Waveform Coding Techniques

Module-2

Topics to be discussed

- Pulse Code Modulation (PCM)
  - Quantization noise and signal to quantization noise ratio
- Differential pulse code modulation
- Delta modulation
  - Quantization noise in DM
- Adaptive Delta modulation

Introduction

- **Modulation** is the process of varying one or more parameters of a carrier signal in accordance with the instantaneous values of the message signal.
- The **message signal** is the signal which is being transmitted for communication and the **carrier signal** is a high frequency signal which has no data, but is used for long distance transmission.
- Modulation is performed by the device known as a modulator, and this technique is mainly used to overcome the interference of the signal.
- Modulation is of two types:

1. **Analog Modulation**
2. **Digital modulation**

Introduction

- In **analog modulation**, a continuously varying sine wave is considered a carrier wave.
- This wave modulates based on the data signal.
- In amplitude modulation, three parameters can be altered, they are: **frequency, amplitude and phase.**
- Types of analog modulation are:

1. Amplitude modulation (AM)
2. Frequency modulation (FM)
3. Phase modulation (PM)

Introduction

- In digital modulation, an analog carrier signal is modulated by a digital signal.
- The process of encoding affects the bandwidth of the transmitted signal and its robustness to channel impairments.
- In digital modulation, a message or information is embedded into the **amplitude**, **phase**, **or** **frequency** of the transmitted signal.
- In the encoding process, the signal is converted from analog to digital form and then the modulated signal is carried by using a carrier wave.
- Digital modulation is of the following types:
    - ASK,FSK, PSK, QAM

Introduction

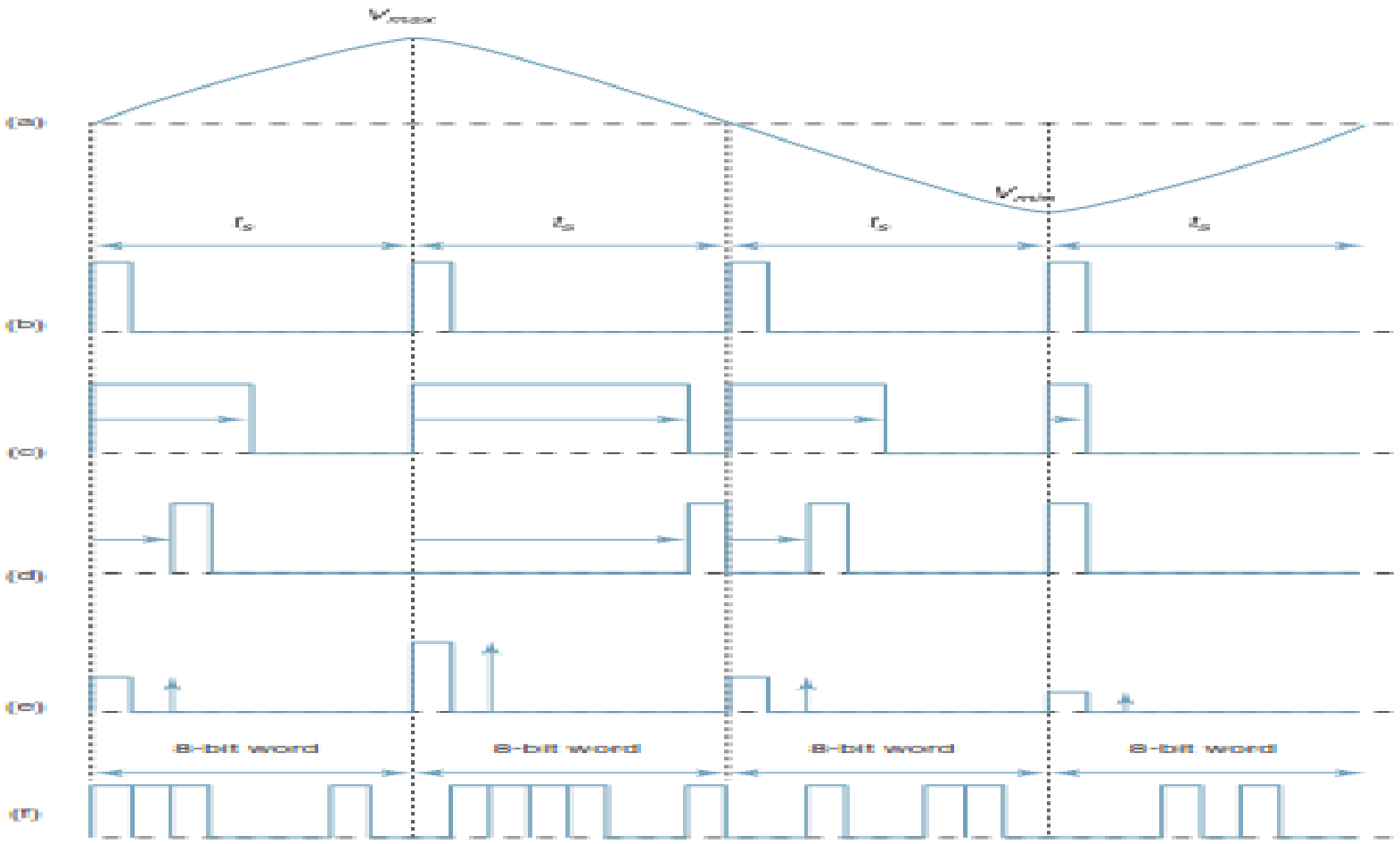
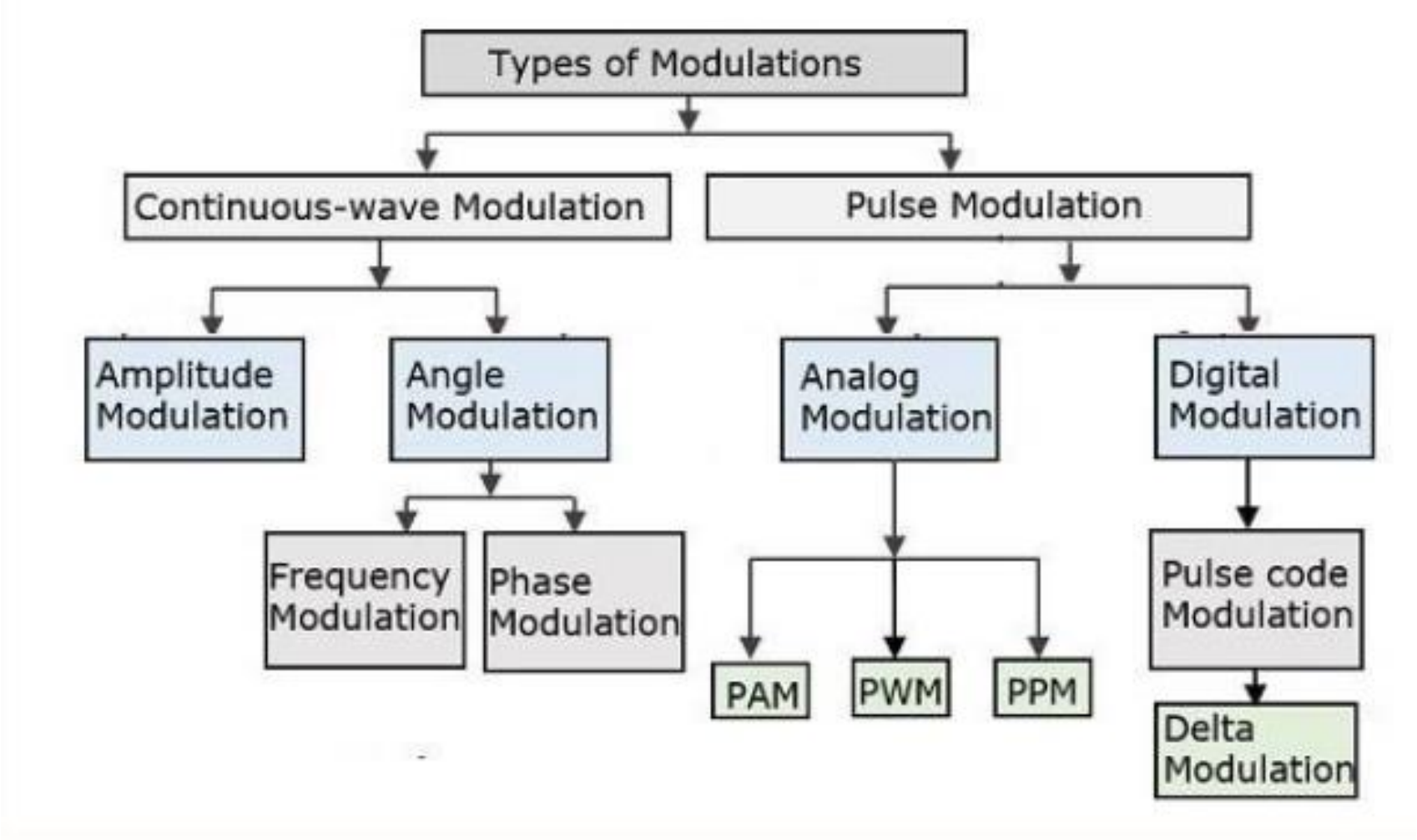


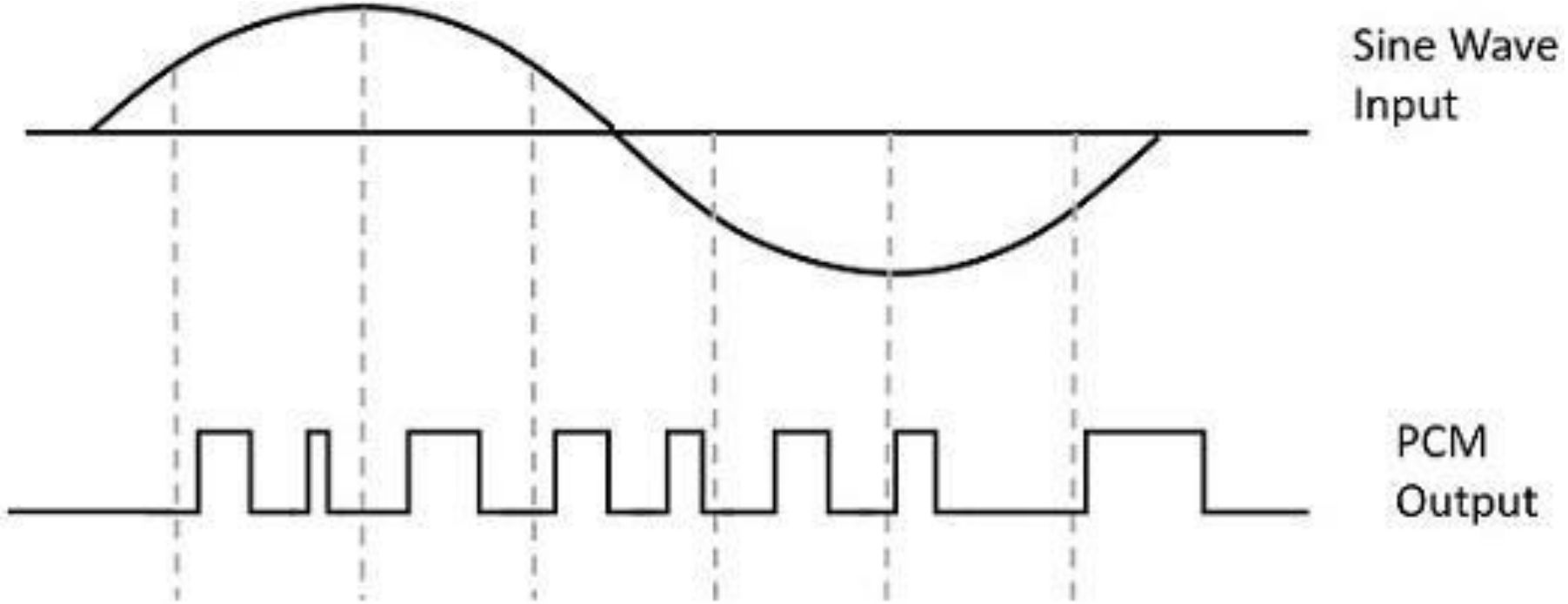
FIGURE 1 Pulse modulation: (a) analog signal; (b) sample pulse; (c) PWM; (d) PPM; (e) PAM; (f) PCM

Introduction



Pulse code modulation (PCM)

- A signal is pulse code modulated to convert its analog information into a binary sequence, i.e.,**1s** and **0s**.
- The output of a PCM will resemble a binary sequence.



Pulse code modulation (PCM)

- Instead of a pulse train, PCM produces a series of numbers or digits, and hence this process is called as **digital**.
- Each one of these digits, though in binary code, represent the approximate amplitude of the signal sample at that instant.
- In Pulse Code Modulation, the message signal is represented by a sequence of coded pulses.
- This message signal is achieved by representing the signal in discrete form in both time and amplitude.
- Pulse code modulations are of two types:

1. Differential pulse code modulation (DPCM)
2. Adaptive differential pulse code modulation (ADPCM)

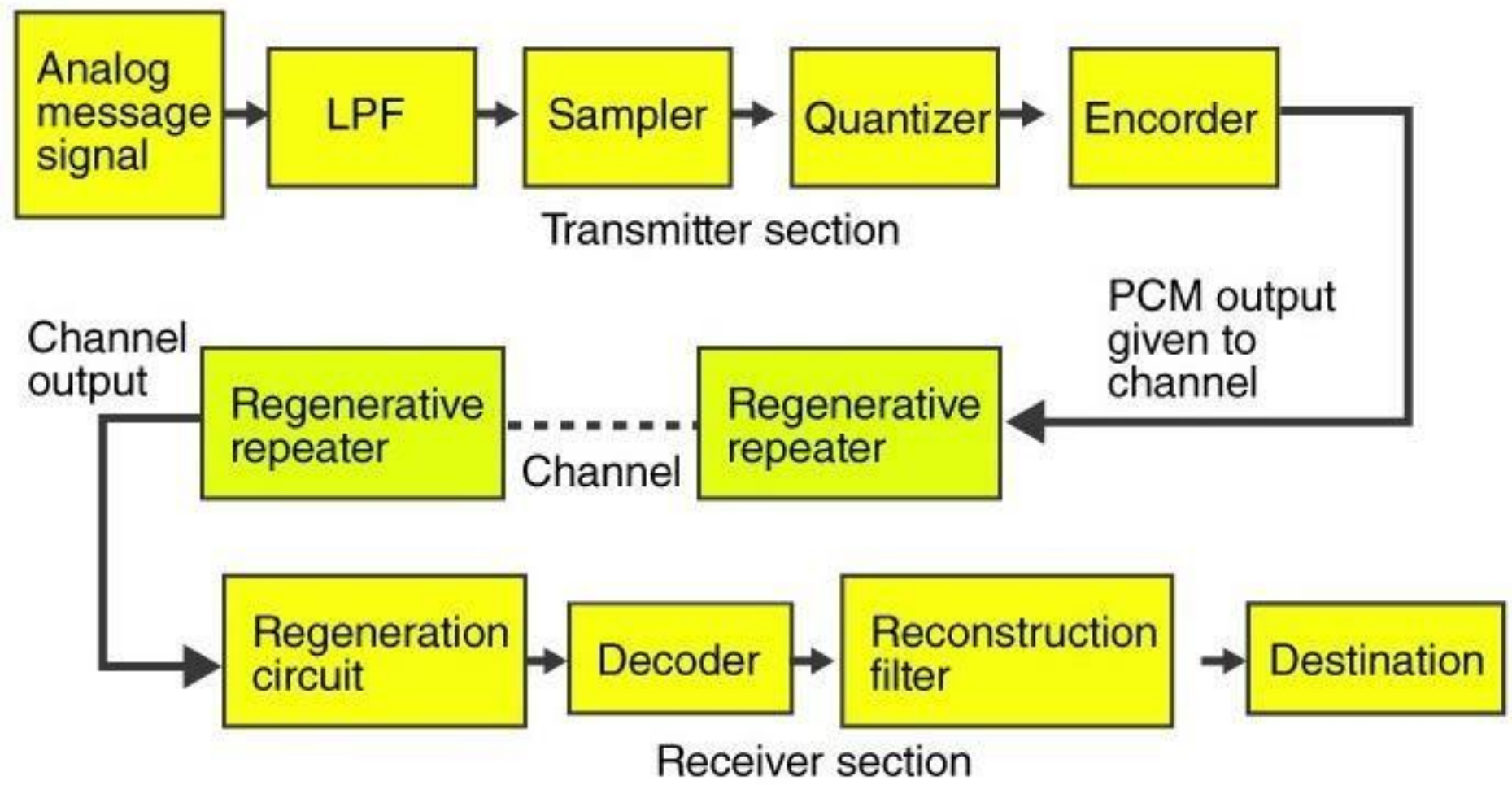
Pulse code modulation (PCM)

- PCM consists of three steps to digitize an analog signal:

1. Sampling
2. Quantization
3. Binary encoding

- Before we sample, we have to filter the signal to limit the maximum frequency of the signal as it affects the sampling rate.
- Filtering should ensure that we do not distort the signal, ie remove high frequency components that affect the signal shape.

Pulse code modulation (PCM)



Pulse code modulation (PCM)

Basic Elements of PCM

- The transmitter section of a Pulse Code Modulator circuit consists of **Sampling, Quantizing** and **Encoding**, which are performed in the analog-to-digital converter section.
- The low pass filter prior to sampling prevents aliasing of the message signal.
- The basic operations in the receiver section are **regeneration of impaired signals, decoding** and **reconstruction** of the quantized pulse train.

Pulse code modulation (PCM)

TRANSMITTER SECTION

Low Pass Filter

- This filter eliminates the high frequency components present in the input analog signal which is greater than the highest frequency of the message signal, to avoid aliasing of the message signal.

Sampler

- This is the technique which helps to collect the sample data at instantaneous values of message signal, so as to reconstruct the original signal.
- The sampling rate must be greater than twice the highest frequency component **W** of the message signal, in accordance with the **sampling theorem**.

Pulse code modulation (PCM)

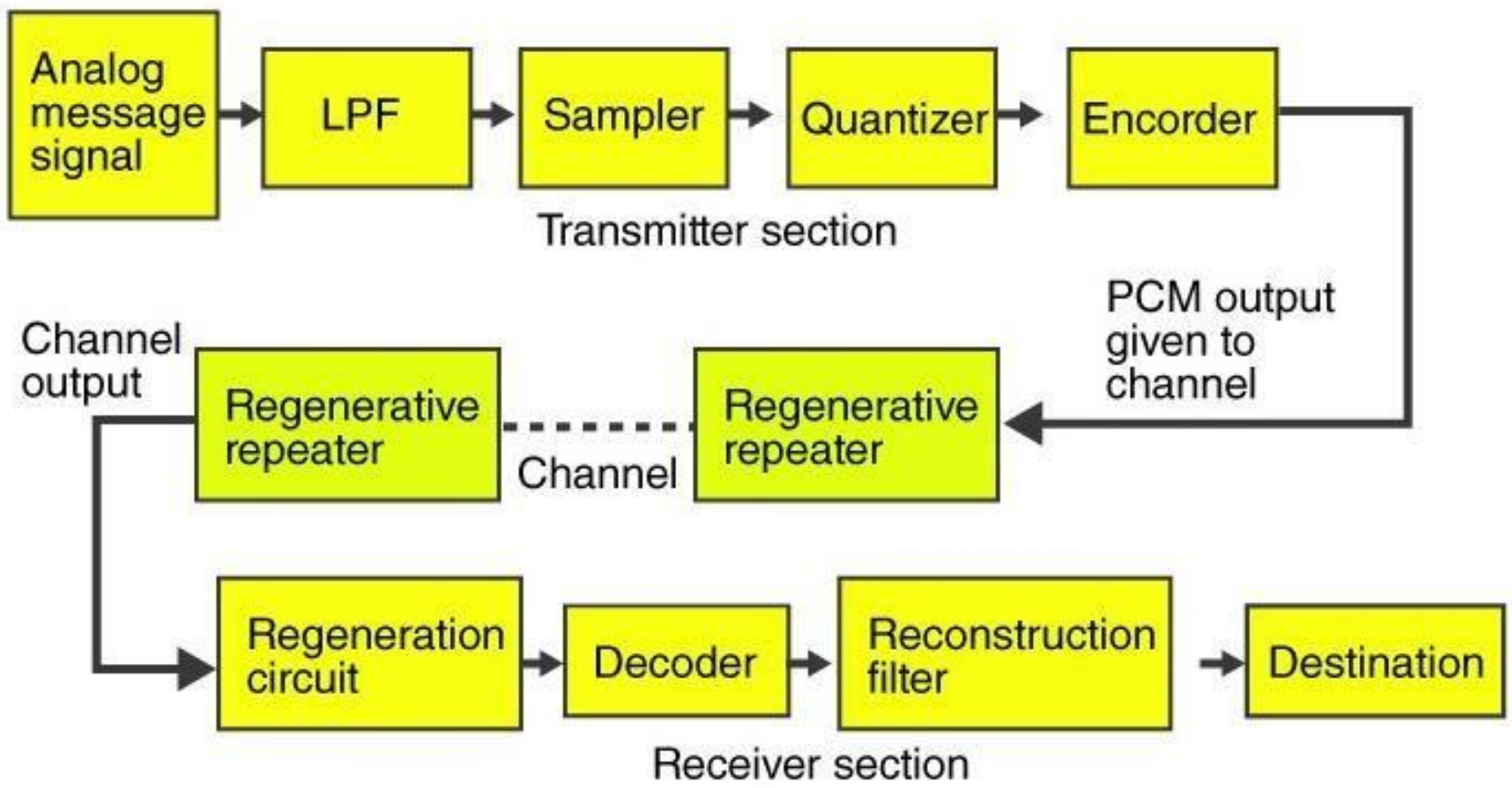
Quantizer

- A Quantizer is a logarithmic function that performs Quantization.
- Amplitude quantization is the process of transforming the sample amplitude of a message signal into discrete amplitudes taken from a finite set of possible amplitudes.

Encoder

- The digitization of analog signal is done by the encoder.
- It designates each quantized level by a binary code.
- The sampling done here is the sample-and-hold process.

Pulse code modulation (PCM)



Pulse code modulation (PCM)

Regenerative Repeater

- This section increases the signal strength.
- The output of the channel also has one regenerative repeater circuit, to compensate the signal loss and reconstruct the signal, and also to increase its strength.

RECIEVER SECTION

Decoder

- The decoder circuit decodes the pulse coded waveform to reproduce the original signal.
- This circuit acts as the demodulator.

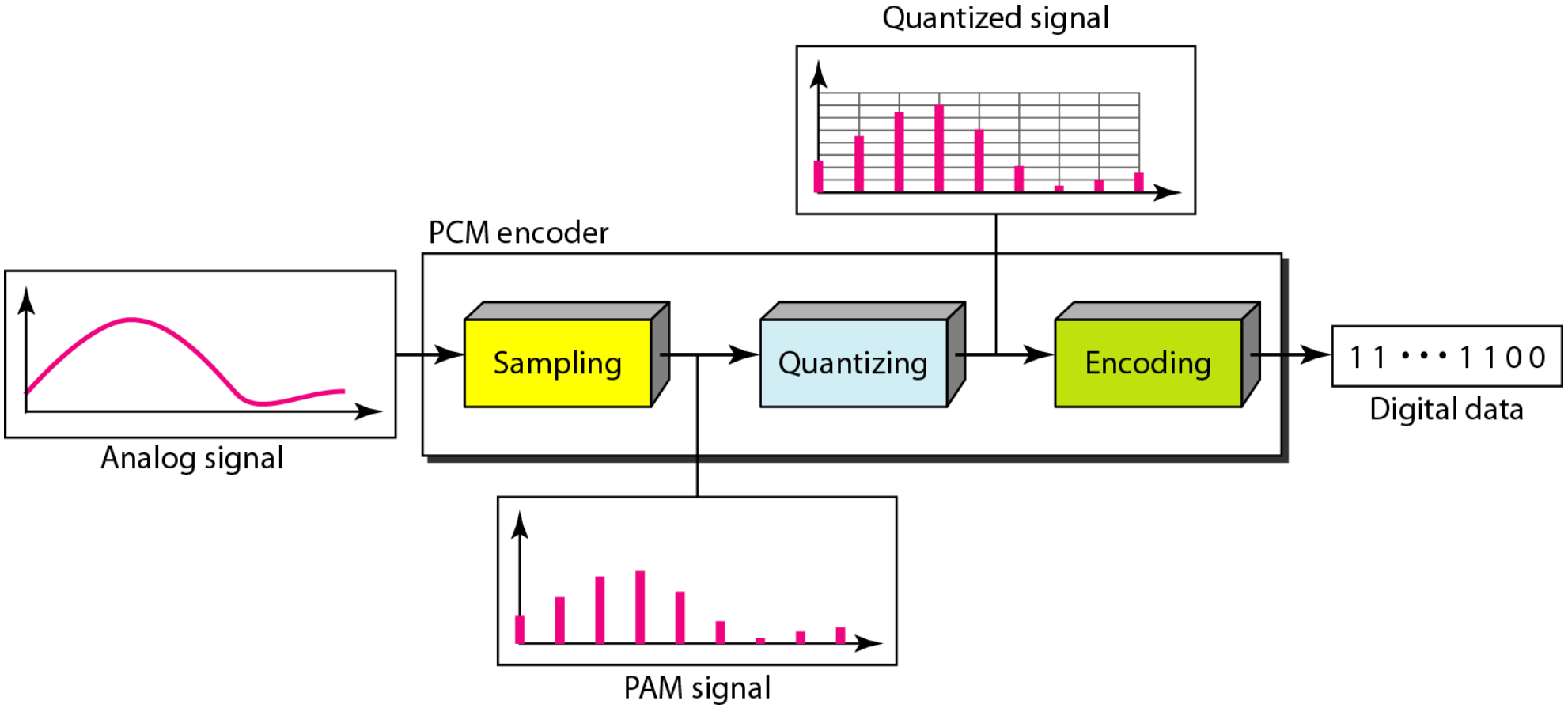
Pulse code modulation (PCM)

Reconstruction Filter

- After the digital-to-analog conversion is done by the regenerative circuit and the decoder,
- A low-pass filter is employed, called as the reconstruction filter to get back the original signal.
- Hence, the Pulse Code Modulator circuit digitizes the given analog signal, codes it and samples it, and then transmits it in a digital form.
- This whole process is repeated in a reverse pattern to obtain the original signal.

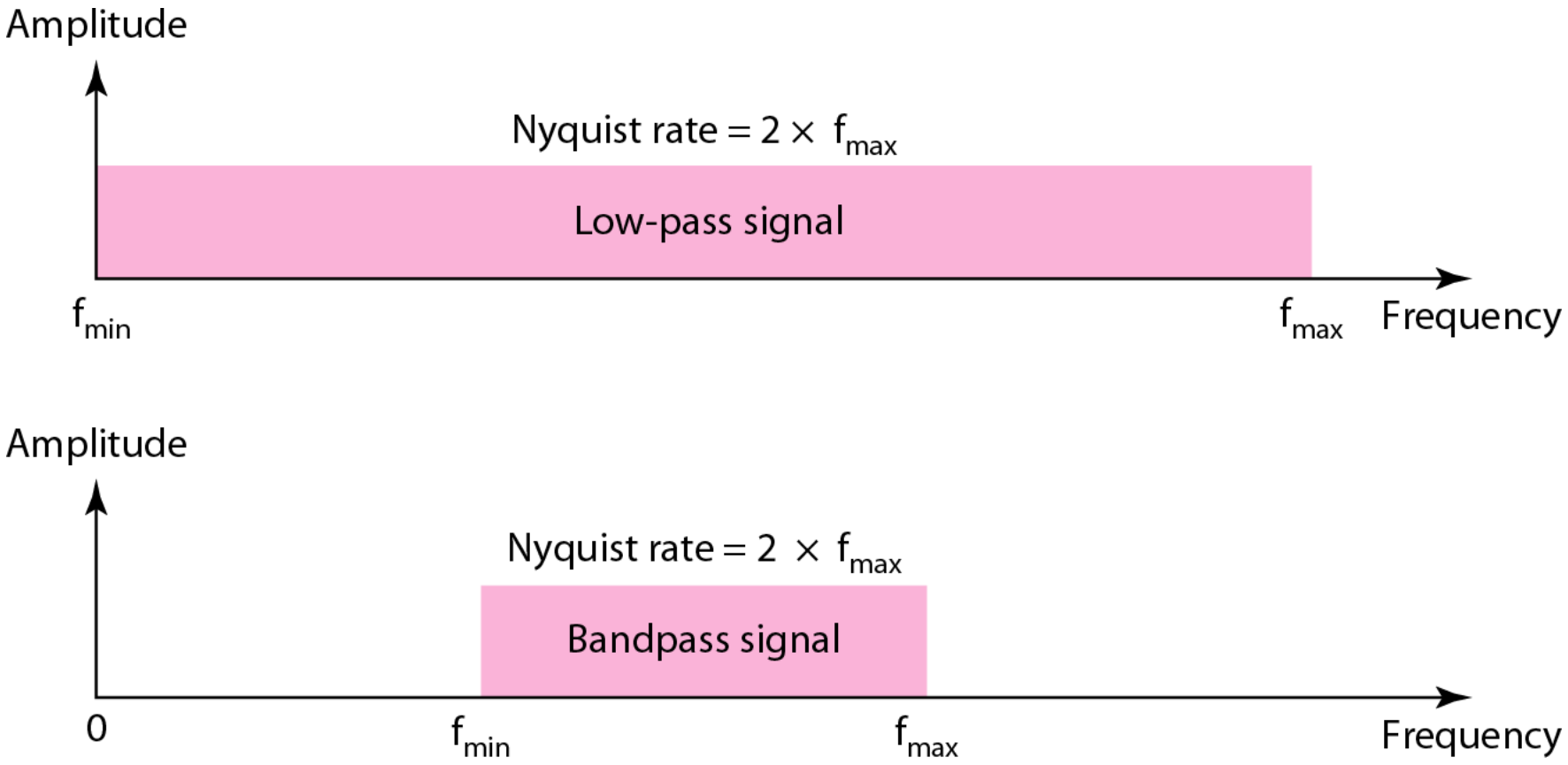
Pulse code modulation (PCM)

- These four sections **LPF, Sampler, Quantizer and Encoder** will act as an analog to digital converter. Encoding minimizes the bandwidth used.



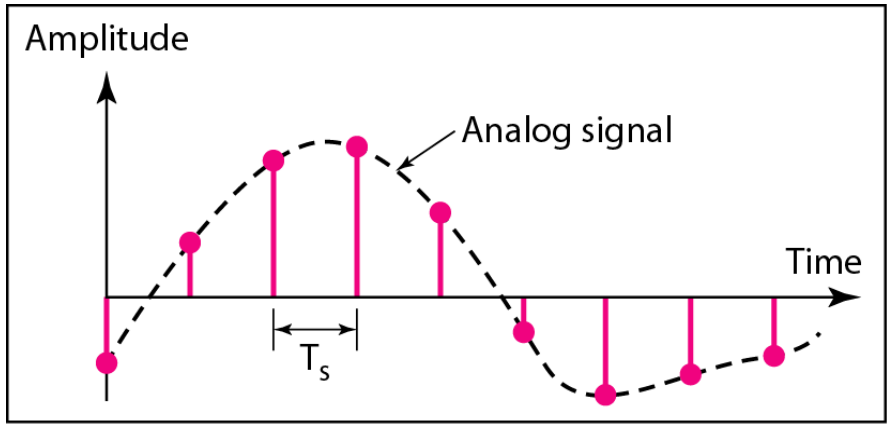
Pulse code modulation (PCM)

- **Low Pass Filter:** Nyquist sampling rate for low-pass and bandpass signals

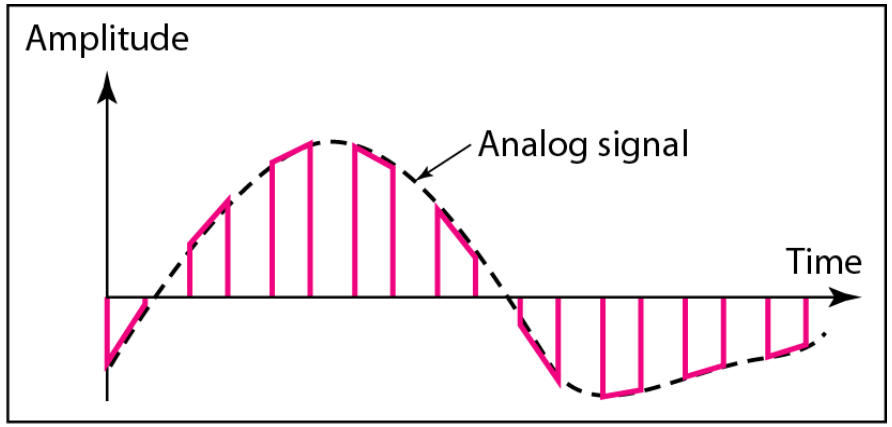


Pulse code modulation (PCM)

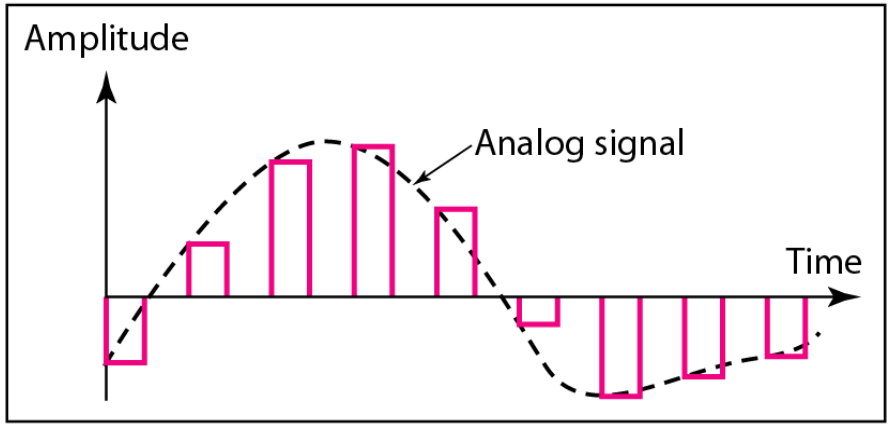
- **Sampling:** Three different sampling methods for PCM



a. Ideal sampling



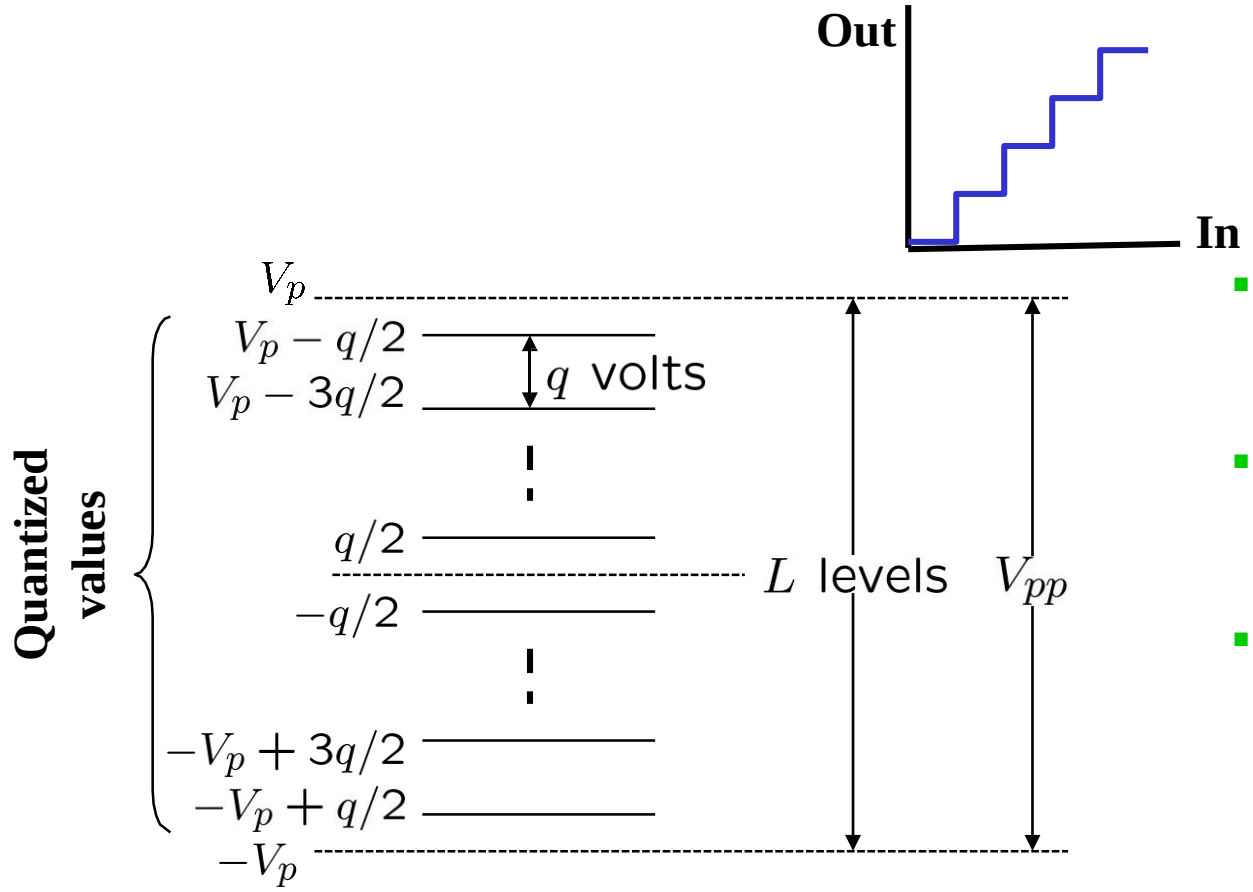
b. Natural sampling



c. Flat-top sampling

Pulse code modulation (PCM)

- **Amplitude quantizing**: Mapping samples of a continuous amplitude waveform to a finite set of amplitudes.



- Average quantization noise power

$$\sigma^2 = \frac{q^2}{12}$$

- Signal peak power

$$V_p^2 = \frac{L^2 q^2}{4}$$

- Signal power to average quantization noise power

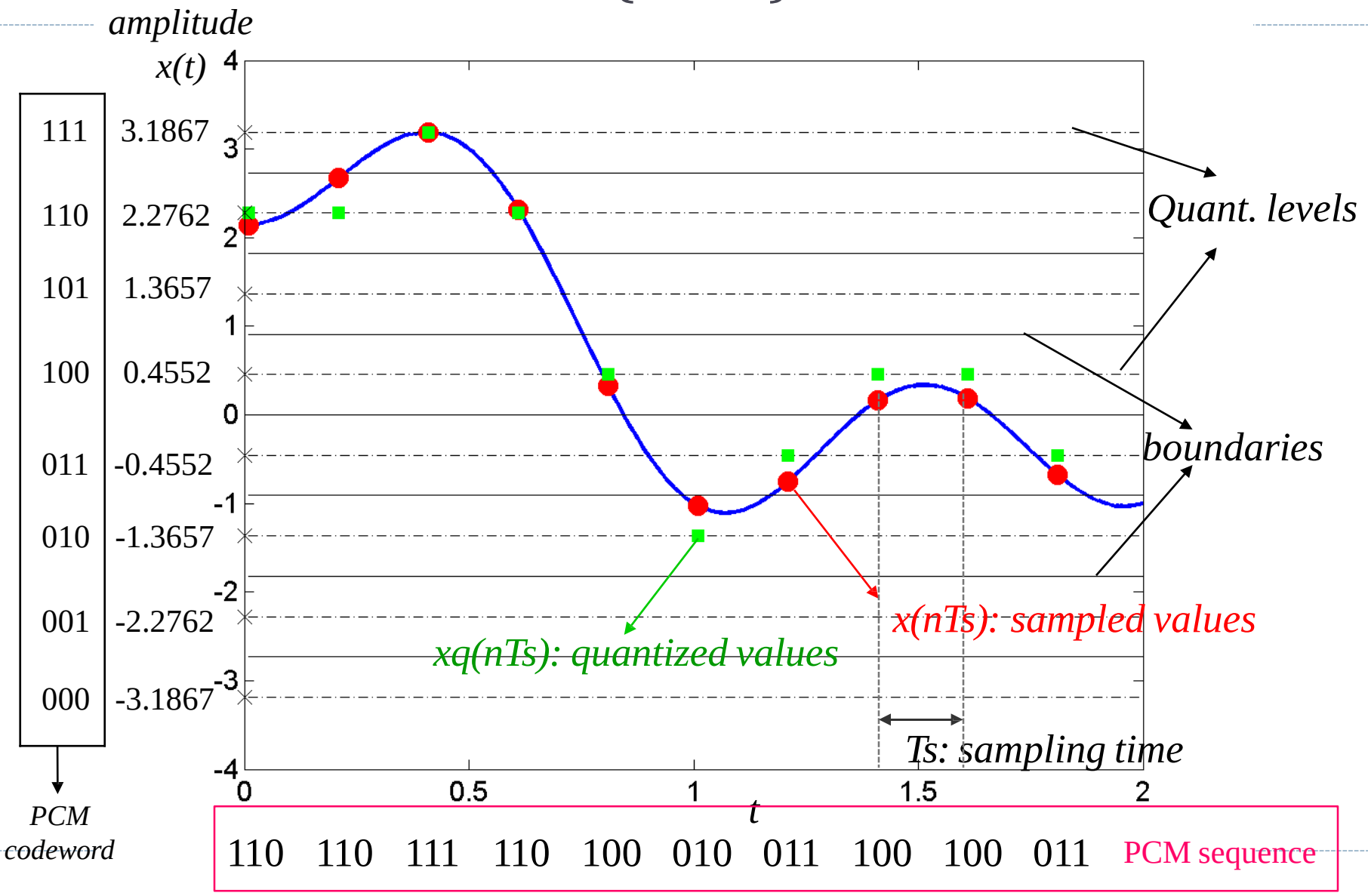
$$\left(\frac{S}{N}\right)_q = \frac{V_p^2}{\sigma^2} = 3L^2$$

Pulse code modulation (PCM)

- A uniform linear quantizer is called Pulse Code Modulation (PCM).
- Pulse code modulation (PCM): Encoding the quantized signals into a digital word (PCM word or codeword).
- Each quantized sample is digitally encoded into a n_b bits codeword where **L** in the number of quantization levels

$$n_b = log_2 L$$

Pulse code modulation (PCM)



Pulse code modulation (PCM)

Bit rate and bandwidth requirements of PCM:

- The bit rate of a PCM signal can be calculated form the number of bits per sample x the sampling rate

$$\boldsymbol{Bit\ Rate = n_b \times f_s}$$

- The bandwidth required to transmit this signal depends on the type of line encoding used.
- A digitized signal will always need more bandwidth than the original analog signal.

Numerical

- We want to digitize the human voice.
- What is the bit rate, assuming 8 bits per sample?

Solution:

Numerical

- We want to digitize the human voice.
- What is the bit rate, assuming 8 bits per sample?

Solution:

- The human voice normally contains frequencies from 0 to 4000 Hz.
- So the sampling rate and bit rate are calculated as follows:

$$\boldsymbol{Sampling\ Rate = 4000 \times 2 = 8000\ samples}$$

$$\boldsymbol{Bit\ Rate = 8000 \times 8 = 64,000 = 64\ kbps}$$