Pulse Code Modulation (PCM)

Pulse Code Modulation (PCM): PCM is a method of converting an analog signal into a digital signal (A/D conversion).

Steps of PCM:

i) Sampling

ii) Quantizing

iii) Encoding

Sampling: Sampling is the process in which the modulating signal is sampled at regular intervals and each sample is proportional to the amplitude of the modulating signal at the time of sampling.

- Sampling is also called **Pulse Amplitude Modulation (PAM)**.

Types of Sampling: There are two types of sampling, namely,

i)Natural Sampling

ii)Flat-topped Sampling

Types of Sampling

Natural Sampling: Natural sampling is a type of sampled signal in which the top of each sample pulse follows the message signal during the pulse width time (τ) of the sampling signal.

Flat-topped Sampling: Flat-topped sampling is a type of sampled signal in which the top of each sample pulse represents **a single level** of message signal during the pulse width time (τ) of the sampling signal.

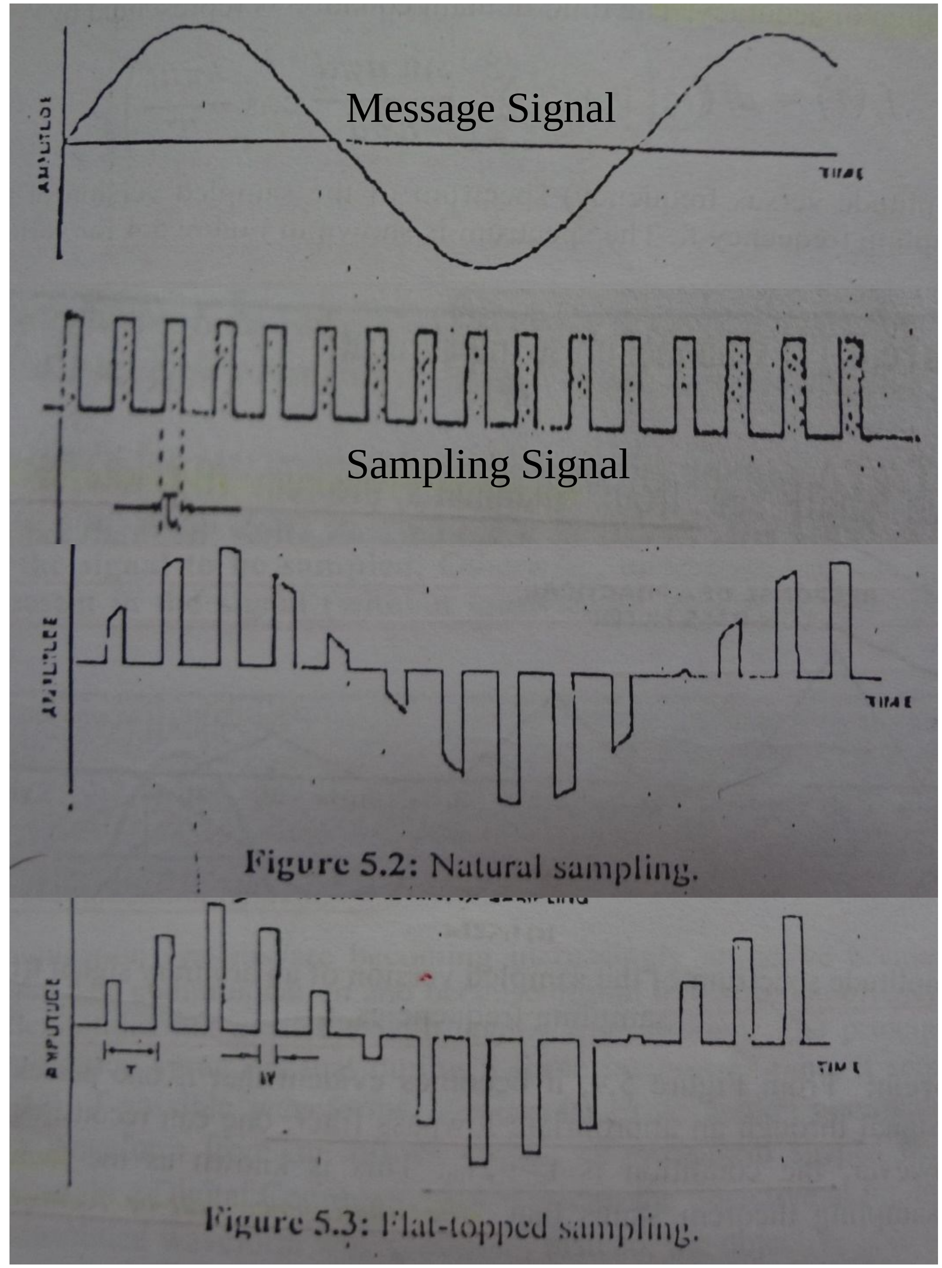

Figure 5.2: Natural sampling.

Figure 5.3: Flat-topped sampling.

Sampling

- **Sampling Theorem:** The sampling theorem states that the intelligence or message signal can be reconstructed by an appropriate low-pass filter when the sampling signal frequency (f_s or sampling rate) is greater than twice the maximum message signal frequency ($f_{m(max)}$).
- When $f_s=2f_{m(max)}$, f_s is known as the Nyquist's sampling frequency or Nyquist's sampling rate.

Aliasing: If sampling is done below the Nyquist's sampling rate, the high frequency components overlap with and distort the original signal. This is called aliasing.

- An anti-aliasing filter is always used at the beginning of each digital processor to band-limit the signal to be sampled.

Quantization and Encoding

Quantization: Quantization is approximation of the level of the samples by the nearest value drawn from a finite assortment of discrete levels.

Encoding: Encoding involves converting the discrete level of the sample after quantization to the binary code of fixed length of bits.

- The number of bits, n, in the code is determined by the total number of discrete levels L, as $L = 2^n$.

Sampling, Quantization and Encoding

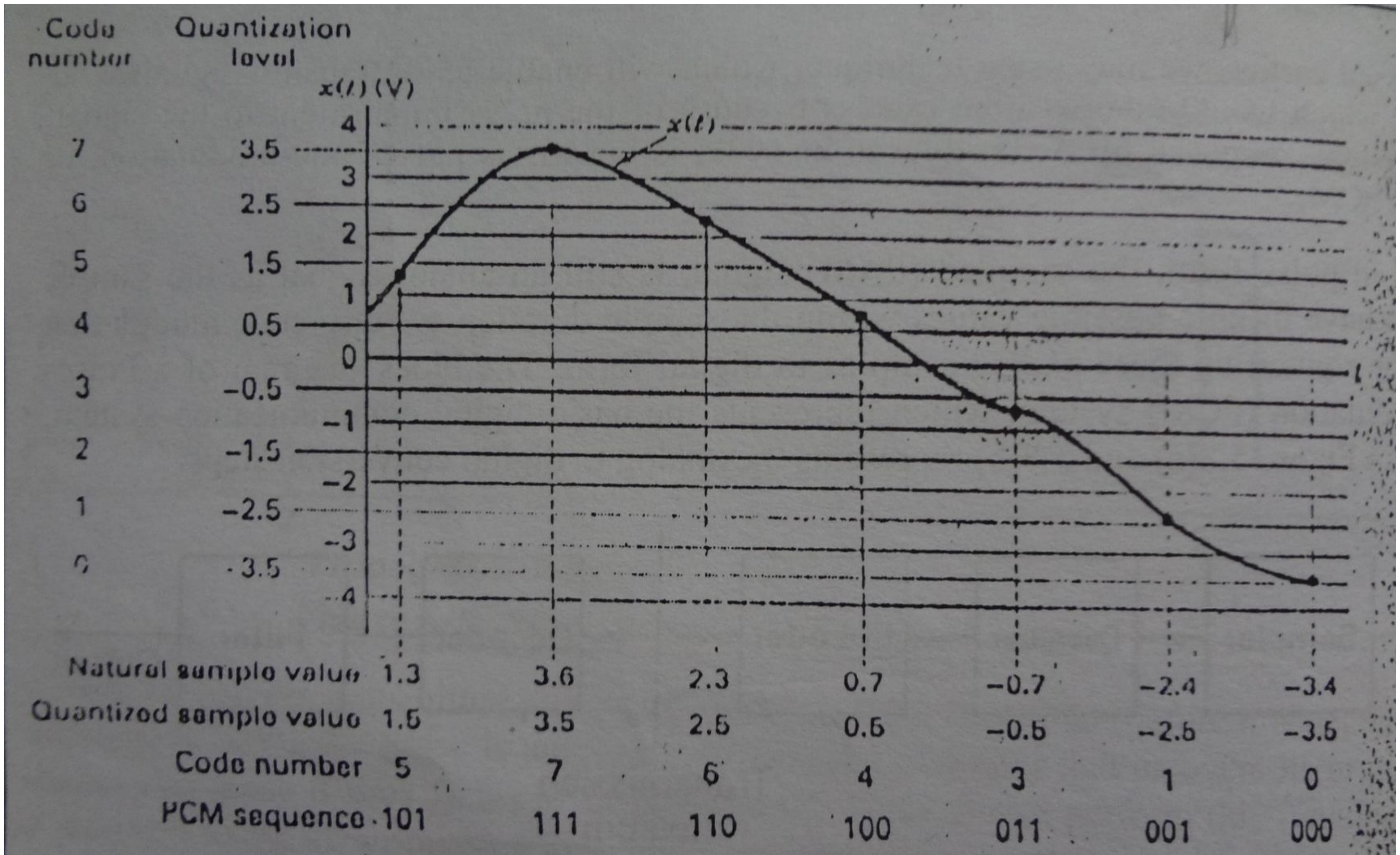

Figure 5.9: Natural samples, quantized samples, and pulse code modulation.

Simplified Block Diagram of a PCM System

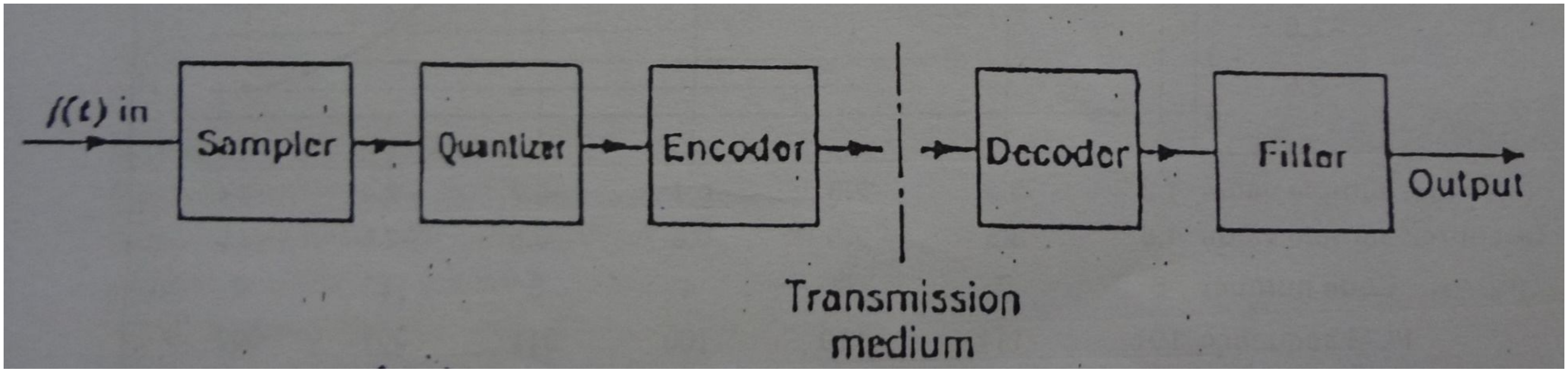

Figure: Simplified Block Diagram of a PCM System

Advantages of digital communications:

- Digital data is more immune to noise than analog signals. As a result, long distance communication can be achieved using digital communication methods.
- Digital circuits are more reliable and can be produced at a lower cost than analog circuits.
- The combination of digital signals using time-division-multiplexing (TDM) is simpler than the combination of analog signals using frequency-division-multiplexing (FDM).

Example 1: Calculate the bit rate of a single channel PCM system that uses the standard band-limited telephone channel.

Solution: In a standard band-limited telephone channel, the bandwidth of the speech signal is restricted between 300Hz and 3400Hz.
The standard sampling rate used is $f_s = 8000$ samples/sec ($f_s > 2f_{m(max)}$).
Now, in a practical PCM system used in the European standard (including Bangladesh), the quantizer uses 256 quantization levels.
So, L=256

$$\text{We know, } L = 2^n$$
$$\Rightarrow n = log_2 L = log_2 256 = 8$$

So, 1 sample is encoded into 8 bits

Thus, 1 sample gives rise to 8 bits
8000 samples give rise to $8 \times 8000 = 64{,}000$ bits= 64 k bits

These 8000 sample values occupy 1 second.
Bit rate=No. of bits/time=64,000 bits/ 1 second=64,000 bits per second=64 kbps