4123702

Data Communications System

By

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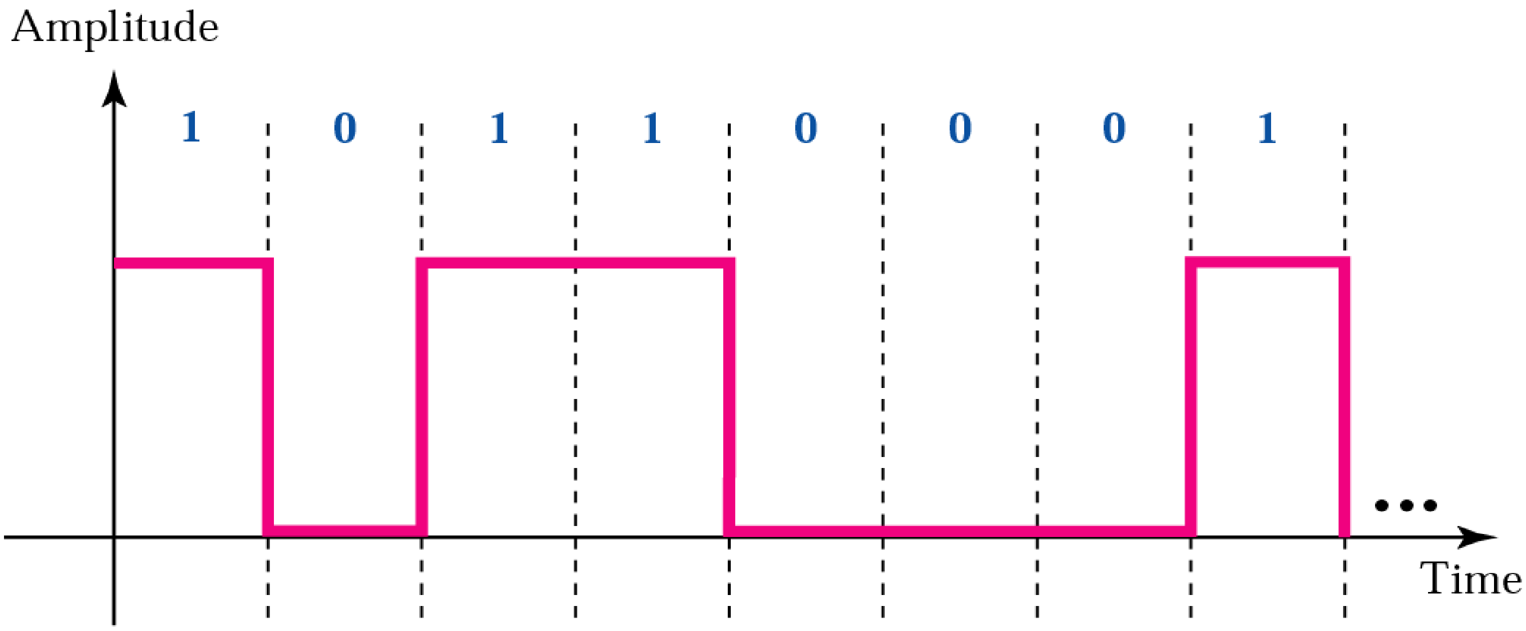
Chapter 4 – Digital Transmission

Digital Transmission

- Methods to transmit data digitally
  - Line coding
  - Block coding
  - Sampling
- Transmission modes
  - Parallel
  - Serial
    - Synchronous
    - Asynchronous

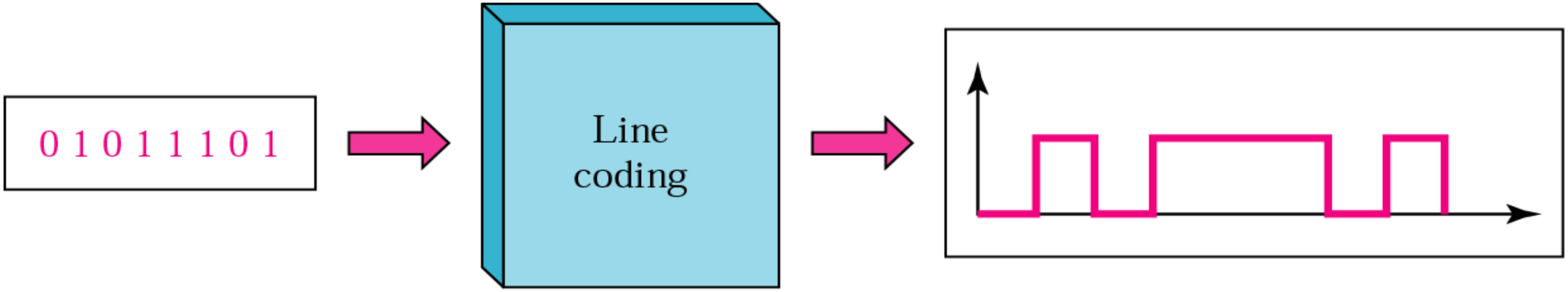
Digital Signals

- Digital – have a limited number of defined values
- Use binary (0s and 1s) to encode information
- Less affected by interference (noise); fewer errors



4.1 Line Coding

- Process of converting binary data to a digital signal

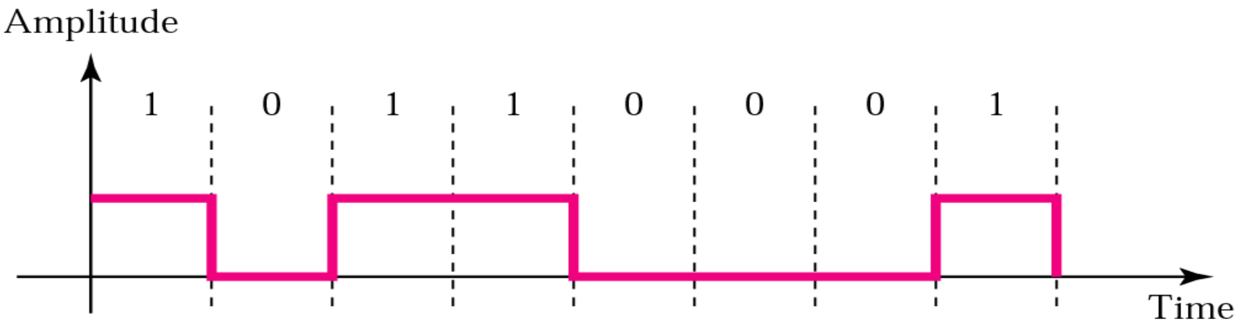


Line Coding Characteristics

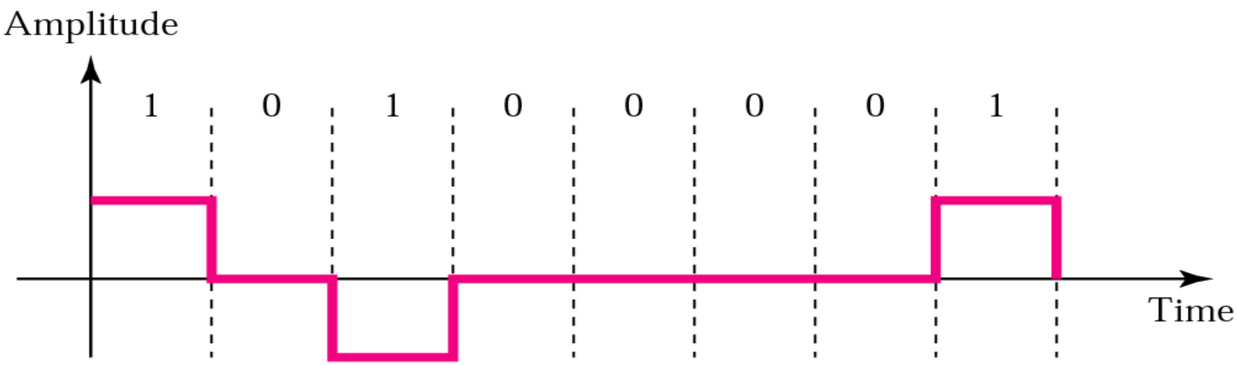
- Signal Level versus Data Level
- Pulse Rate versus Bit Rate
- DC Components
- Self-Synchronization

Signal Level versus Data Level

- Signal level – number of different values allowed in a signal
- Data level – number of symbols used to represent data



a. Two signal levels, two data levels



b.Three signal levels, two data levels

Pulse Rate versus Bit Rate

- Pulse rate – defines number of pulses per second
  - Pulse – minimum amount of time required to transmit a symbol
- Bit rate – defines number of bits per second

$$\text{Bit rate} = \text{Pulse rate} \times \log_2 L$$

*When **L** is the number of data level of the signal*

Example 1

A signal has two data levels with a pulse duration of 1 ms. We calculate the pulse rate and bit rate as follows:

$$\text{Pulse Rate} = \frac{1}{1 \times 10^{-3}} = 1000 \text{ pulses/s}$$

$$\text{Bit Rate} = \text{Pulse Rate} \times \log_2 L$$

$$= 1000 \times \log_2 2 = 1000 \text{ bps}$$

Example 2

A signal has four data levels with a pulse duration of 1 ms. We calculate the pulse rate and bit rate as follows:

$$\text{Pulse Rate} = \frac{1}{1\times10^{-3}} = 1000 \text{ pulses/s}$$

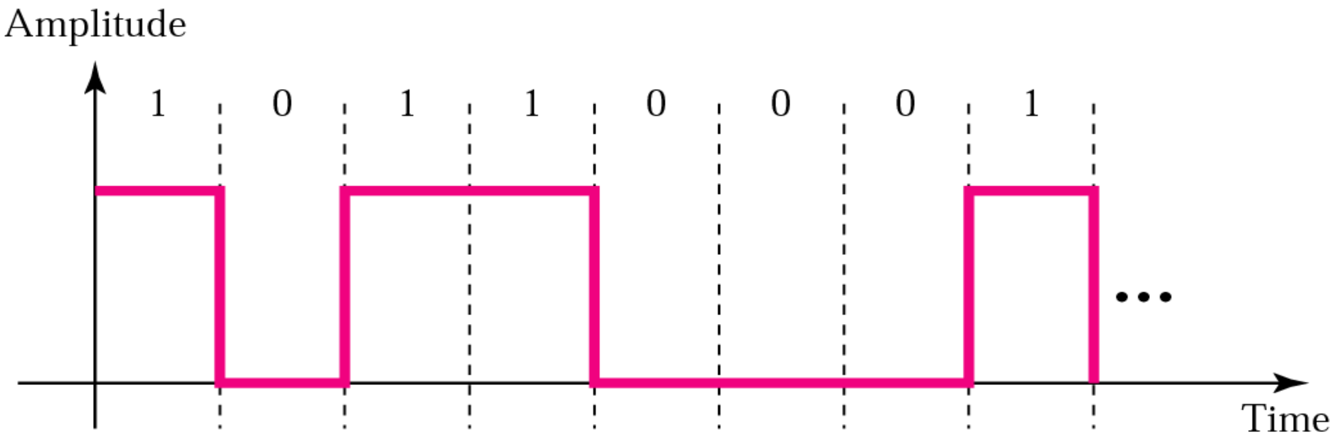
$$\text{Bit Rate} = \text{Pulse Rate} \times \log_2 L$$

$$= 1000 \times \log_2 4 = 2000 \text{ bps}$$

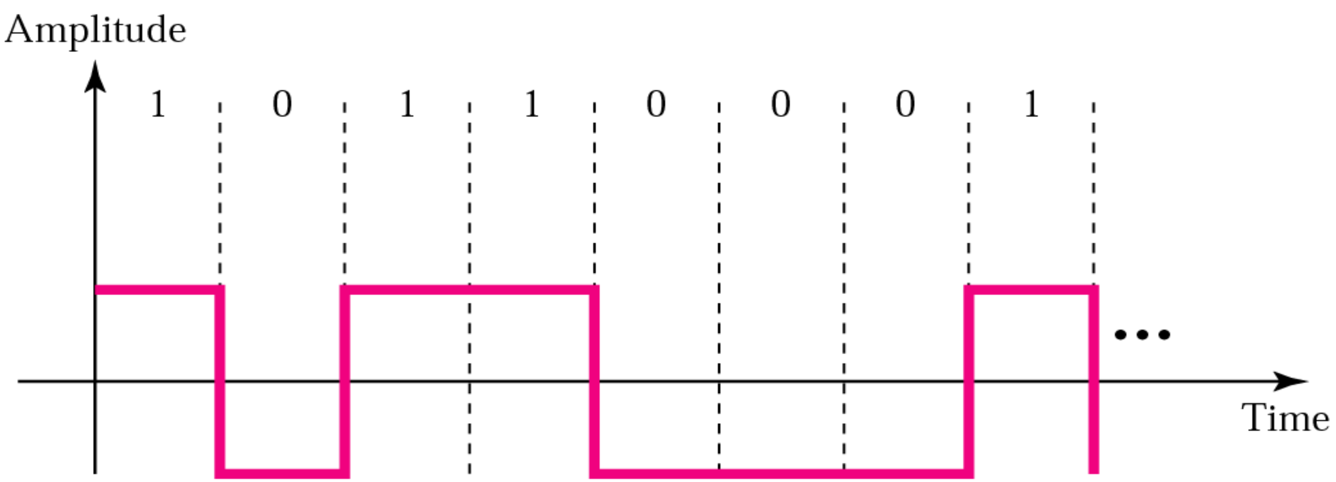
DC Components

- Residual direct-current (dc) components or zero frequencies are undesirable
  - Some systems do not allow passage of a dc component (such as a transformer); may distort the signal and create output errors
  - DC component is extra energy residing on the line and is useless

DC Component



a. A signal with dc component

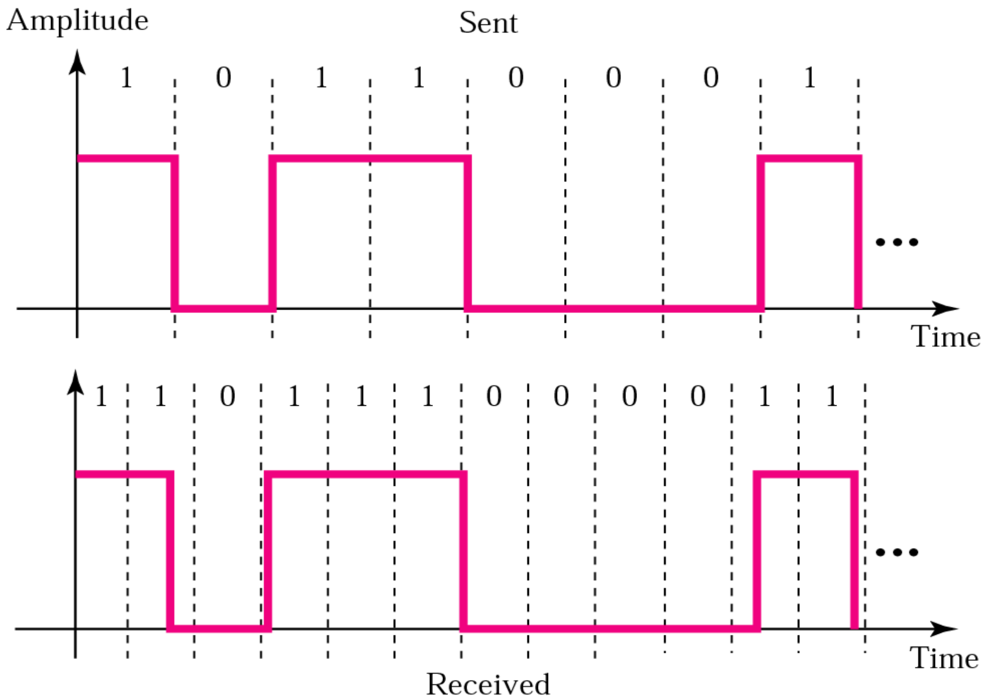


b. A signal without dc component

Self-Synchronization

- Digital signal includes timing information in the data being transmitted to prevent misinterpretation

Figure 4.16 Lack of synchronization



Example 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

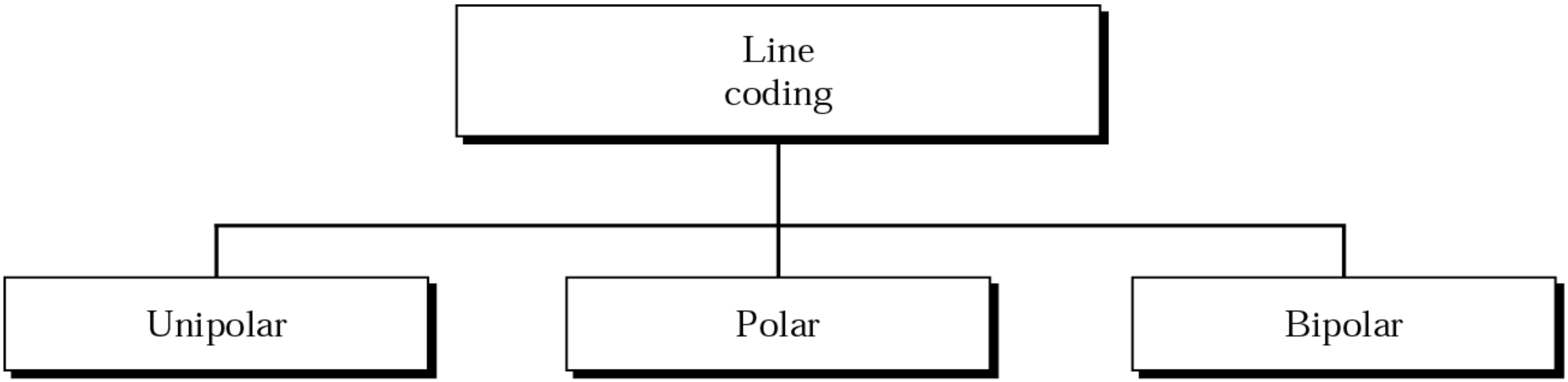
At 1 Kbps:

1000 bits sent ➔1001 bits received➔1 extra bps

At 1 Mbps:

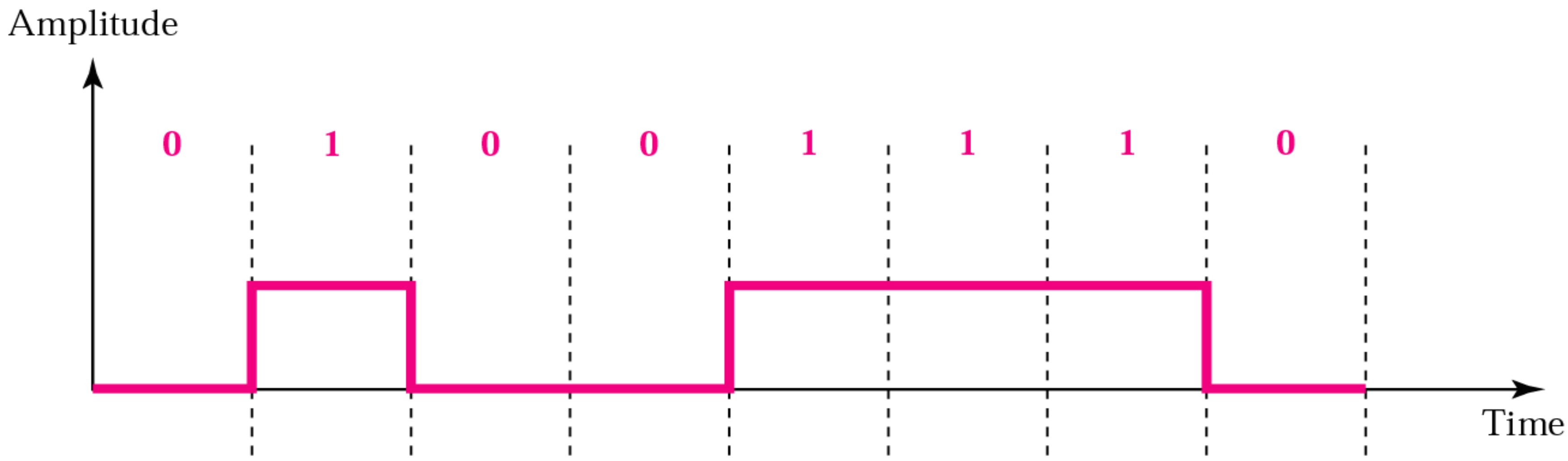
1,000,000 bits sent ➔1,001,000 bits received➔1000 extra bps

Line Coding Schemes



Unipolar

- Simplest method; inexpensive
- Uses only one voltage level
- Polarity (+ or -) is usually assigned to binary 1; a 0 is represented by zero voltage



Unipolar

- Potential problems:
  - DC component
  - Lack of synchronization

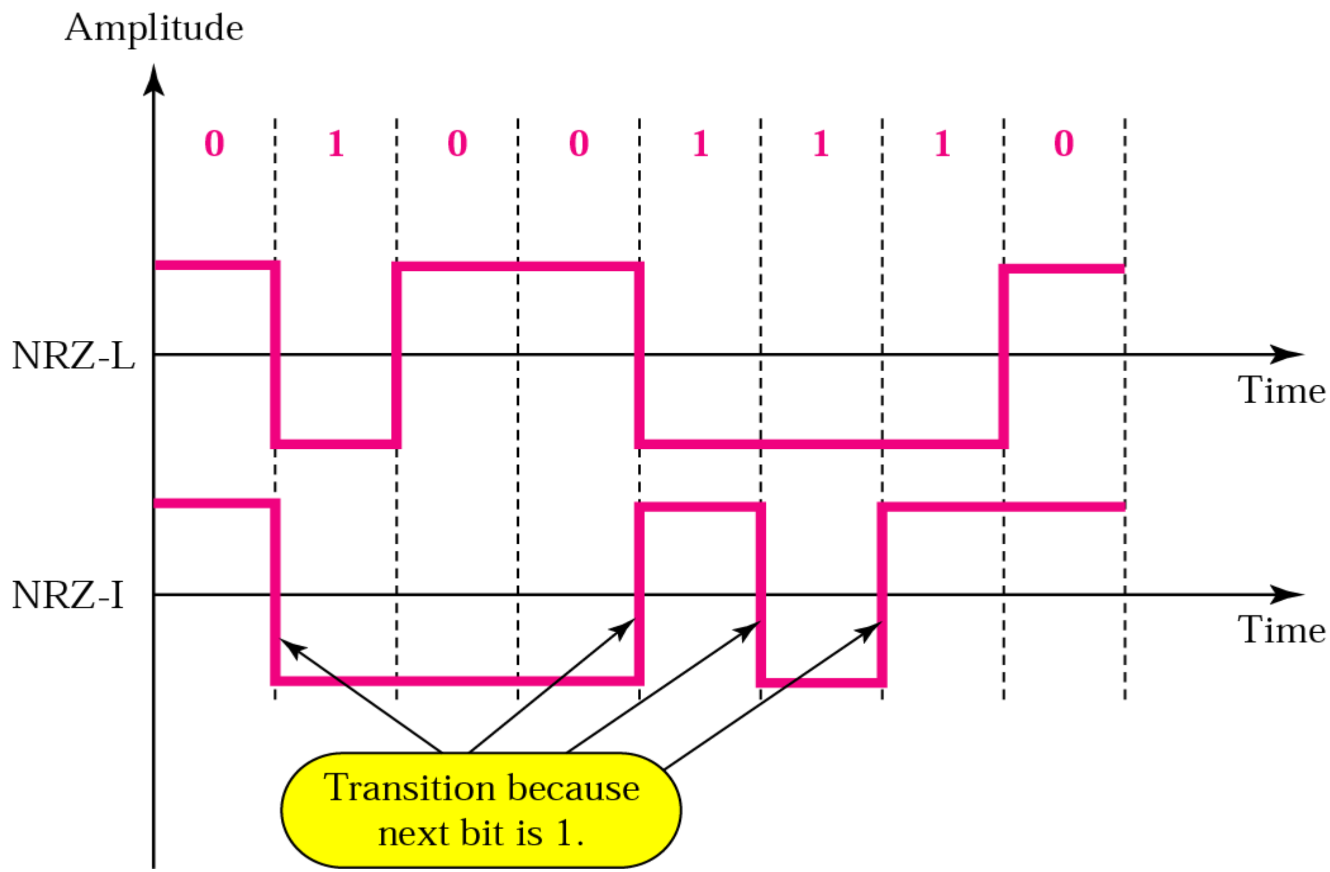
Polar

- Uses two voltage levels, one positive and one negative
- Alleviates DC component
- Variations
  - Nonreturn to zero (NRZ)
  - Return to zero (RZ)
  - Manchester
  - Differential Manchester

Nonreturn to Zero (NRZ)

- Value of signal is always positive or negative
- NRZ-L (NRZ-Level)
  - Signal level depends on bit represented; positive usually means 0, negative usually means 1
  - Problem : synchronization of long streams of 0s or 1s
- NRZ-I (NRZ-Invert)
  - Inversion of voltage represents a 1 bit
  - 0 bit represented by no change
  - Allows for synchronization

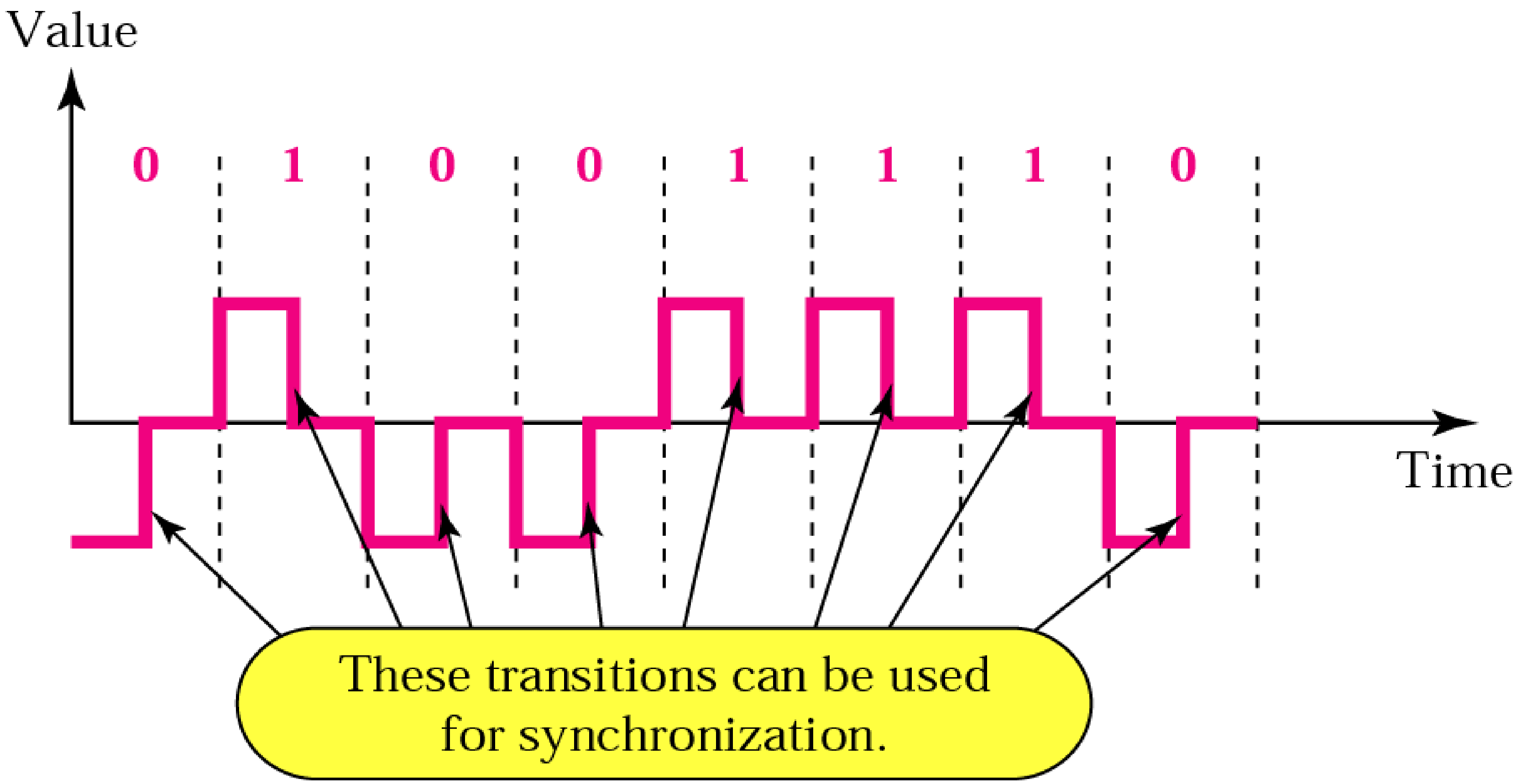
NRZ-L and NRZ-I Encoding



Return to Zero (RZ)

- In NRZ-I, long strings of 0s may still be a problem
- May include synchronization as part of the signal for both 1s and 0s
- How?
  - Must include a signal change during each bit
  - Uses three values: positive, negative, and zero
  - 1 bit represented by positive-to-zero
  - 0 bit represented by negative-to-zero

RZ Encoding


Value
0
1
0
0
1
1
1
0
Time
These transitions can be used for synchronization.

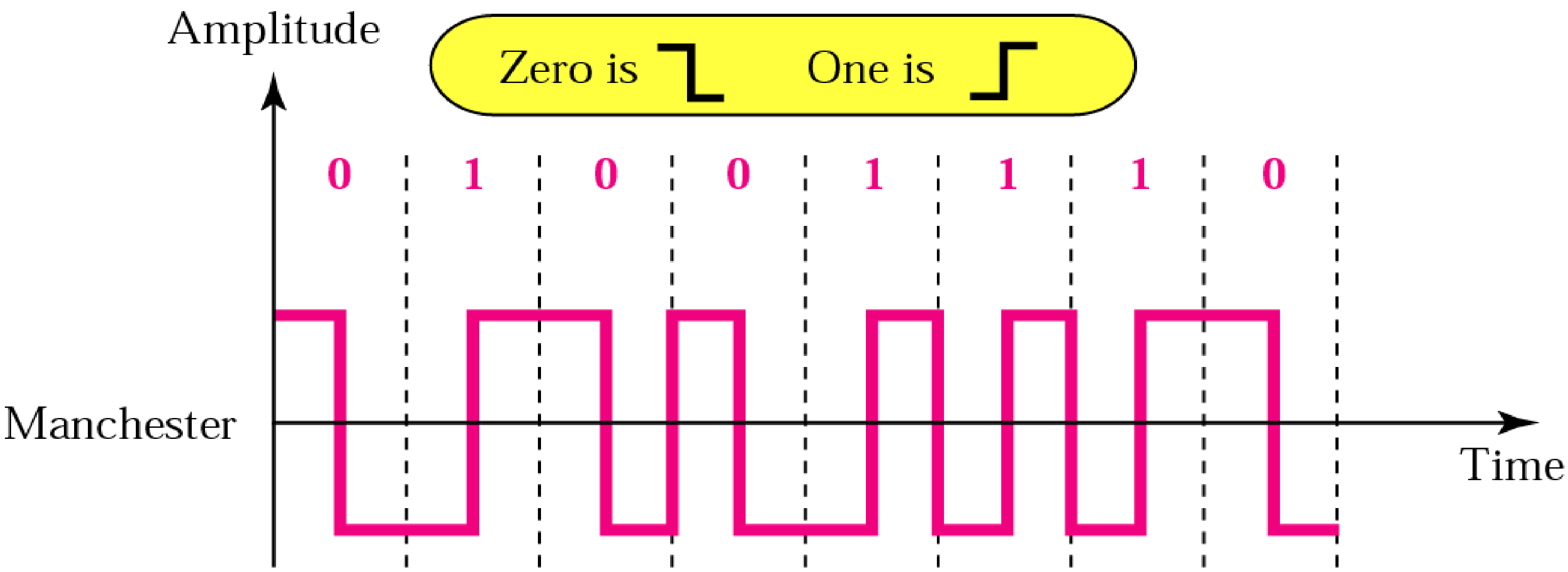
RZ Encoding

- Disadvantage
  - Requires two signal changes to encode each bit; more bandwidth necessary

Manchester

- Uses an inversion at the middle of each bit interval for both synchronization and bit representation
- Negative-to-positive represents binary 1
- Positive-to-negative represents binary 0
- Achieves same level of synchronization with only two levels of amplitude

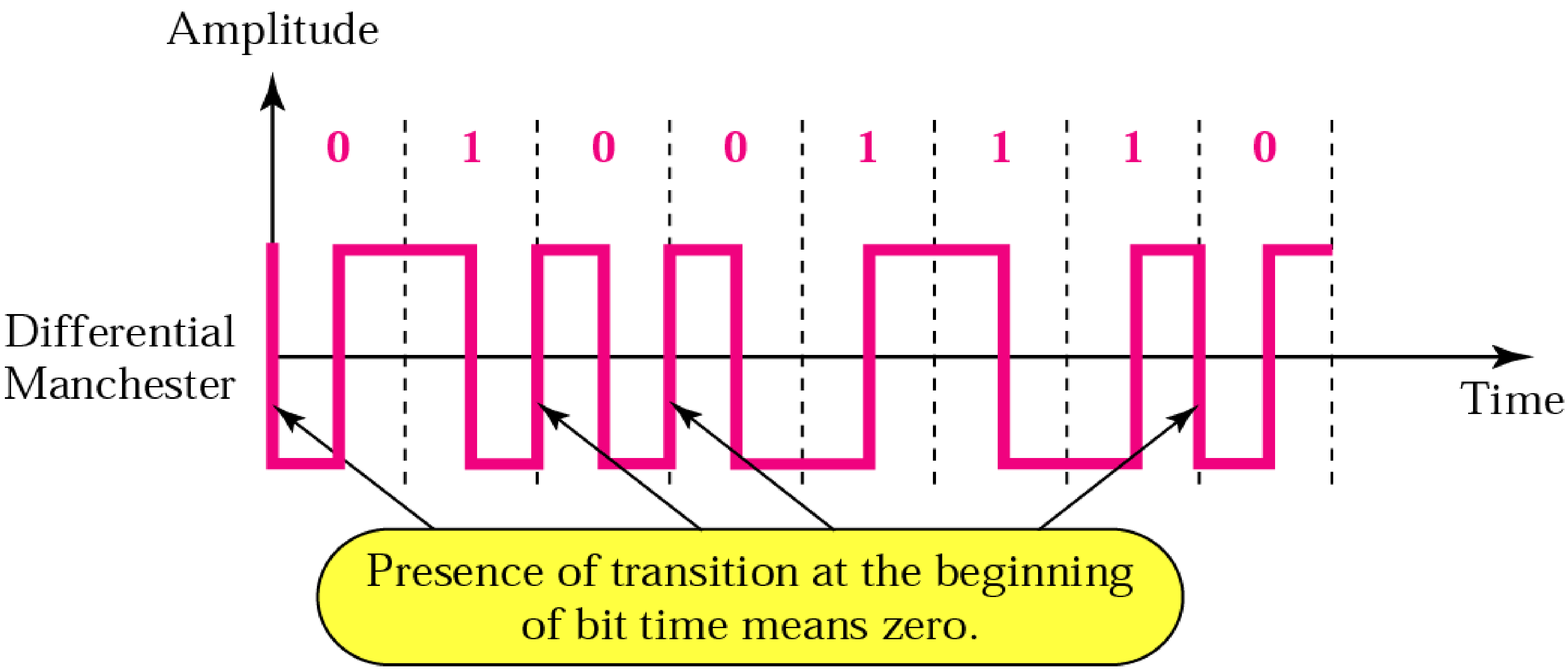
Manchester Encoding



Differential Manchester

- Inversion at middle of bit interval is used for synchronization
- Presence or absence of additional transition at beginning of interval identifies the bit
- Transition means binary 0; no transition means 1
- Requires two signal changes to represent binary 0 but only one to represent 1

Differential Manchester

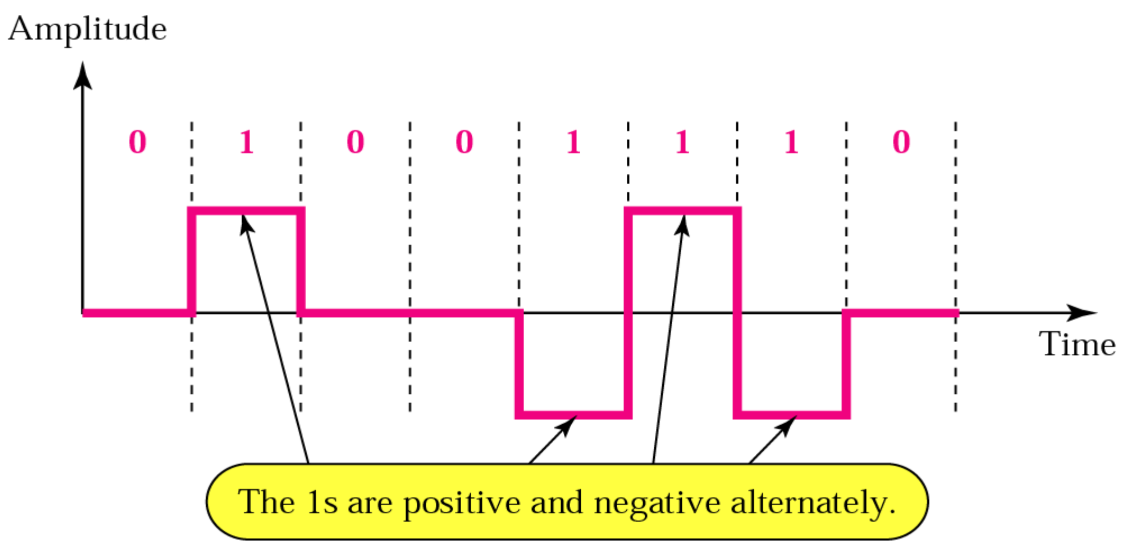


Bipolar Encoding

- Uses three voltage levels: positive, negative, and zero
- Zero level represents binary 0; 1s are represented with alternating positive and negative voltages, even when the 1 bits are not consecutive
- Two schemes
  - Alternate mark inversion (AMI)
  - Bipolar *n*-zero substitution (B*n*ZS)

Bipolar AMI

- Neutral, zero voltage represents binary 0
- Binary 1s represented by alternating positive and negative voltages

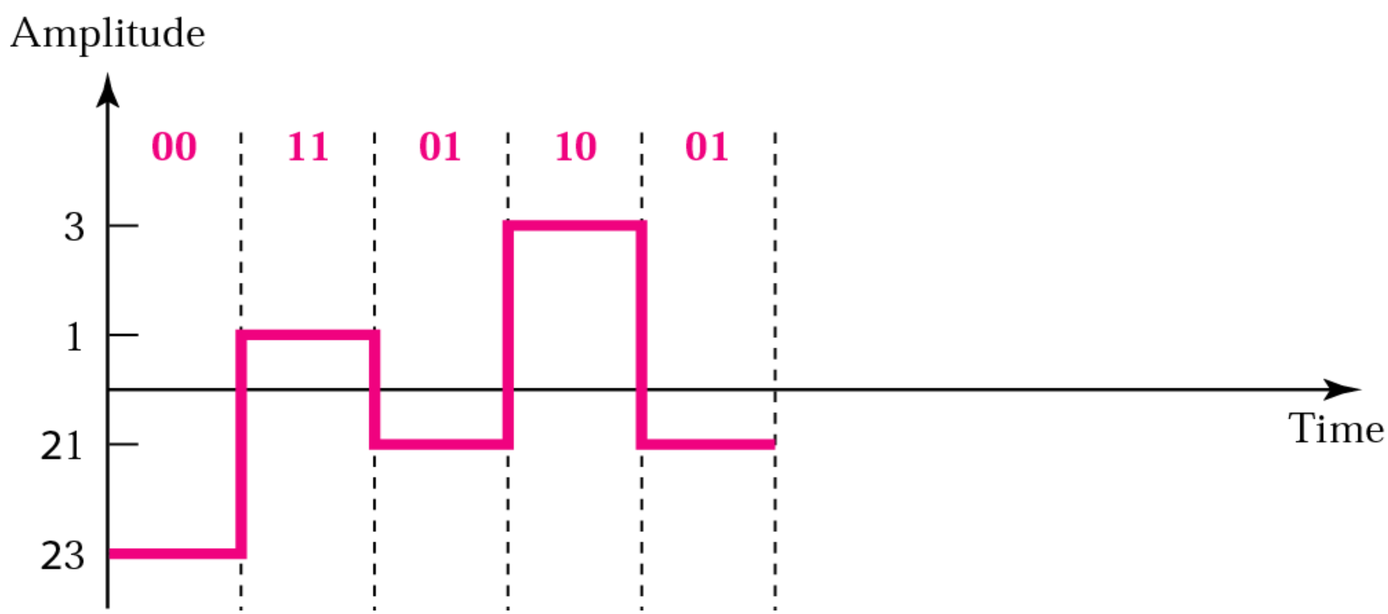


Bipolar *n*-zero substitution (B*n*ZS)

- Solves problem of synchronizing sequential 0s, often occurring in long-distance transmission
- If *n* consecutive zeros occur, some of the bits in those *n* bits become positive or negative
- Substitution violates rules of AMI in a manner that receiver knows the bits are actually 0s and not 1s

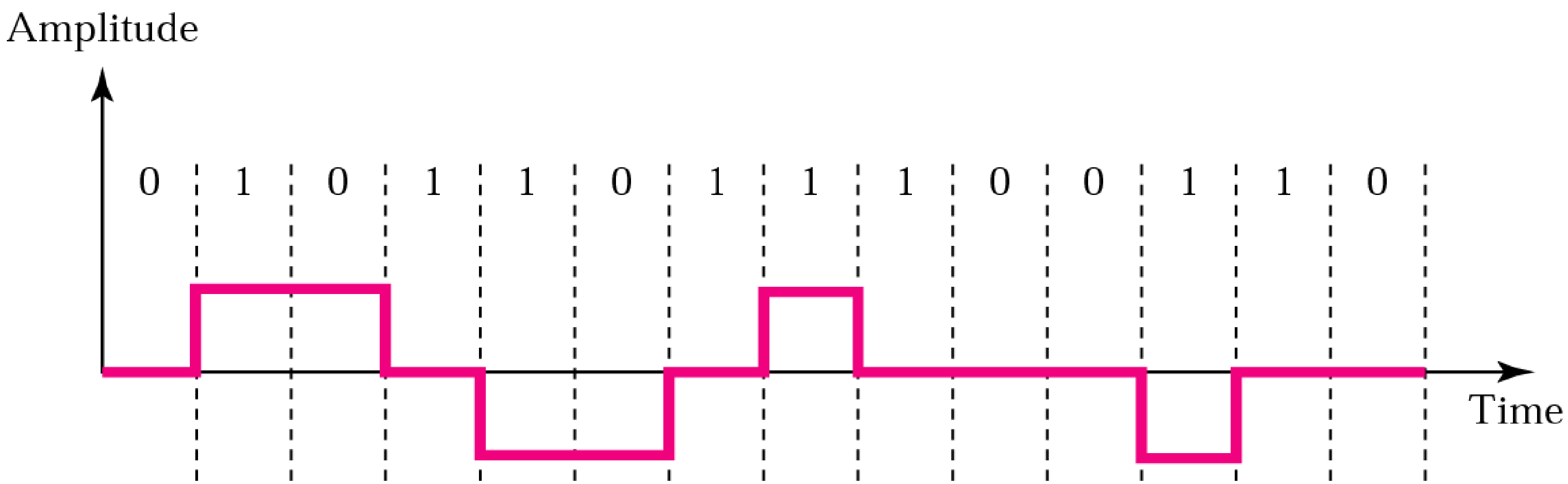
Other Schemes

- 2B1Q (two binary, one quaternary) uses four voltage levels
  - One pulse can represent 2 bits; more efficient



Other Schemes

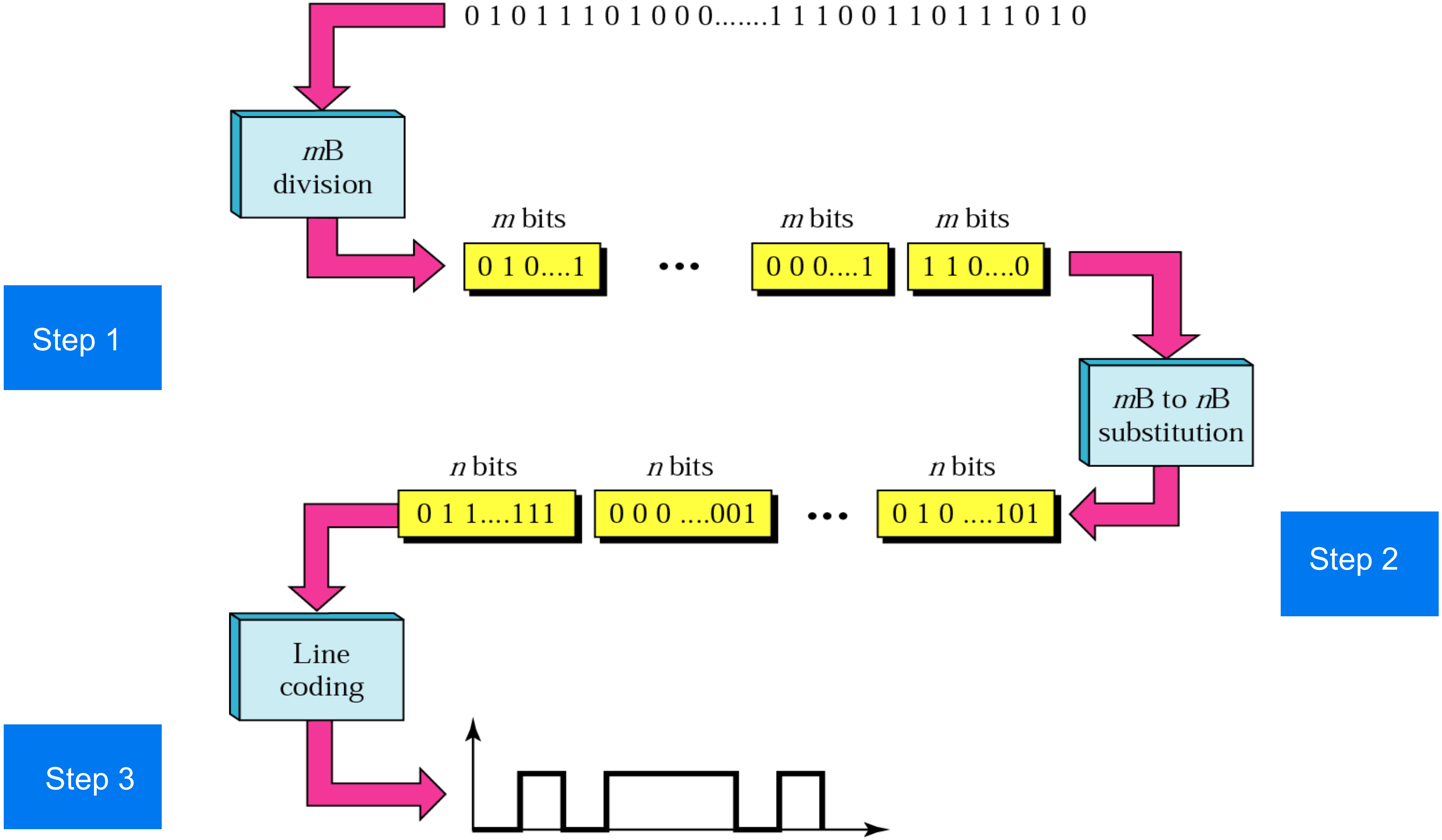
- MLT-3 (multi-line transmission, three level) – similar to NRZ-I using three levels of signals; signal transitions occur at beginning of 1 bit, no transition at beginning of 0



4.2 Block Coding

- Coding method to ensure synchronization and detection of errors
- Three steps: division, substitution, and line coding

Steps in Transformation



Transformation Steps

- Step 1: bit stream is divided into groups of *m* bits
- Step 2: substitute an *m*-bit code for an *n*-bit group
  - Codes with no more than three consecutive 0s or 1s are used to achieve synchronization
  - Since only a subset of blocks are used, if one or more bits are changed and an invalid code is received, a receiver can easily detect the error
- Step 3: line encoding scheme is then used to create the signal

Common Block Codes

- 4B/5B – every 4 bits of data is encoded into a 5-bit code; NRZ-1 is usually used for line coding
- 8B/10B – group of 8 bits of data is substituted by a 10-bit code
- 8B/6T – each 8-bit group is substituted with a six-symbol code; uses less bandwidth since three signal levels may be used

Figure 4.16 Substitution in block coding

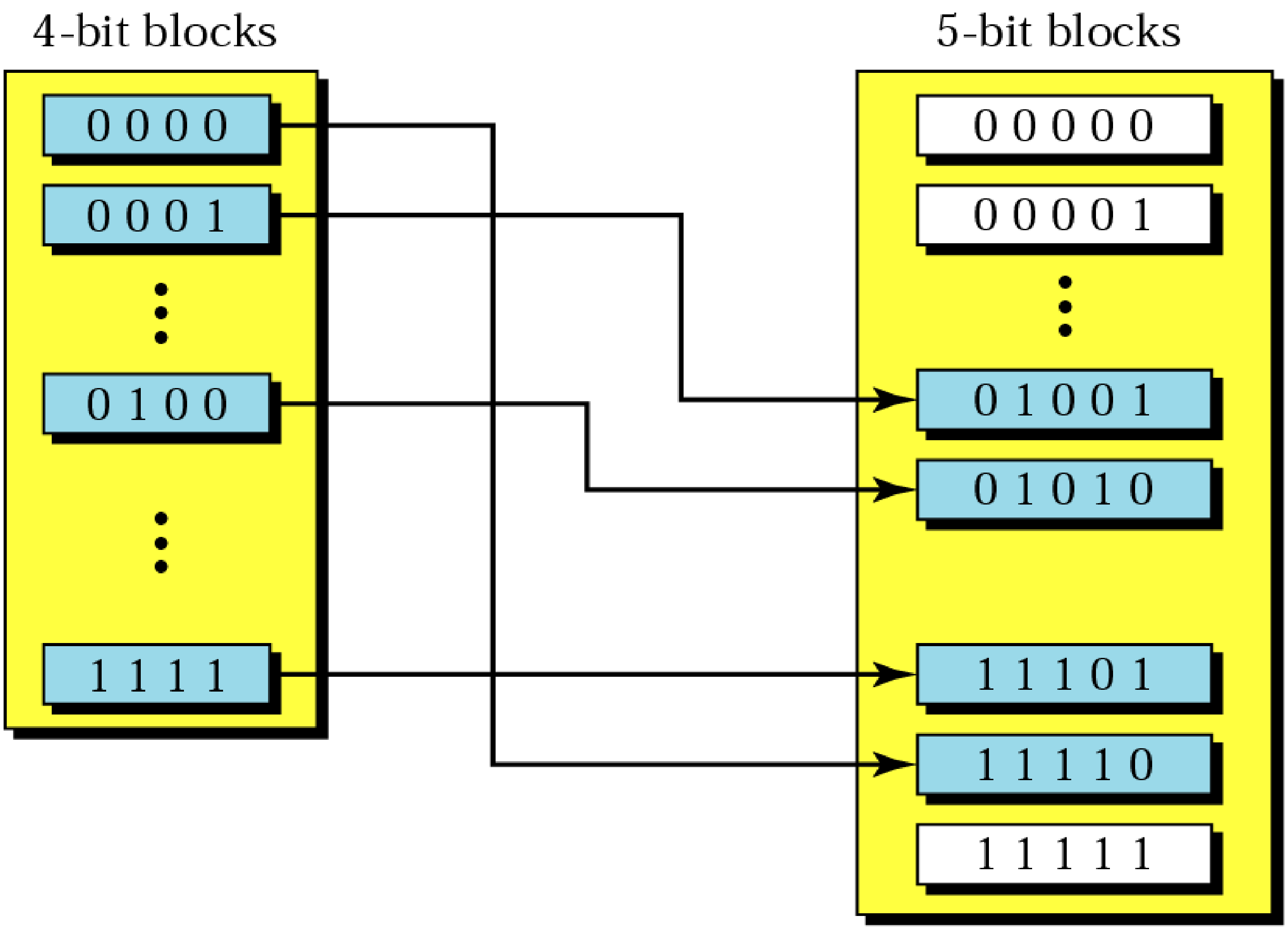


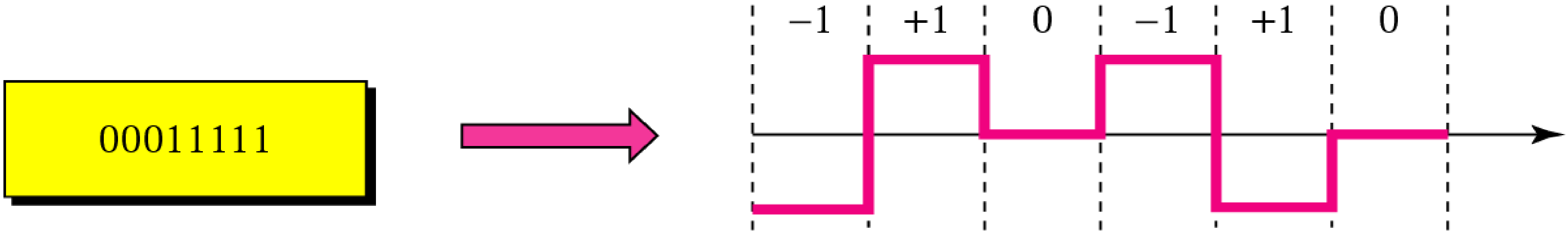
Table 4.1 4B/5B encoding

Data	Code	Data	Code
0000	**11110**	1000	**10010**
0001	**01001**	1001	**10011**
0010	**10100**	1010	**10110**
0011	**10101**	1011	**10111**
0100	**01010**	1100	**11010**
0101	**01011**	1101	**11011**
0110	**01110**	1110	**11100**
0111	**01111**	1111	**11101**

Table 4.1 4B/5B encoding (Continued)

Data	Code
Q (Quiet)	**00000**
I (Idle)	**11111**
H (Halt)	**00100**
J (start delimiter)	**11000**
K (start delimiter)	**10001**
T (end delimiter)	**01101**
S (Set)	**11001**
R (Reset)	**00111**

Figure 4.17 Example of 8B/6T encoding

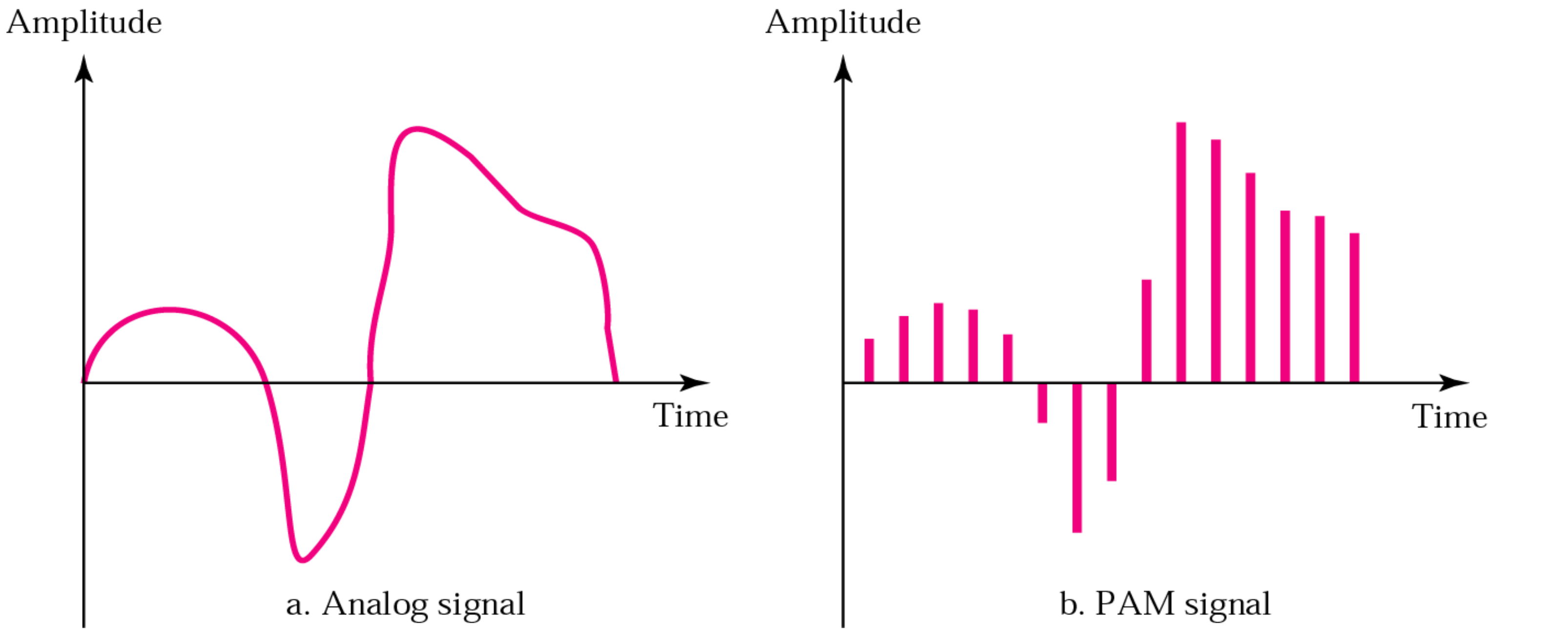


4.3 Sampling

- Analog data must often be converted to digital format (ex: long-distance services, audio)
- Sampling is process of obtaining amplitudes of a signal at regular intervals

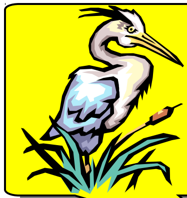
Pulse Amplitude Modulation (PAM)

- Analog signal's amplitude is sampled at regular intervals; result is a series of pulses based on the sampled data
- Pulse Coded Modulation (PCM) is then used to make the signal digital



a. Analog signal

b. PAM signal



Note:

Pulse amplitude modulation has some applications, but it is not used by itself in data communication. However, it is the first step in another very popular conversion method called pulse code modulation.

Pulse Coded Modulation (PCM)

- First quantizes PAM pulses; an integral value in a specific range to sampled instances is assigned
- Each value is then translated to its 7-bit binary equivalent
- Binary digits are transformed into a digital signal using line coding

Figure 4.19 Quantized PAM signal

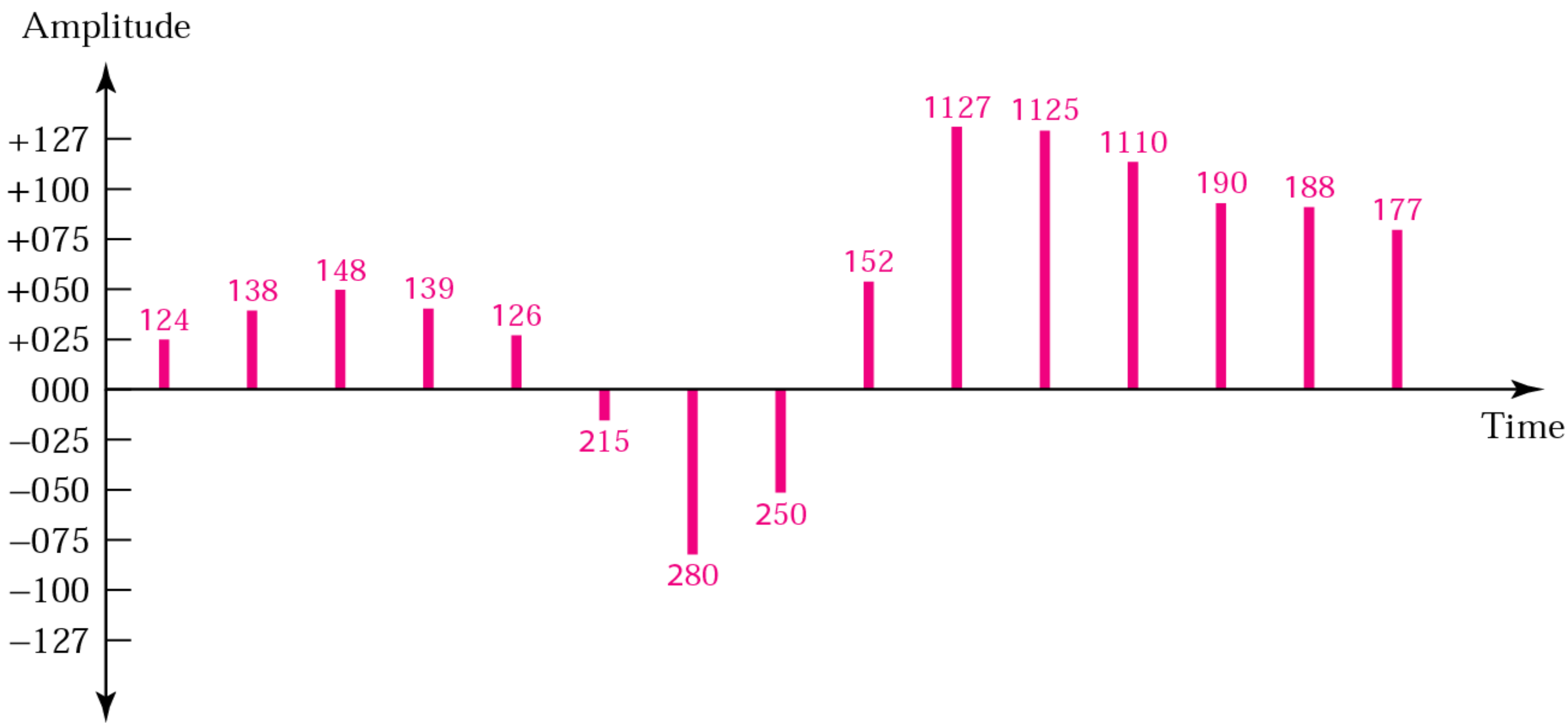


Figure 4.20 Quantizing by using sign and magnitude

+024	00011000	–015	10001111	+125	01111101
+038	00100110	–080	11010000	+110	01101110
+048	00110000	–050	10110010	+090	01011010
+039	00100111	+052	00110110	+088	01011000
+026	00011010	+127	01111111	+077	01001101

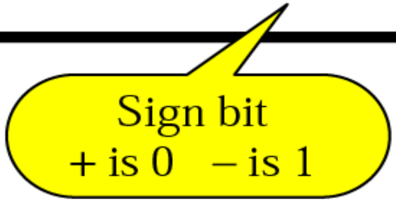
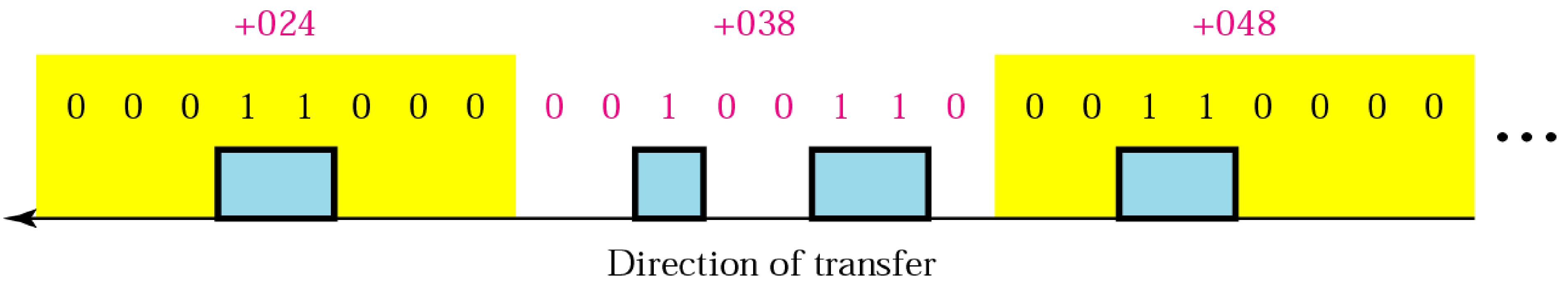
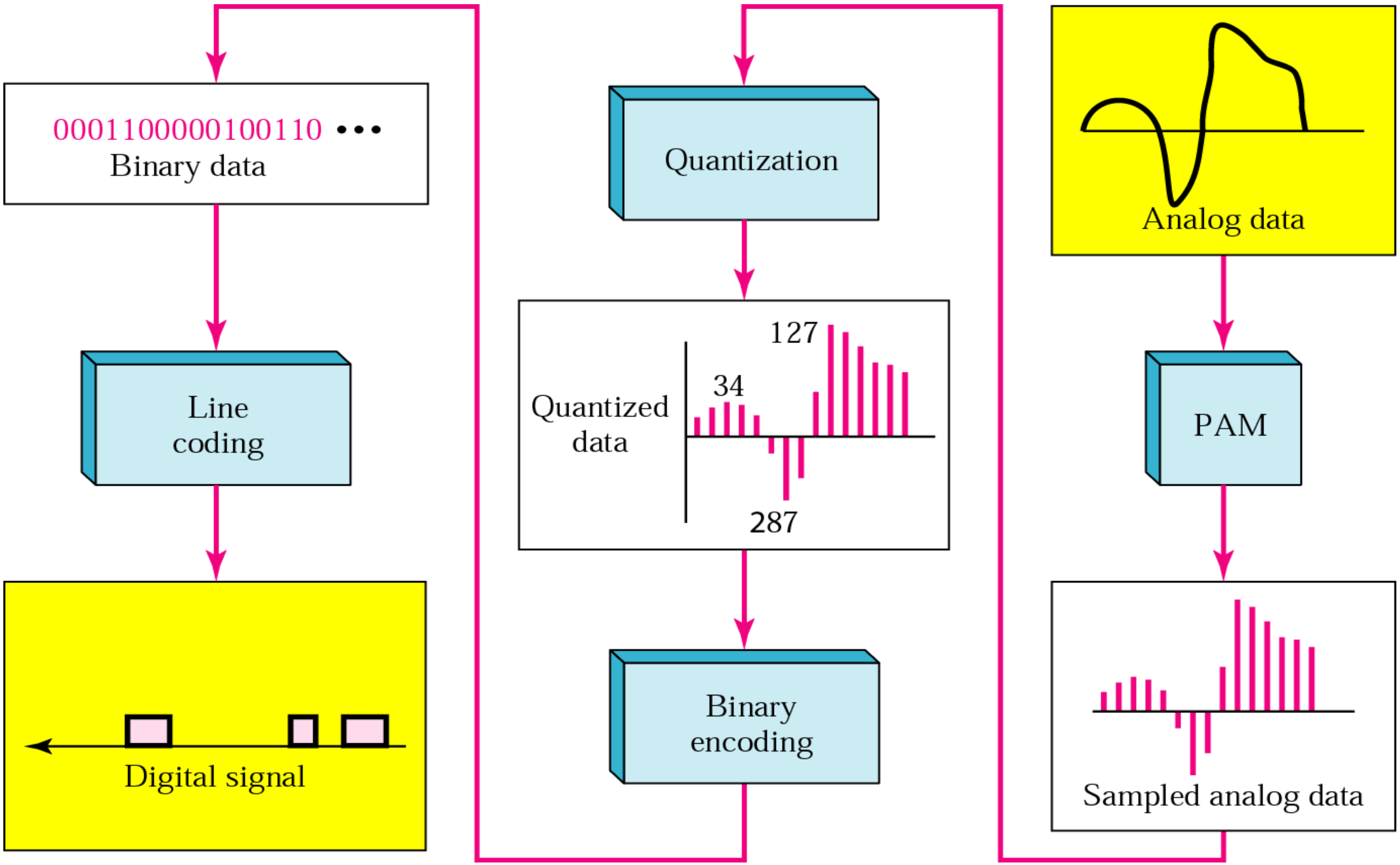


Figure 4.21 PCM

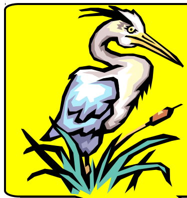


Digitization of an Analog Signal



Sampling Rate: Nyquist Theorem

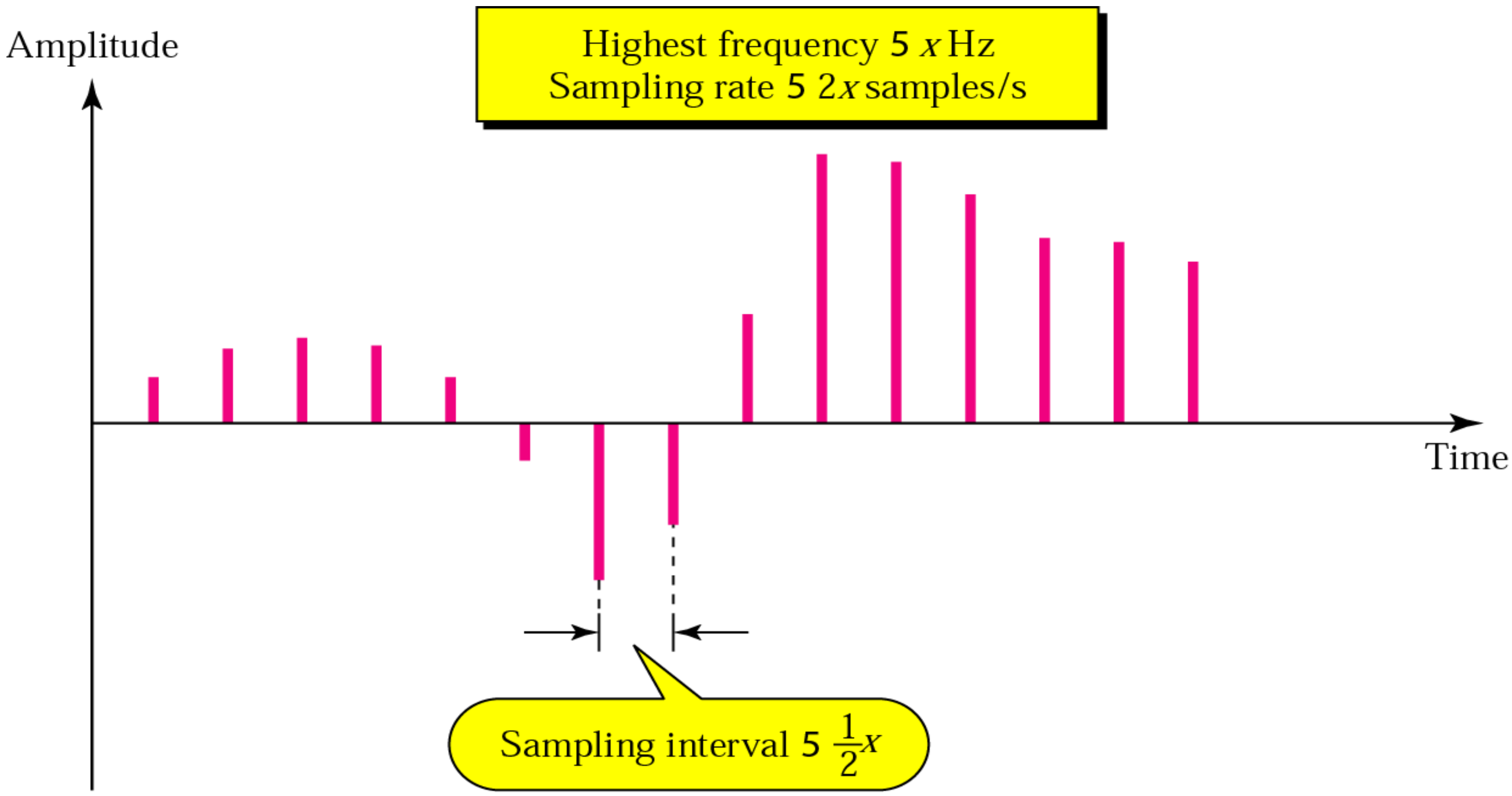
- Accuracy of digital reproduction of a signal depends on number of samples
- Nyquist theorem: number of samples needed to adequately represent an analog signal is equal to twice the highest frequency of the original signal

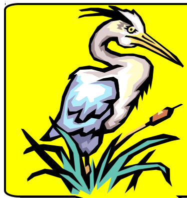


Note:

According to the Nyquist theorem, the sampling rate must be at least 2 times the highest frequency.

Figure 4.23 Nyquist theorem





Note:

Note that we can always change a band-pass signal to a low-pass signal before sampling. In this case, the sampling rate is twice the bandwidth.

Example 4

What sampling rate is needed for a signal with a bandwidth of 10,000 Hz (1000 to 11,000 Hz)?

Solution

The sampling rate must be twice the highest frequency in the signal:

Sampling rate = 2 x (11,000) = 22,000 samples/s

Example 5 (How many bit per sample)

A signal is sampled. Each sample requires at least 12 levels of precision (+0 to +5 and -0 to -5). How many bits should be sent for each sample?

Solution

We need 4 bits; 1 bit for the sign and 3 bits for the value. A 3-bit value can represent 23 = 8 levels (000 to 111), which is more than what we need. A 2-bit value is not enough since 22 = 4. A 4-bit value is too much because 24 = 16.

Example 6 (Bit rate)

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

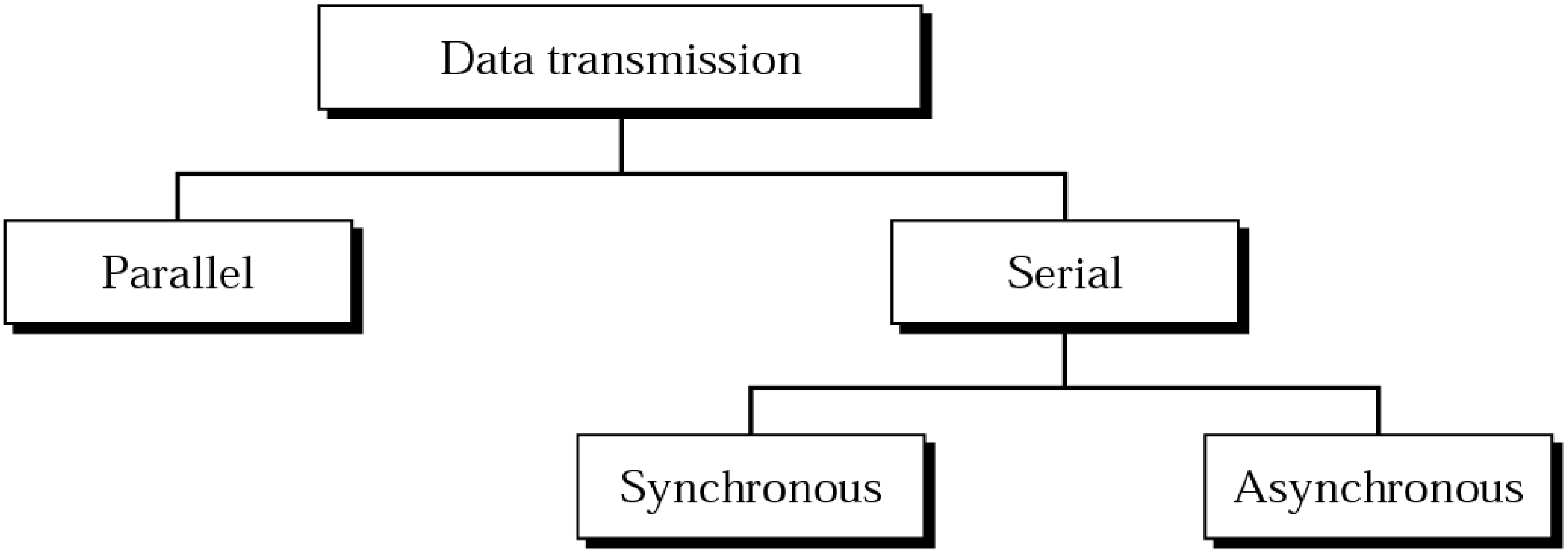
Solution

The human voice normally contains frequencies from 0 to 4000 Hz.

Sampling rate = 4000 x 2 = 8000 samples/s

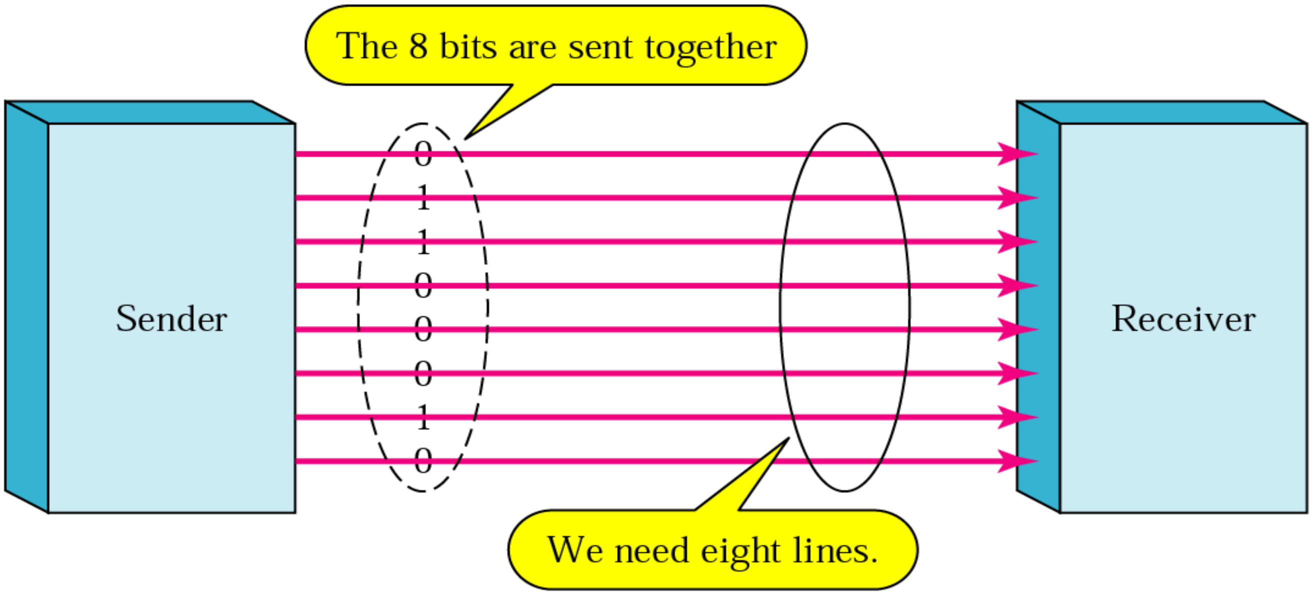
Bit rate = sampling rate x number of bits per sample

4.4 Transmission Mode



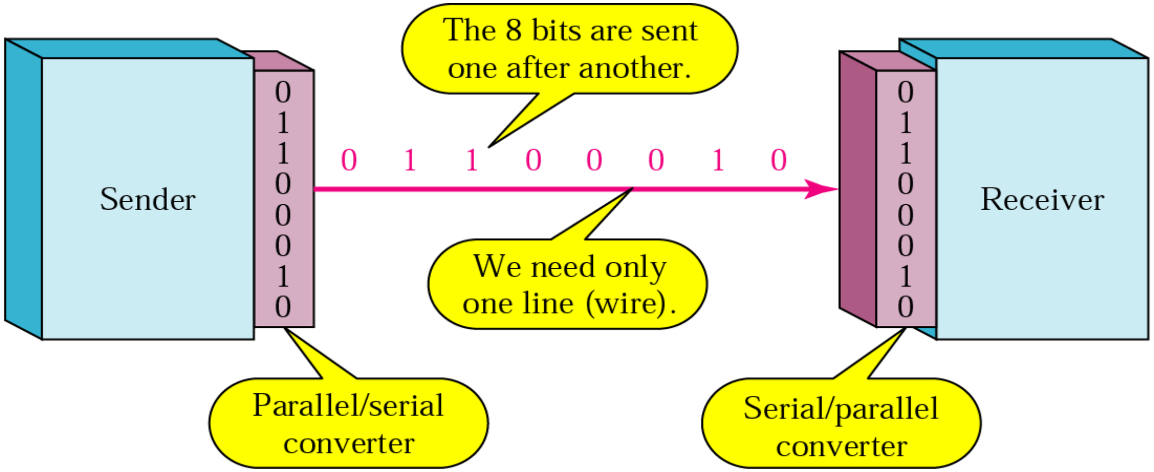
Parallel Transmission

- Bits in a group are sent simultaneously, each using a separate link
- *n* wires are used to send *n* bits at one time
- Advantage: speed
- Disadvantage: cost; limited to short distances



Serial Transmission

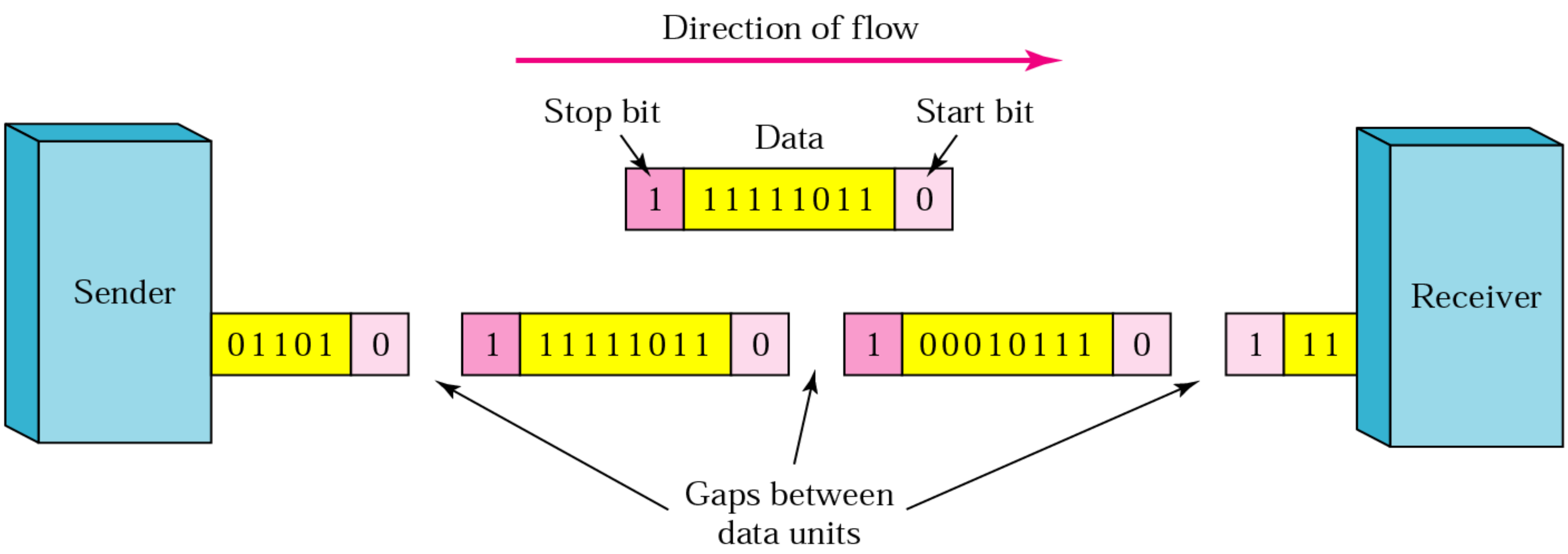
- Transmission of data one bit at a time using only one single link
- Advantage: reduced cost
- Disadvantage: requires conversion devices
- Methods:
  - Asynchronous
  - Synchronous



Asynchronous Transmission

- Transfer of data with start and stop bits and a variable time interval between data units
- Timing is unimportant
- Start bit alerts receiver that new group of data is arriving
- Stop bit alerts receiver that byte is finished
- Synchronization achieved through start/stop bits with each byte received

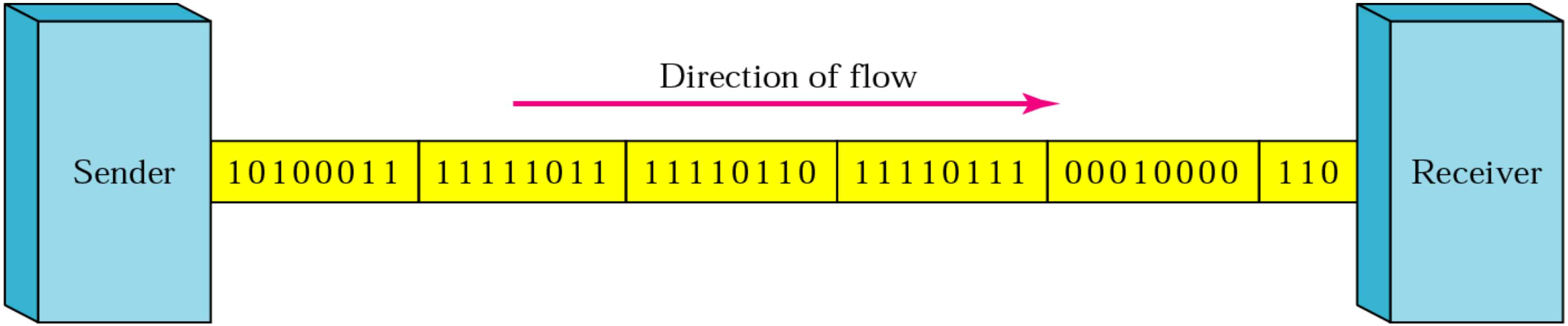
Asynchronous Transmission



Asynchronous Transmission

- Requires additional overhead (start/stop bits)
- Slower
- Cheap and effective
- Ideal for low-speed communication when gaps may occur during transmission (ex: keyboard)

Synchronous Transmission



Synchronous Transmission

- Requires constant timing relationship
- Bit stream is combined into longer frames, possibly containing multiple bytes
- Any gaps between bursts are filled in with a special sequence of 0s and 1s indicating idle
- Advantage: speed, no gaps or extra bits
- Byte synchronization accomplished by data link layer

Credits

- All figures obtained from publisher-provided instructor downloads

  Data Communications and Networking, 3rd edition by Behrouz A. Forouzan. McGraw Hill Publishing, 2004