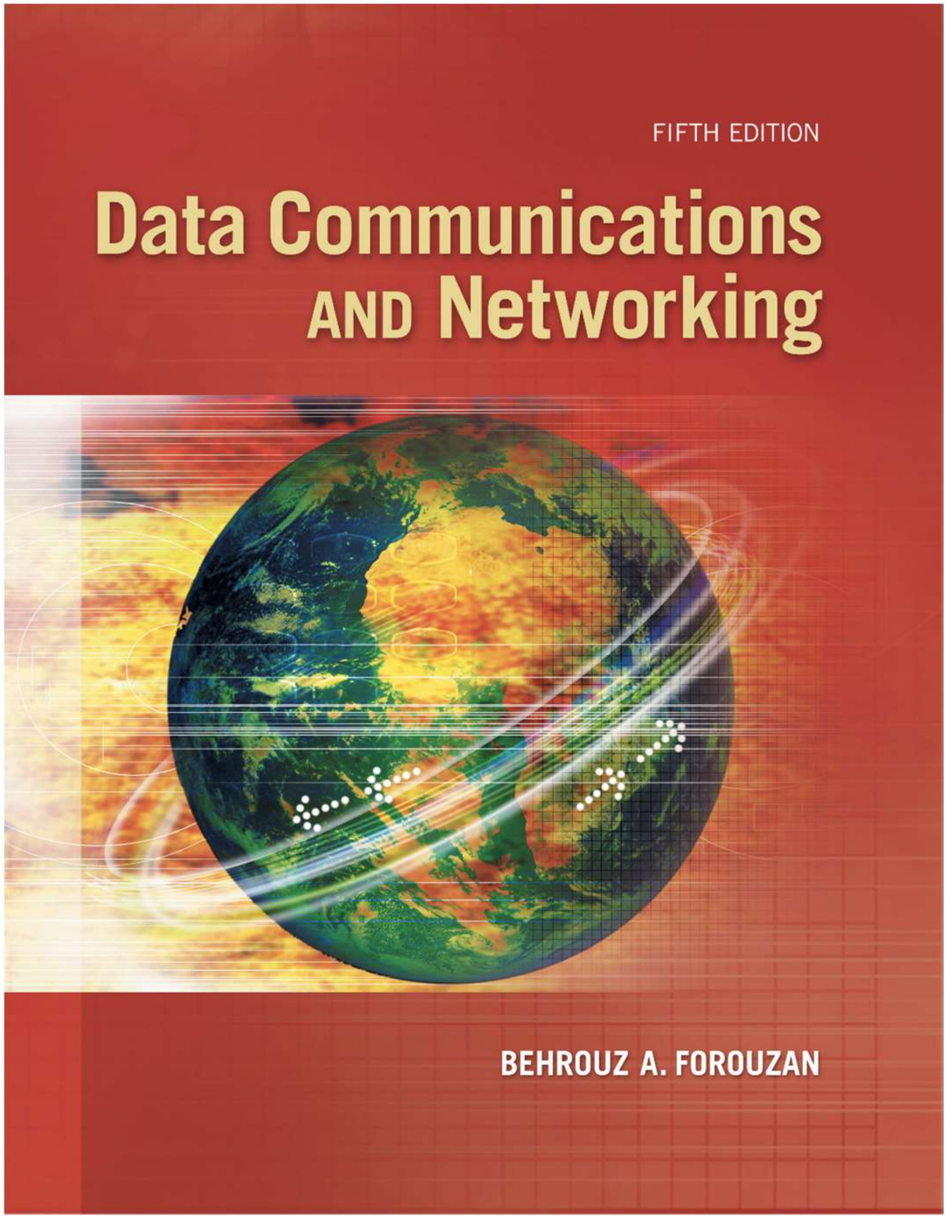
Chapter 4

Digital Transmission



4-1 DIGITAL-TO-DIGITAL CONVERSION

How we can represent digital data by using digital signals?

The conversion involves three techniques:

- *line coding*
- *block coding*
- *scrambling*

Line coding is always needed; block coding and scrambling may or may not be needed.

4.4.1 Line Coding

- ***Line coding is the process of converting digital data to digital signals.***

- ***We assume that data, in the form of text, numbers, graphical images, audio, or video, are stored in computer memory as sequences of bits (see Chapter 1).***

- ***Line coding converts a sequence of bits to a digital signal. At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal. Figure 4.1 shows the process.***

Figure 4.1: Line coding and decoding

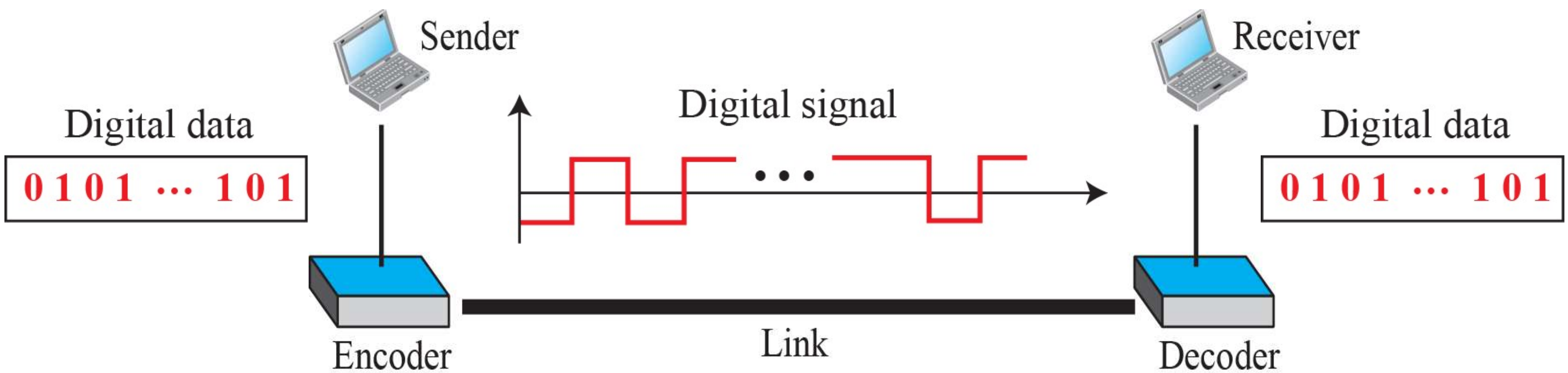
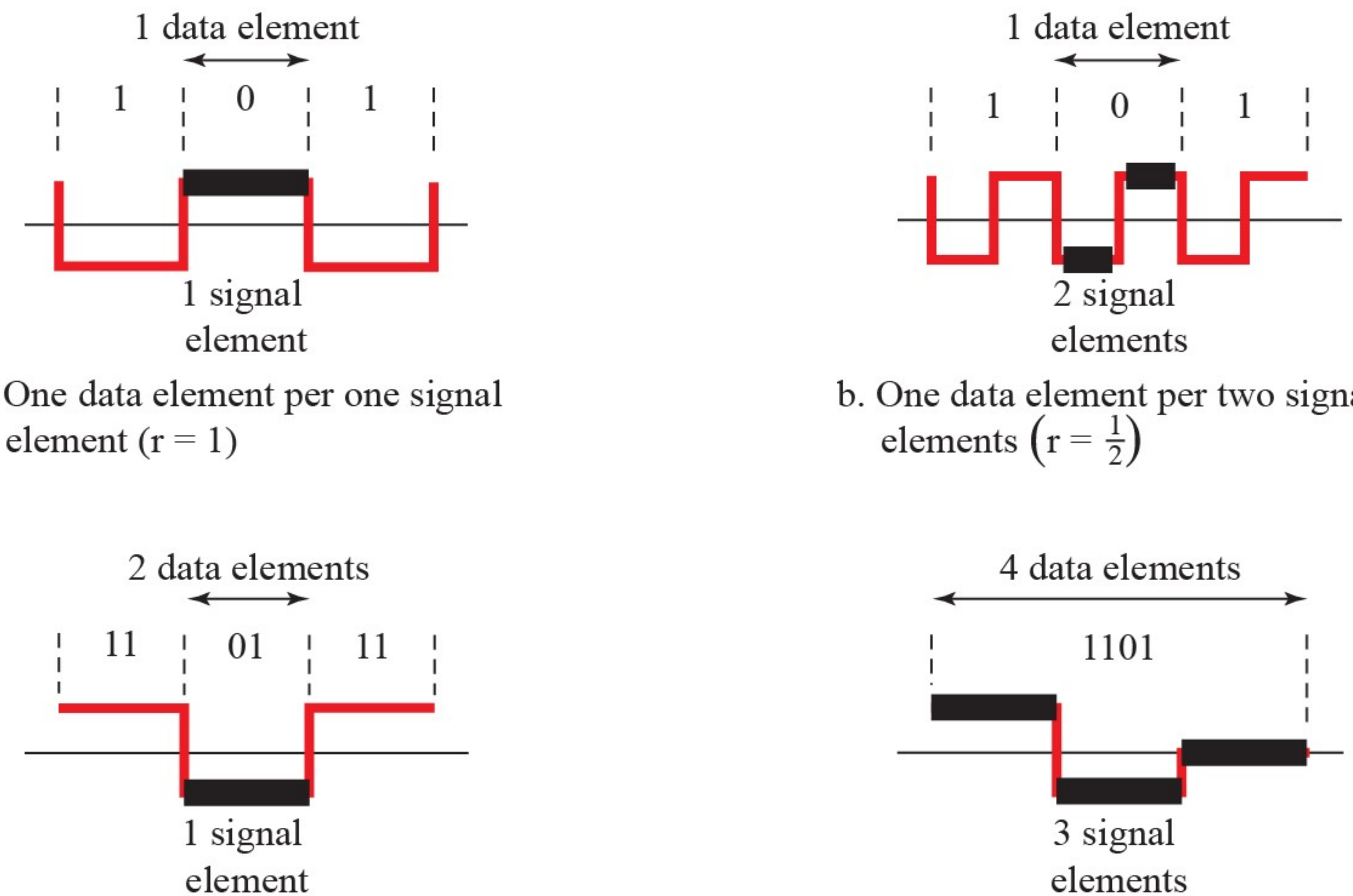


Figure 4.2: Signal elements versus data elements



a. One data element per one signal element ($r = 1$)

b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$

c. Two data elements per one signal element ($r = 2$)

d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Example 4.1

A signal is carrying data in which one data element is encoded as one signal element ($r = 1$). If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and 1?

Solution

We assume that the average value of c is 1/2. The baud rate is then

$$S = c \times N \times (1 / r) = 1/2 \times 100{,}000 \times (1/1) = 50{,}000 = 50 \text{ kbaud}$$

Example 4.2

The maximum data rate of a channel (see Chapter 3) is $N_{max} = 2 \times B \times \log2\ L$ (defined by the Nyquist formula). Does this agree with the previous formula for N_{max}?

Solution

A signal with L levels actually can carry log2 L bits per level. If each level corresponds to one signal element and we assume the average case (c = 1/2), then we have

$$N_{max} = (1/c) \times B \times r = 2 \times B \times \log_2 L$$

Example 4.3

In a digital transmission, the receiver clock is 0.1 percent faster than the sender clock. How many extra bits per second does the receiver receive if the data rate is 1 kbps? How many if the data rate is 1 Mbps?

Solution

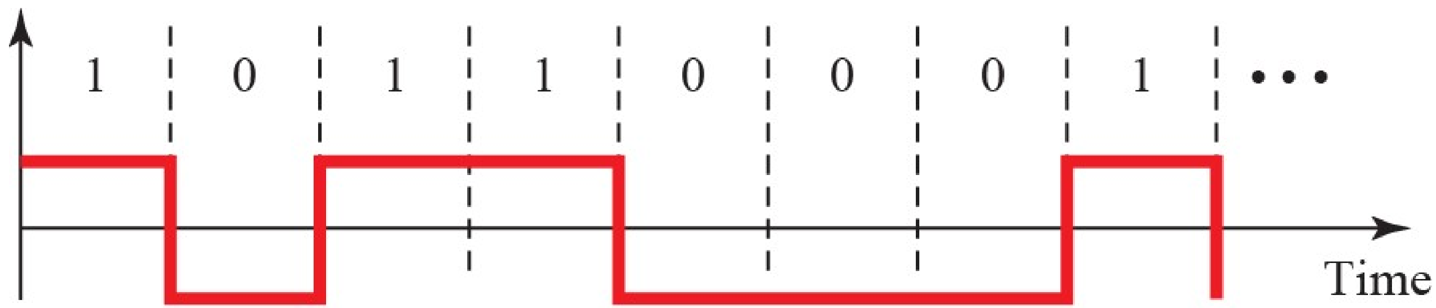
At 1 kbps, the receiver receives 1001 bps instead of 1000 bps.

$$1000 \text{ bits sent} \rightarrow 1001 \text{ bits received} \rightarrow 1 \text{ extra bps}$$

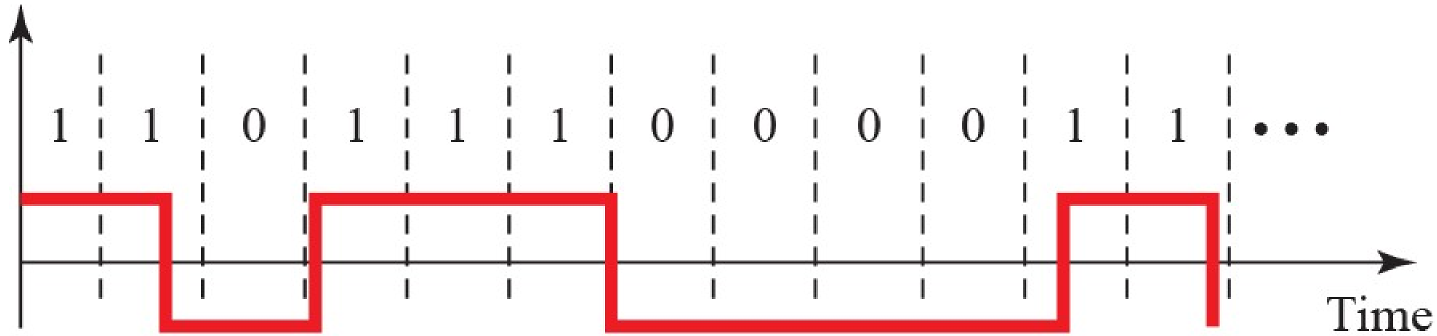
At 1 Mbps, the receiver receives 1,001,000 bps instead of 1,000,000 bps.

$$1{,}000{,}000 \text{ bits sent} \rightarrow 1{,}001{,}000 \text{ bits received} \rightarrow 1000 \text{ extra bps}$$

Figure 4.3:* *Effect of lack of synchronization



a. Sent



b. Received

4.4.2 Line Coding Schemes

We can roughly divide line coding schemes into five broad categories, as shown in Figure 4.4.
There are several schemes in each category. We need to be familiar with all schemes discussed in this section to understand the rest of the book. This section can be used as a reference for schemes encountered later.

Figure 4.4: Line coding scheme

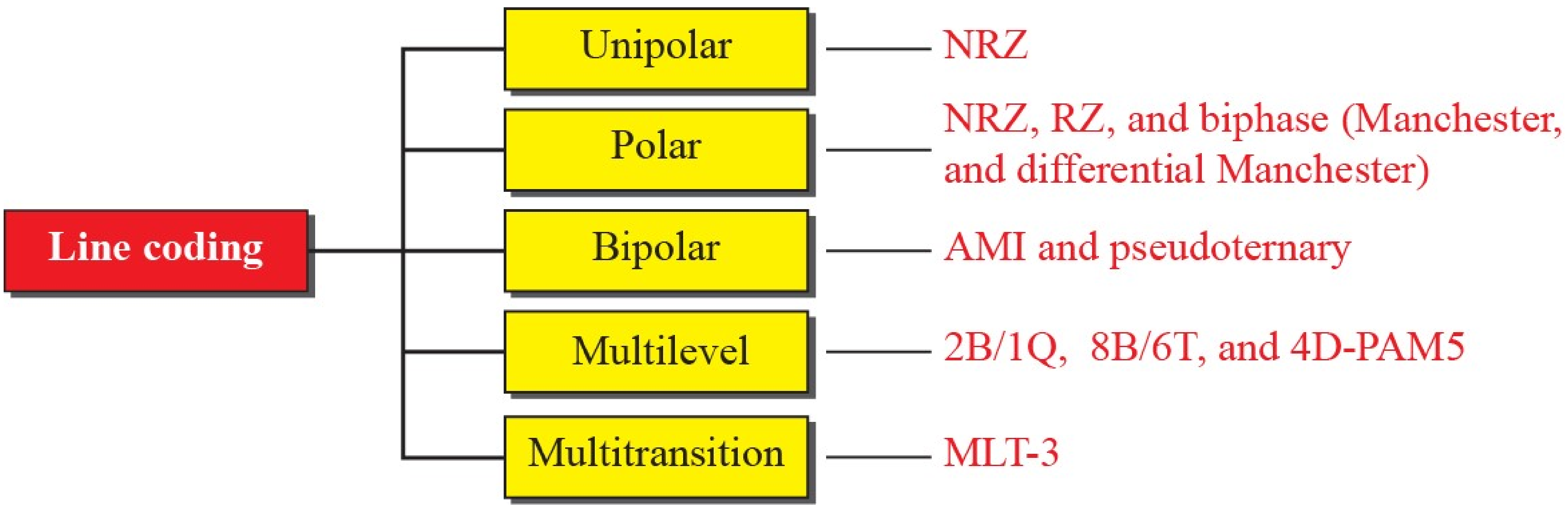


Figure 4.5:* *Unipolar NRZ scheme

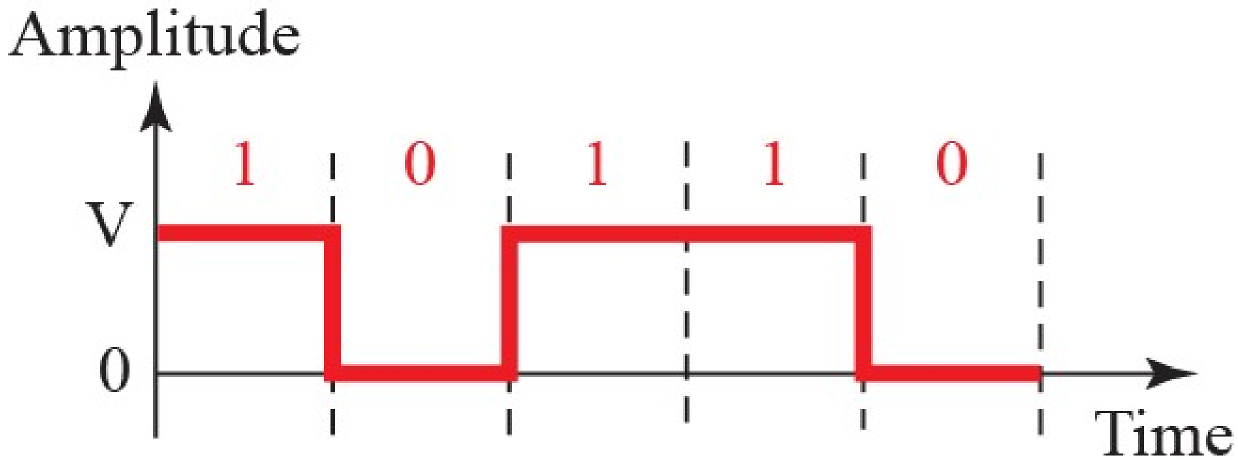
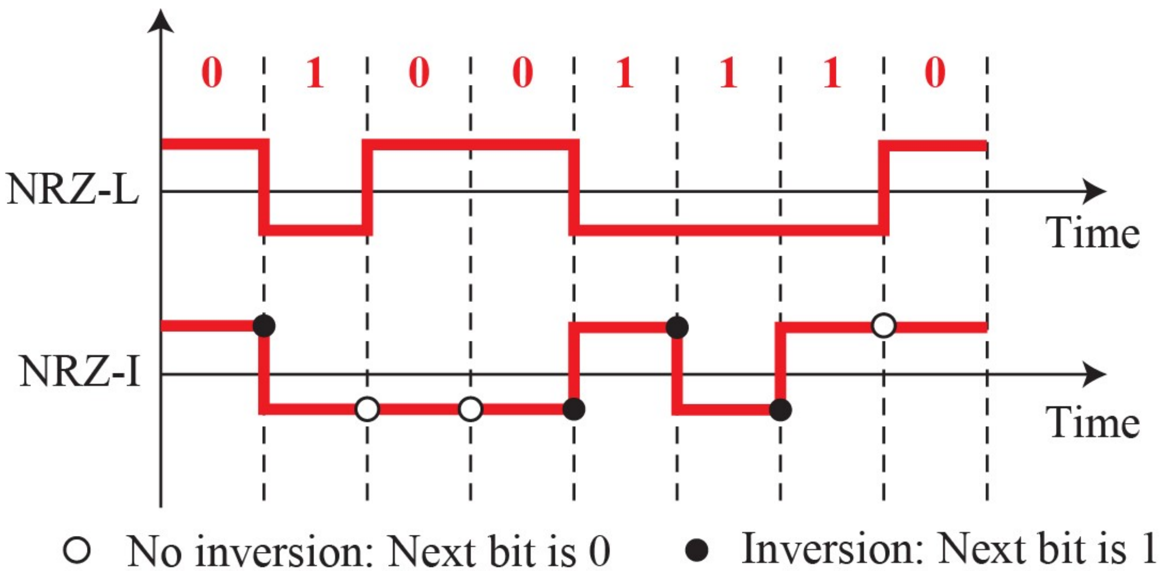
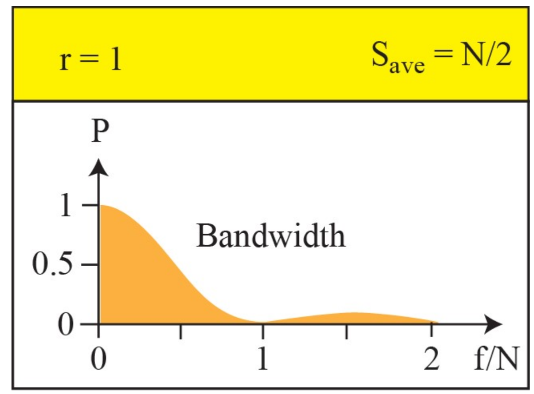


Figure 4.6: Polar schemes (NRZ-L and NRZ-I)





Example 4.4

A system is using NRZ-I to transfer 10-Mbps data. What are the average signal rate and minimum bandwidth?

Solution

The average signal rate is $S = N/2 = 500$ kbaud. The minimum bandwidth for this average baud rate is $B_{min} = S = 500$ kHz.

Figure 4.7: Polar schemes (RZ)

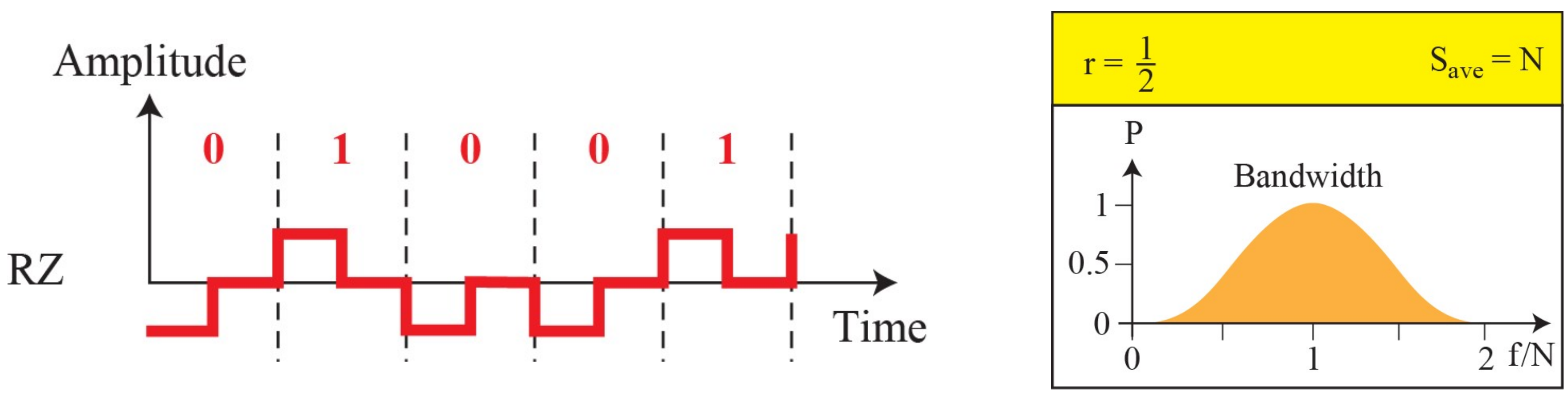


Figure 4.8: Polar biphase

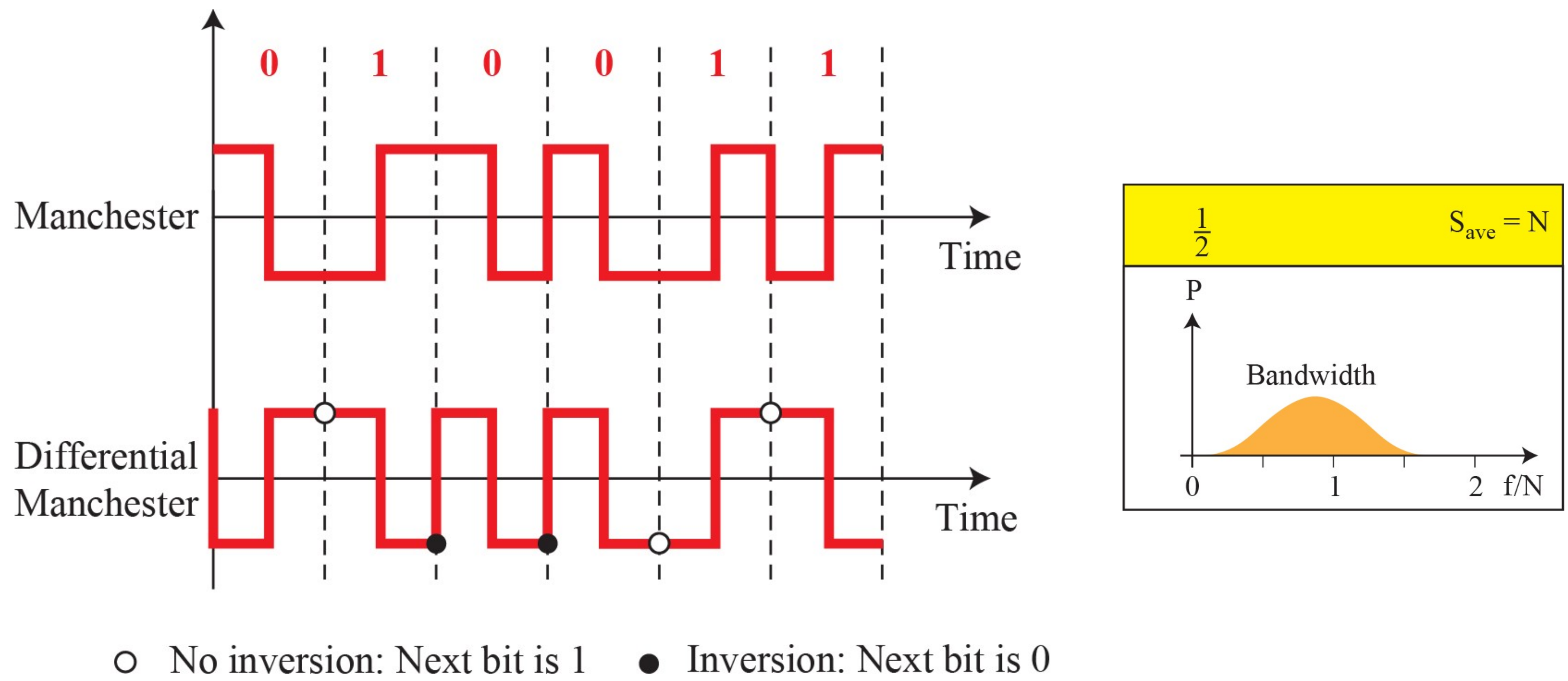
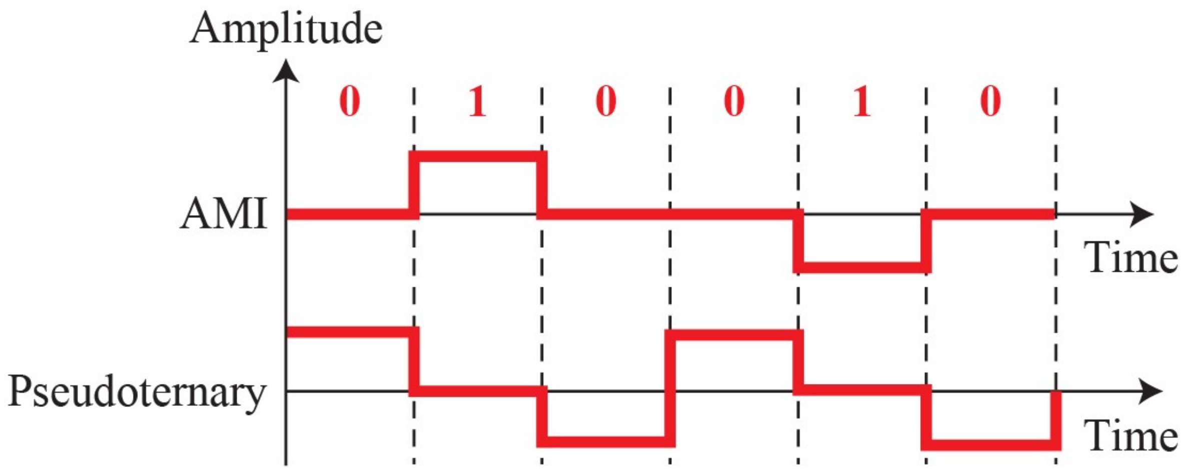


Figure 4.9: Bipolar schemes: AMI and pseudoternary



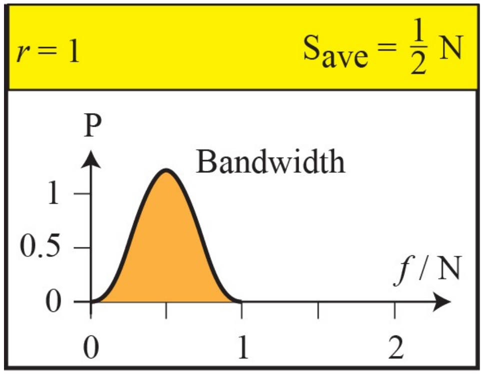


Table 4.1: Summary of line coding schemes

Category	*Scheme*	*Bandwidth (average)*	*Characteristics*
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Polar	NRZ-L	$B = N/2$	No self-synchronization if long 0s or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long 0s, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = N/2$	No self-synchronization for long 0s, DC

4-2 ANALOG-TO-DIGITAL CONVERSION

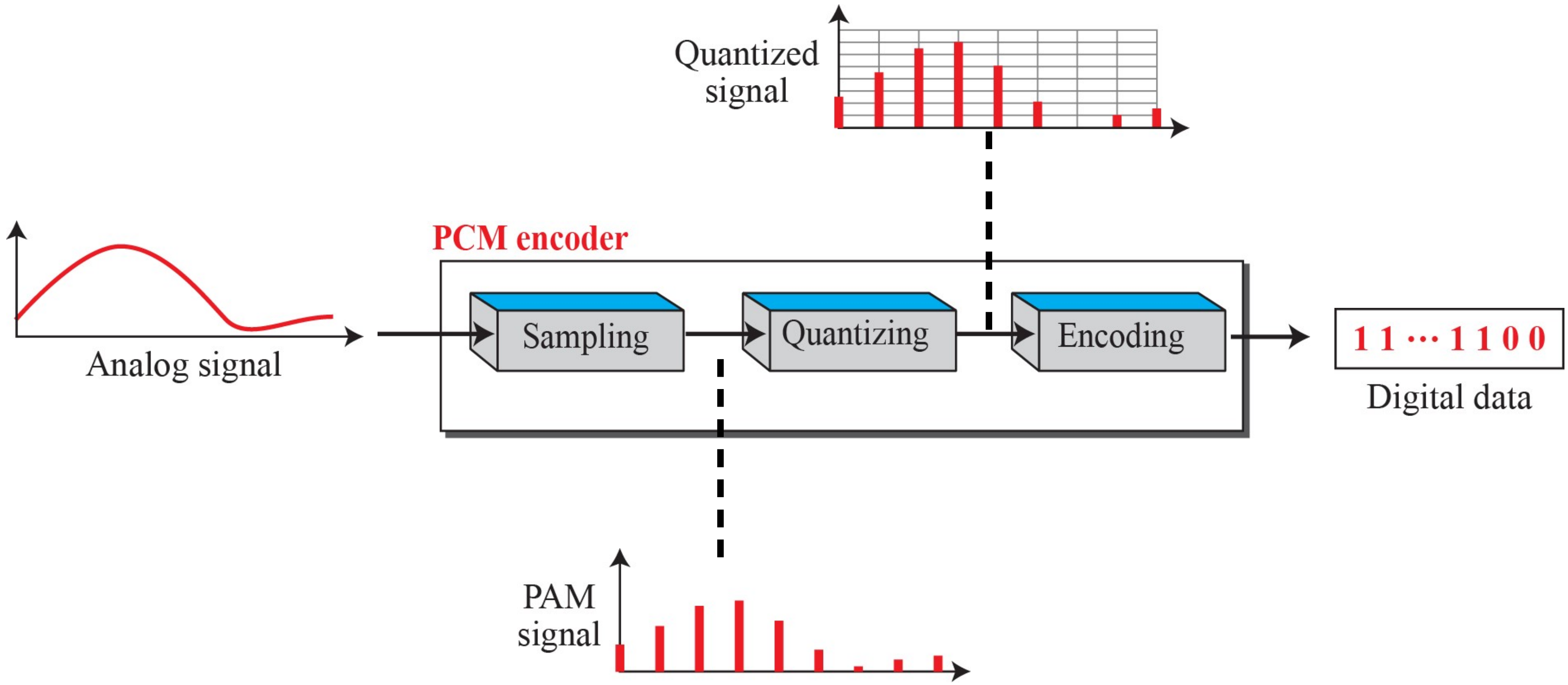
The techniques described in Section 4.1 convert digital data to digital signals. Sometimes, however, we have an analog signal such as one created by a microphone or camera.

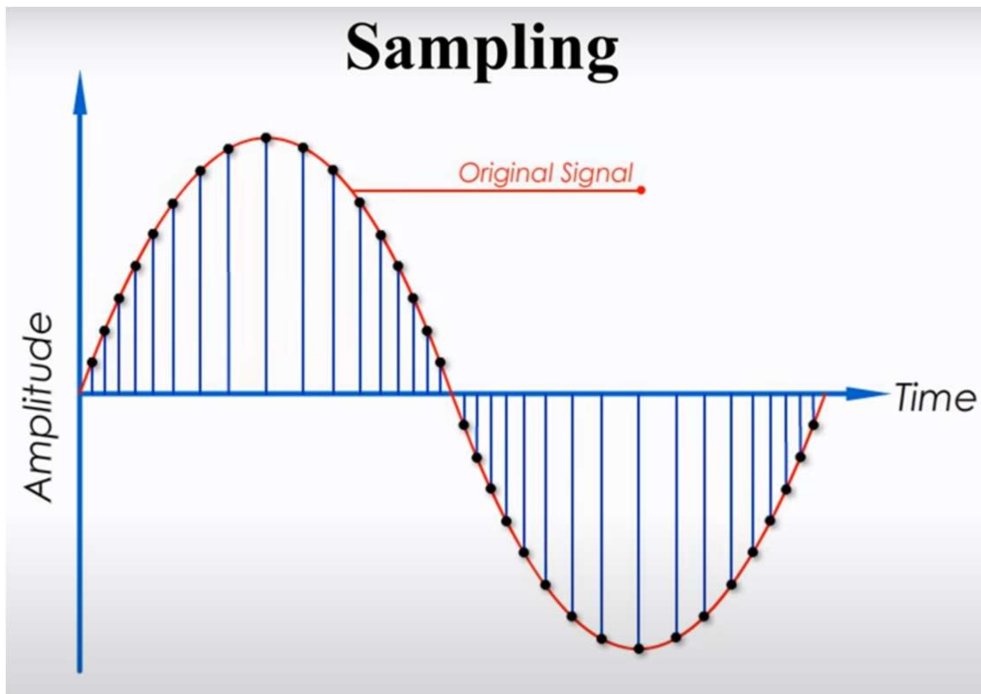
In this section we describe two techniques, pulse code modulation and delta modulation.

4.2.1 Pulse Code Modulation (PCM)

The most common technique to change an analog signal to digital data (digitization) is called pulse code modulation (PCM). A PCM encoder has three processes, as shown in Figure 4.24.

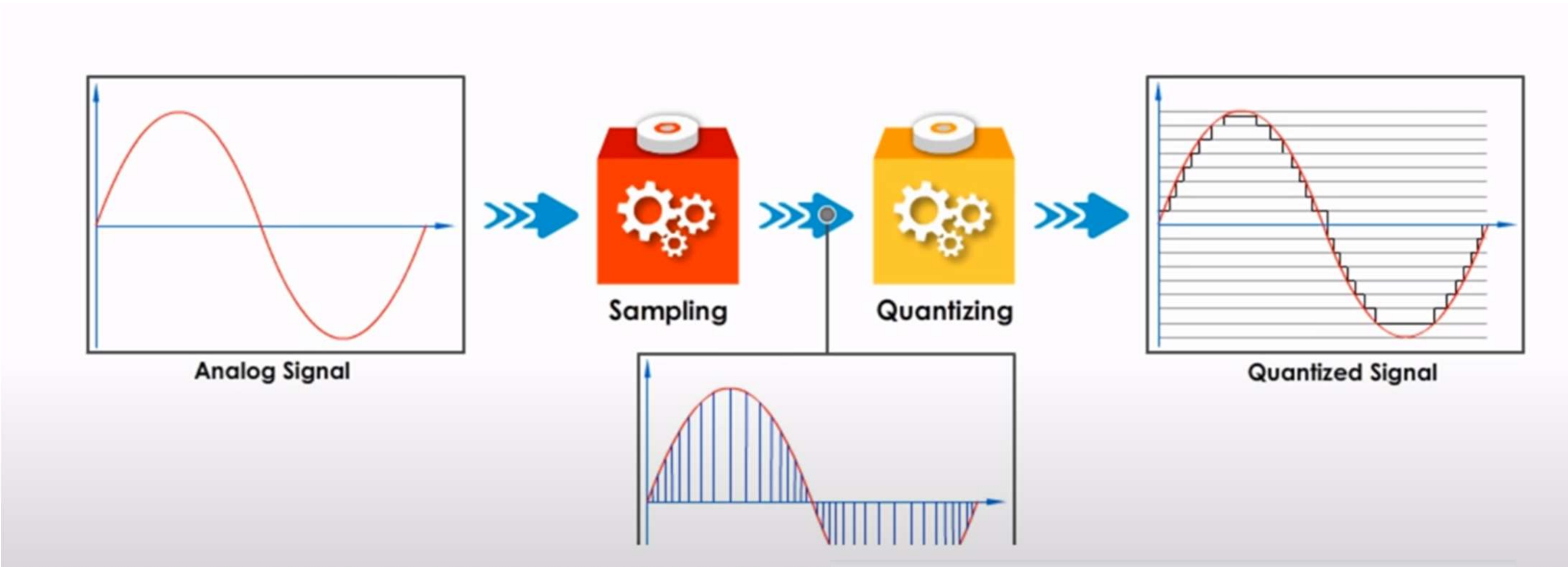
Figure 4.21: ***Components of PCM encoder***

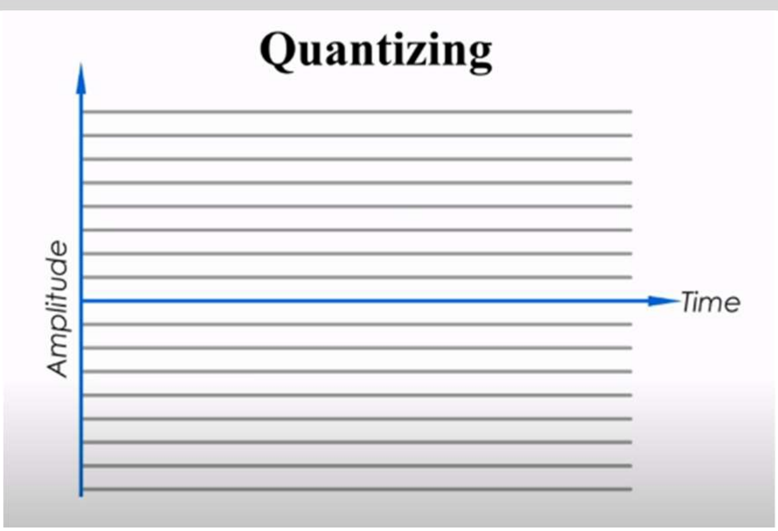


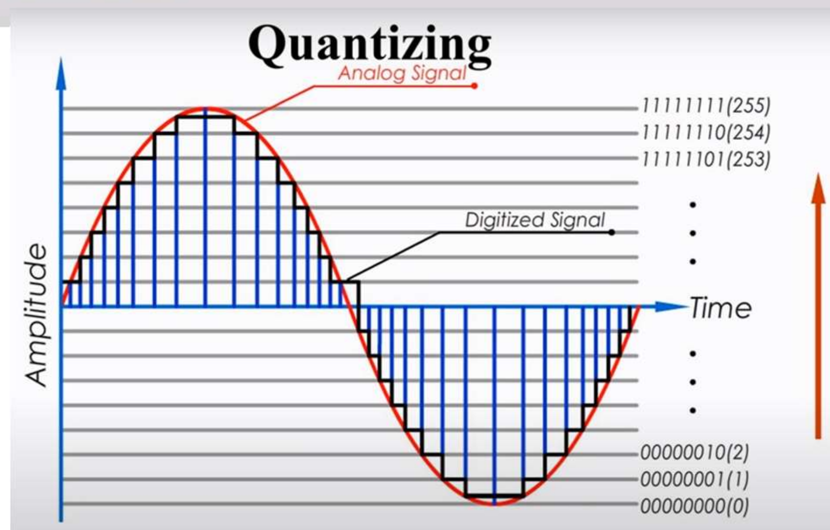


Sample rate is 34 times per second. 1 Second analog signal is sampled 34 times.

Quantization







Encoding

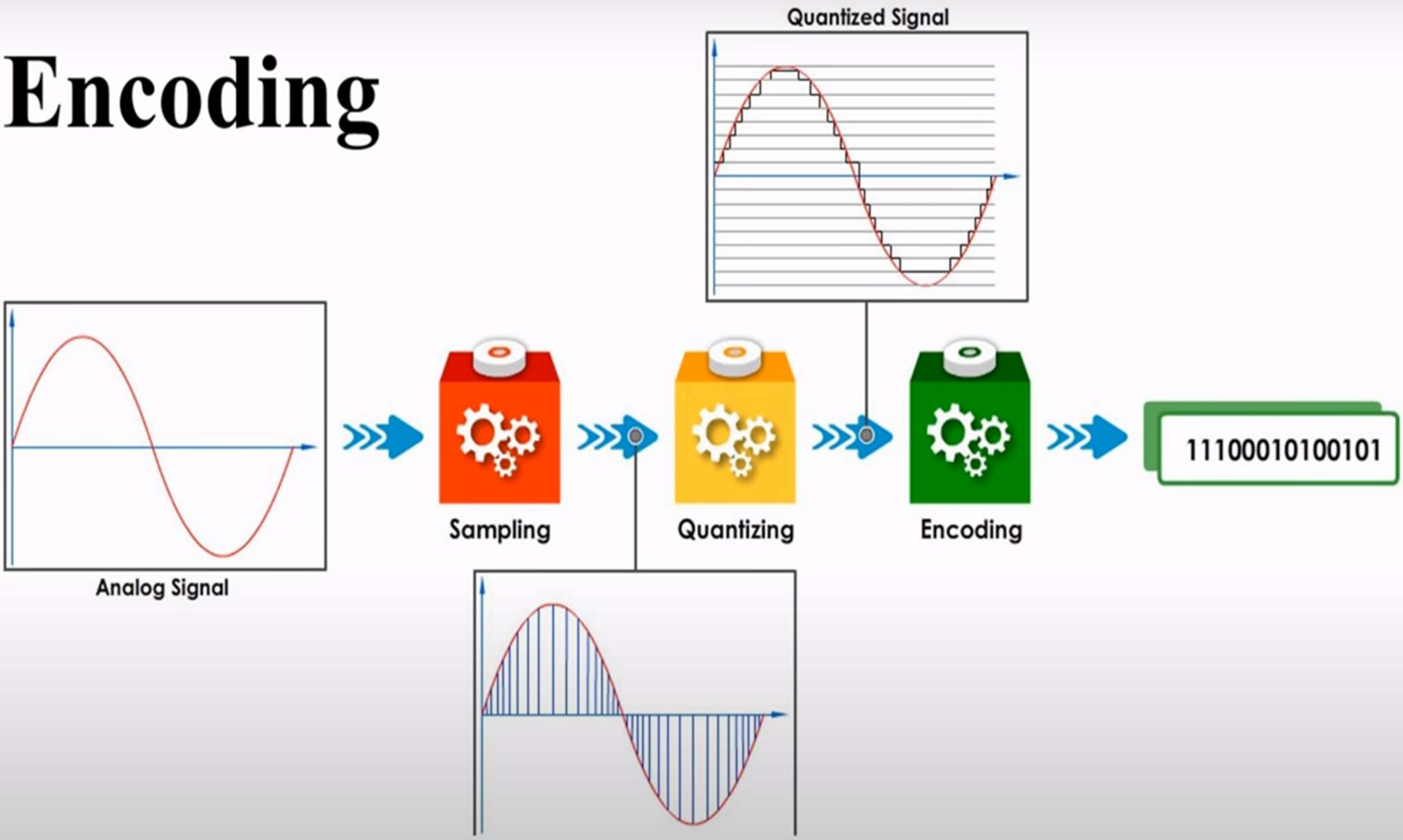

Quantized Signal
Sampling
Quantizing
Encoding
11100010100101
Analog Signal

***Figure 4.22:* Three different sampling methods for PCM**

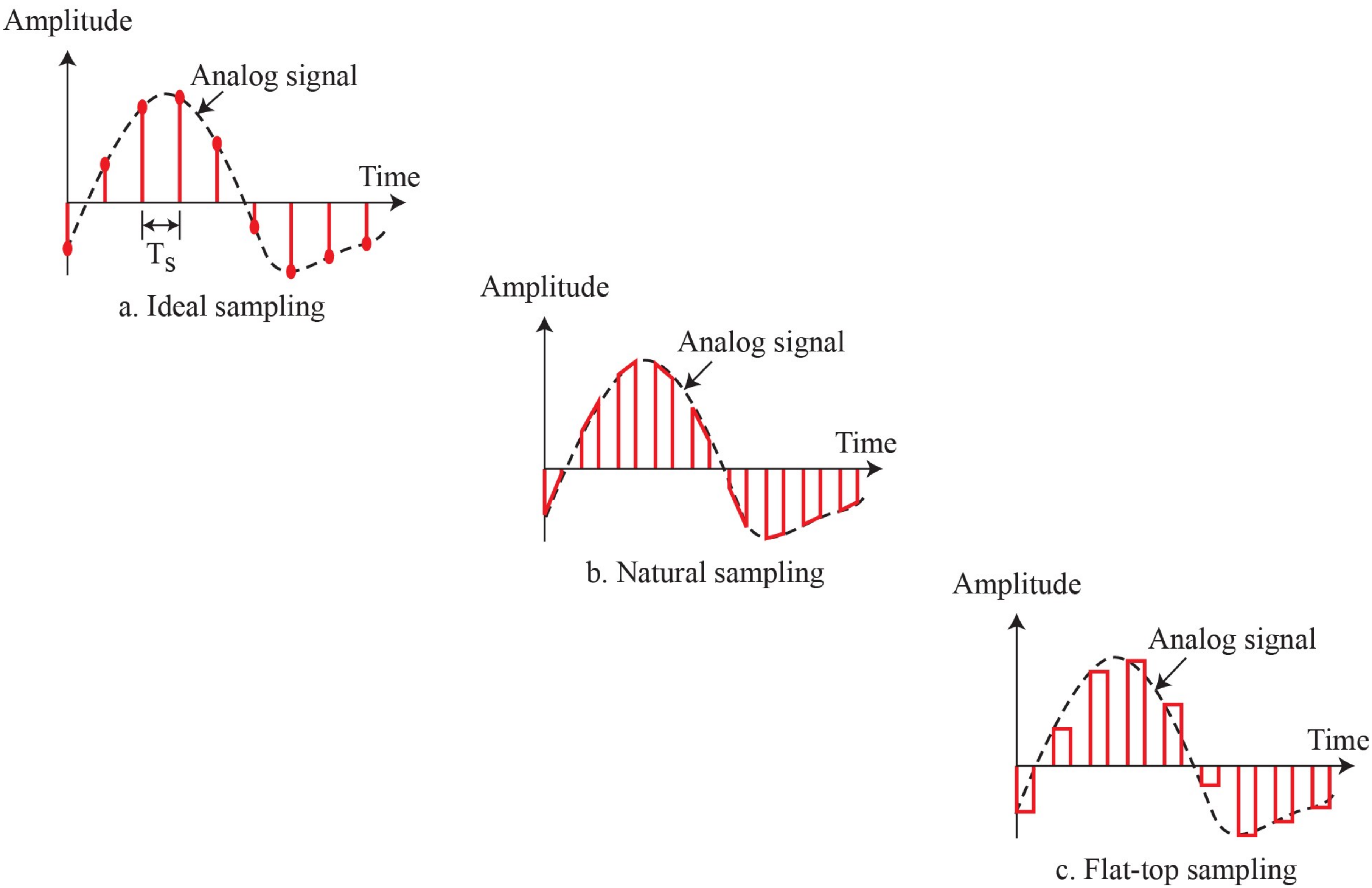
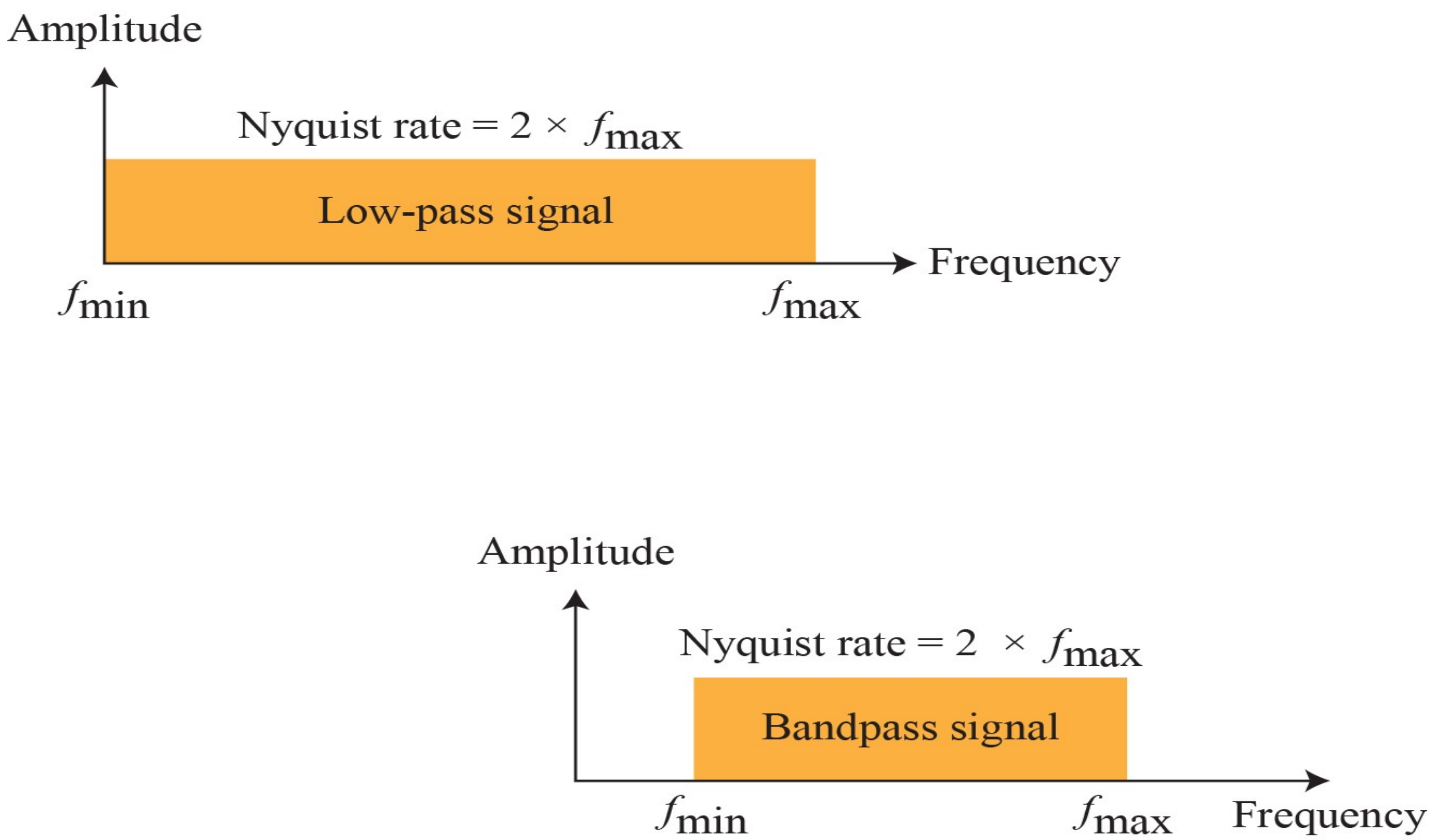


Figure 4.23: Nyquist sampling rate for low-pass and bandpass signals



4.2.2 Delta Modulation (DM)

PCM is a very complex technique. Other techniques have been developed to reduce the complexity of PCM. The simplest is delta modulation. PCM finds the value of the signal amplitude for each sample; DM finds the change from the previous sample. Figure 4.28 shows the process. Note that there are no code words here; bits are sent one after another.

Figure 4.28: The process of delta modulation

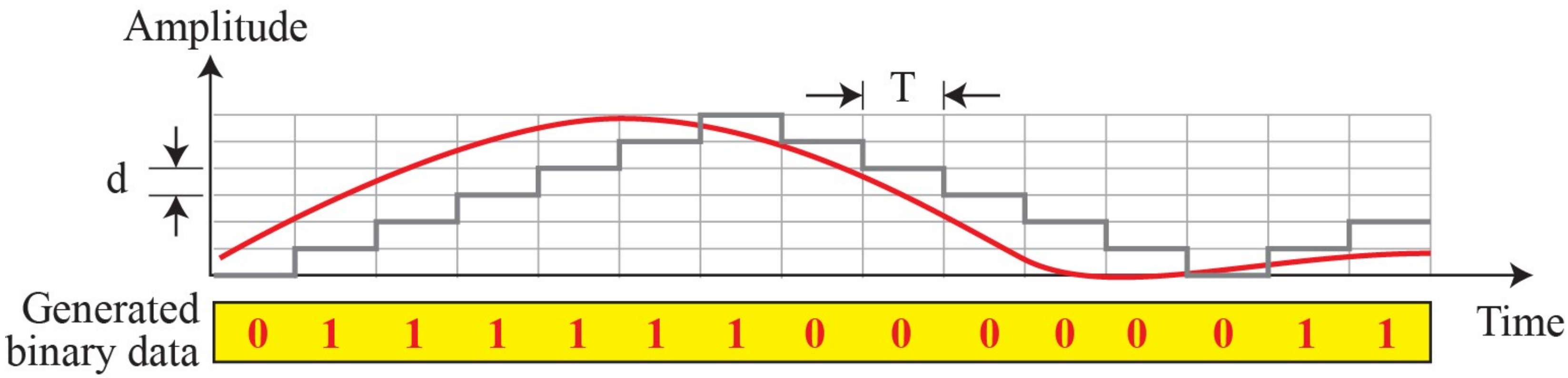


Figure 4.29: Delta modulation components

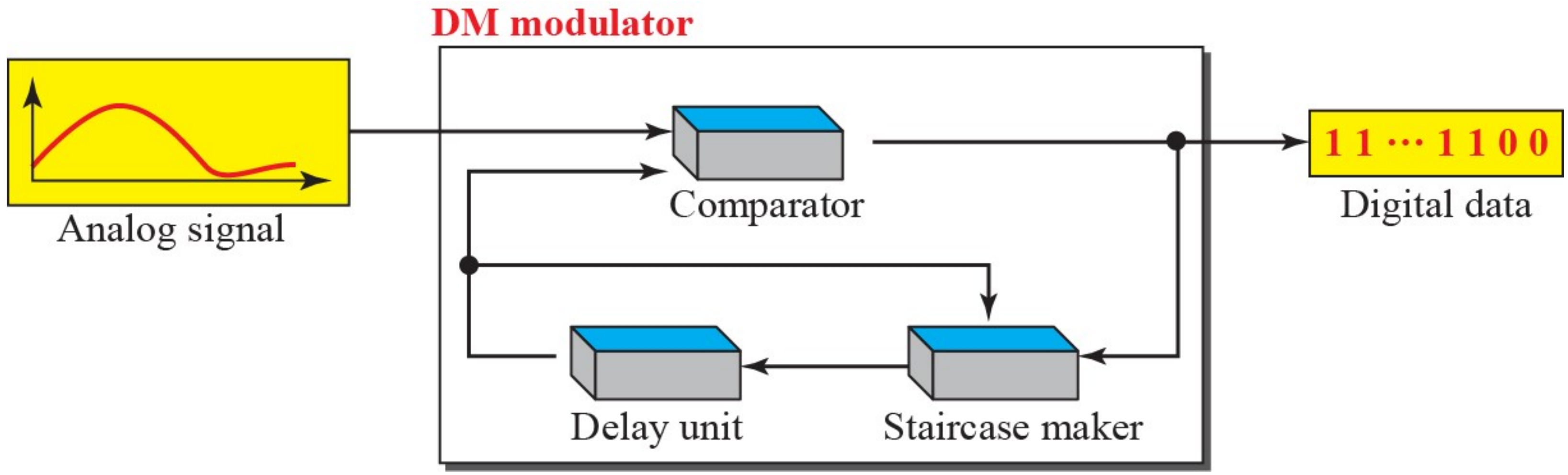
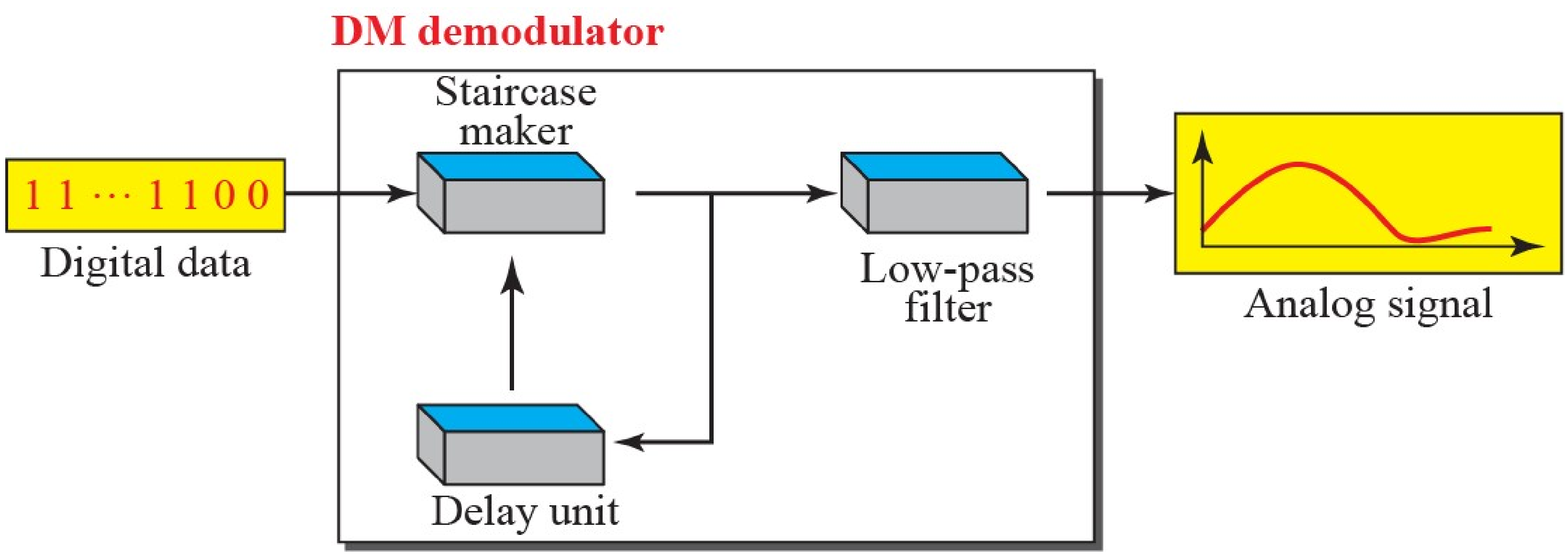


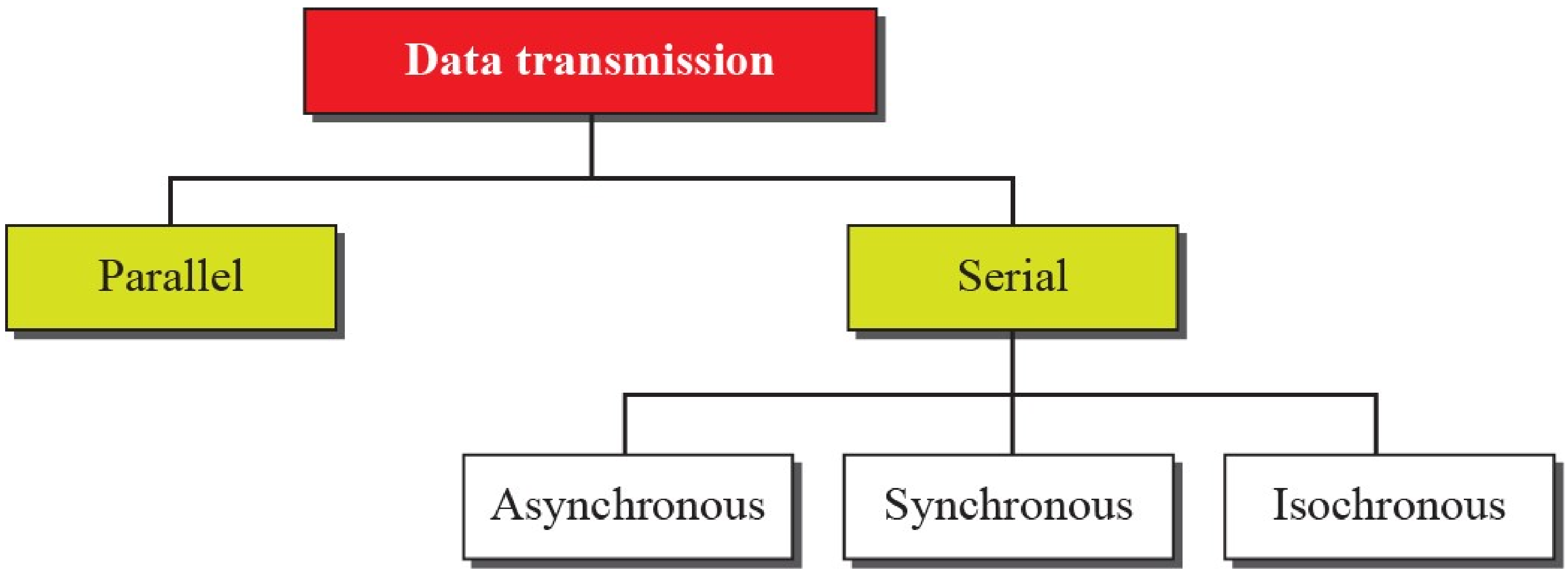
Figure 4.30: Delta demodulation components



4-3 TRANSMISSION MODES

Of primary concern when we are considering the transmission of data from one device to another is the wiring, and of primary concern when we are considering the wiring is the data stream. Do we send 1 bit at a time; or do we group bits into larger groups and, if so, how? The transmission of binary data across a link can be accomplished in either parallel or serial mode. and isochronous (see Figure 4.31).

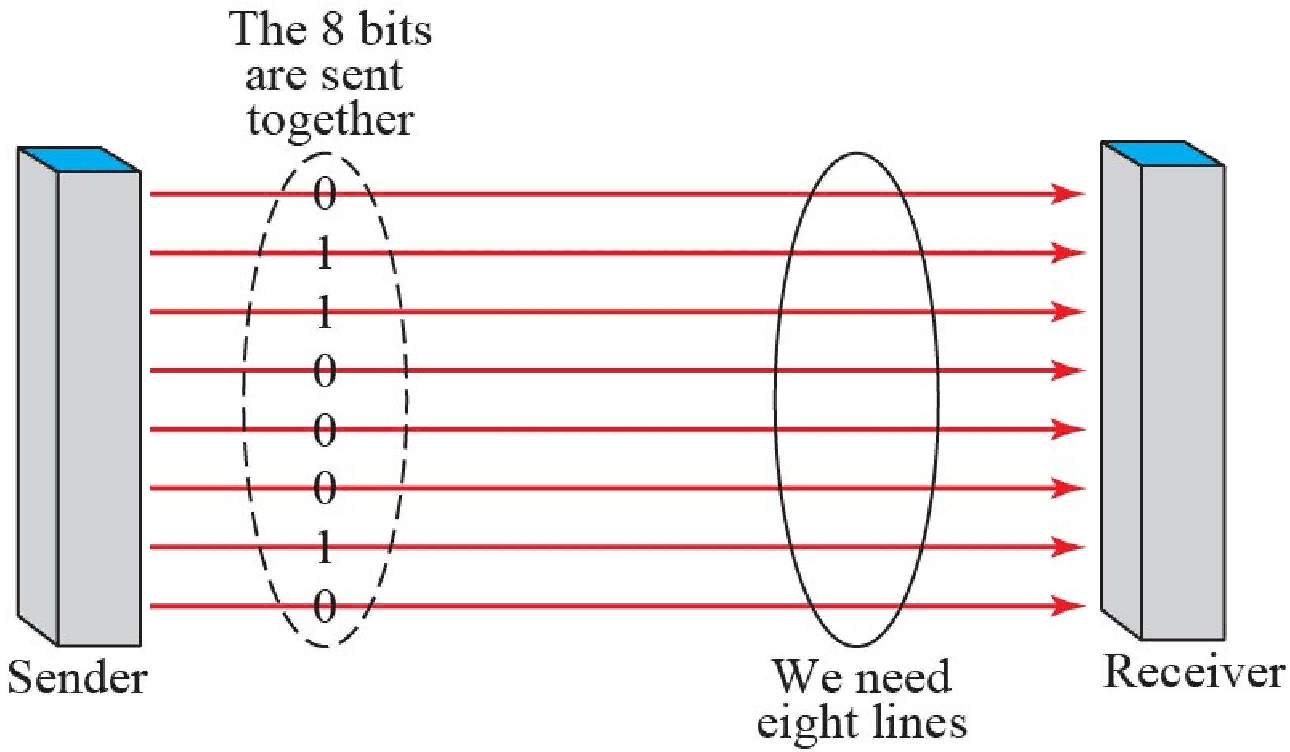
Figure 4.31: Data transmission modes



4.3.1 Parallel Transmission

Line coding is the process of converting digital data to digital signals. We assume that data, in the form of text, numbers, graphical images, audio, or video, are stored in computer memory as sequences of bits (see Chapter 1). Line coding converts a sequence of bits to a digital signal. At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal. Figure 4.1 shows the process.

Figure 4.32: Parallel transmission



4.3.2 Serial Transmission

In serial transmission one bit follows another, so we need only one communication channel rather than n to transmit data between two communicating devices (see Figure 4.33)..

Figure 4.33: Serial transmission

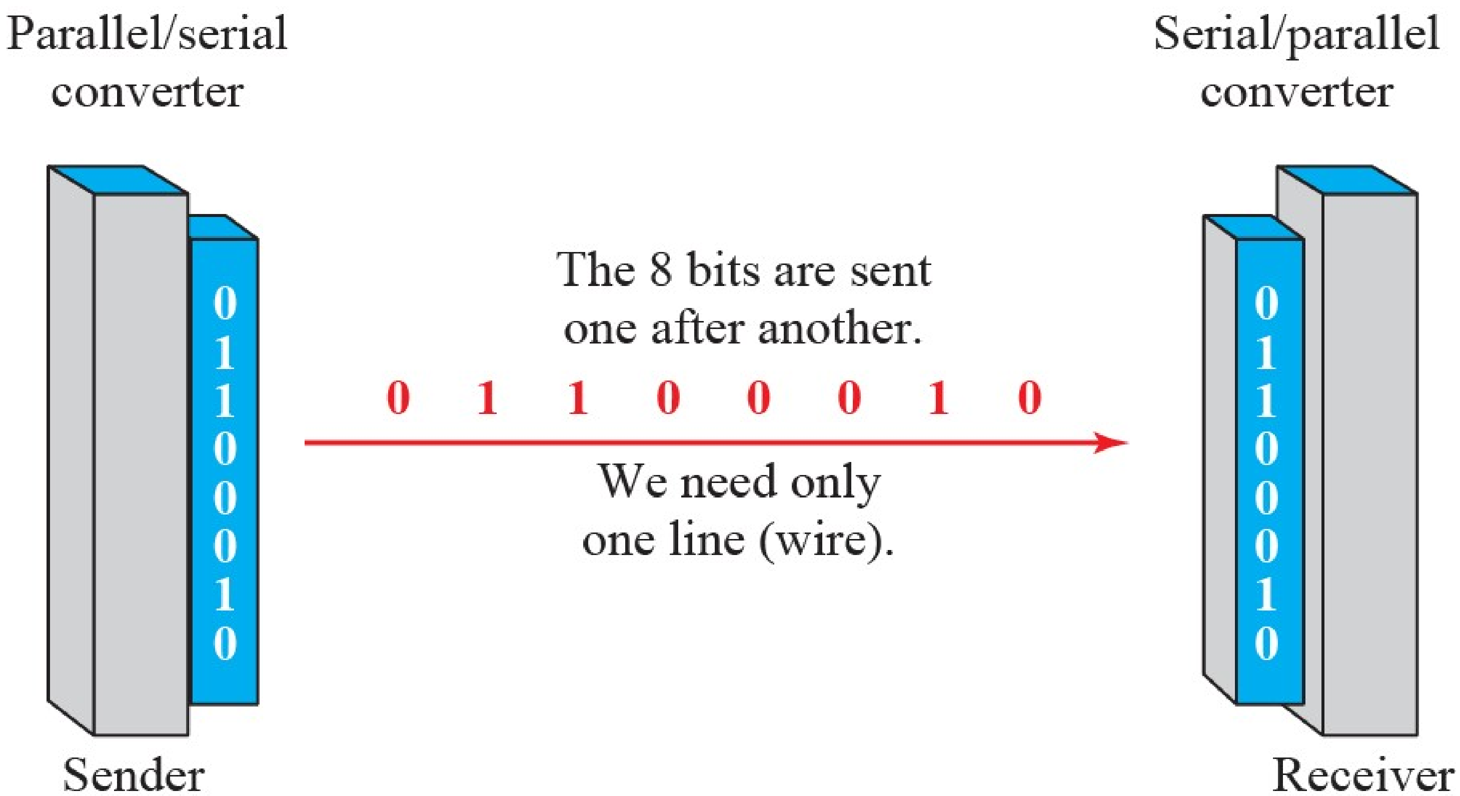
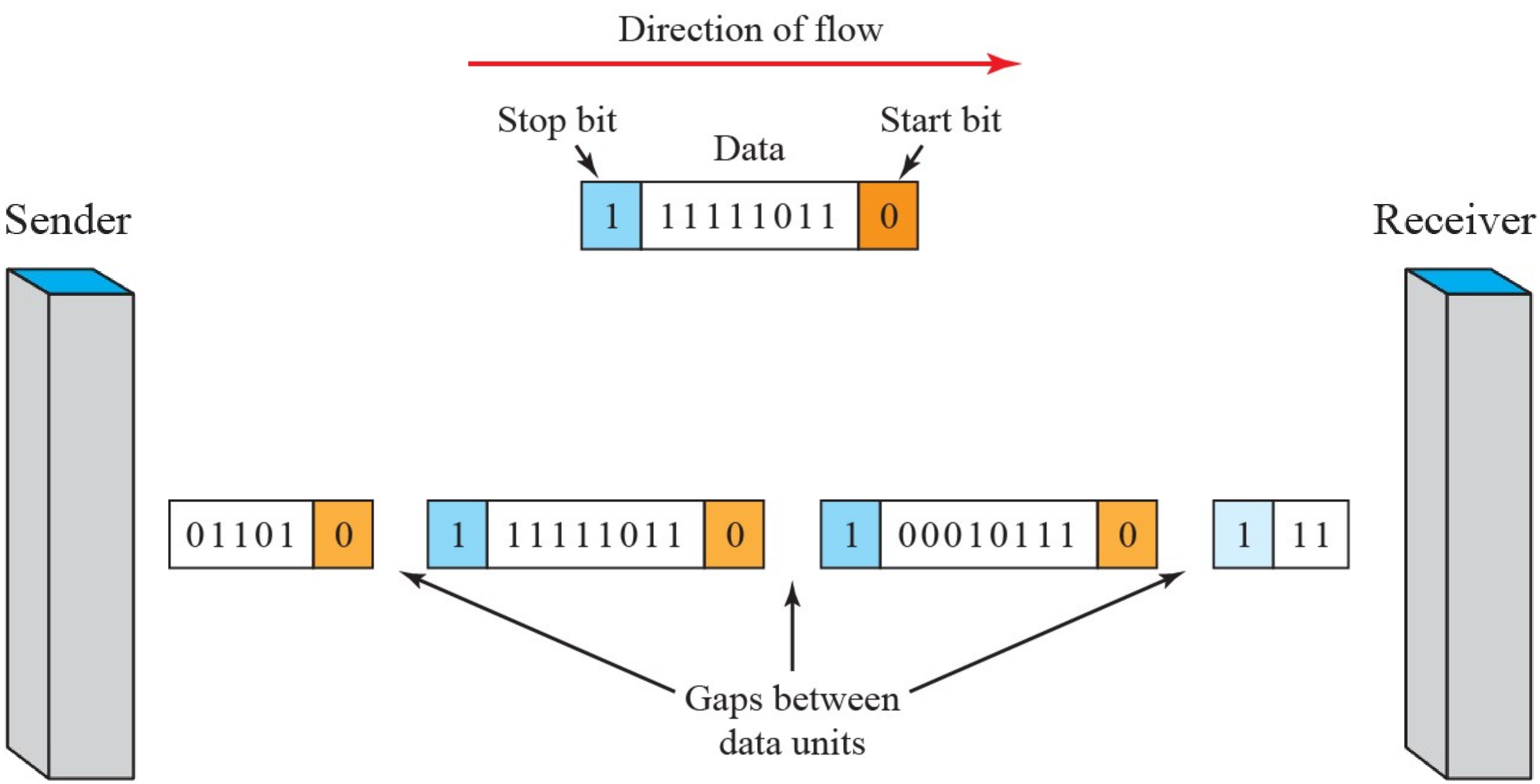


Figure 4.34: Asynchronous transmission



https://www.electricaltechnology.org/2020/05/difference-between-synchronous-asynchronous-transmission.html

Figure 4.35: Synchronous transmission