Vietnam National University HCMC

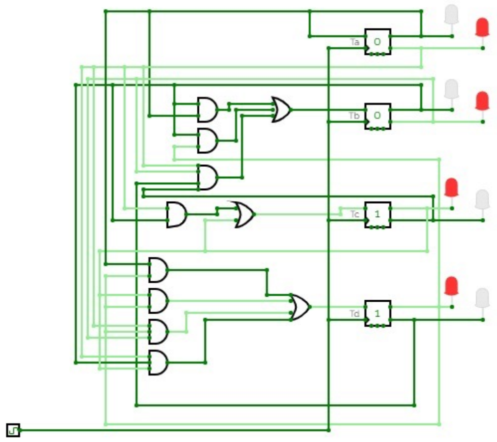
International University

School of Electrical Engineering

EE053IU

Digital Logic Design

Lecture 13: Data Transmission



INSTRUCTOR: Dr. Vuong Quoc Bao

1. Data Transmission Media

- All data transmission systems in their most basic form have a data source (sending device) at one end and a receiving device at the other.
- The two devices are connected by a transmission medium, which can be wire, coaxial cable, twisted pair cable, optical fiber cable, or space (wireless).
- A digital signal is a changing electrical or electromagnetic quantity that carries information through the medium. When data are sent without modulation, usually over wires or cables, it is called ***baseband transmission***. When data are modulated and sent through a wireless medium, it is called ***broadband transmission***.

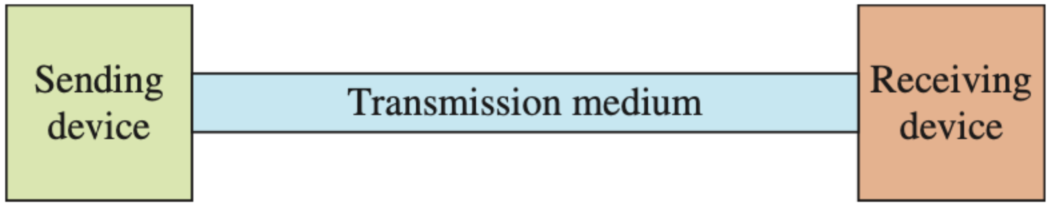


FIGURE 13–1 Basic data transmission system.

Wire Connections

- The simplest connection between sending and receiving devices is a wire or a conductive trace on a printed circuit board (PCB).

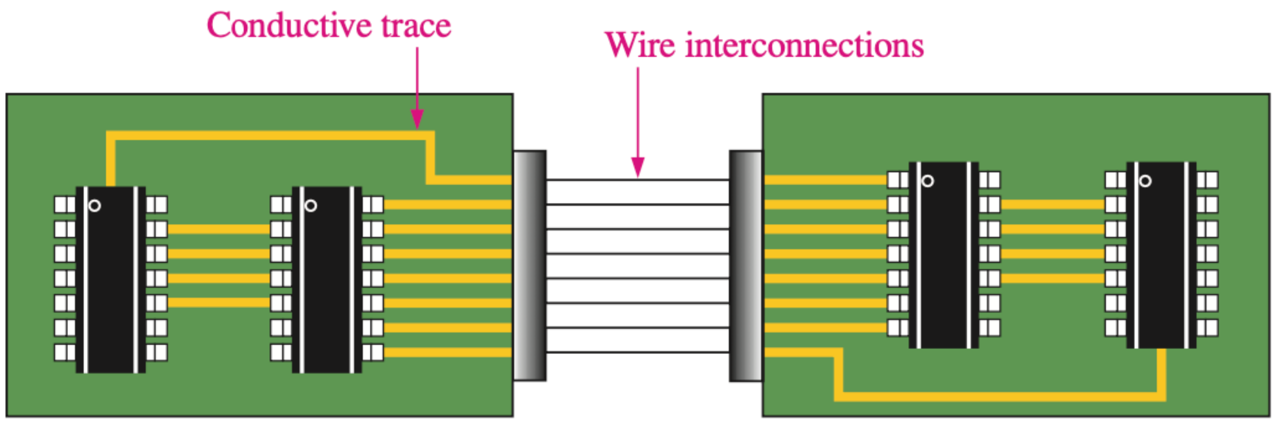


FIGURE 13–2 Conductive traces on PCBs and wire interconnections between boards.

Coaxial Cable

- Coaxial cable (coax) consists of a center conductor within an insulating dielectric material. A copper braided or foil shield surrounds the dielectric to protect the conductor against electromagnetic interference (EMI).

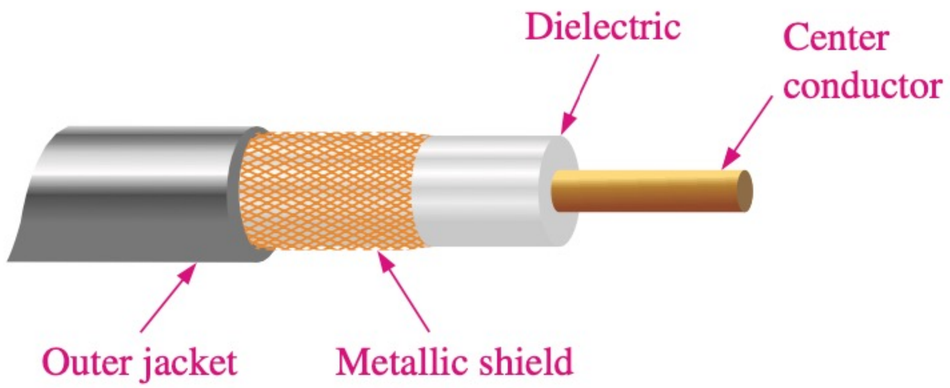


FIGURE 13–3 Construction view of a coaxial cable.

Twisted Pair Cable

- Unshielded twisted pair (UTP) cable is used extensively for indoor telephone application as well as some outdoor uses.
- Cross talk, a type of distortion, is minimized when twisted pairs are bundled together. The two wires in each pair are twisted so that they cross each other at nearly 90°, ideally cancelling any electromagnetic fields generated by the signals in the wires.

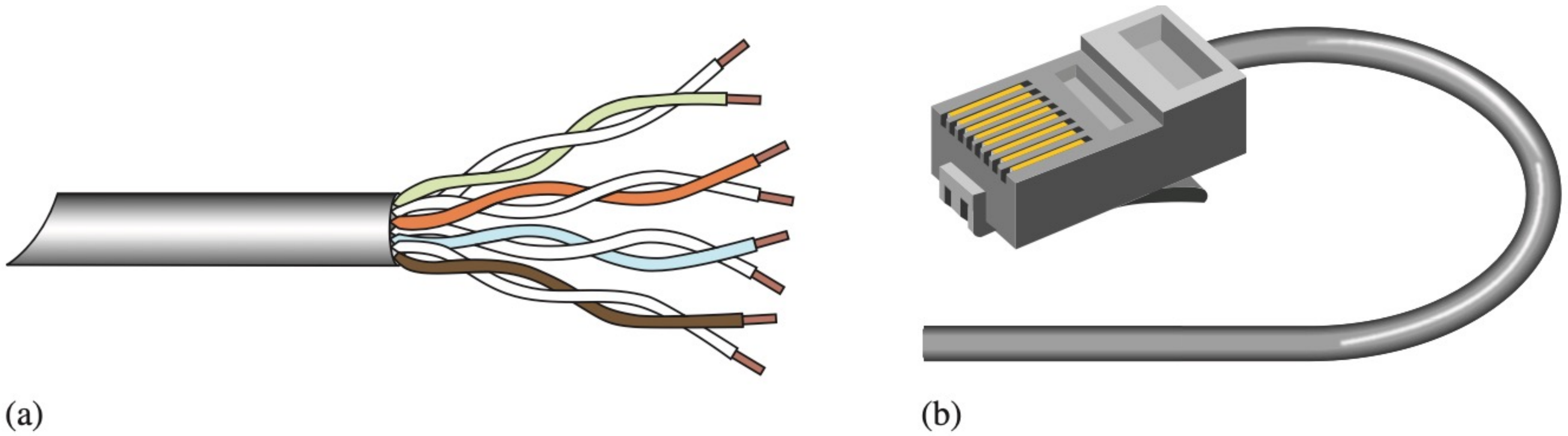


FIGURE 13–4 Example of an unshielded twisted pair (UTP) cable and connector.

Optical Fiber Cable

- Instead of using electrical pulses to transmit information through copper lines, fiber optics uses light pulses transmitted through optical fibers.

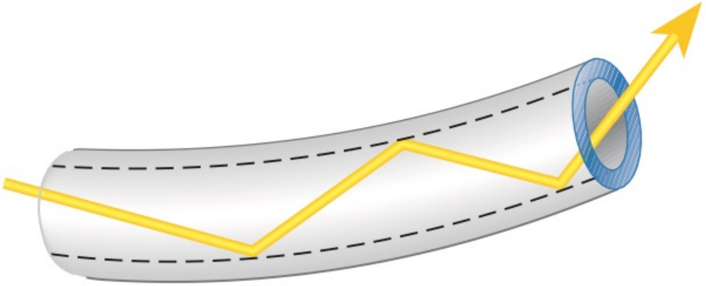
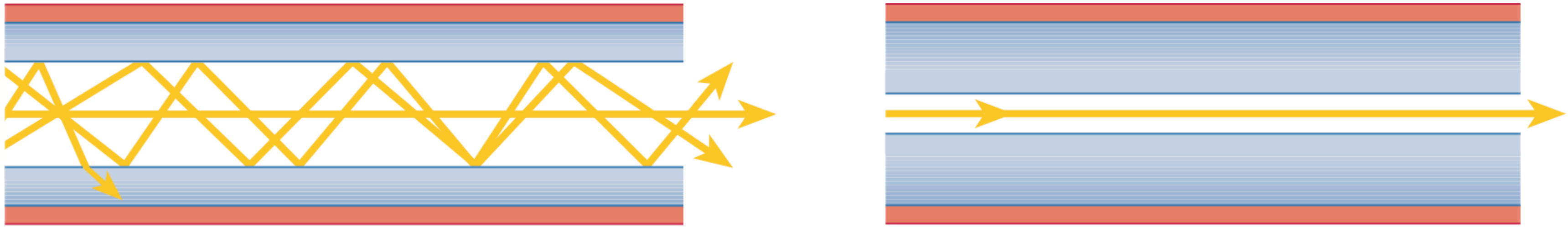


FIGURE 13–6 Light propagating through an optical fiber while reflecting off the internal surface.

Modes of Light Propagation



(a) Multimode

(b) Single mode

FIGURE 13–7 Modes of light propagation in an optical fiber.

A Fiber-Optic Data Communications Link

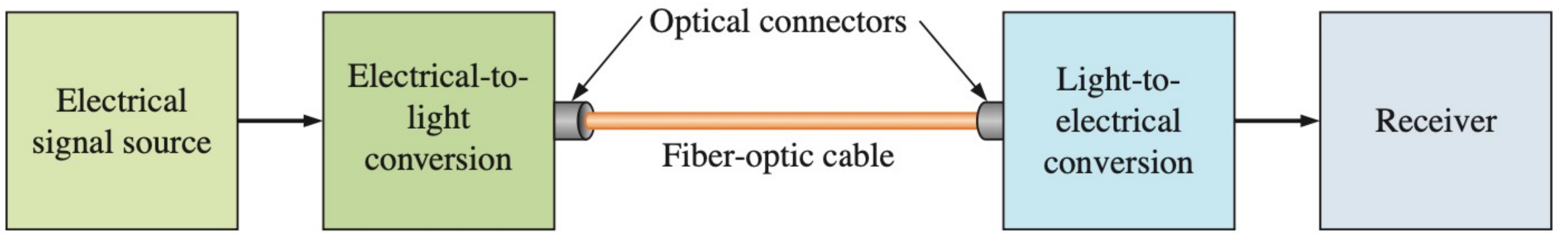


FIGURE 13–8 Basic block diagram of a fiber-optic communications link.

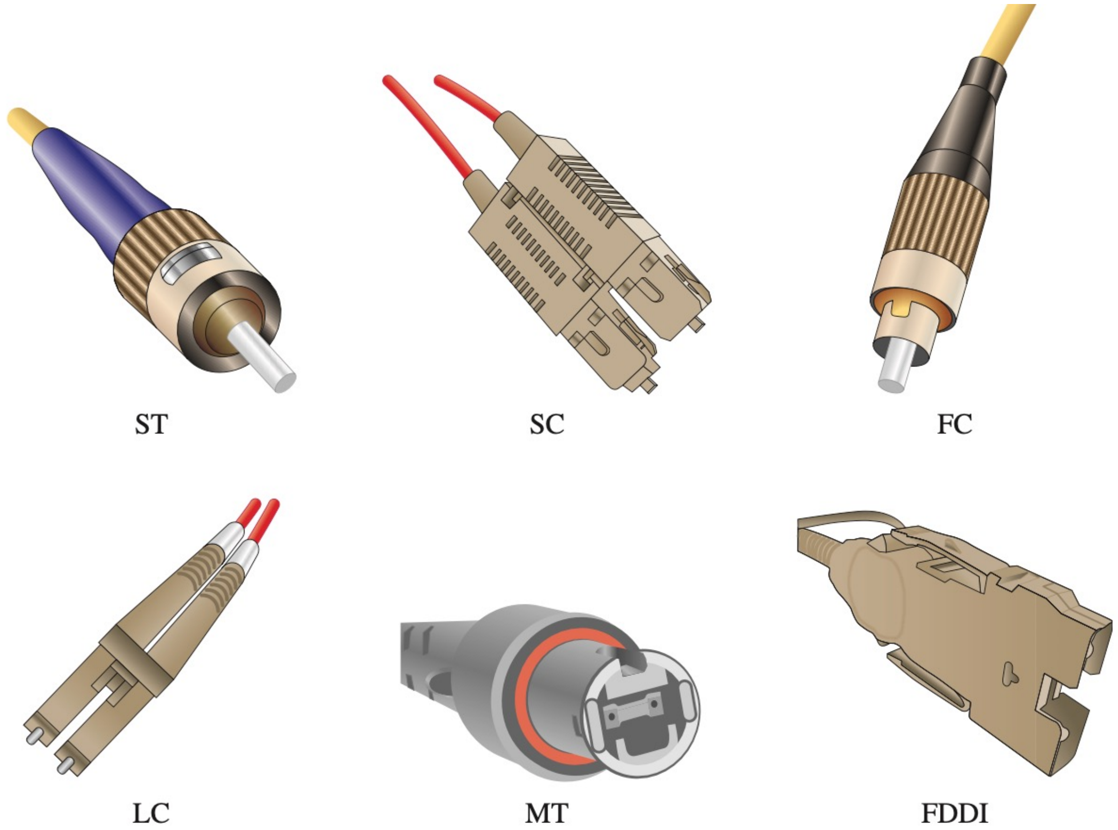


FIGURE 13–9 Typical types of optical fiber connectors.

Wireless Transmission

The transmission of data through air and space via electromagnetic waves without the use of physical connections between sending and receiving systems is known as wireless transmission.

The Electromagnetic Spectrum

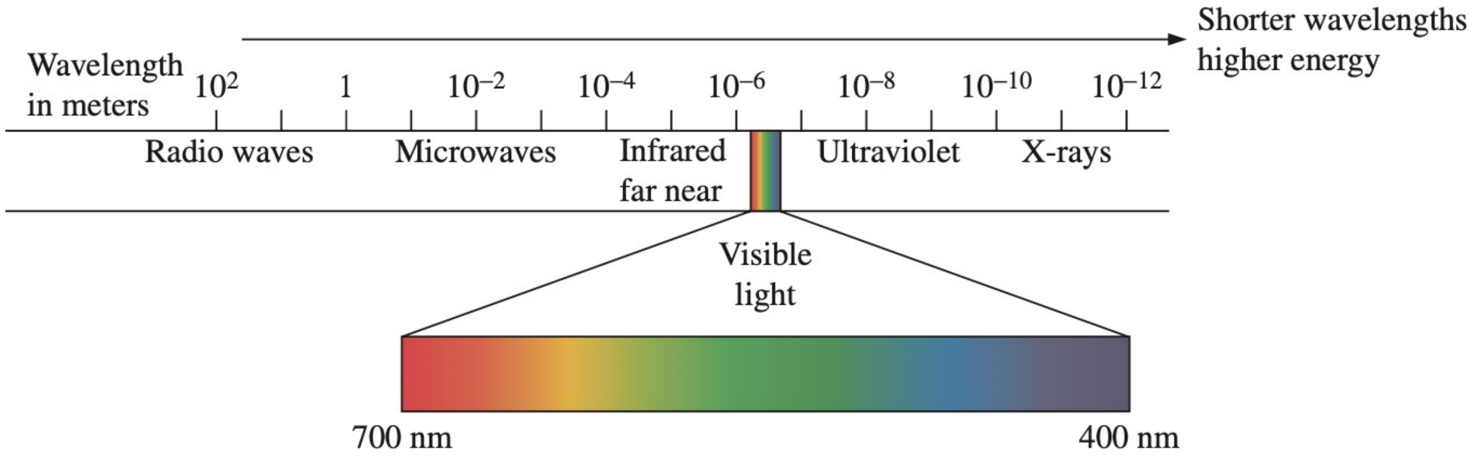


FIGURE 13–10 The electromagnetic spectrum.

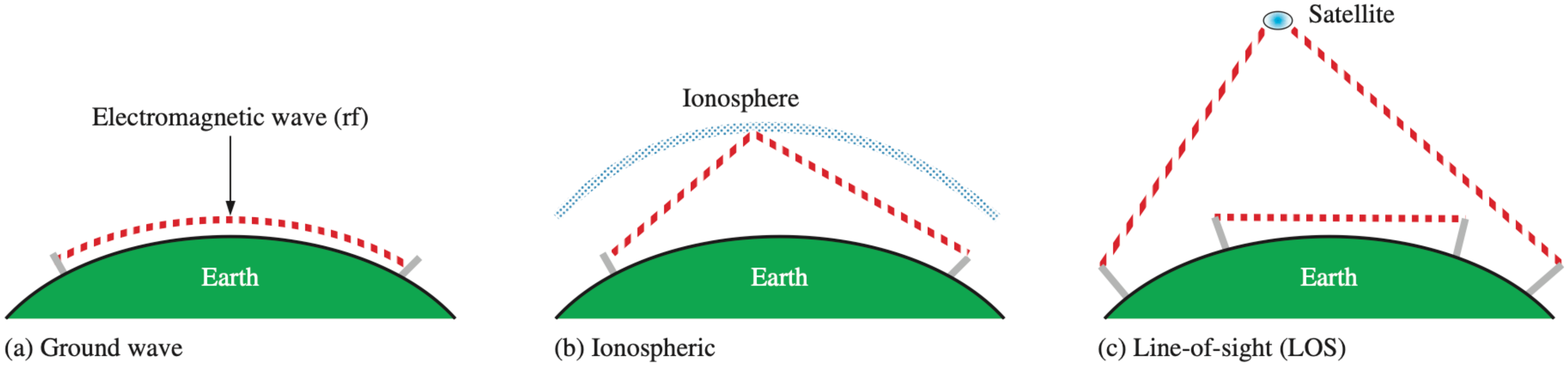


FIGURE 13–11 Ways in which rf and microwave signals can propagate.

2. Methods and Modes of Data Transmission

Serial and Parallel Data

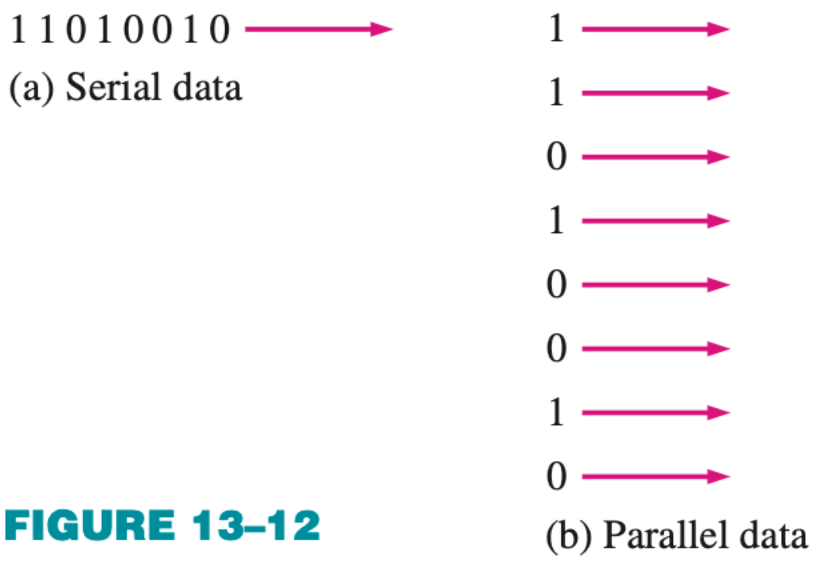


FIGURE 13–12

A data **packet** is one complete piece of information of a longer message. Typically, many packets make up the entire message.

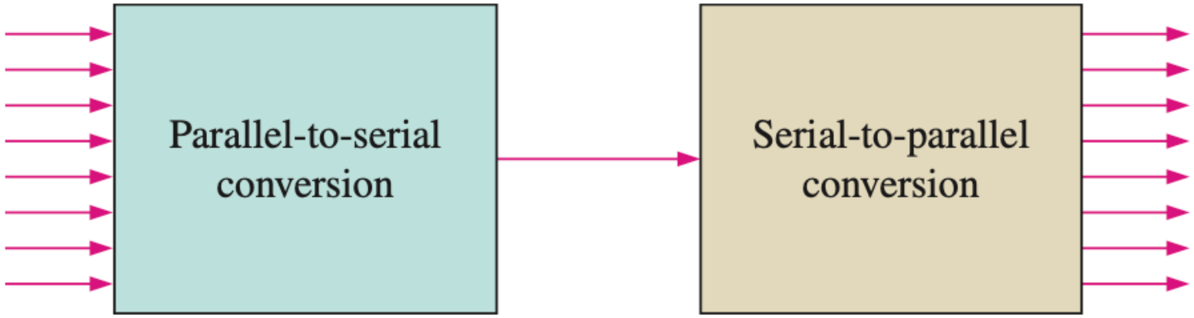


FIGURE 13–13 Digital data conversions.

Asynchronous Data

In **asynchronous** systems, the sending and receiving devices operate with separate oscillators having the same clock frequency

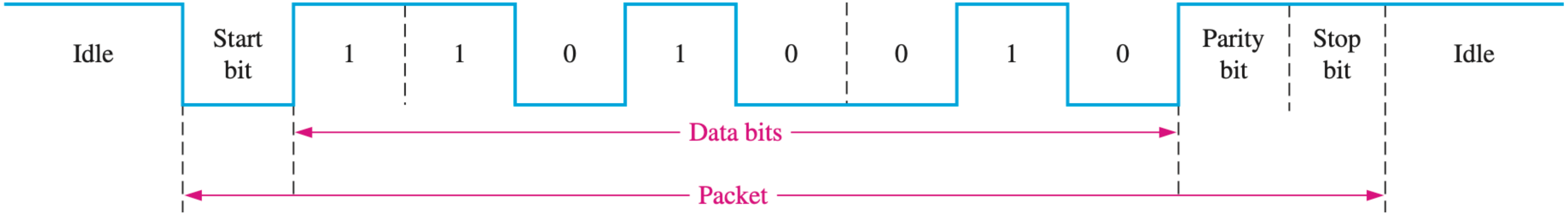


FIGURE 13–14 Example of a serial transmission of a data packet for a given data code.

Synchronous Data

In synchronous data transmission, both the sender and the receiver derive timing from the same clock signal, which originates at the sender end of the system.

FIGURE 13–15 Data formats that require separate timing for synchronization.

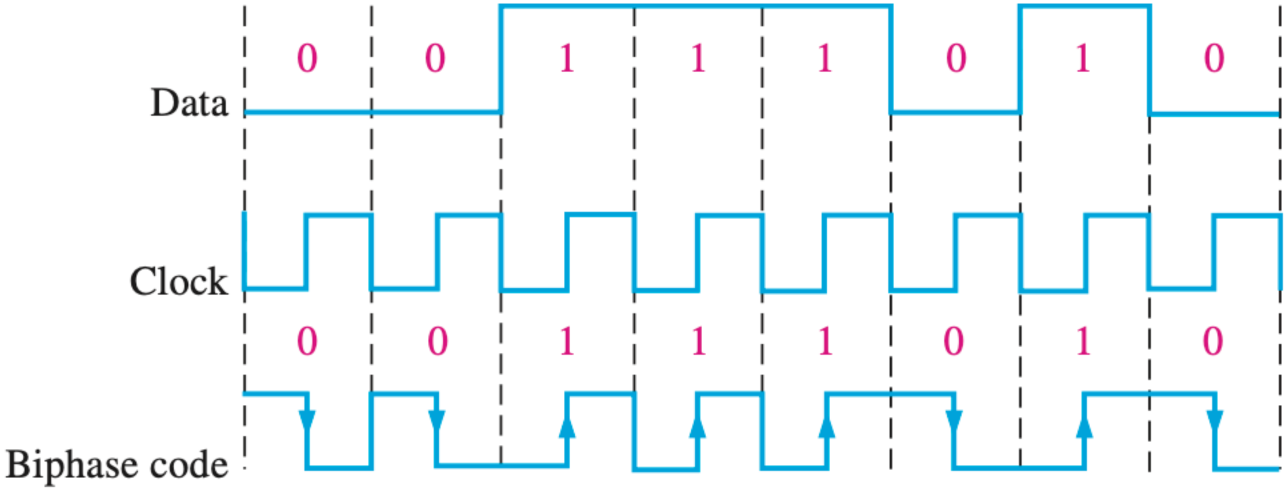


FIGURE 13–16 Example of Manchester encoded data and timing.

EXAMPLE 13–1

Determine the biphase (Manchester) code for the data and clock shown in Figure 13–17(a).

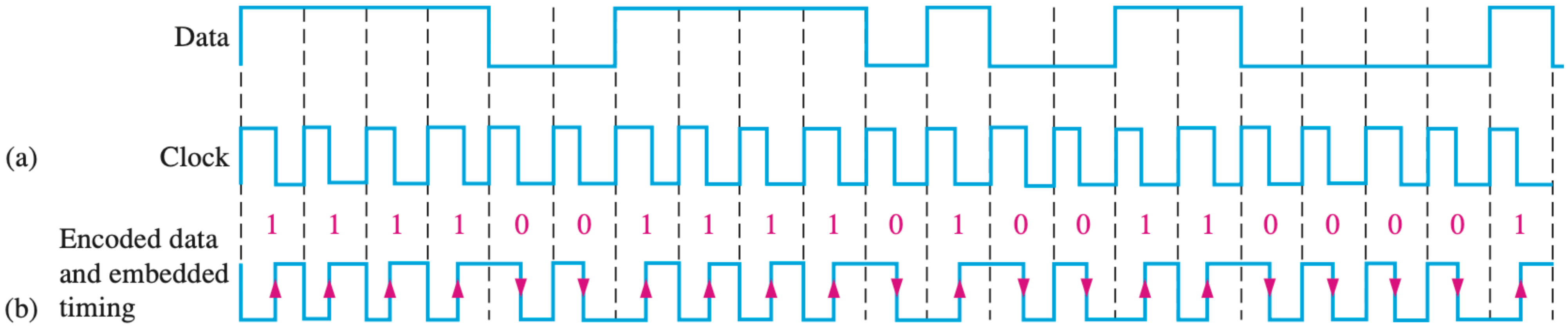


FIGURE 13–17

Solution

The encoded data and embedded timing are shown in Figure 13–17(b). As the arrowheads indicate, the rising edges are 1s and the falling edges are 0s that occur in the middle of each bit time (period of the clock).

Synchronous Frames

FIGURE 13–18 Basic synchronous frame structure.

- **Preamble** A group of bits at the beginning of a frame that is used to alert the receiver that a new frame has arrived and to synchronize the receiver's clock with the transmitted clock.
- **Address fields** A group of bits containing the address(s) of the sender and the receiver. One or both addresses may be present in a given protocol.
- **Control field** This group of bits identifies the type of data being sent, such as hand- shaking (establishes a connection), file transfers, and the size of the data.
- **Data field** This sequence is the actual information being sent and can be of a fixed length or a variable length. If it is a fixed-length field, a group of bits called a pad is used to fill in if the actual data field is less than the fixed field.
- **Frame check** This field contains an error check such as parity, CRC (cyclic redundancy check), or checksum, which is a value computed by a simple algorithm of the data bits in the frame.
- **End frame** A group of bits that tells the receiver when the end of the frame occurs.

Data Rate

- **Data rate** is the speed of data transfer. In a serial data transmission the rate can be stated as bit rate or baud; bit rate is the preferred measure.
- The **bit rate** is the number of bits (1s and 0s) per second (bps);
- The **baud** is the symbol rate or the number of data symbols (some- times known as transitions or events) per second.

$$\text{Bit rate} = (\text{Number of bits per symbol})\,(\text{Baud})$$

or

$$\text{Baud} = \frac{\text{Bit rate}}{\text{Number of bits per symbol}}$$

$$\text{Baud} = (1\ \text{symbol/ms})(1000\ \text{ms/s}) = 1000\ \text{baud} = 1\ \text{kbaud}$$

The data rate in terms of bit rate is

$$\text{Bit rate} = (8\ \text{bits/symbol})(1000\ \text{symbols/s}) = 8000\ \text{bps} = 8\ \text{kbps}$$

EXAMPLE 13–2

A certain analog waveform is represented by sixteen-voltage levels that are being transmitted. Each level (symbol) is represented by a 4-bit code. Assuming that eight symbols are transmitted in 1 μs, express the data rate as bit rate and as baud.

Solution

$$\text{Bit rate} = (4 \text{ bits/symbol})(8 \text{ symbols}/\mu\text{s}) = 32 \text{ bits}/\mu\text{s} = \mathbf{32\ Mbps}$$

$$\text{Baud} = \frac{32 \text{ Mbps}}{4 \text{ bits per symbol}} = \mathbf{8\ Mbaud}$$

Transmission Efficiency

$$\text{Efficiency} = \frac{\text{Data bits}}{\text{Total bits}} = \frac{8 \text{ bits}}{11 \text{ bits}} = 0.727 \text{ or } 72.7\%$$

EXAMPLE 13–3

A certain system transmits a block of information containing ten packets each with eight data bits, a start bit, and a stop bit. Additional "overhead" bits include a 4-bit synchronization code at the beginning of the block and a parity bit at the end of the block. Determine the transmission efficiency.

Solution

$$\text{Data bits} = (8 \text{ data bits})(10 \text{ packets}) = 80 \text{ bits}$$

$$\text{Overhead bits} = (1)(10 \text{ start bits}) + (1)(10 \text{ stop bits}) + 4 \text{ synchronization bits} + 1 \text{ parity bit} = 25 \text{ bits}$$

$$\text{Total bits} = \text{Data bits} + \text{Overhead bits} = 80 + 25 = 105$$

$$\text{Efficiency} = \frac{\text{Data bits}}{\text{Total bits}} = \frac{80}{105} = \mathbf{0.762 \text{ or } 76.2\%}$$

Transmission Modes

- In the **simplex mode**, data flow in only one direction from the sender (transmitter) to the receiver. In a computer, for example, data flow one way from the computer to the printer.
- In the **half-duplex mode**, the data flow both ways but not at the same time in the same channel. For example, a sender transmits information to the receiver and the receiver responds back to the sender after it has received the information.
- In the **full-duplex mode**, the data flow both ways simultaneously in the same channel. The bandwidth of the channel is divided between the two directions.

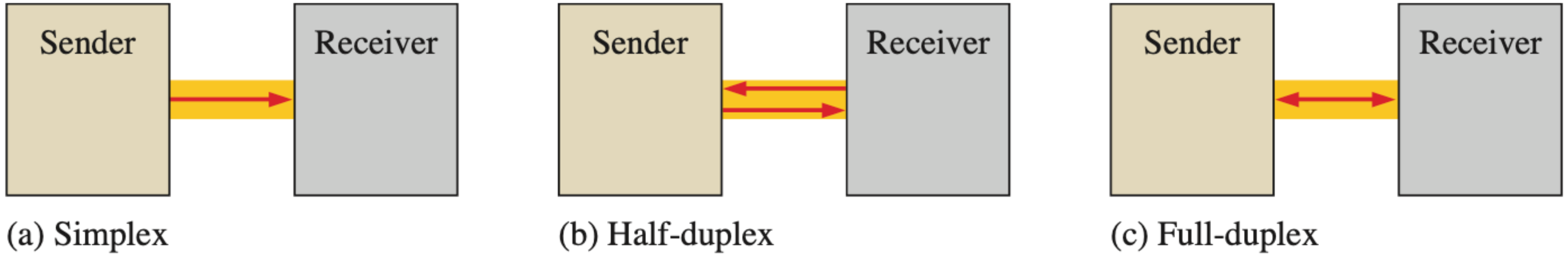


FIGURE 13–19 Data transmission modes.

3. Modulation of Analog Signals with Digital Data

Amplitude-Shift Keying

Amplitude-shift keying (ASK) is a form of modulation in which a digital signal varies the amplitude of a higher frequency sine wave (carrier).

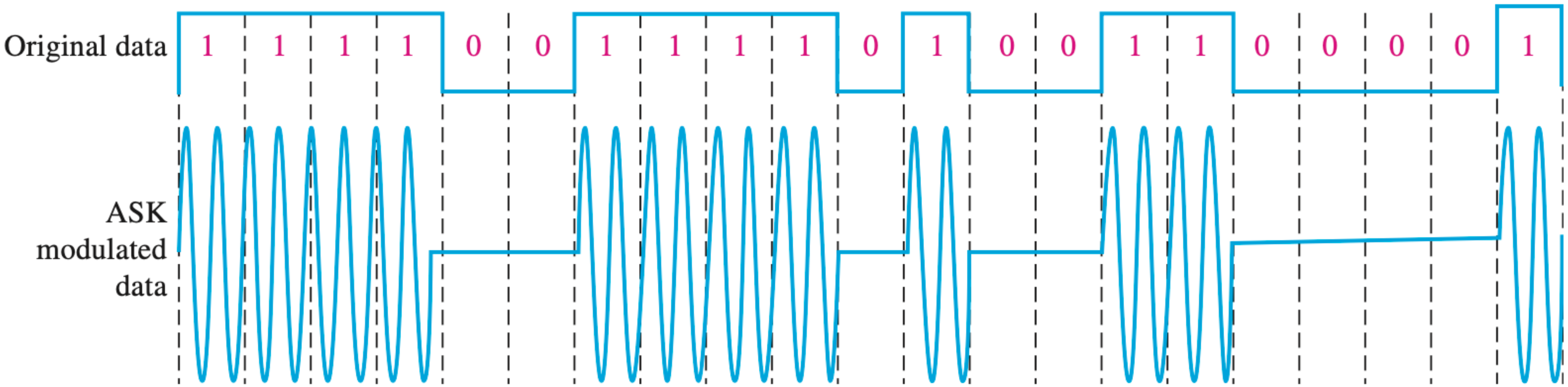


FIGURE 13–20 Illustration of amplitude-shift keying (ASK).

Frequency-Shift Keying

Frequency-shift keying (FSK) is a form of modulation in which a digital signal modulates the frequency of a higher frequency sine wave (carrier).

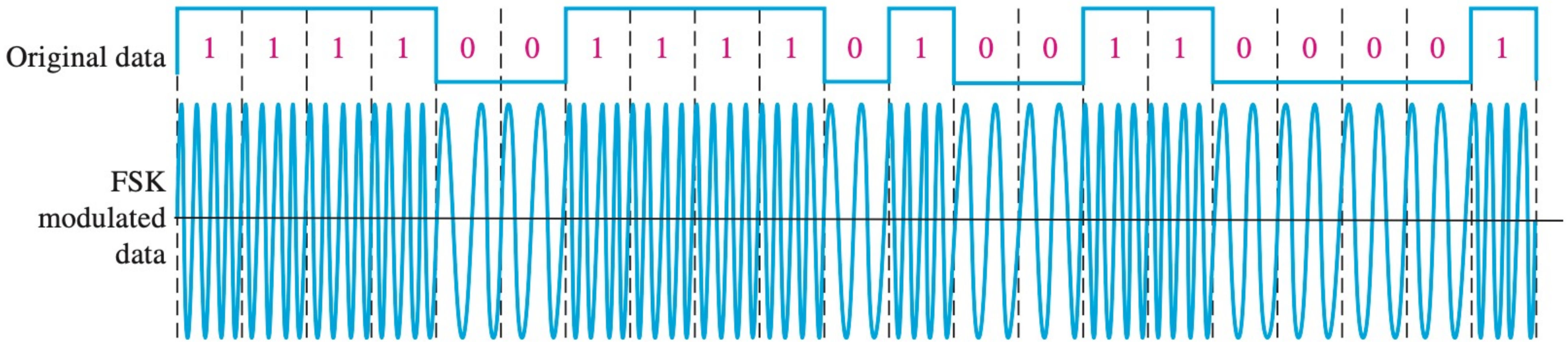


FIGURE 13–21 Illustration of frequency-shift keying (FSK).

Phase-Shift Keying

Phase-shift keying (PSK) is a form of modulation in which a digital signal modulates the phase of a higher frequency sine wave.

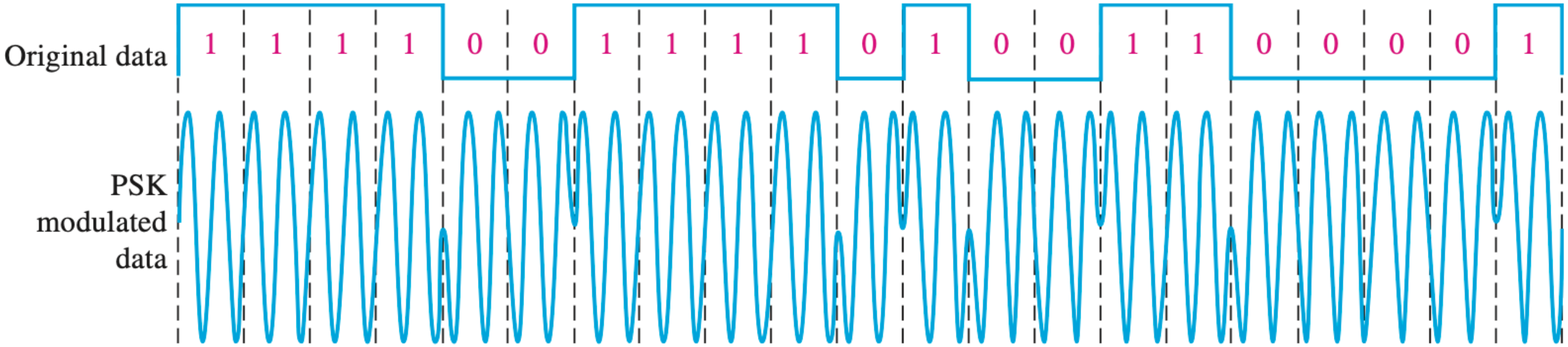


FIGURE 13–22 Illustration of phase-shift keying (PSK).

Quadrature Amplitude Modulation

Quadrature amplitude modulation (QAM) is widely used in telecommunications and in digital cable TV. Digital QAM uses a combination of PSK and ASK to send information. Quadrature refers to a 90° phase difference.

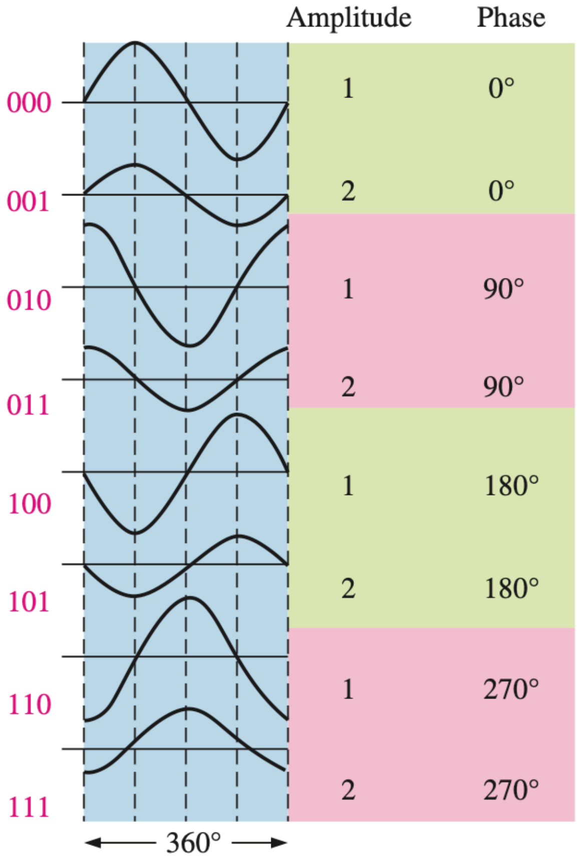


FIGURE 13–23 Eight amplitude/phase combinations (modulation states) represent one of the eight 3-bit groups. Only one cycle of each modulation state is shown.

M-QAM

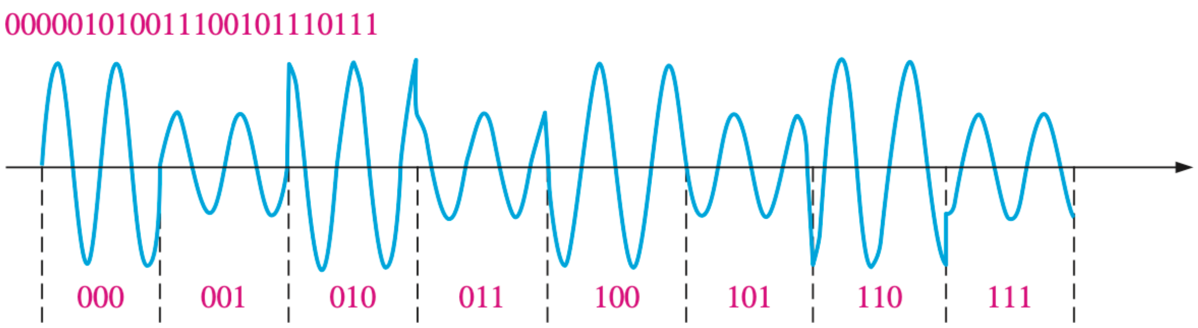


FIGURE 13–24 Illustration of an 8-QAM transmission of the binary sequence shown.

Constellation Maps

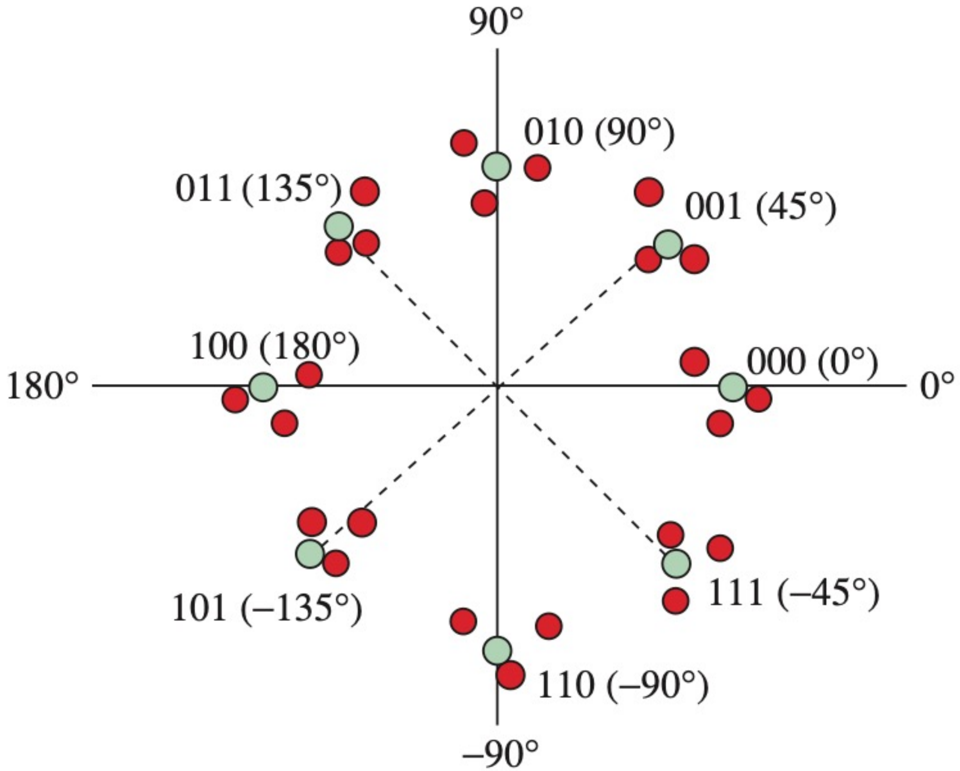


FIGURE 13–25 Constellation map for a 3-bit PSK transmission. The phases are 0°, 45°, 90°, 135°, 180°, −45°, −90°, and −135°, as indicated.

4. Modulation of Digital Signals with Analog Data

Pulse Amplitude Modulation

In pulse amplitude modulation (PAM), the heights or amplitudes of the pulses are varied according to the modulating analog signal; each pulse represents a value of the analog signal.

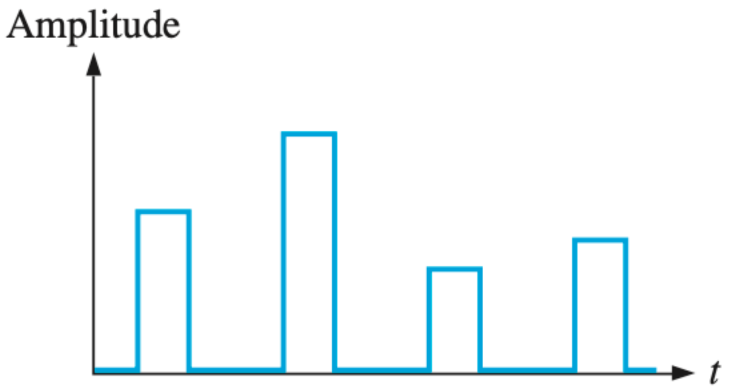


FIGURE 13–27 A simple PAM signal.

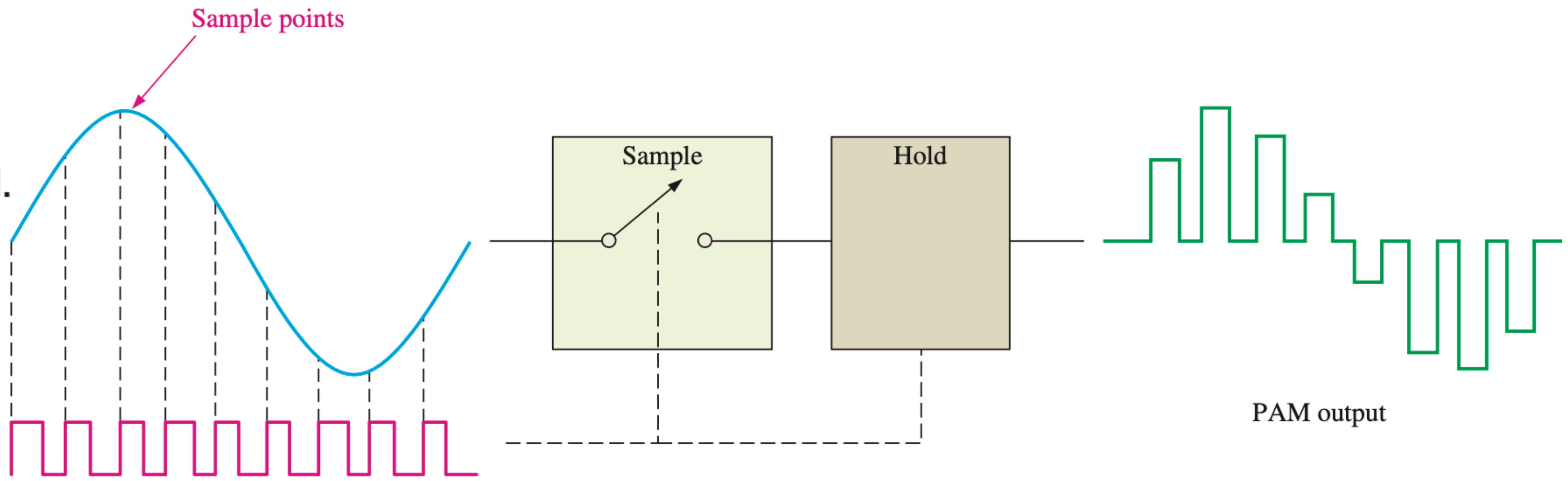


FIGURE 13–28 Basic method of pulse amplitude modulation.

Pulse Width Modulation

In pulse width modulation (PWM), the width or duration of the pulses and duty cycle are varied according to the modulating analog signal; each pulse represents a value of the analog signal.

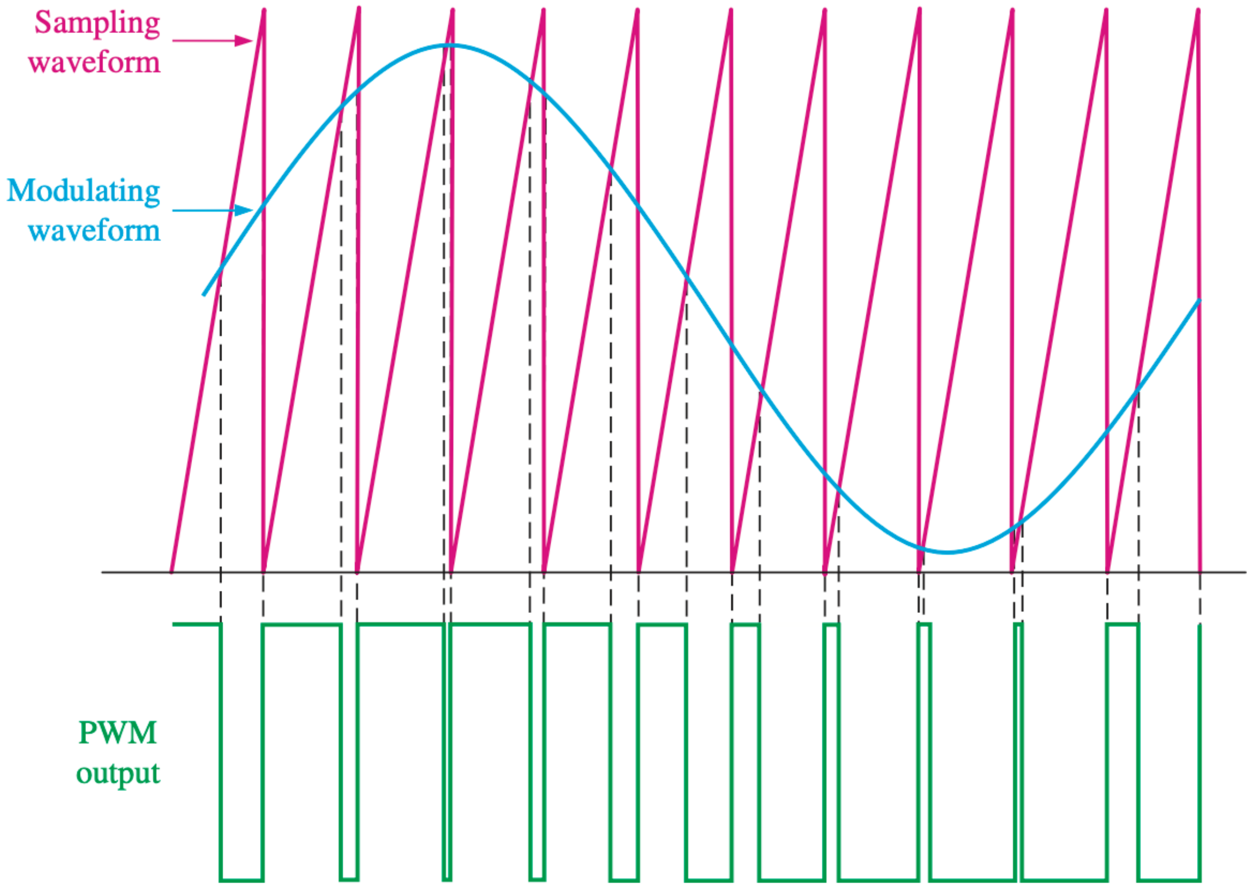


FIGURE 13–29 Illustration of PWM.

Pulse Width Modulation

In pulse width modulation (PWM), the width or duration of the pulses and duty cycle are varied according to the modulating analog signal; each pulse represents a value of the analog signal.

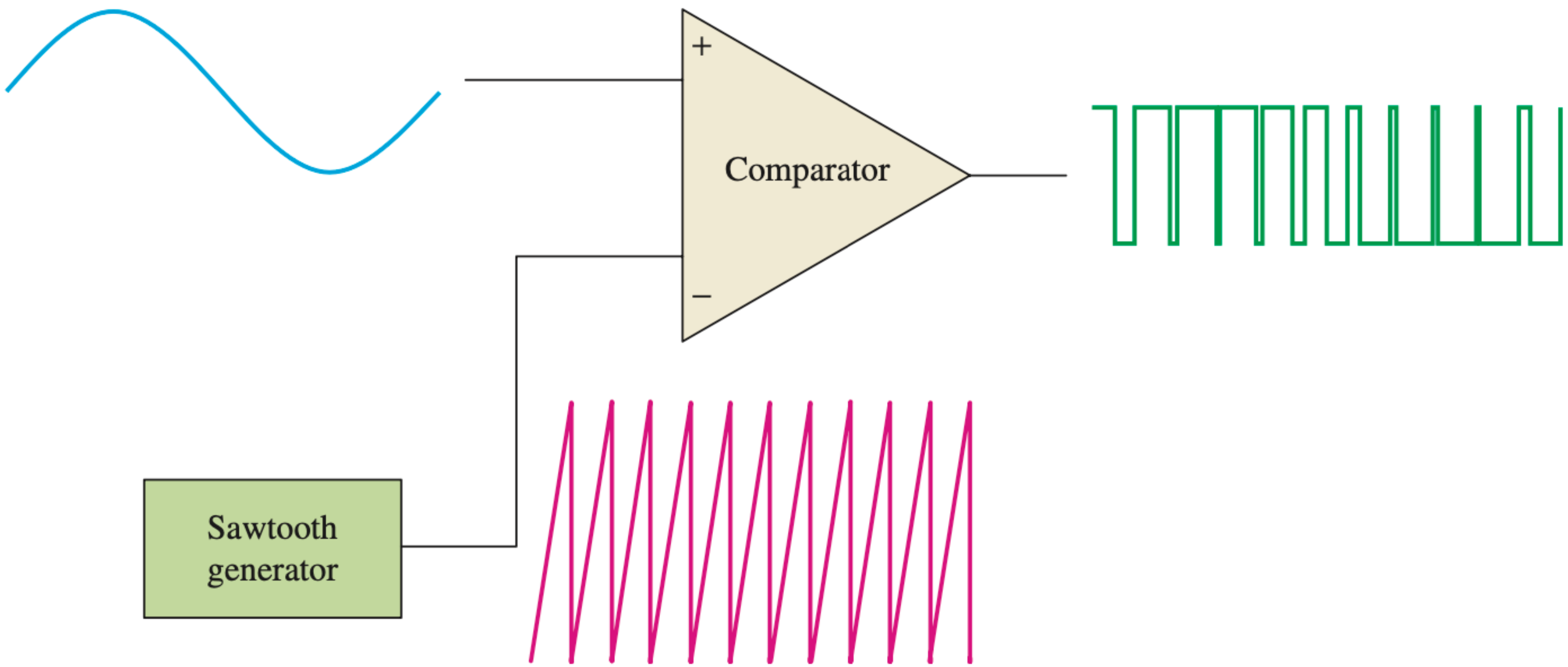


FIGURE 13–30 A basic method of pulse width modulation.

Pulse Position Modulation

In pulse position modulation (PPM), also known as pulse phase modulation, the position of each pulse relative to a reference or timing signal is varied proportional to the modulating signal waveform. The amplitude and width of the pulses in a PPM system are kept constant.

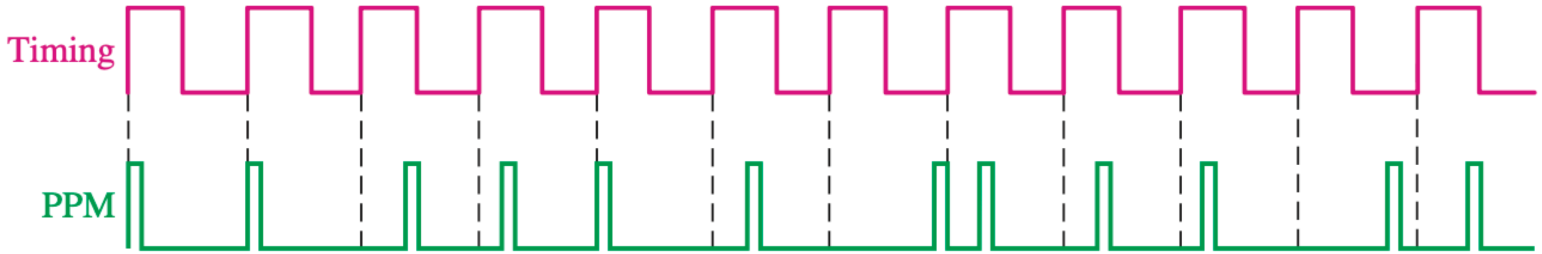


FIGURE 13–33 Example of a PPM signal with timing.

Pulse Position Modulation

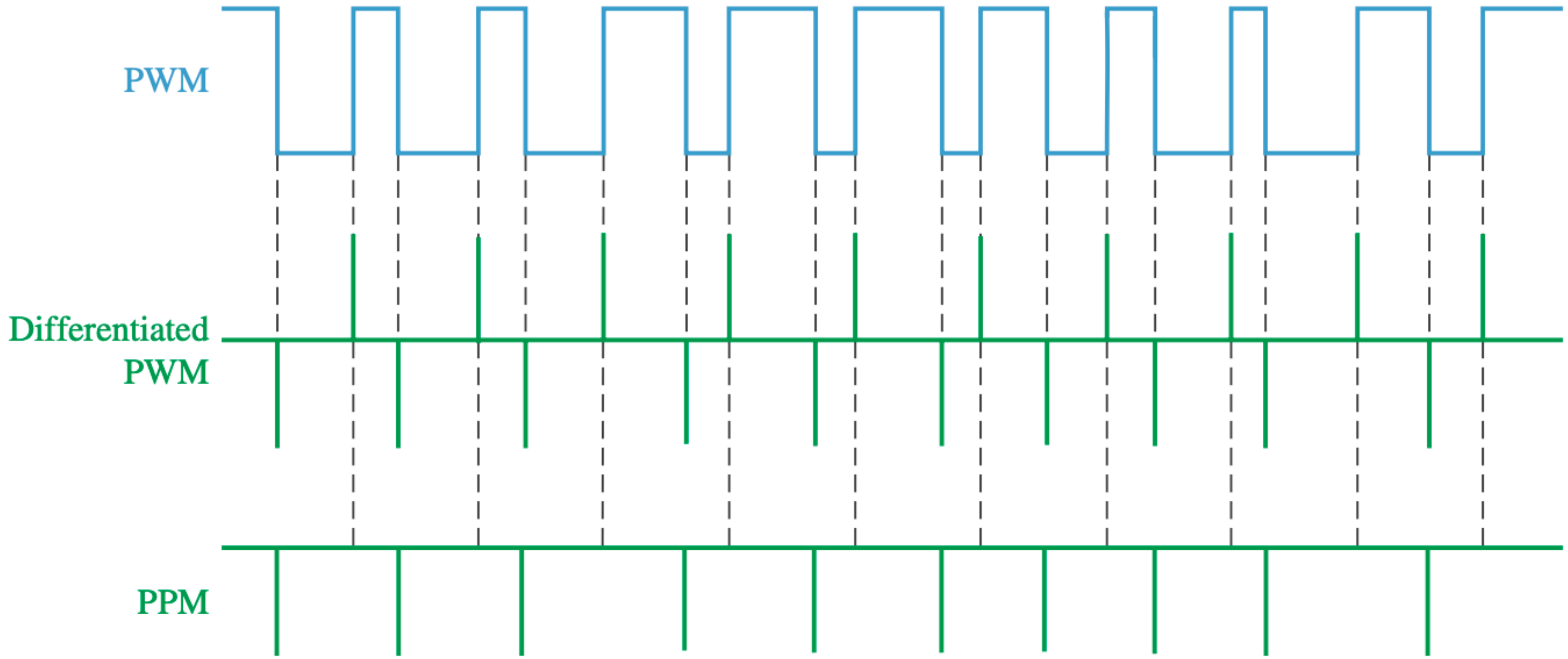


FIGURE 13–34 A method of generating PPM.

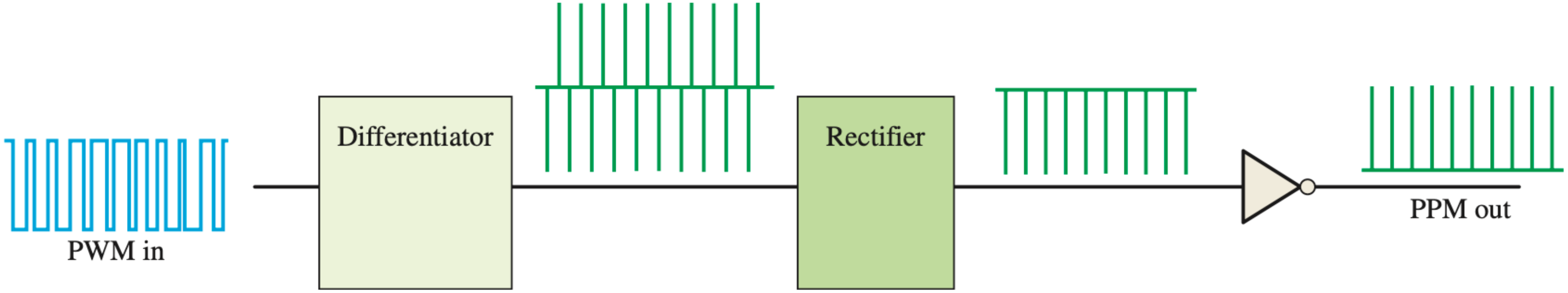


FIGURE 13–35 PPM system block diagram.

PPM Encoding

A certain number of data bits (D) are encoded by a single pulse in one of 2^D possible positions during a specified fixed time period (T). The data rate is D/T bits per second (bps).

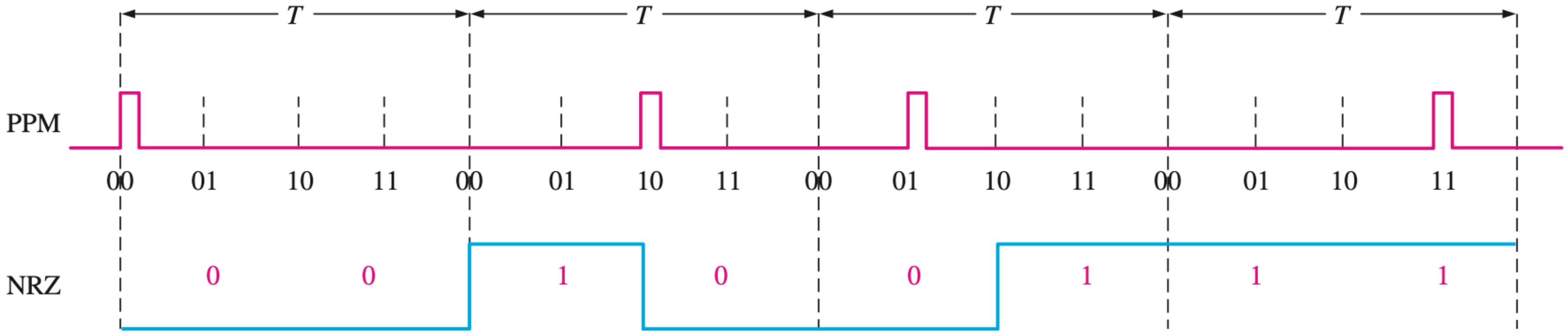


FIGURE 13–36 Encoding of a PPM signal.

EXAMPLE 13–6

For a PPM system with four data bits and a time period of 1 μs, determine the data rate. How many possible pulse positions are there in each time period?

Solution

The data rate is

$$\frac{D}{T} = \frac{4}{1\ \mu s} = \mathbf{4\ Mbps}$$

The number of possible pulse positions in each period is

$$2^D = 2^4 = \mathbf{16}$$

Pulse Code Modulation

Pulse code modulation (PCM) involves sampling of an analog signal amplitude at regular intervals and converting the sampled values to a digital code.

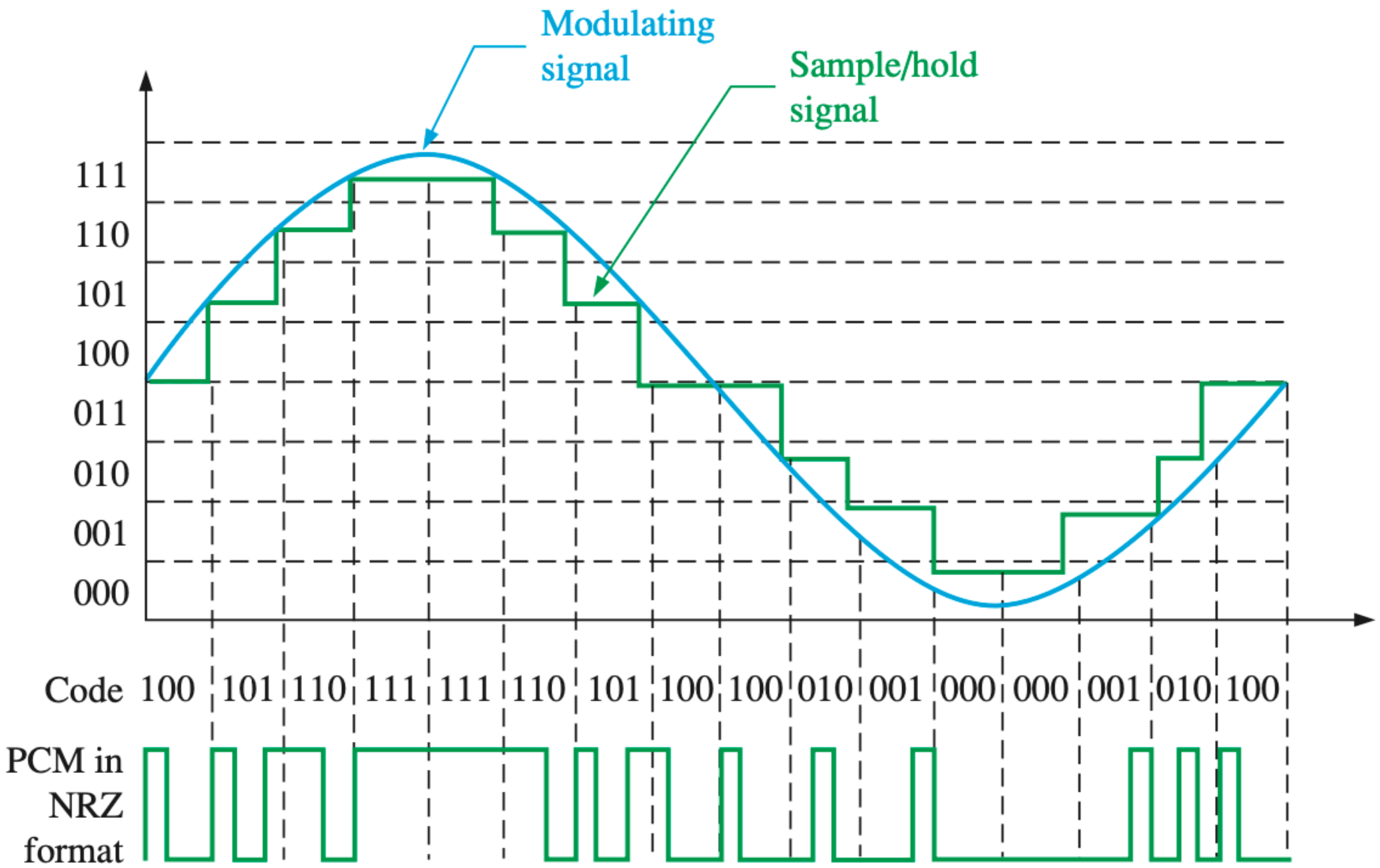


FIGURE 13–37 Concept of PCM with eight levels.

Pulse Code Modulation

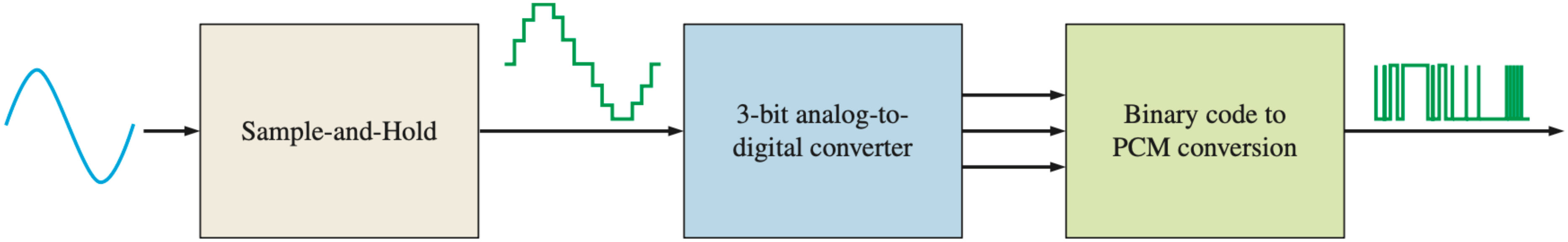


FIGURE 13–38 Block diagram of a PCM system.

EXAMPLE 13–7

In a PCM system with 32 levels, determine the number of code bits for each sample of an analog signal.

Solution

$$\text{Code bits} = 32 = 2^5$$

Five bits represent each sample.

Digital Data Systems

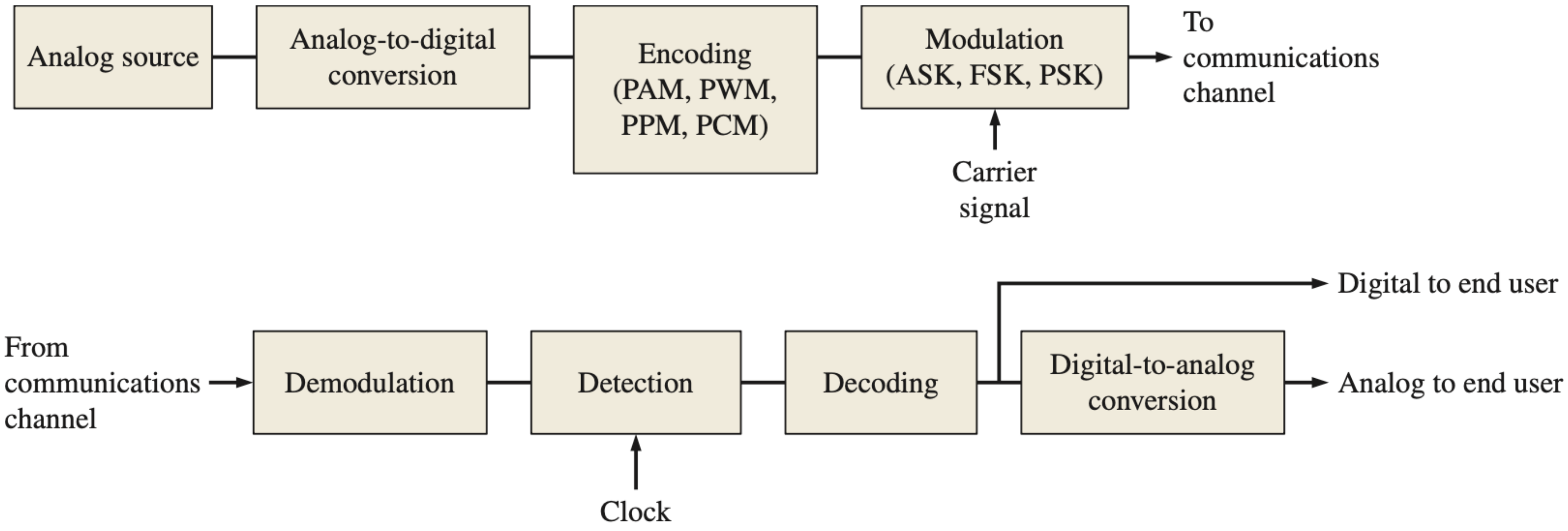


FIGURE 13–39 General function block diagram of a data transmission system.

5. Multiplexing and Demultiplexing

Time-Division Multiplexing

Time-division multiplexing (TDM) is a technique in which data from several sources are interleaved on a time basis and sent on a single communication channel or data link

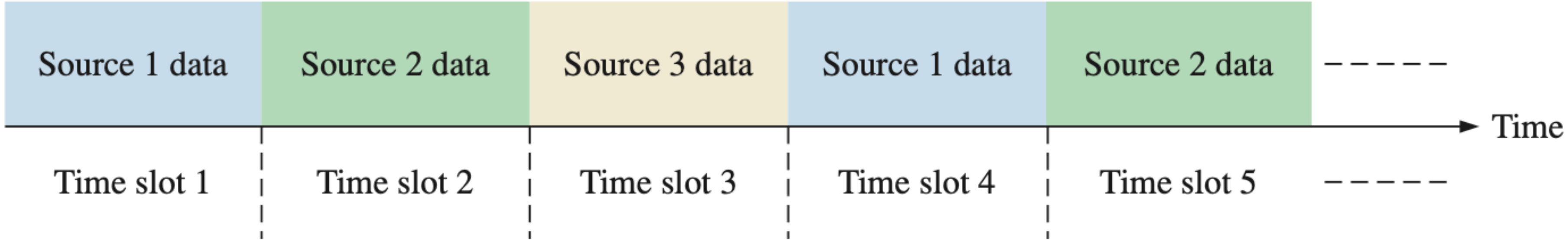


FIGURE 13–40 Basic concept of TDM.

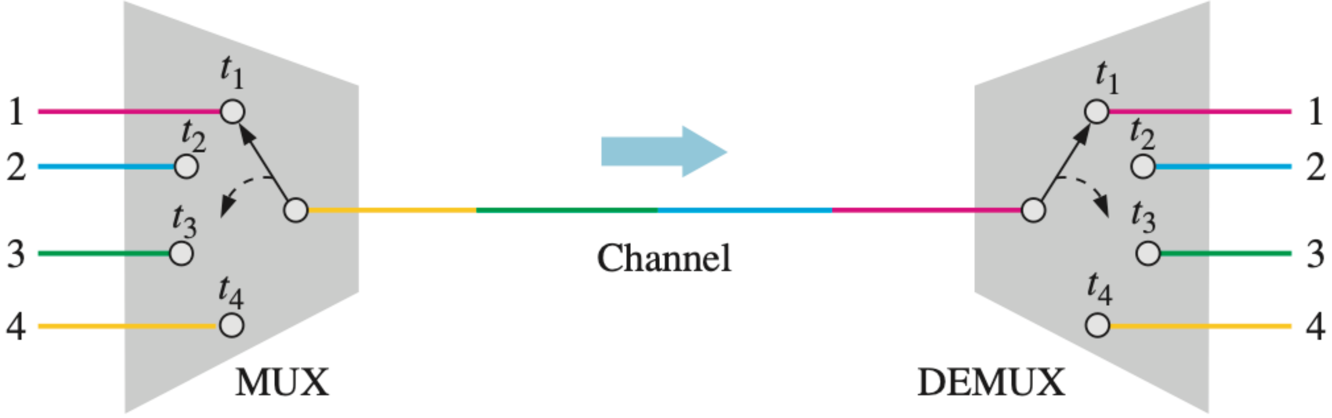


FIGURE 13–41 Simple illustration of TDM.

Bit-Interleaved TDM

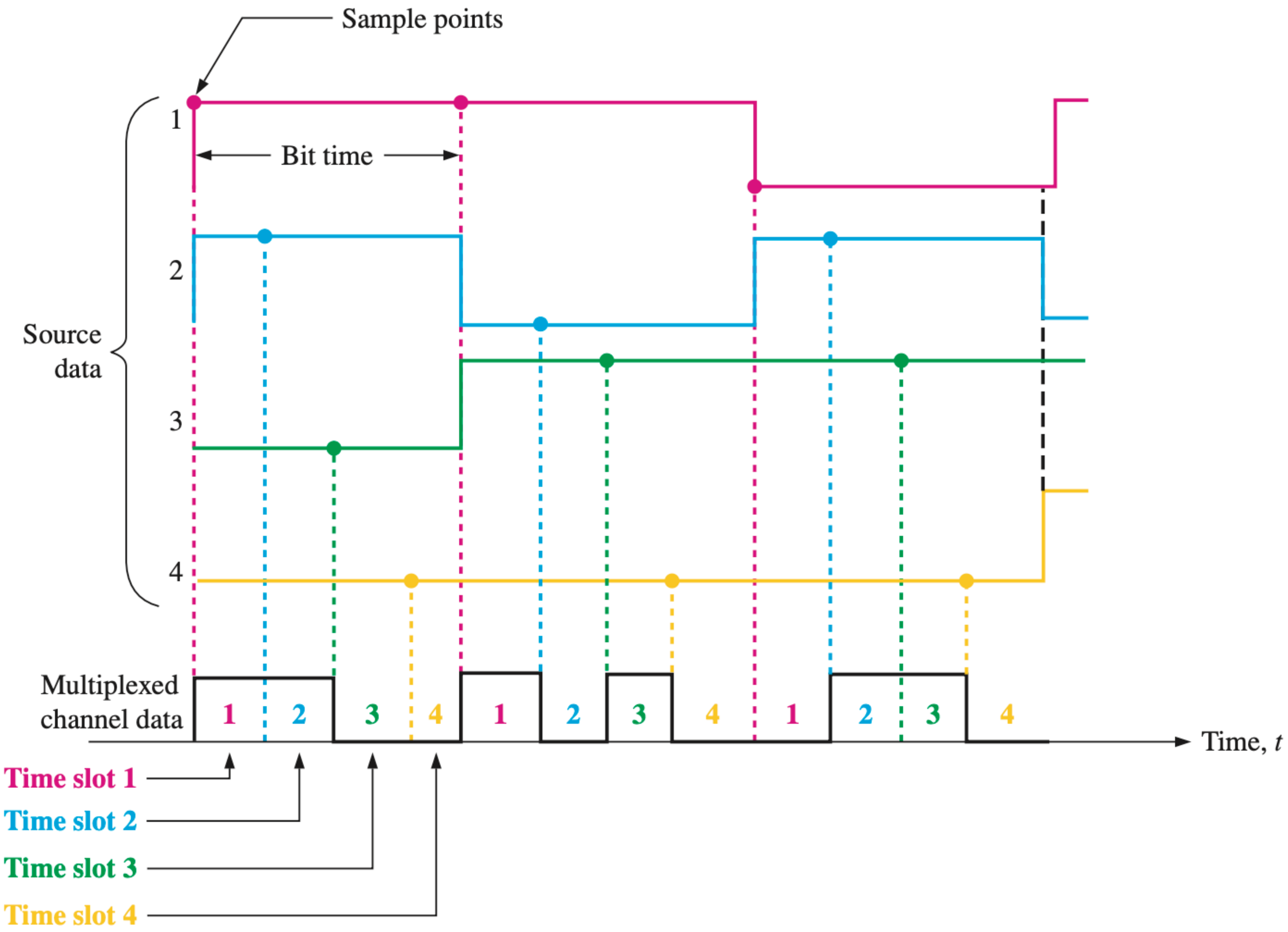


FIGURE 13–42 Illustration of TDM bit interleaving.

Byte-Interleaved TDM

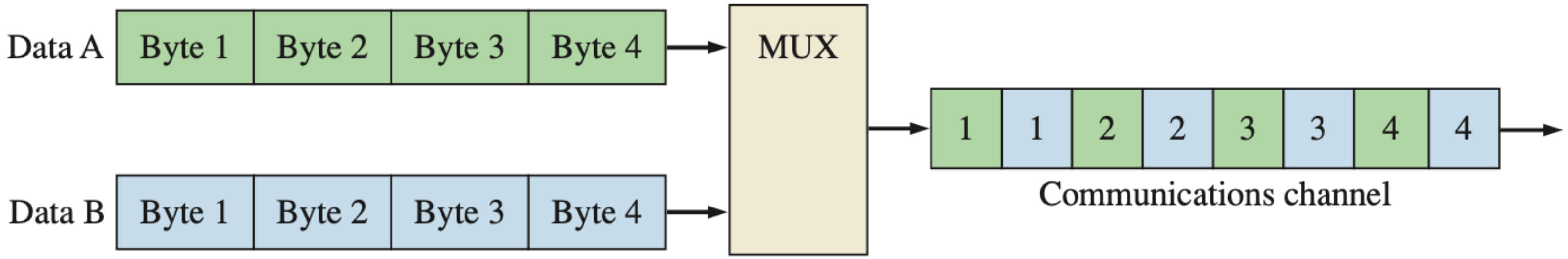


FIGURE 13–43 Basic idea of byte-interleaved TDM.

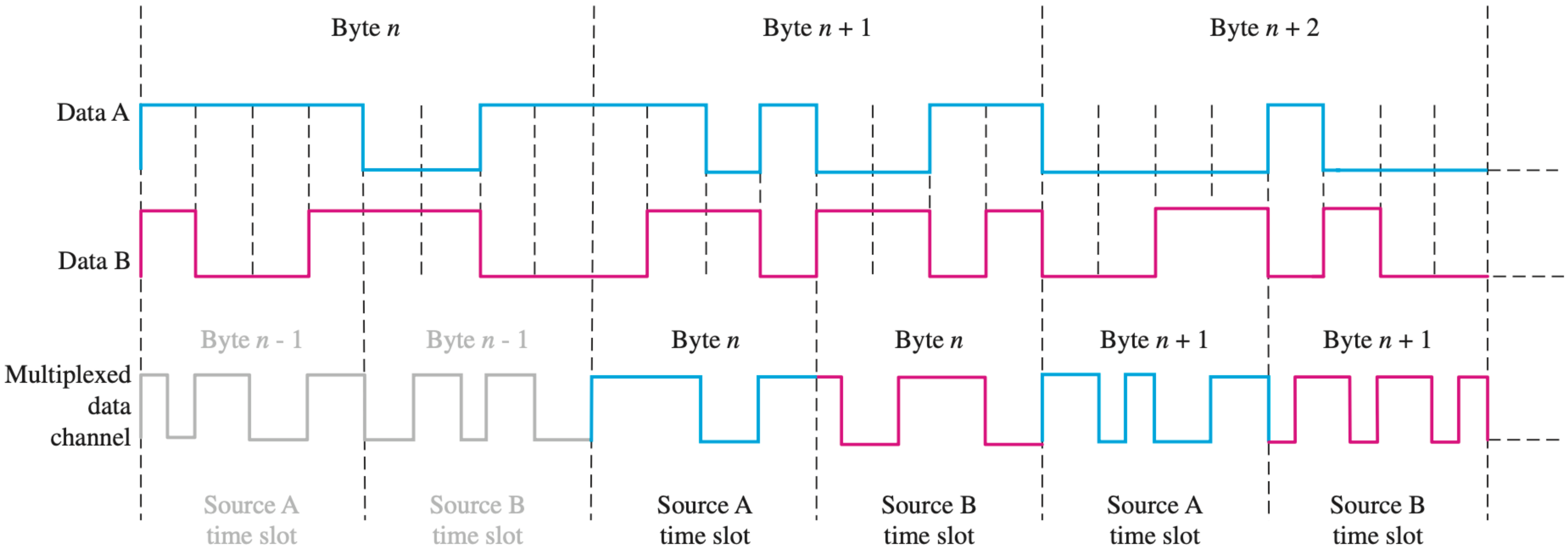


FIGURE 13–44 Byte-interleaved TDM with two data sources.

Synchronous TDM

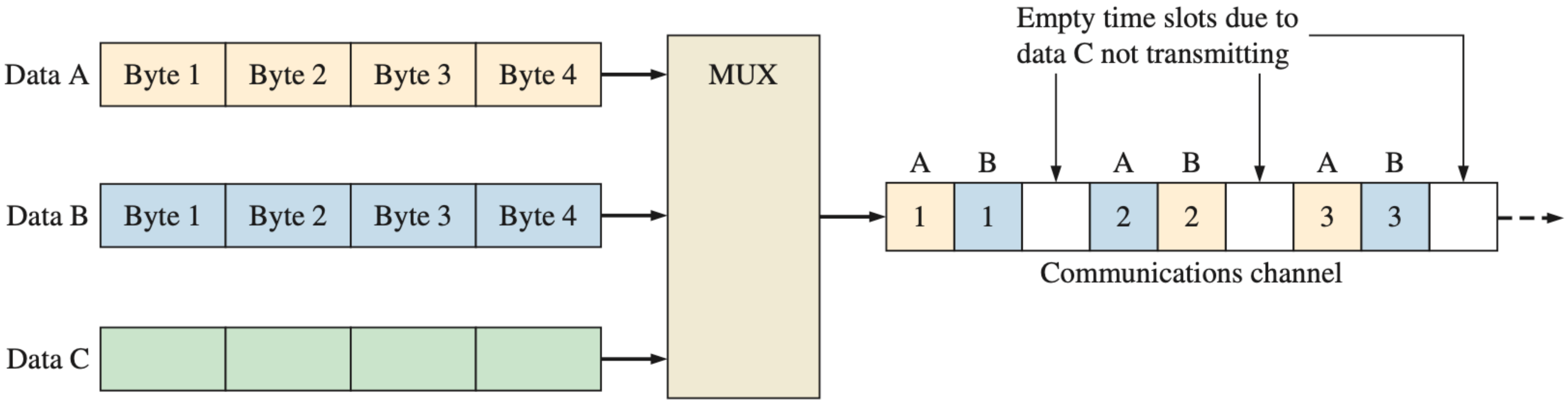


FIGURE 13–45 Example of a 3-source synchronous TDM with one data source inactive.

Statistical TDM

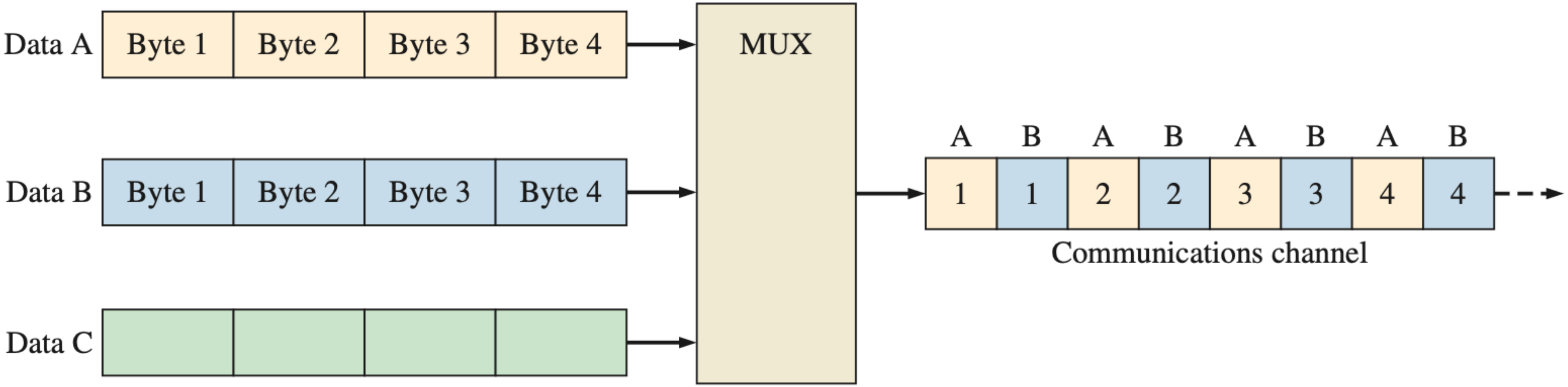


FIGURE 13–46 Example of a 3-source statistical TDM with one source inactive.

- A T1 line can carry 24 digitized telephone conversations and is capable of transmitting data at a rate of 1.544 Mbps. A voice signal is sampled 8,000 times per second, and each sample is converted to a byte of digital data. A voice signal requires a transmission rate of

$$\text{Voice transmission rate} = (8000\ \text{samples/s})(8\ \text{bits/sample}) = 64\ \text{kbps}$$

- The number of digitized voice signals that can be multiplexed on a T1 line is

$$\text{Voice signals} = \frac{1.544\ \text{Mbps}}{64\ \text{kbps}} = 24$$

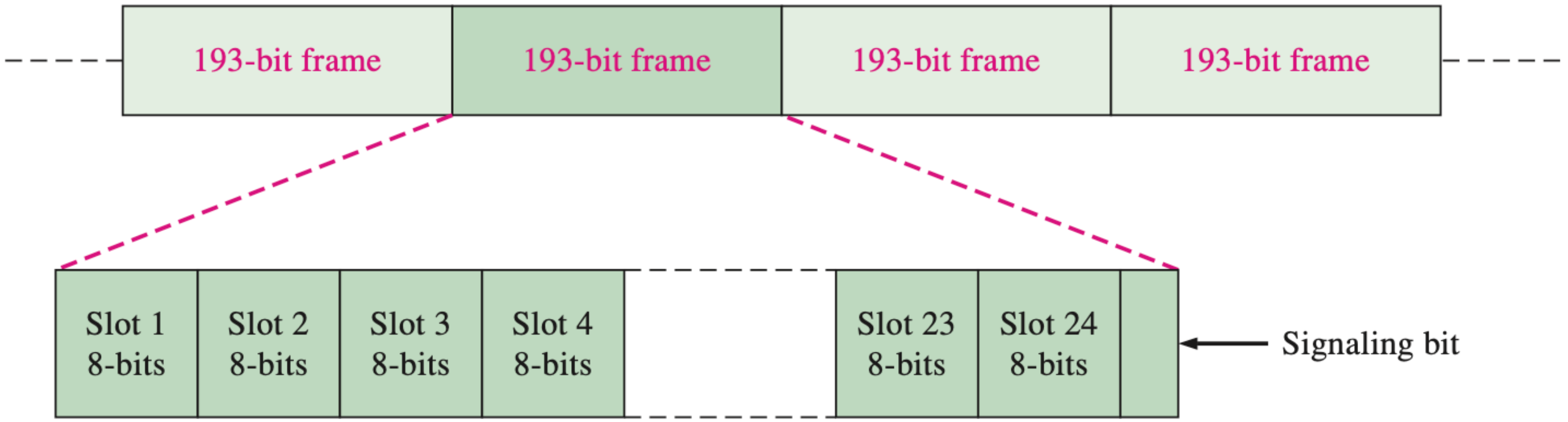


FIGURE 13–47 T1 channel transmission.

Frequency-Division Multiplexing

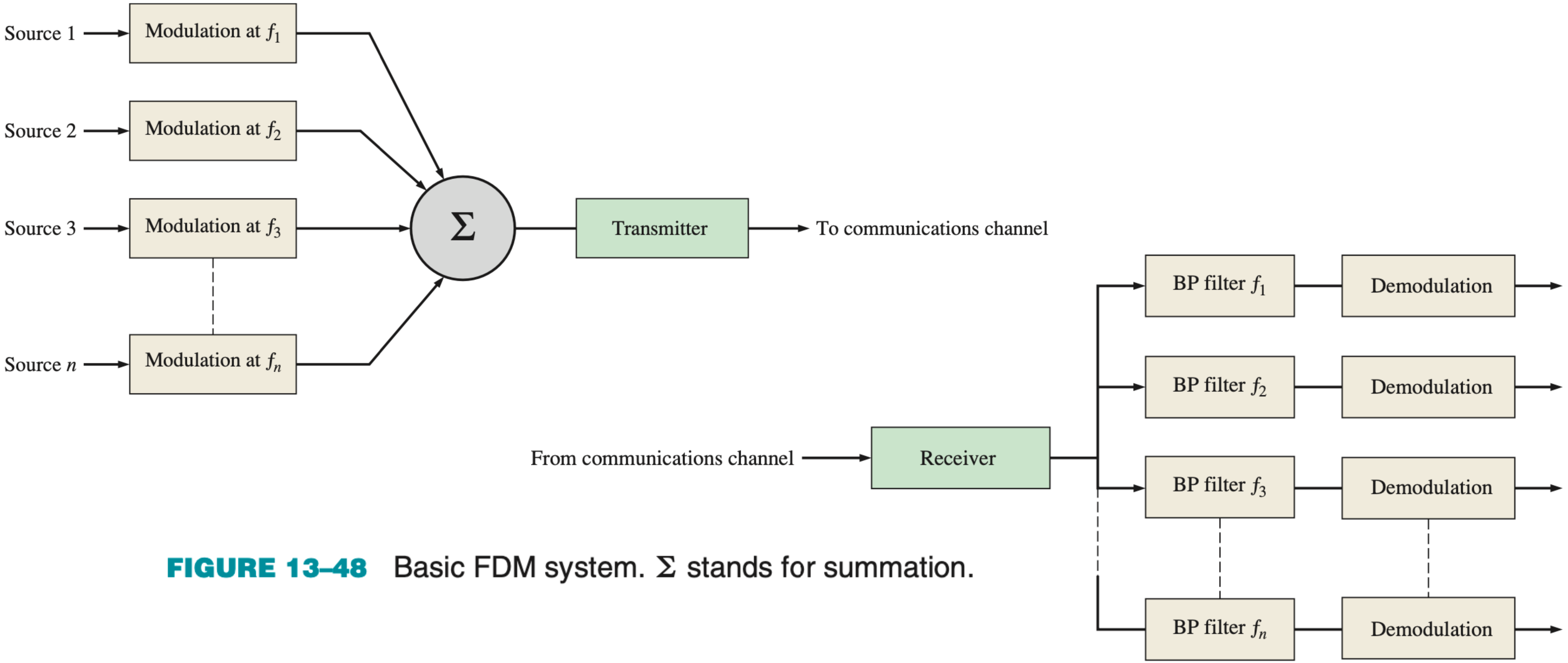


FIGURE 13–48 Basic FDM system. Σ stands for summation.

Frequency-division multiplexing (FDM) is a broadband technique in which the total band-width available to a system is divided into frequency sub-bands and information is sent in analog form

Frequency-Division Multiplexing

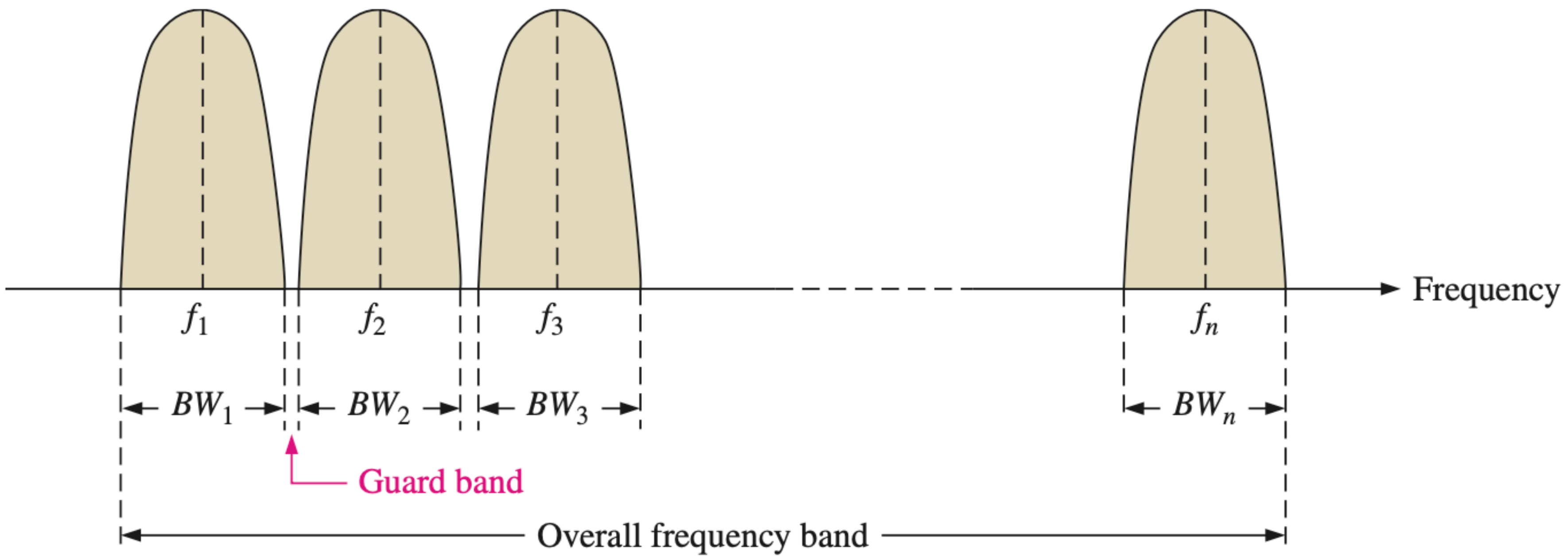


FIGURE 13–49 Frequency spectrum of an FDM transmission.

6. Bus Basics

The Bus

A bus allows two or more devices to communicate with each other, generally for the pur- pose of transmitting data. A bus is a set of physical wires and connectors and a set of elec- trical specifications. A bus can be either internal or external to a system.

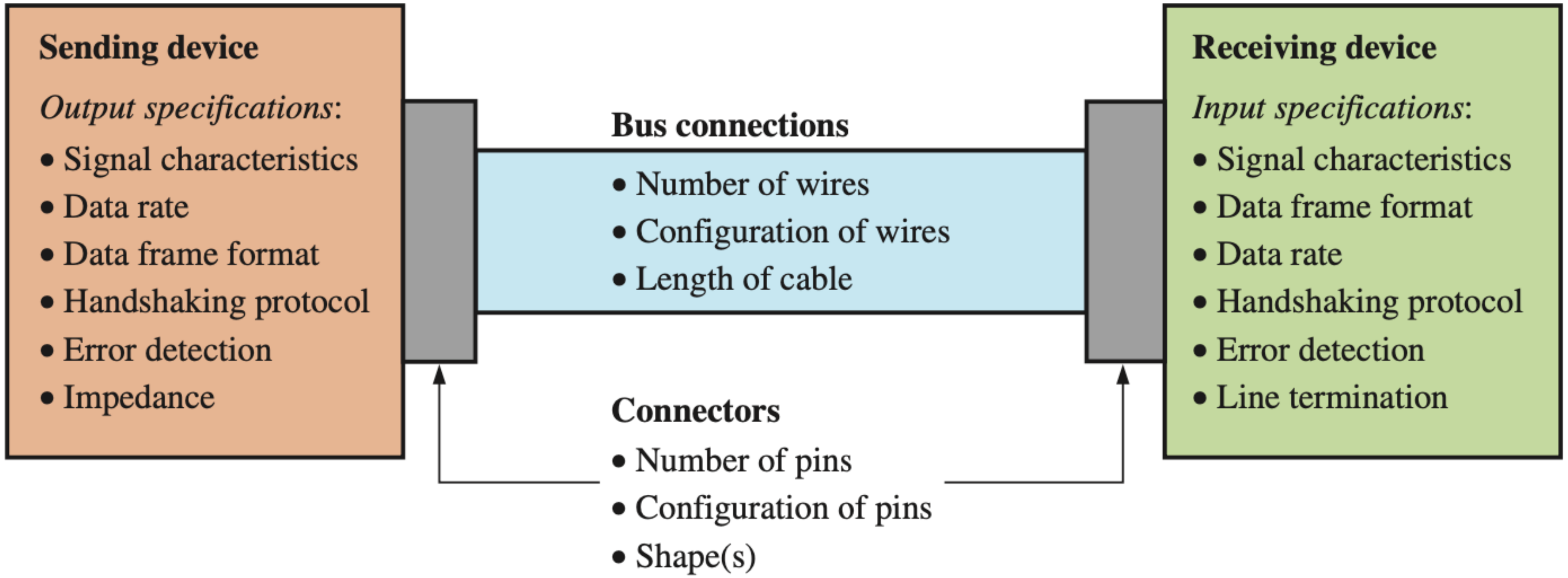


FIGURE 13–50 Physical and electrical definition of a typical bus.

Parallel and Serial Buses

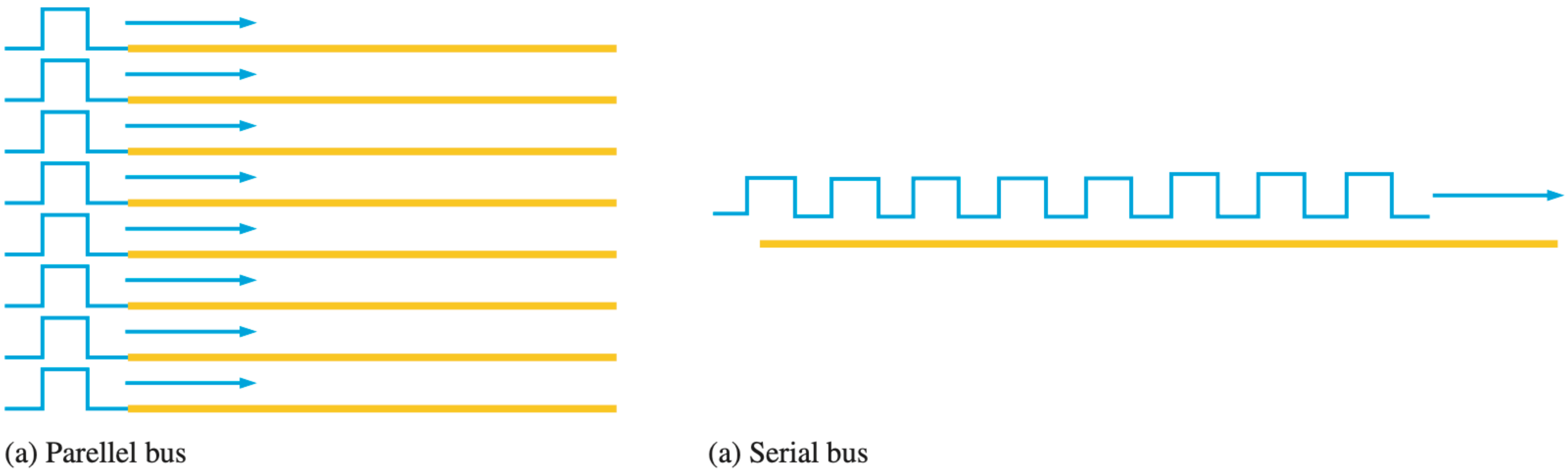


FIGURE 13–51 Comparison of parallel and serial buses.

Internal and External Buses

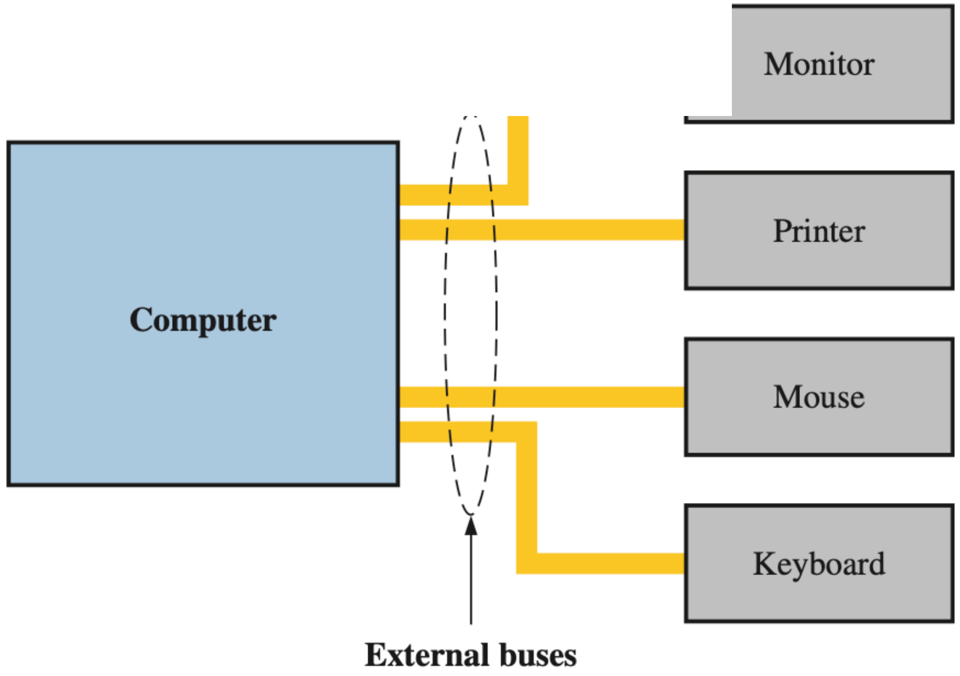


FIGURE 13–52 Example of external bus application.

General Bus Characteristics

A bus is typically described by the following parameters:

- **Width** The number of bits that a bus can transmit at one time. The width of typical buses can vary from 1 bit for a serial bus up to 64 bits for a parallel bus.
- **Frequency** The clock frequency at which a bus can operate
- **Transfer speed** The number of bytes per clock cycle
- **Bandwidth** The number of bytes per clock cycle times the number of clock cycles per second; that is, transfer speed times frequency. Bus bandwidth is sometimes called *throughput*.

$$\textbf{Bus bandwidth} = \frac{\textbf{Width (bits)} \times \textbf{Frequency (MHz)}}{\textbf{8 bits per byte}}$$

$$\textbf{Bus bandwidth} = \frac{((\textbf{Width (bits)} \times \textbf{Frequency (MHz)})/\textbf{8 bits per byte})10^6}{2^{20}}$$

EXAMPLE 13–8

A certain bus is specified with a width of 32 bits and a frequency of 66 MHz. Determine the bus bandwidth expressed as two different values, according to the decimal and binary definitions of M. Note that Bps is bytes per second.

Solution

Using the decimal definition of M (10^6) in the unit of MBps,

$$\text{Bandwidth} = \frac{32\text{ bits} \times 66\text{ MHz}}{8\text{ bits per byte}} = \textbf{264 MBps}$$

Using the binary definition of M (2^{20}),

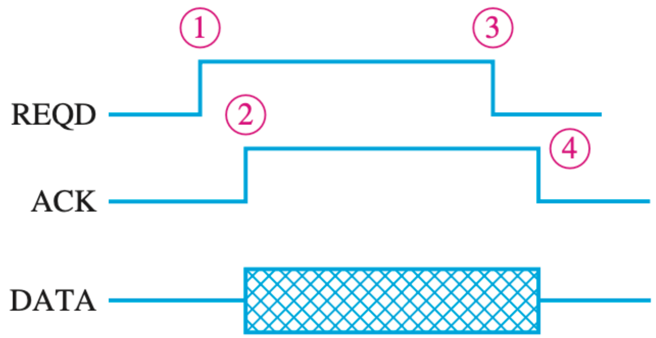
$$\text{Bandwidth} = \frac{((32\text{ bits} \times 66\text{ MHz})/8\text{ bits per byte})\ 10^6}{2^{20}} = \textbf{252 MBps}$$

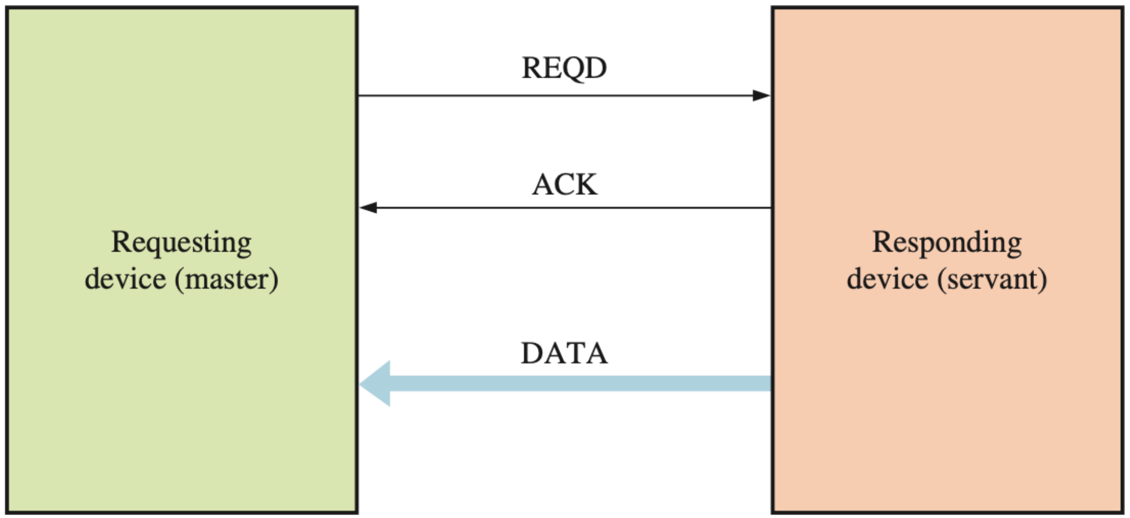
Bus Protocol

Bus protocol is a set of rules that allow two or more devices to communicate through a bus.

Buses provide for data transfer, address selection, and control.

Handshaking





1. Master sends request for data (REQD) to servant.
2. Servant sends an acknowledgement (ACK) and places data on bus.
3. Master receives data and removes request.
4. Servant removes acknowledge and is ready for next request.

FIGURE 13–53 Simple example of handshake and data transfer.

Synchronous and Asynchronous Buses

- A synchronized bus includes a clock in the control lines and has a fixed protocol that is relative to the clock. A synchronous bus is fast but has the disadvantage that every device connected to it must operate at the same clock frequency. Also, the physical length of the bus may be limited because of having to carry a high-frequency clock signal.
- An asynchronous bus is not clocked, so it can serve various devices with different clock rates. The asynchronous bus uses a handshake protocol to establish communication.

Single-Ended vs. Differential Buses

- Single-ended operation uses one wire for data and one wire for ground, where the signal voltage on the wire is with respect to ground.
- Differential operation uses two wires for data and one wire for ground. The data signal is sent on one wire in the twisted pair and its complement (inversion) is sent on the other wire.

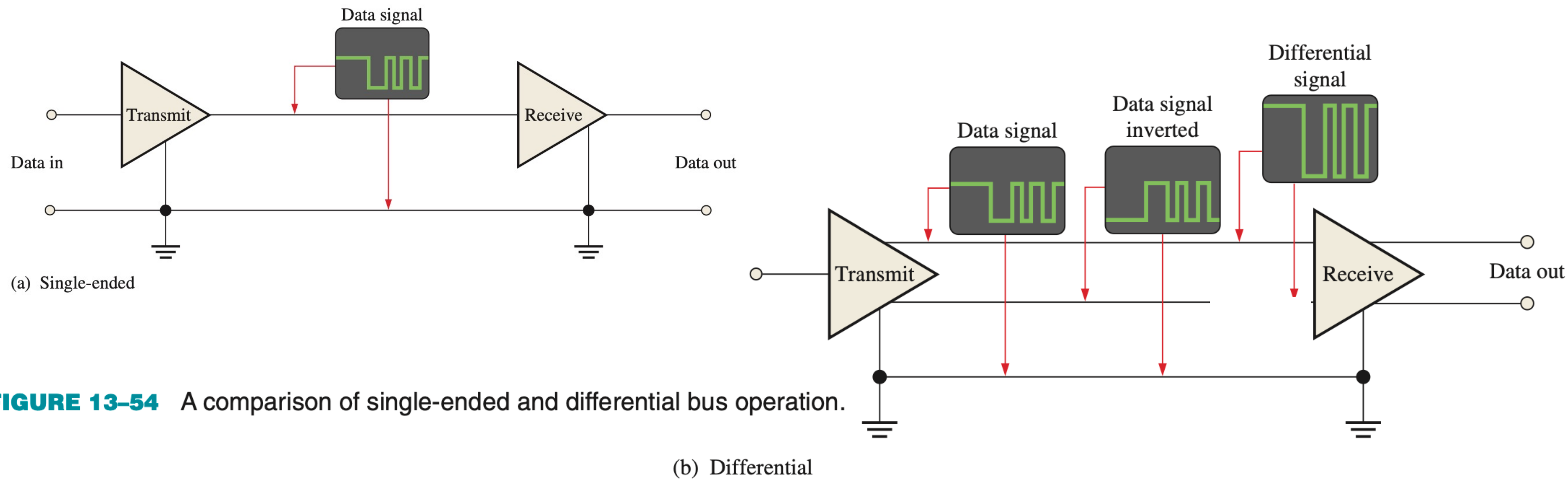


FIGURE 13–54 A comparison of single-ended and differential bus operation.

7. Parallel Buses

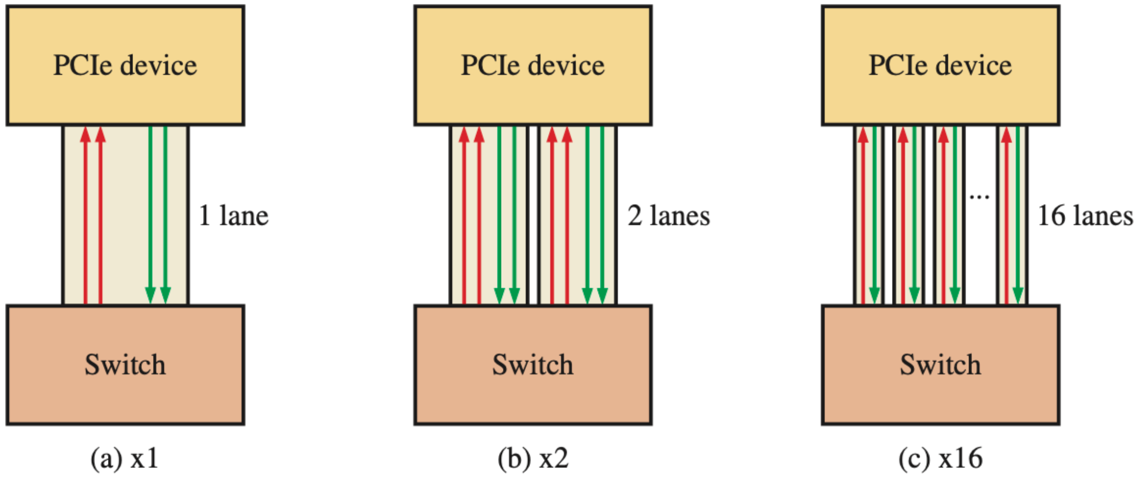


FIGURE 13–57 PCI-Express lane configurations.

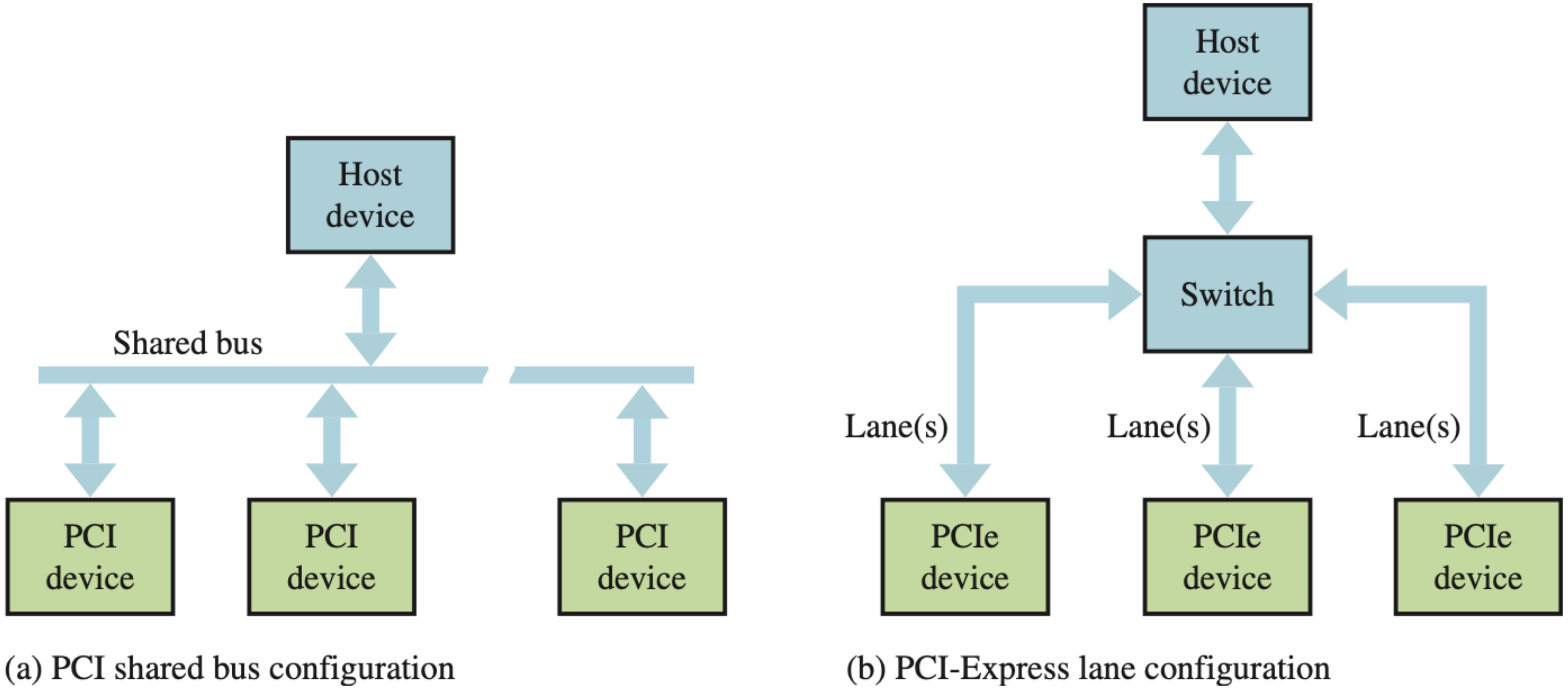


FIGURE 13–56 Comparison of PCI and PCI-Express.

8. The Universal Serial Bus (USB)

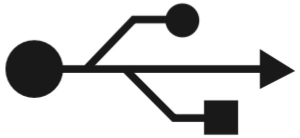


FIGURE 13–62 USB symbol.

TABLE 13–6

	Low-Speed	Full-Speed	High-Speed	Super-Speed
USB 1.0	•	•		
USB 1.1	•	•		
USB 2.0	•	•	•	
USB 3.0	•	•	•	•

TABLE 13–7

Data Rate	Maximum Value
Low-speed	0.1875 MBps
Full-speed	1.5 MBps
High-speed	60 MBps
Super-speed	625 MBps

TABLE 13–8

	USB 1.1	USB 2.0	USB 3.0
Max cable length	9.8 ft. (3.0 m)	16.4 ft. (5.0 m)	9.8 ft. (3.0 m)
Maximum total length	49.2 ft. (15 m)	82.0 ft. (25 m)	49.2 ft. (15 m)

8. The Universal Serial Bus (USB)

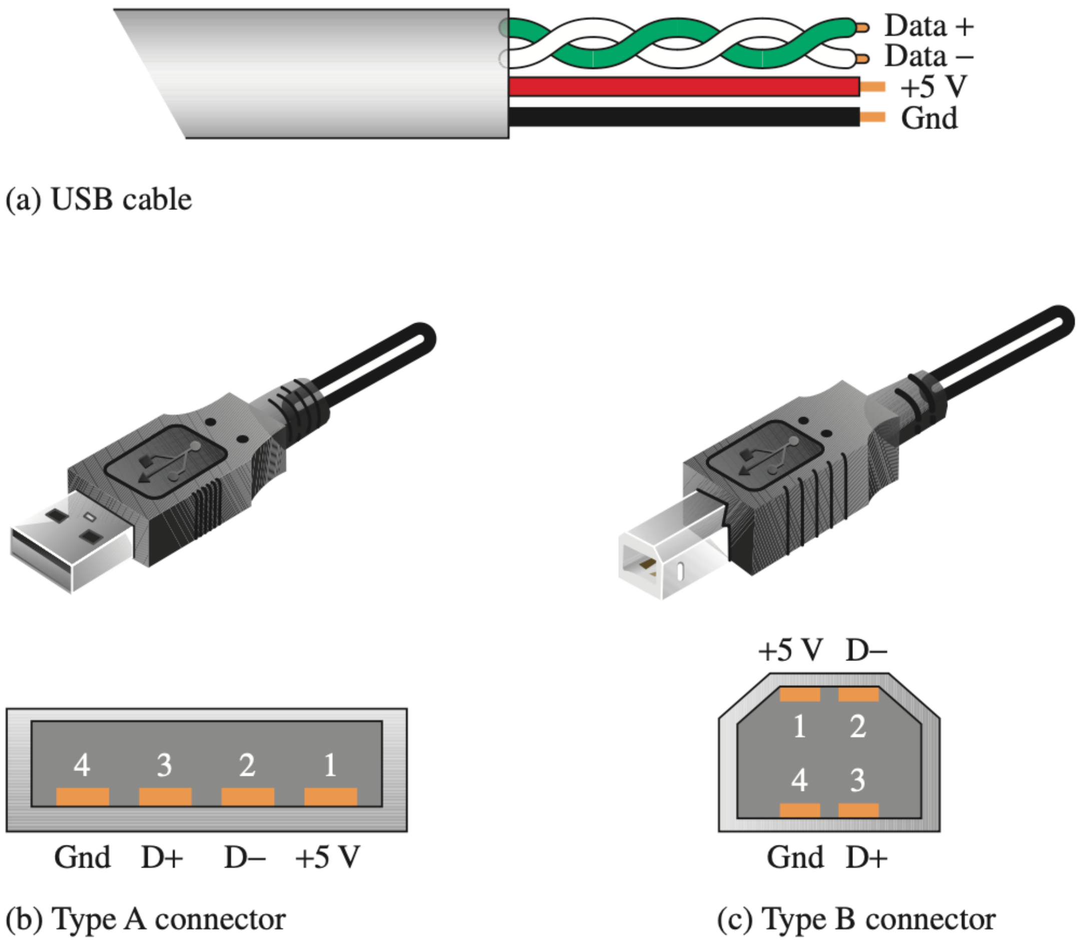


FIGURE 13–63 USB cable and connectors for USB standards through 2.0.

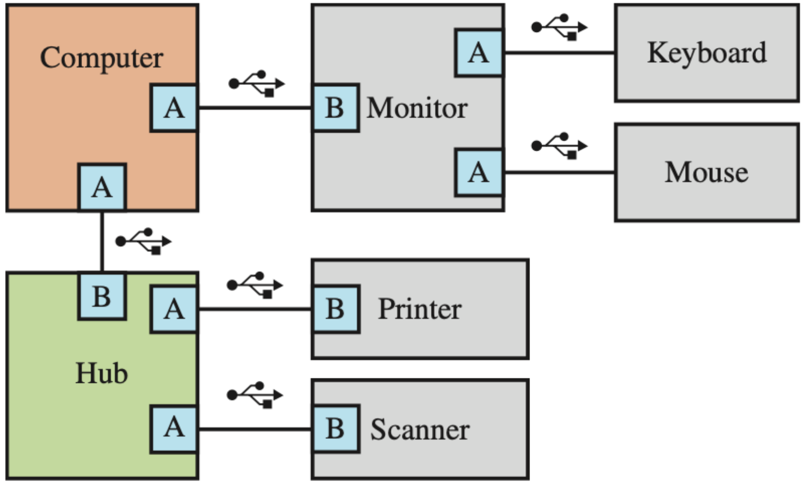


FIGURE 13–66 Example of USB applications.

9. Bus Interfacing

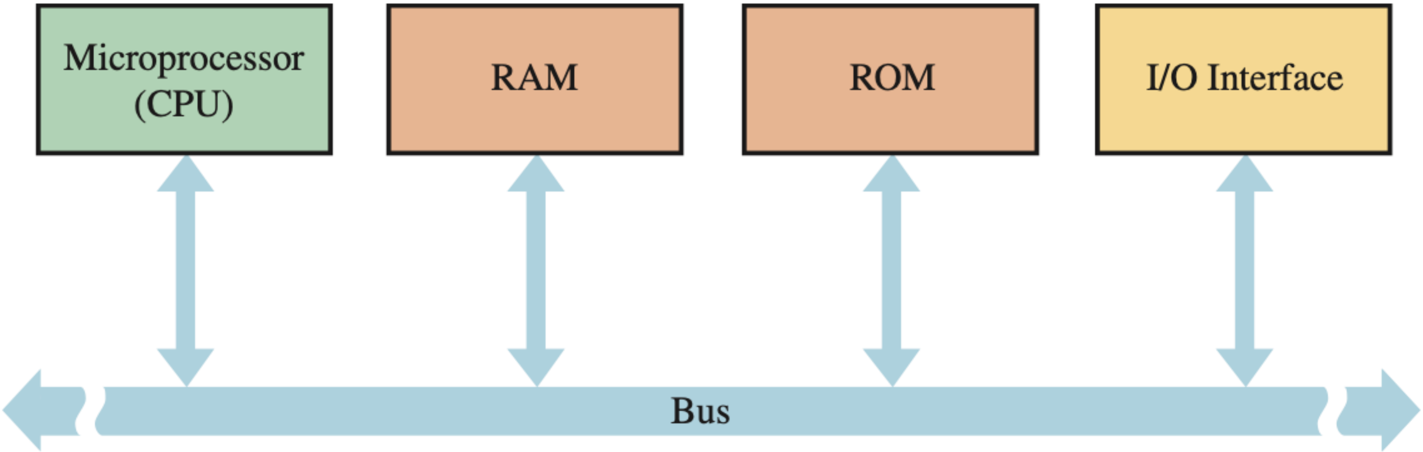


FIGURE 13–74 The interconnection of microprocessor-based system components by a bidirectional, multiplexed bus.

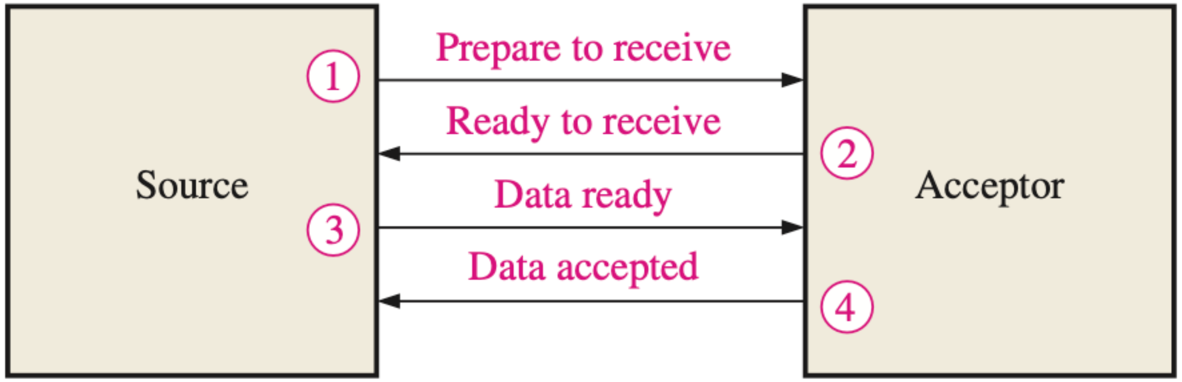
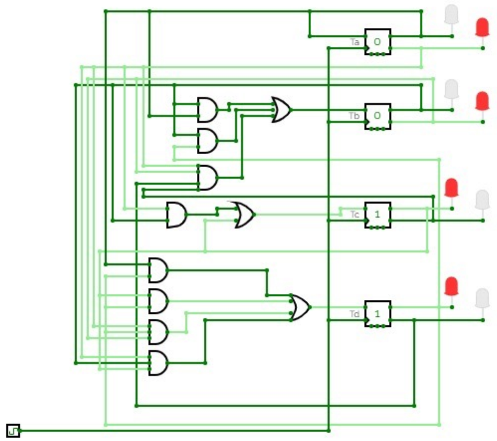


FIGURE 13–75 An example of a handshaking sequence.

THE END

Lecture 13: Data Transmission



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