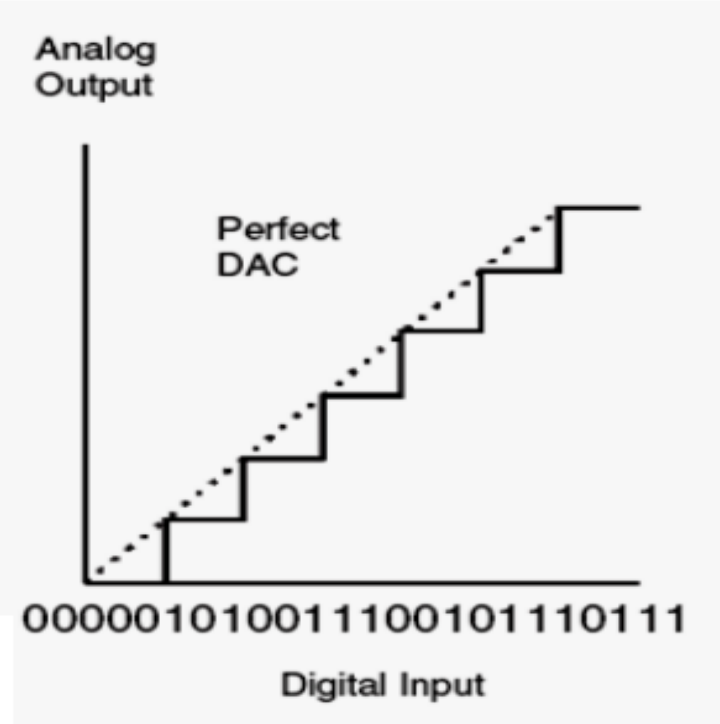
The range of an ADC is given as

$$R = (V_{\max} - V_{\min}).$$

$$Q = \frac{(V_{\max} - V_{\min})}{2^n - 1} = \frac{R}{2^n - 1}$$

$$2^n = 1 + \frac{R}{Q}$$

$$n = \frac{\log\left(1 + \frac{R}{Q}\right)}{\log 2}$$



Example 1 :

Determine the smallest step size (resolution) of a 4-bit ADC, which has maximum output voltage of 12 V.

Solution

$$Q = \frac{(12 - 0)}{2^4 - 1} = \frac{12}{15} = 0.8\ \text{V}$$

Example 2 :

Determine the smallest step size (resolution) of an 8-bit ADC in the range −5 V to +5 V.

Solution

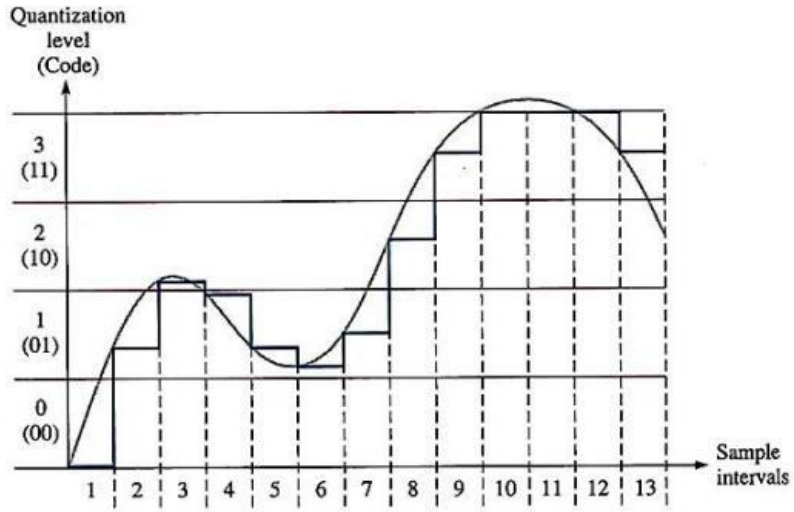
$$Q = \frac{(5 - (-5))}{2^8 - 1} = \frac{10}{255} = 0.04\,\text{V} \qquad (7$$

Example 3 :

An ADC has a range of 5 V and a resolution of 5 mV. Determine the number of bits required.

Solution

$$n = \frac{\log\left(1 + \frac{5}{0.005}\right)}{\log 2} = 9.97 = 10 \text{ bits}$$



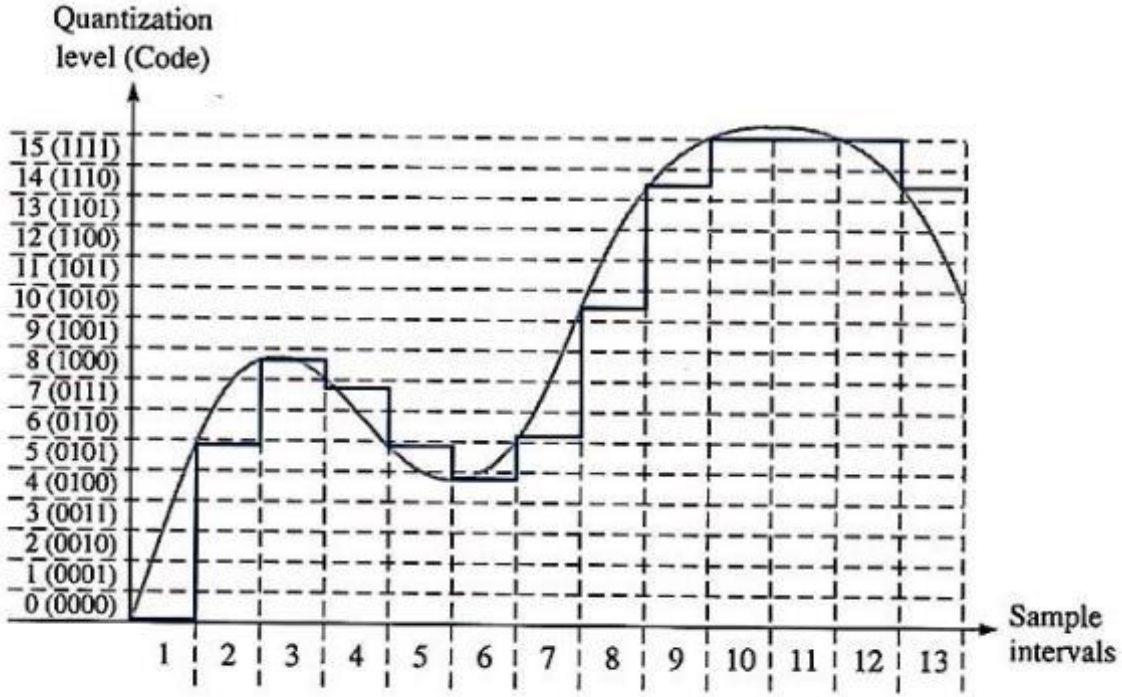
▲ FIGURE 12–7

Sample-and-hold output waveform with four quantization levels. The original analog waveform is shown in light gray for reference.

SAMPLE INTERVAL	QUANTIZATION LEVEL	CODE
1	0	00
2	1	01
3	2	10
4	1	01
5	1	01
6	1	01
7	1	01
8	2	10
9	3	11
10	3	11
11	3	11
12	3	11
13	3	11

▶ TABLE 12–1

Two-bit quantization for the waveform in Figure 12–7.



◀ FIGURE 12–9

Sample-and-hold output waveform with sixteen quantization levels. The original analog waveform is shown in light gray for reference.

SAMPLE INTERVAL	QUANTIZATION LEVEL	CODE
1	0	0000
2	5	0101
3	8	1000
4	7	0111
5	5	0101
6	4	0100
7	6	0110
8	10	1010
9	14	1110
10	15	1111
11	15	1111
12	15	1111
13	14	1110

◀ TABLE 12–2

Four-bit quantization for the waveform in Figure 12–9.