Lecture – 1

Introductory Concepts of Digital Logic

Lesson Outcomes

After completing this lecture, students will be able to

- *Explain the basic differences between digital and analog quantities*
- *Show how voltage levels are used to represent digital quantities*
- *Describe various parameters of a pulse waveform such as rise time, fall time, pulse width, frequency, period, and duty cycle*
- *Explain the basic logic functions of NOT, AND, and OR*
- *Describe several types of logic operations and explain their application in an example system*

Key Terms

- Analog
- Digital
- Binary
- Bit
- Pulse
- Duty cycle
- Clock
- Timing diagram

- NOT
- Inverter
- AND
- OR
- Programmable logic
- SPLD
- CPLD
- FPGA

- Data
- Serial
- Parallel
- Logic
- Input
- Output
- Gate

- Microcontroller
- Embedded system
- Compiler
- Integrated circuit (IC)
- Fixed-function logic
- Troubleshooting

Analog vs digital

- An **analog** quantity is one having continuous values.
- A **digital** quantity is one having a discrete set of values.

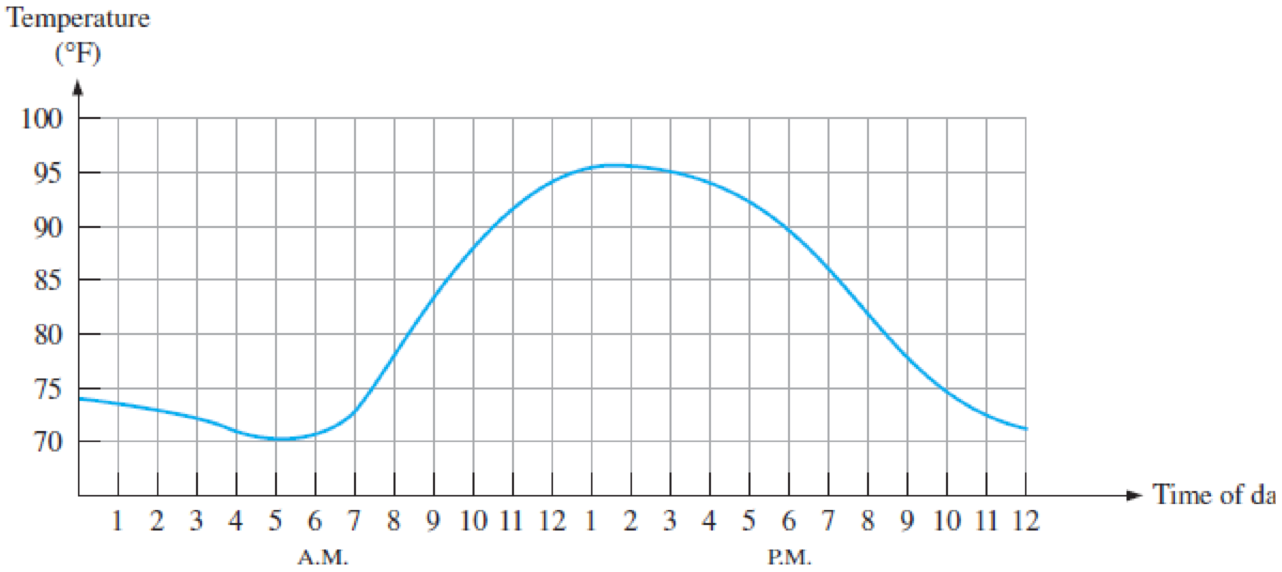
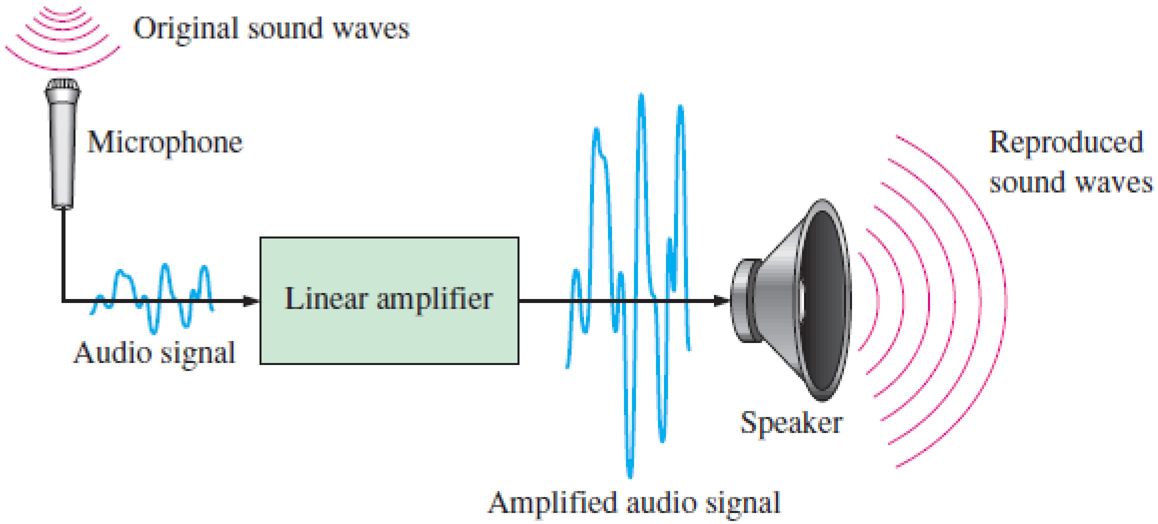
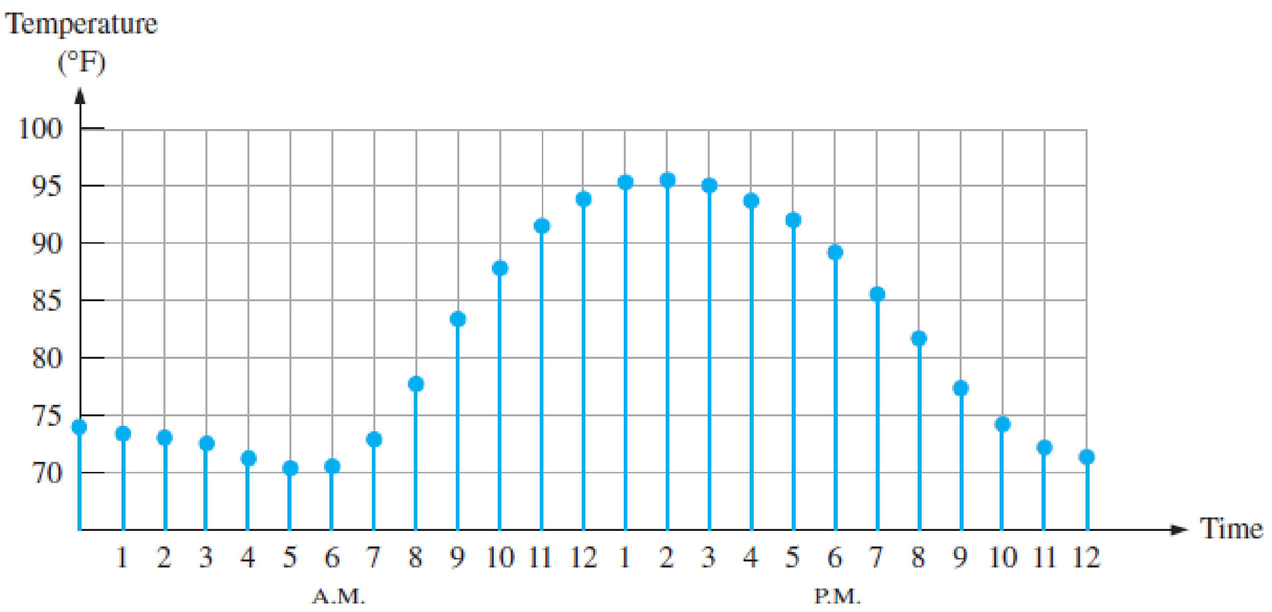


FIGURE 1–1 Graph of an analog quantity (temperature versus time).



Advantage of digital over analog:

- ❑ Digital data can be processed and transmitted more efficiently and reliably than analog data.
- ❑ Digital data has a great advantage when storage is necessary.
- ❑ Noise does not affect digital data nearly as much as it does analog signals.



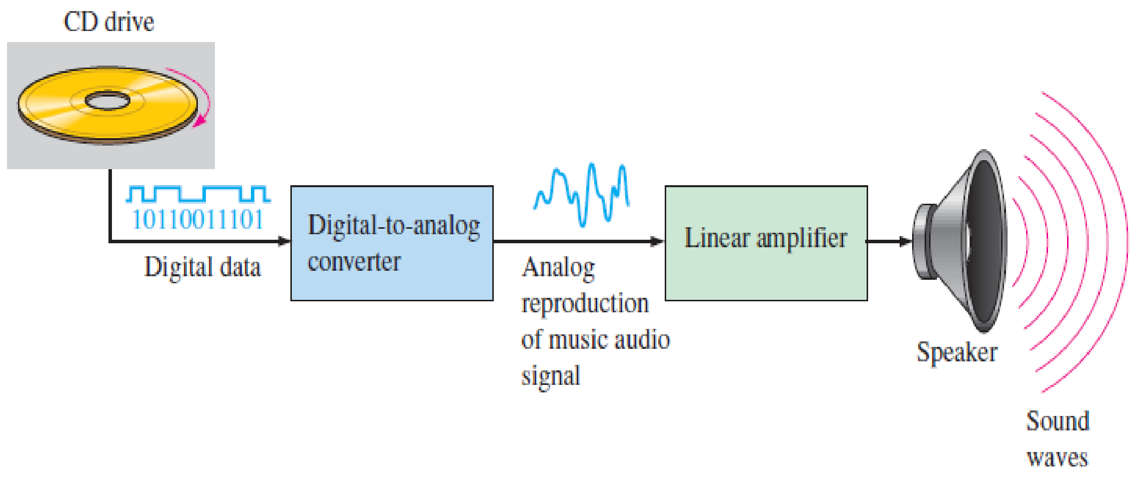


FIGURE 1–4 Basic block diagram of a CD player. Only one channel is shown.

Binary digits, logic levels and digital waveform

- Each of the two digits in the **binary** system, 1 and 0, is called a *binary digit* or **bit**.
- In positive logic, 1 represents **HIGH** voltage and 0 represents **LOW** voltage.

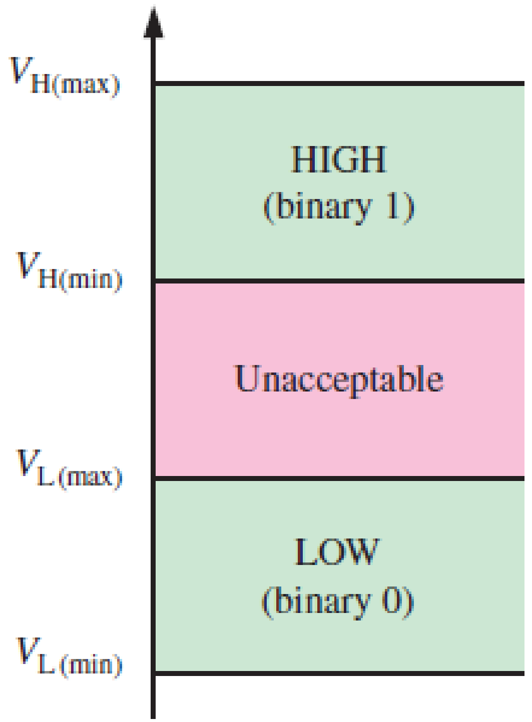


FIGURE 1–6 Logic level ranges of voltage for a digital circuit.

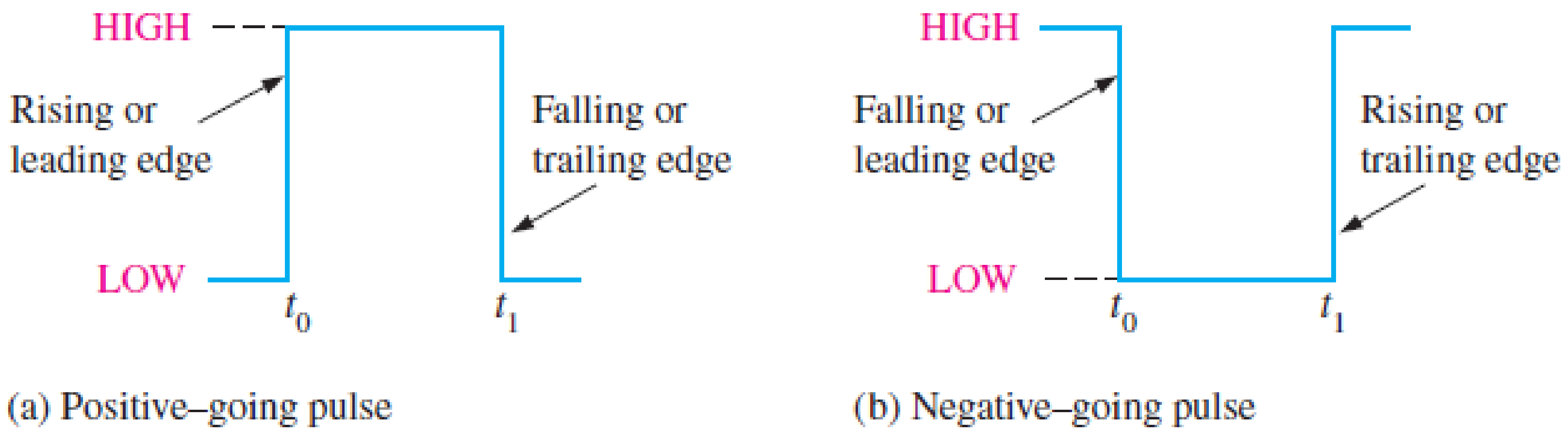
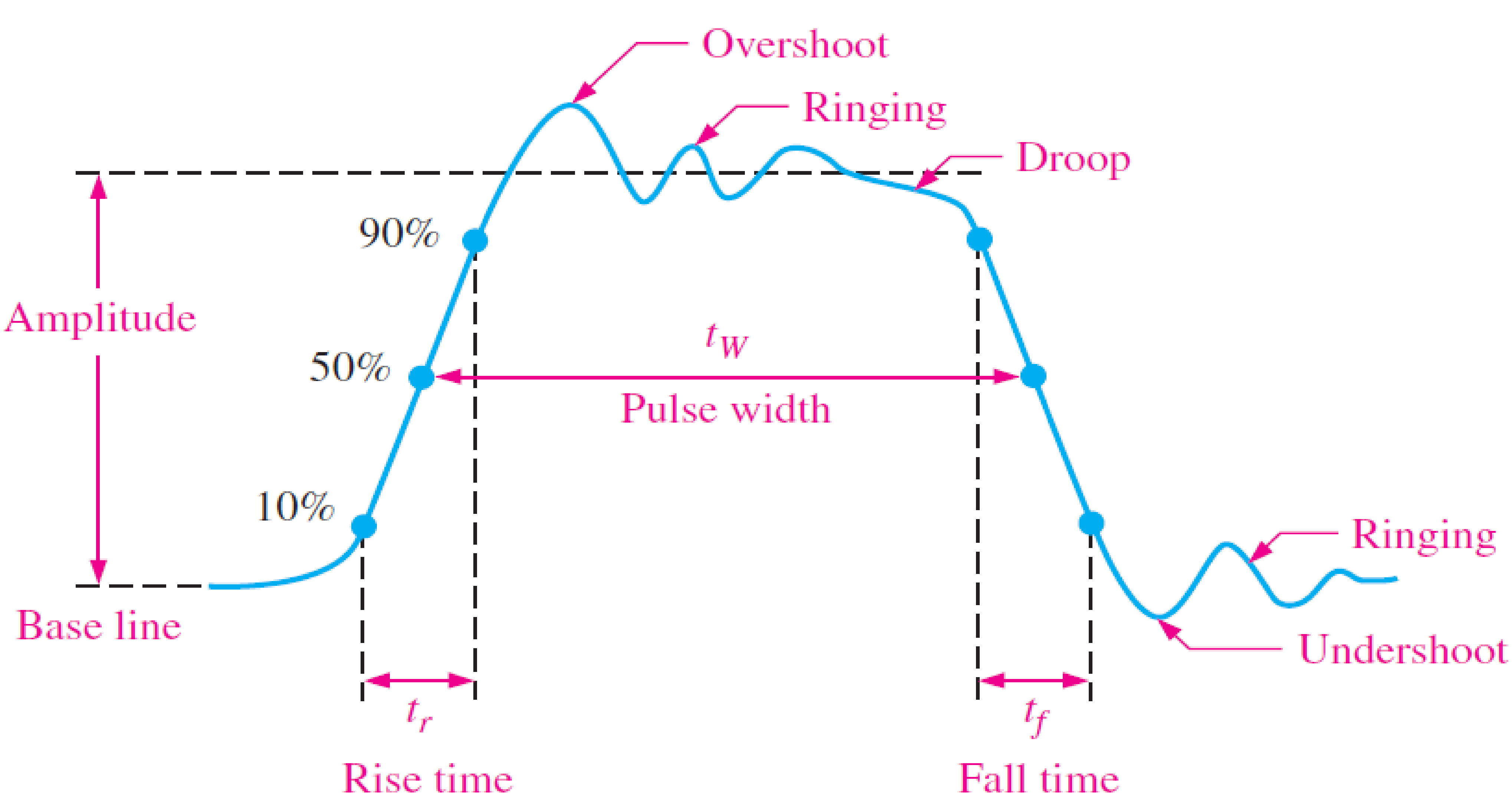
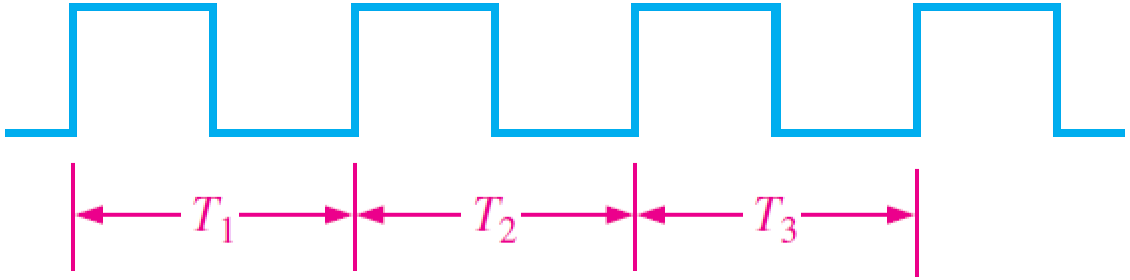


FIGURE 1–7 Ideal pulses.

Non ideal pulse

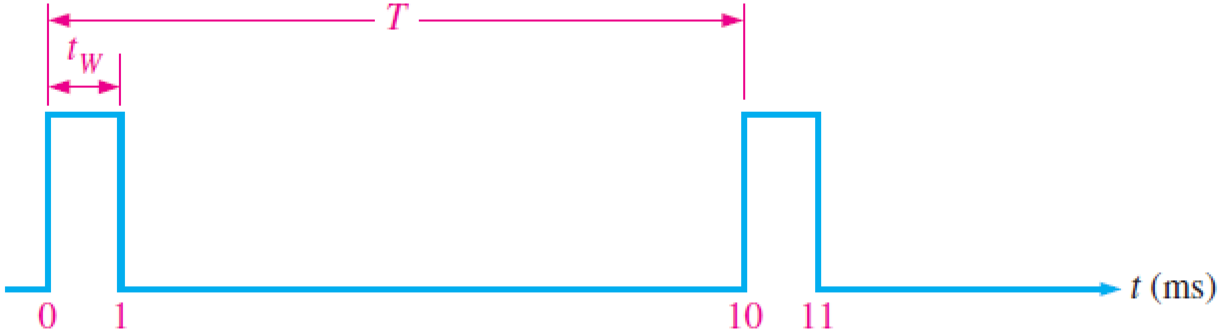


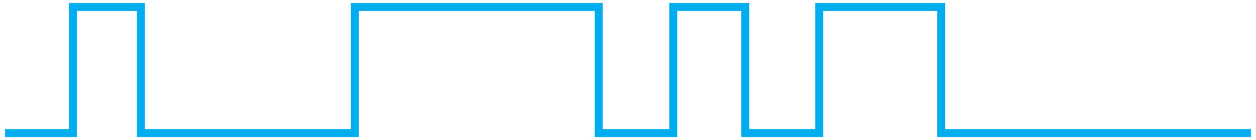


$$\text{Period} = T_1 = T_2 = T_3 = \ldots = T_n$$

$$\text{Frequency} = \frac{1}{T}$$

(a) Periodic (square wave)





(b) Nonperiodic

$$\boxed{\textbf{Duty cycle} = \left(\frac{t_W}{T}\right)100\%}$$

Clock

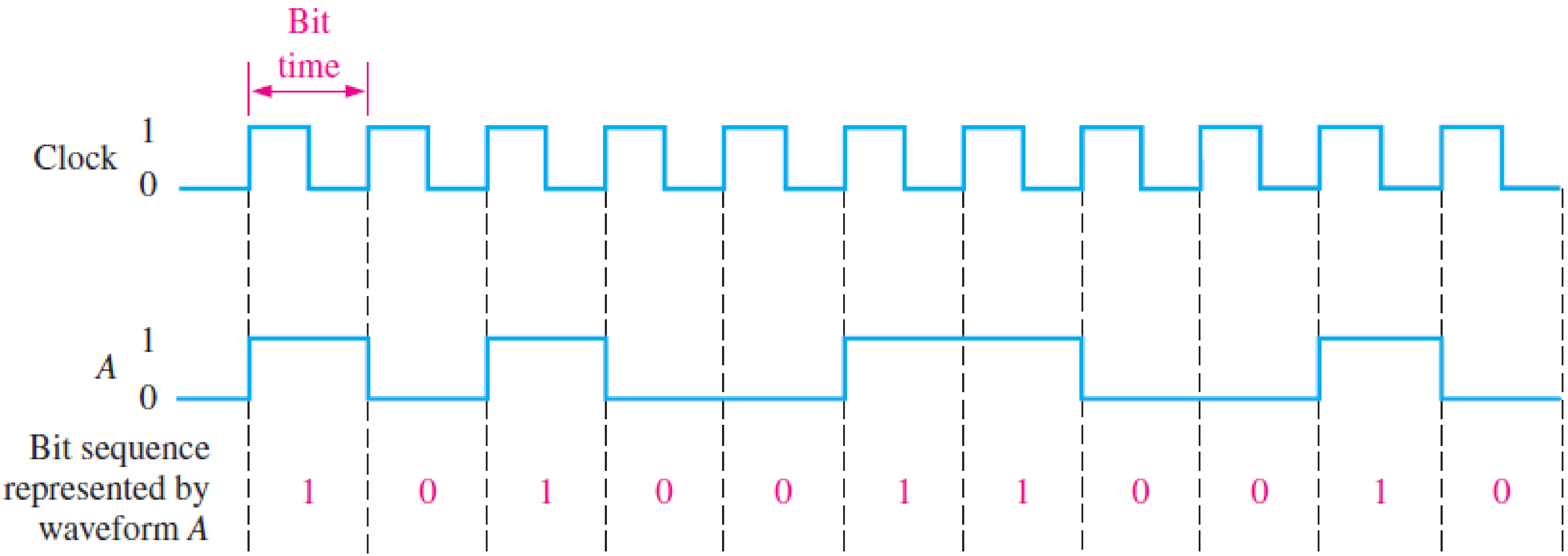


FIGURE 1–11 Example of a clock waveform synchronized with a waveform representation of a sequence of bits.

Timing diagram

- A *timing diagram* is basically a graph that accurately displays the relationship of two or more waveforms with respect to each other on a time basis.

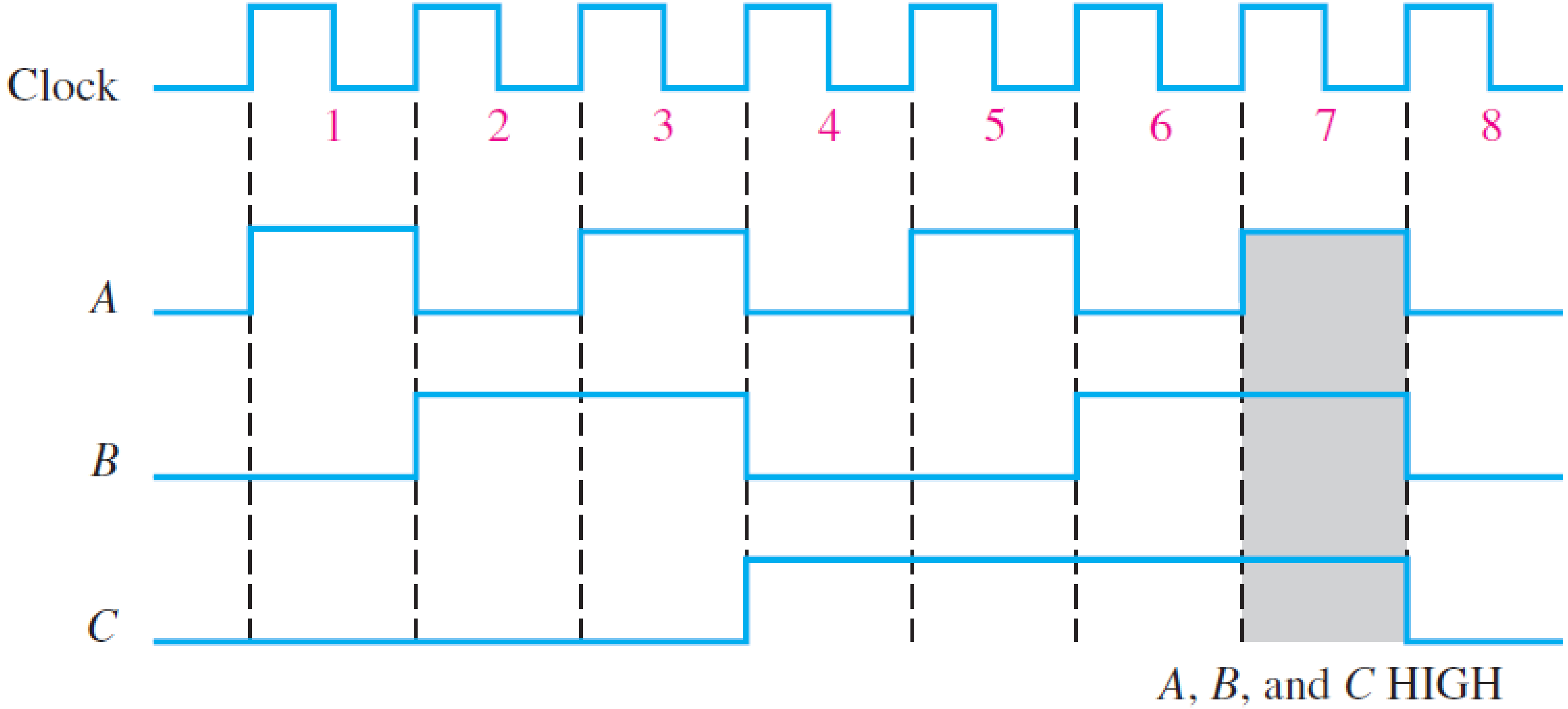
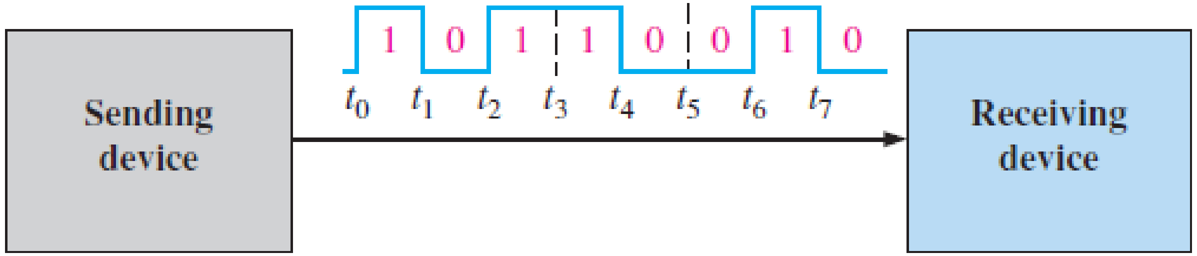


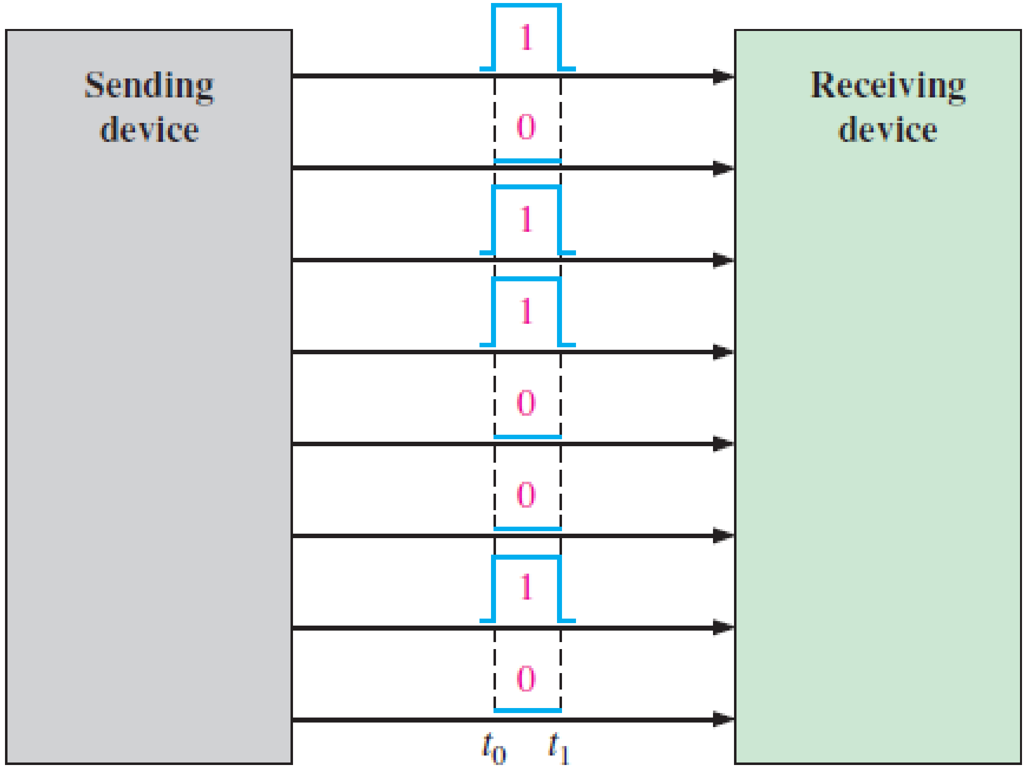
FIGURE 1–12 Example of a timing diagram.

Data transfer

- Binary data are transferred in two ways: serial and parallel.
  - ✓ When bits are transferred in **serial** form from one point to another, they are sent one bit at a time along a single line.
  - ✓ When bits are transferred in **parallel** form, all the bits in a group are sent out on separate lines at the same time.



(a) Serial transfer of 8 bits of binary data. Interval t_0 to t_1 is first.



(b) Parallel transfer of 8 bits of binary data. The beginning time is t_0.

Example 1-1

a) Determine the total time required to serially transfer the eight bits contained in waveform A, and indicate the sequence of bits. The left-most bit is the first to be transferred. The 1 MHz clock is used as reference.

b) What is the total time to transfer the same eight bits in parallel?

SOLUTION:

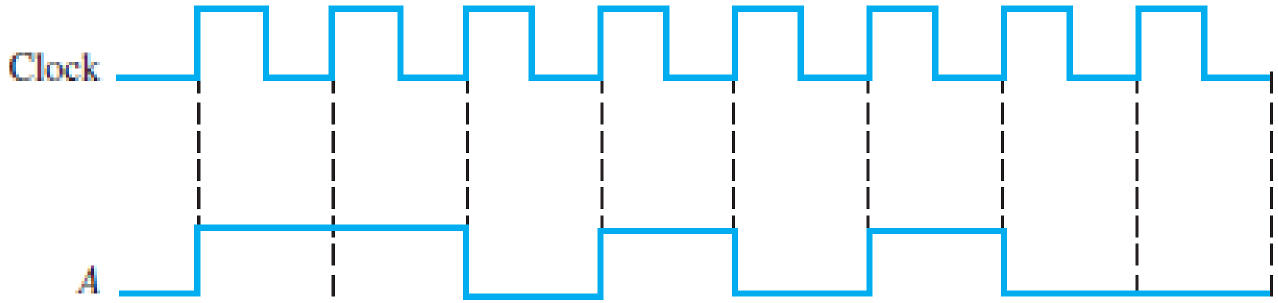
(a) Since the frequency of the clock is 1 MHz,

the period is $T = \frac{1}{f} = \frac{1}{1\ \text{MHz}} = 1\ \mu\text{s}$

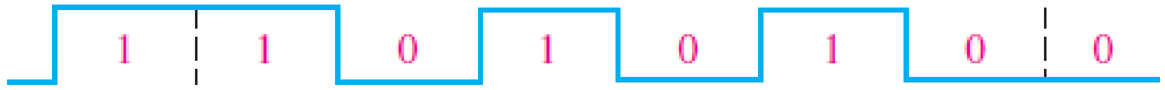
It takes 1 μs to transfer each bit in the waveform.

The total transfer time for 8 bits is

$$8 \times 1\ \mu\text{s} = \mathbf{8\ \mu s}$$



Sequence of bits:



(b) A parallel transfer would take 1 μs for all eight bits.

Basic logic functions

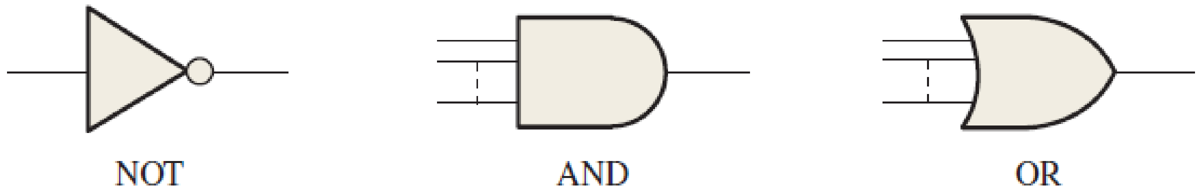


FIGURE 1–16 The basic logic functions and symbols.

FIGURE 1–17 The NOT function.

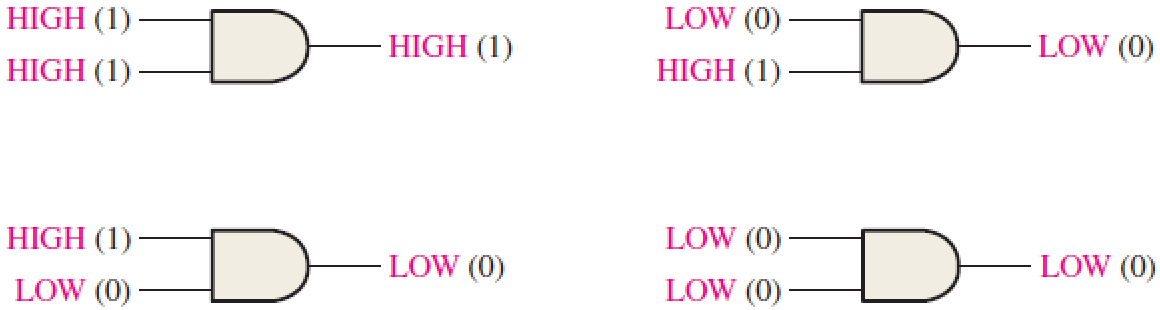


FIGURE 1–18 The AND function.

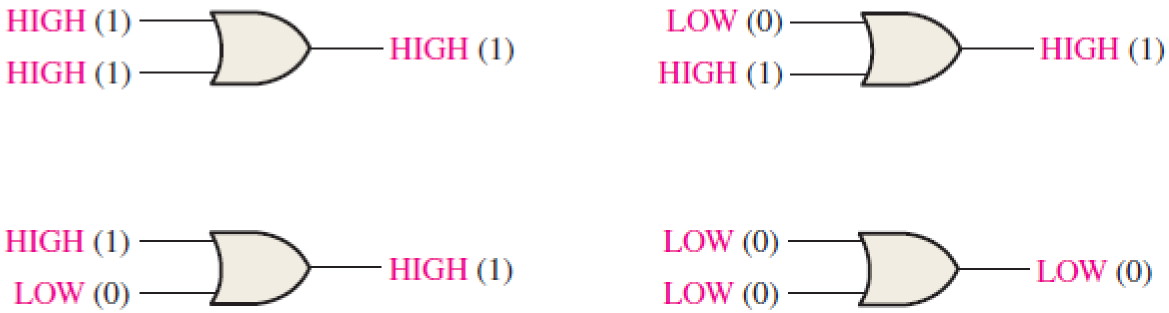


FIGURE 1–19 The OR function.

Combinational and sequential logic functions

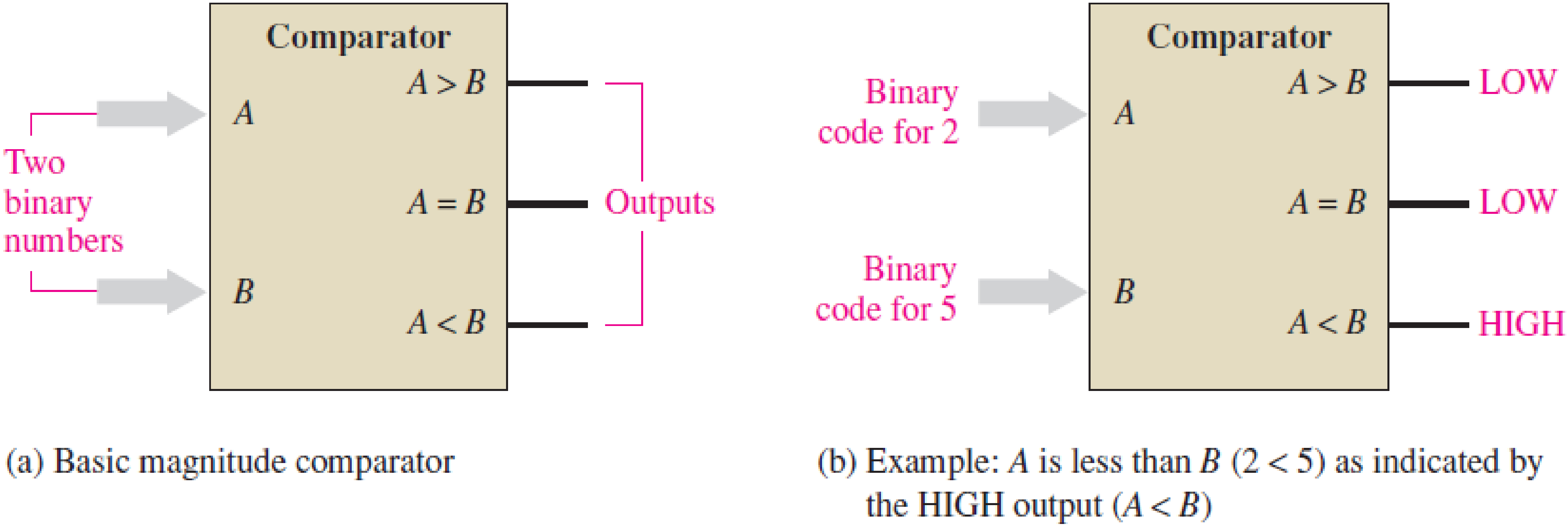
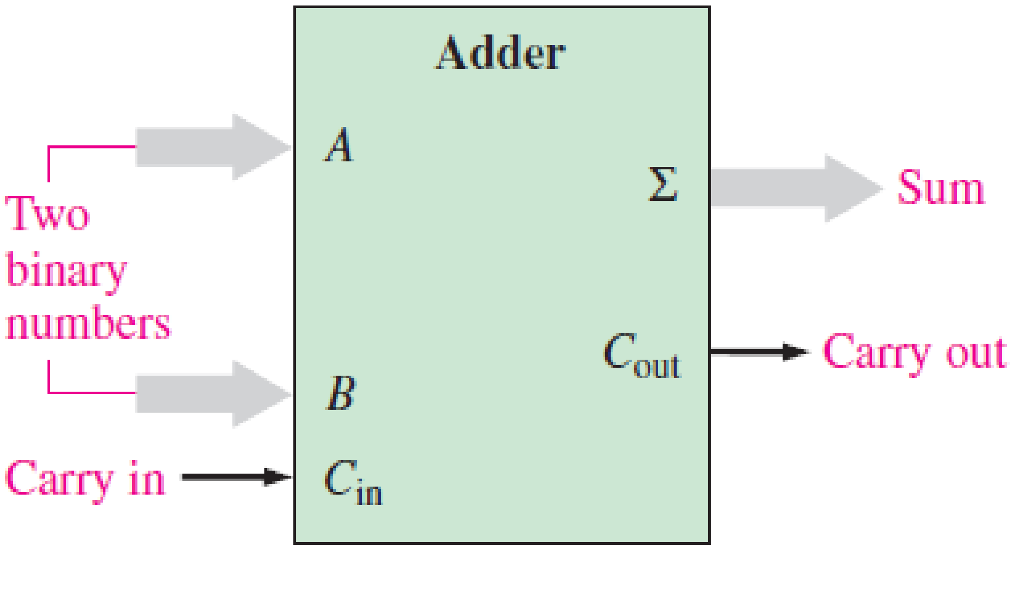
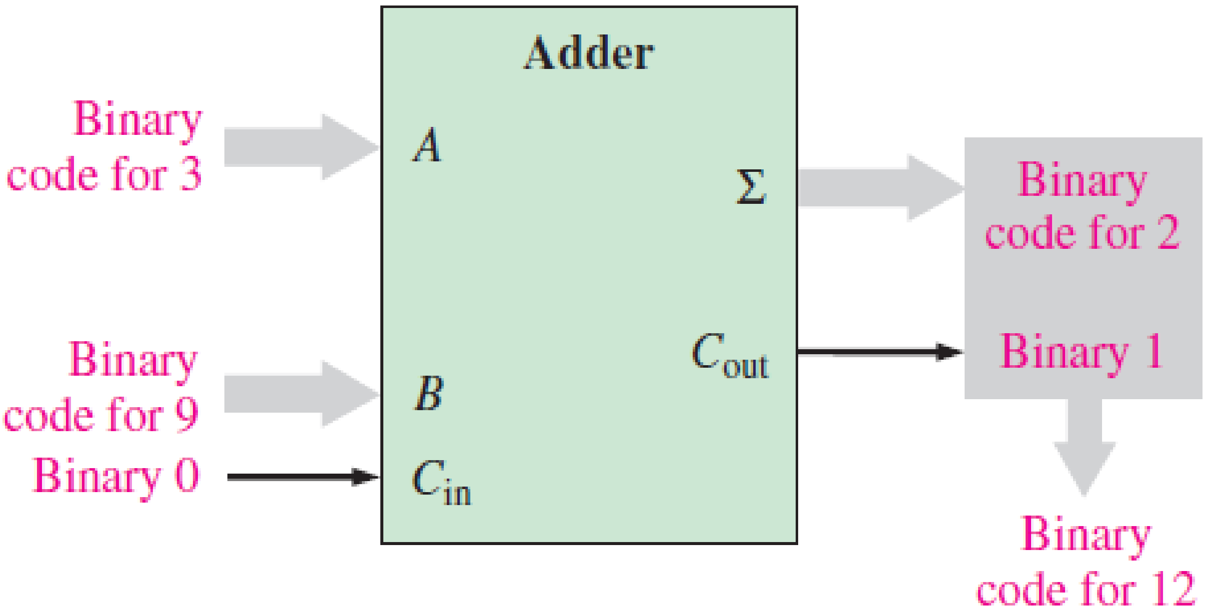


FIGURE 1–20 The comparison function.

Combinational and sequential logic functions

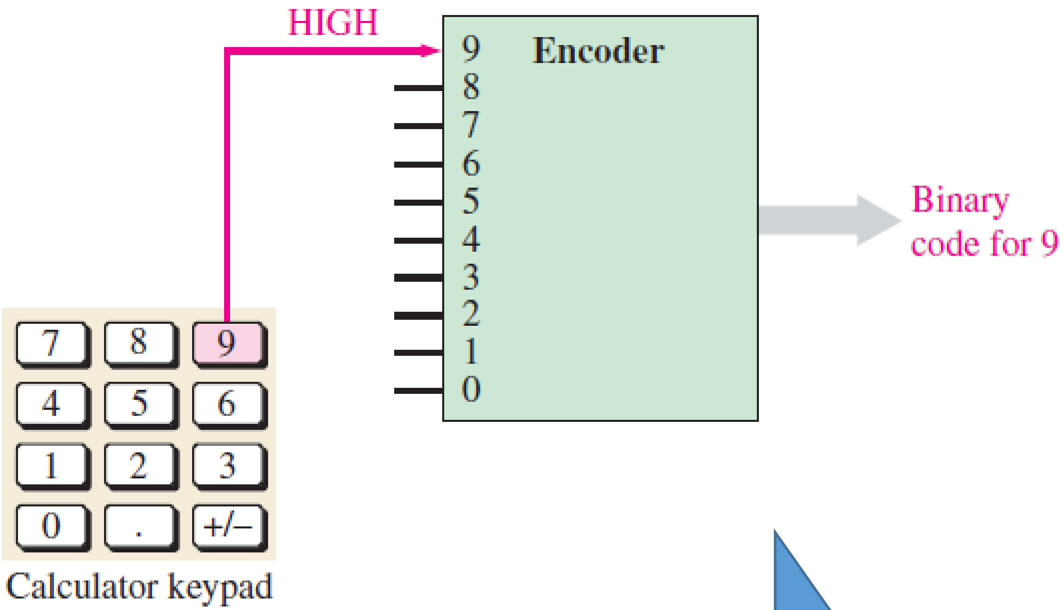


(a) Basic adder



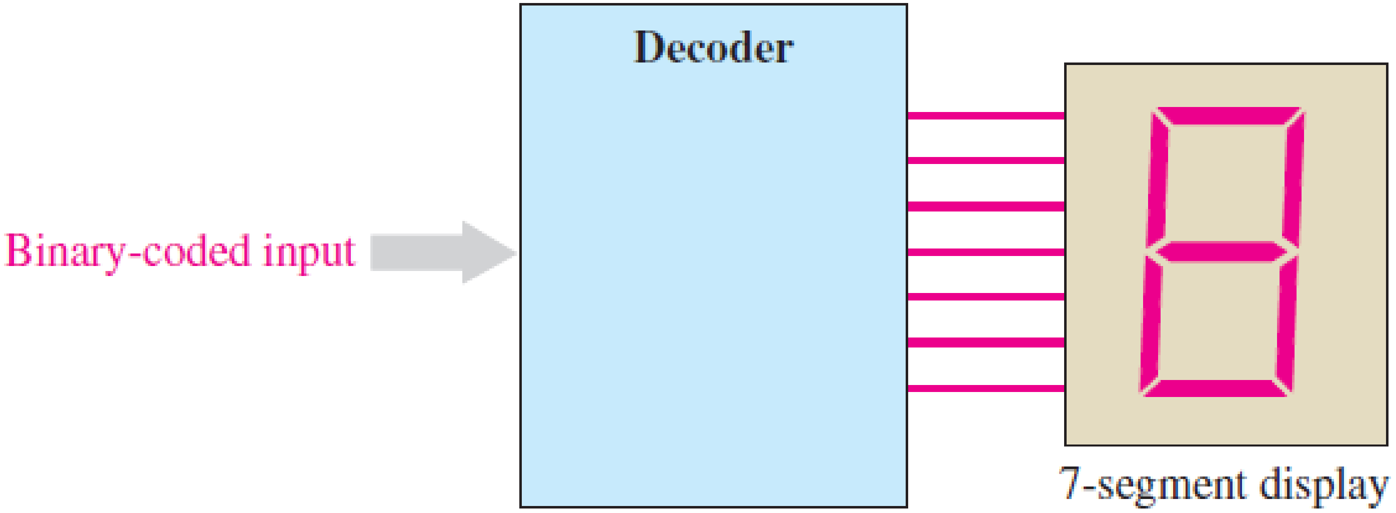
(b) Example: A plus B (3 + 9 = 12)

Combinational and sequential logic functions



An **encoder** used to encode a calculator keystroke into a binary code for storage or for calculation.

A **decoder** used to convert a special binary code into a 7-segment decimal readout.



Data selection functions (multiplexing-demultiplexing)

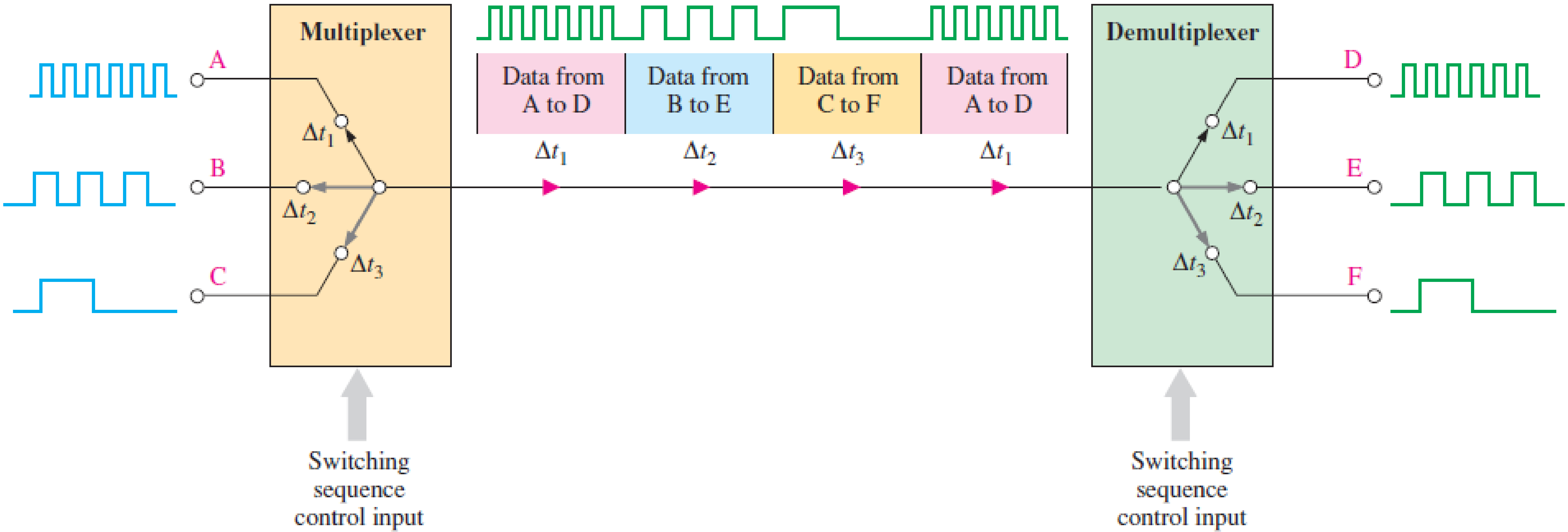
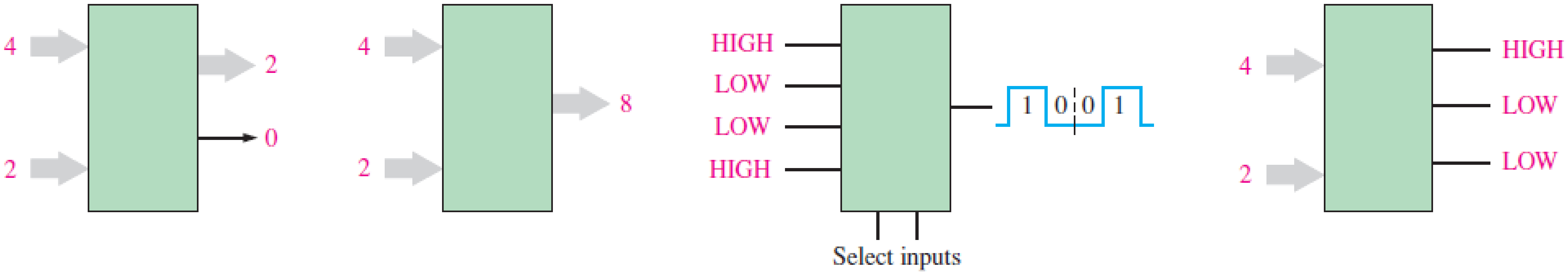


FIGURE 1–24 Illustration of a basic multiplexing/demultiplexing application.

Example 1-2

Problems: Based on your observation of the inputs and outputs, name the logic function of each block shown in Figures.



(a) (b) (c) (d)

ANSWER:

(a) Subtractor

(b) Multiplier

(c) Multiplexure

(d) Comparator

Data storage function (register)

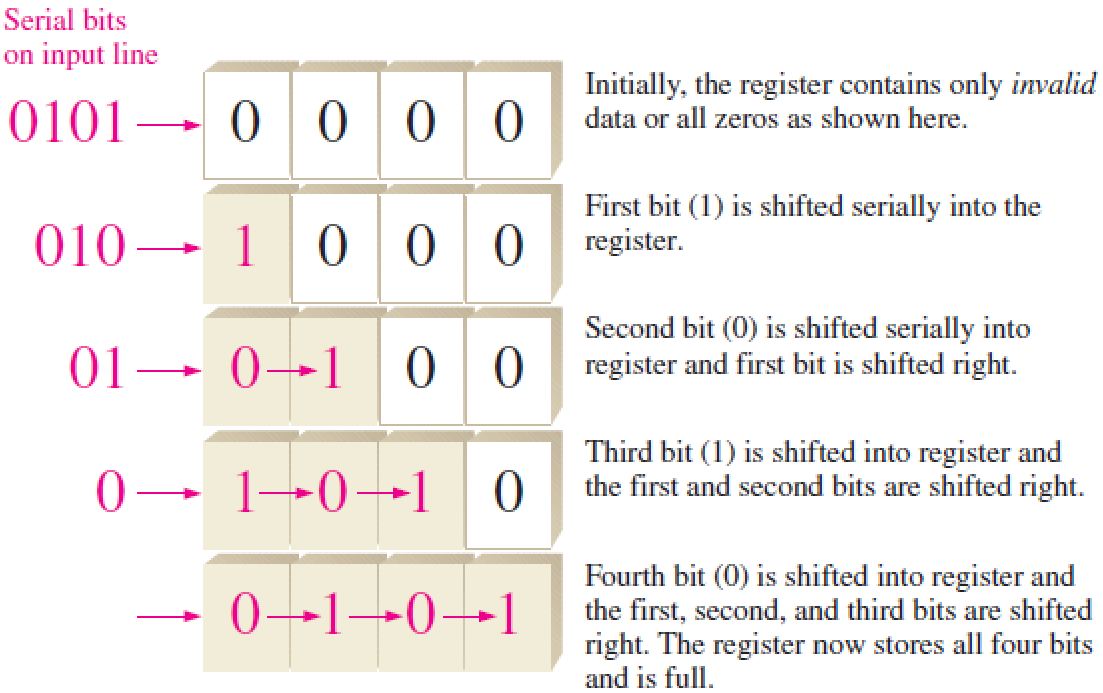
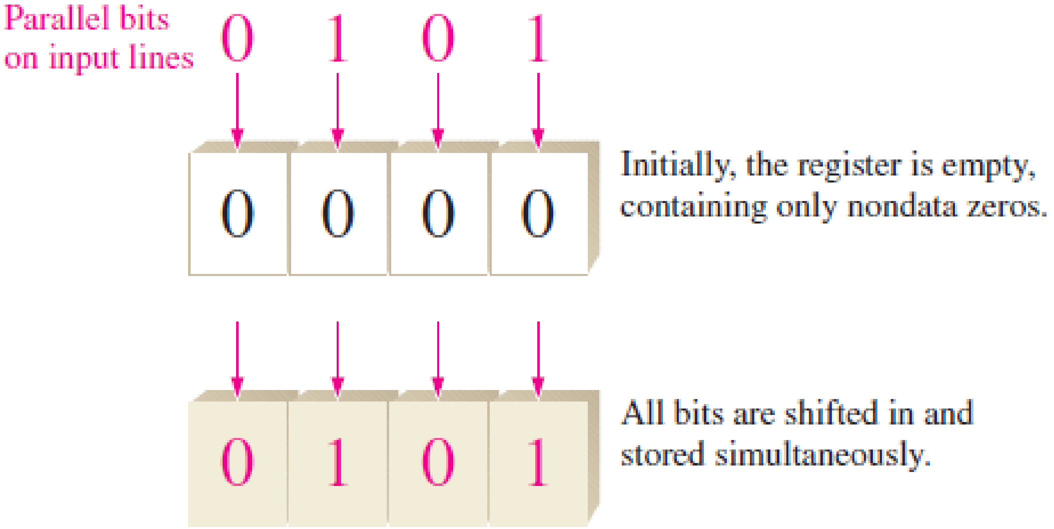


FIGURE 1–25 Example of the operation of a 4-bit serial shift register. Each block represents one storage "cell" or flip-flop.



6 Example of the operation of a 4-bit parallel shift register.

Counting function

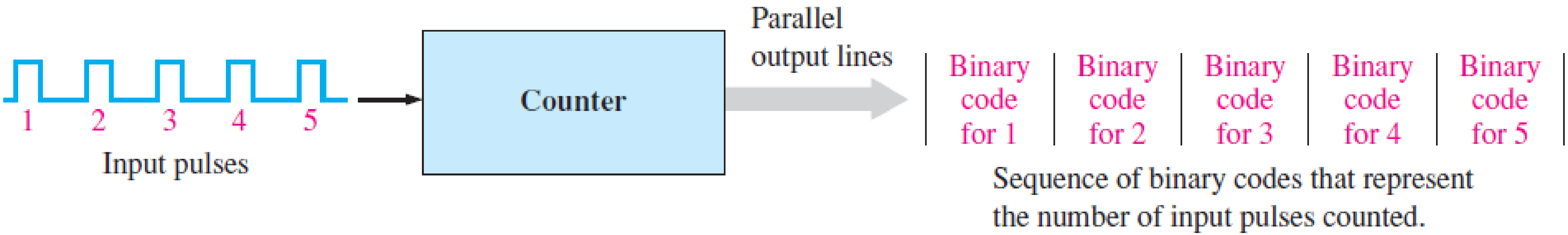
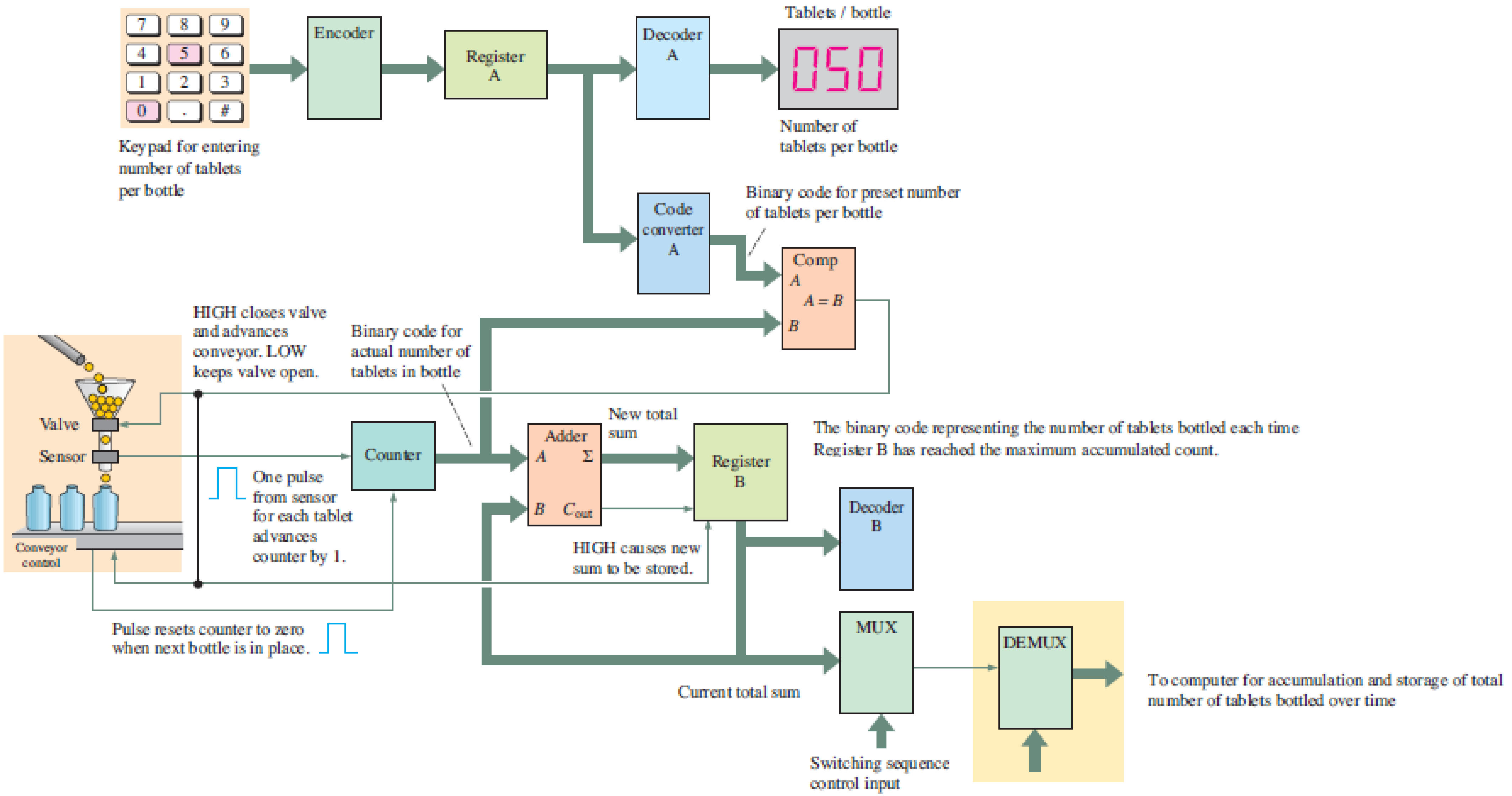


FIGURE 1–27 Illustration of basic counter operation.

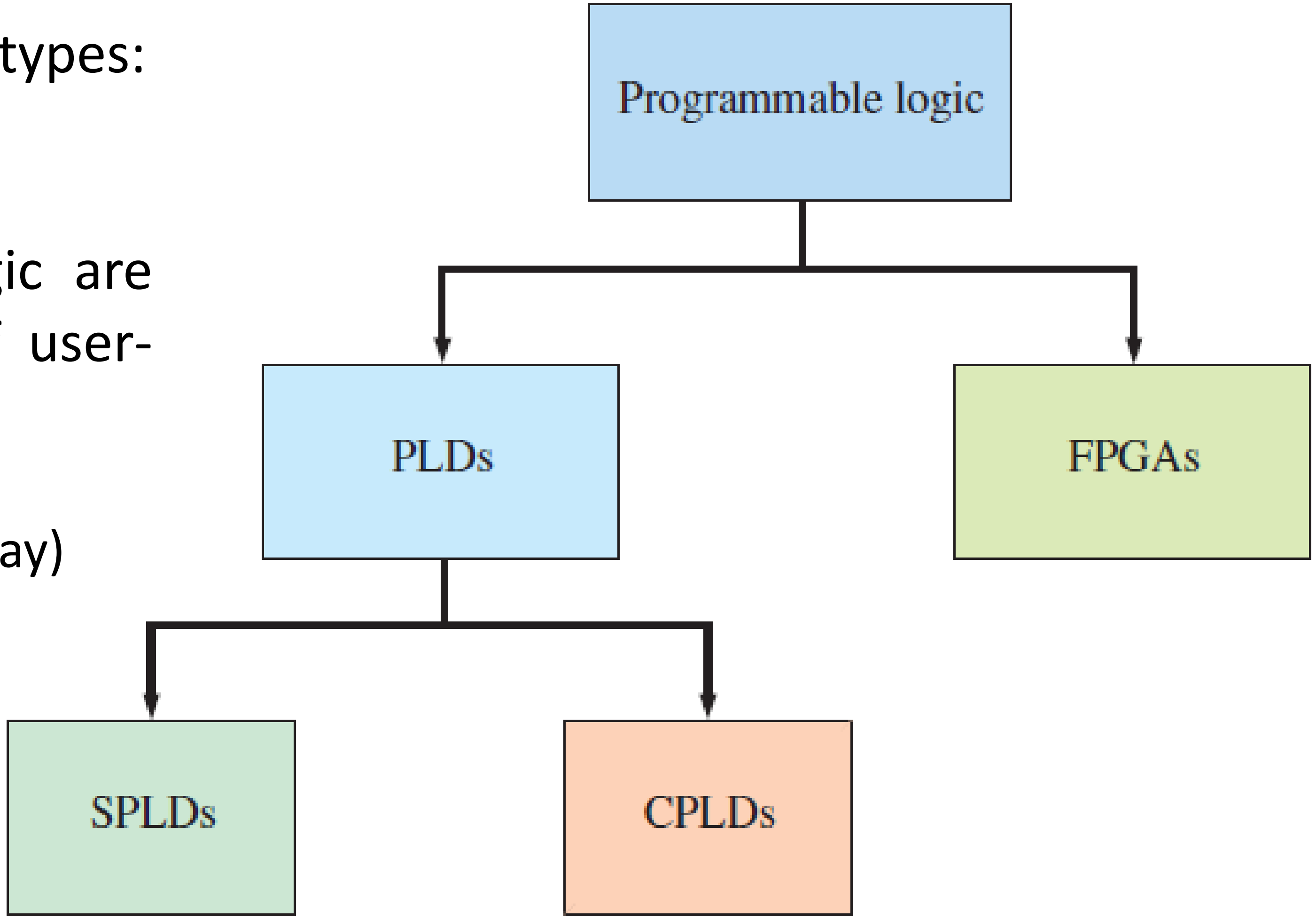
Process control (tablet bottling system)



Programmable logic

Digital integrated circuits (ICs) are two types:
(1) Fixed Function Logic Devices (FLDs)
(2) Programmable Logic Devices (PLDs)

- ❑ Many types of programmable logic are available, two major categories of user-programmable logic are:
  - ➢ **PLD** (programmable logic device)
  - ➢ **FPGA** (field-programmable gate array)
- ❑ PLDs are two types:
  - ✓ SPLDs (simple PLDs)
  - ✓ CPLDs (complex PLDs)



Simple programmable logic devices

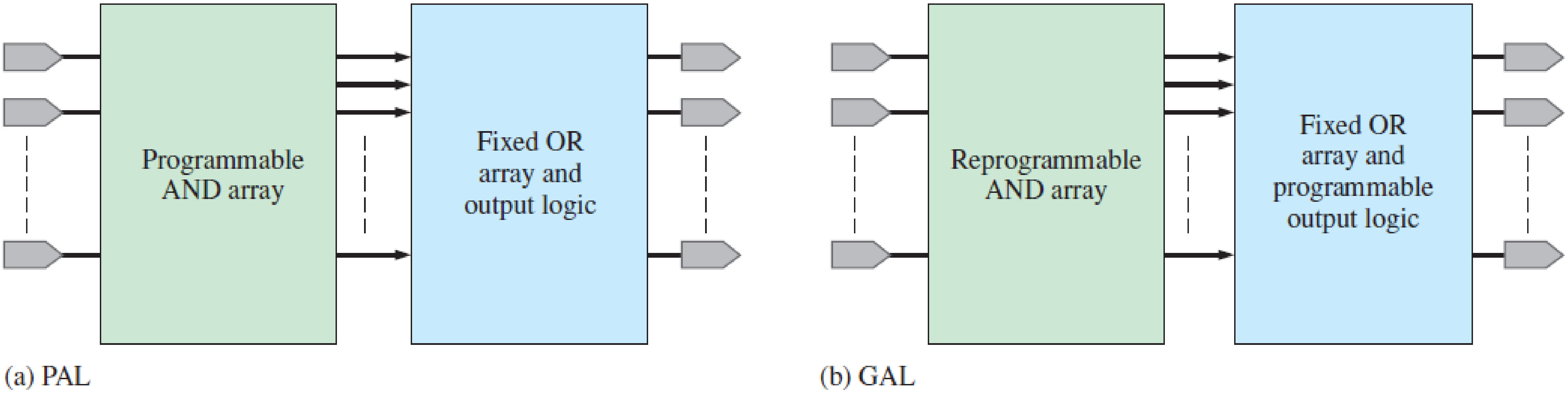


FIGURE 1–30 Block diagrams of simple programmable logic devices (SPLDs).

Complex programmable logic devices

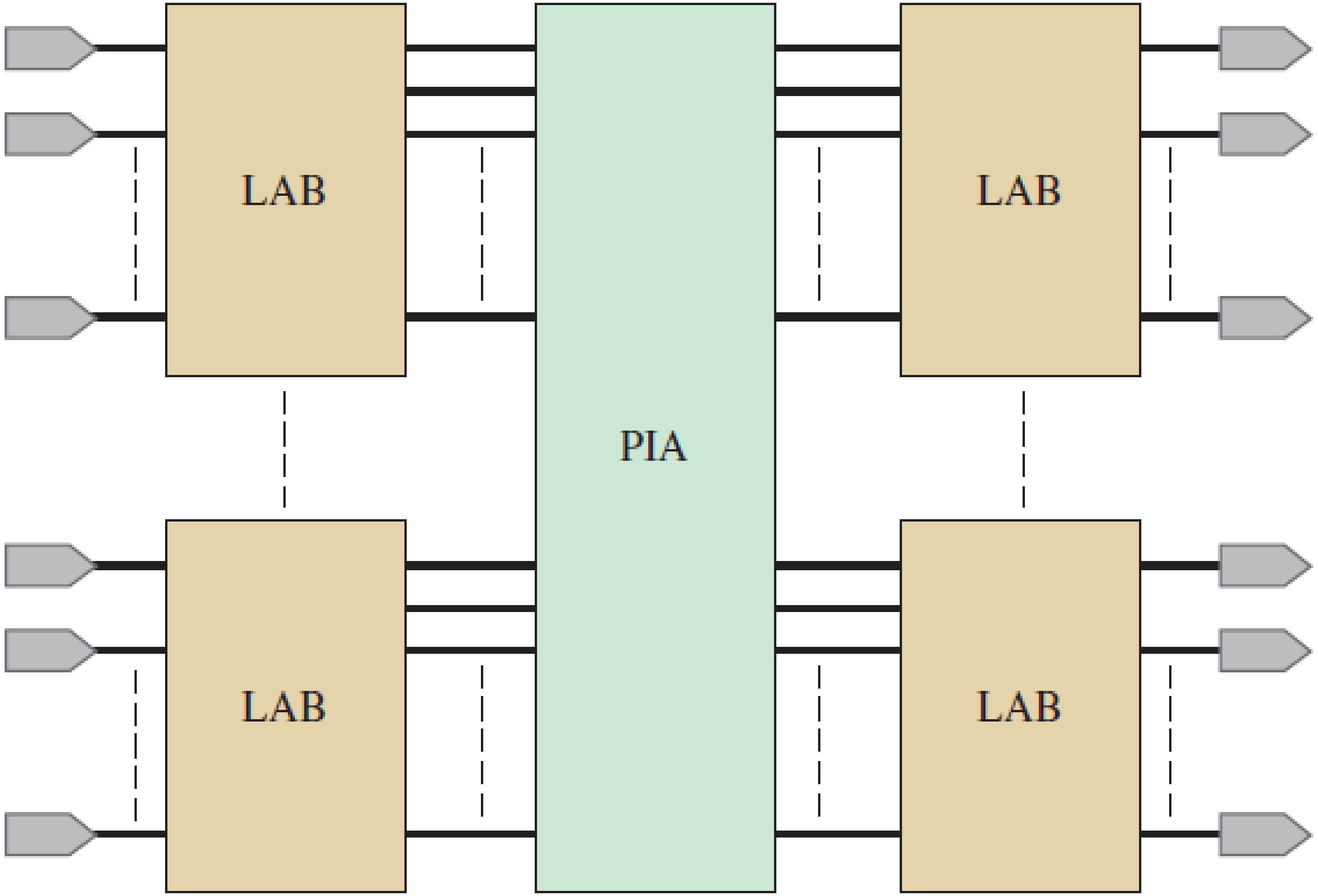


FIGURE 1–32 General block diagram of a CPLD.

Field programmable gate array

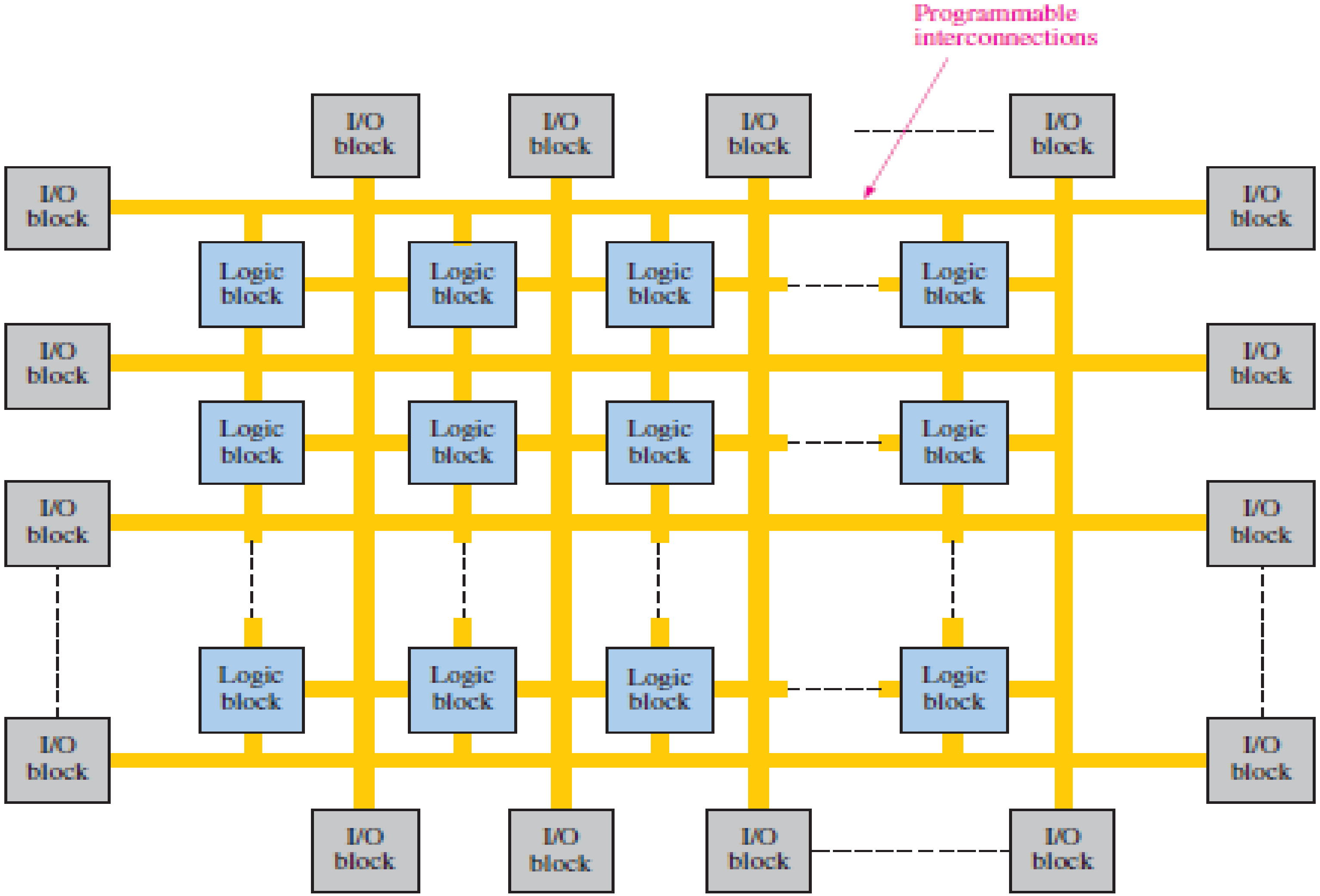


FIGURE 1–34 Basic structure of an FPGA.

Programming process

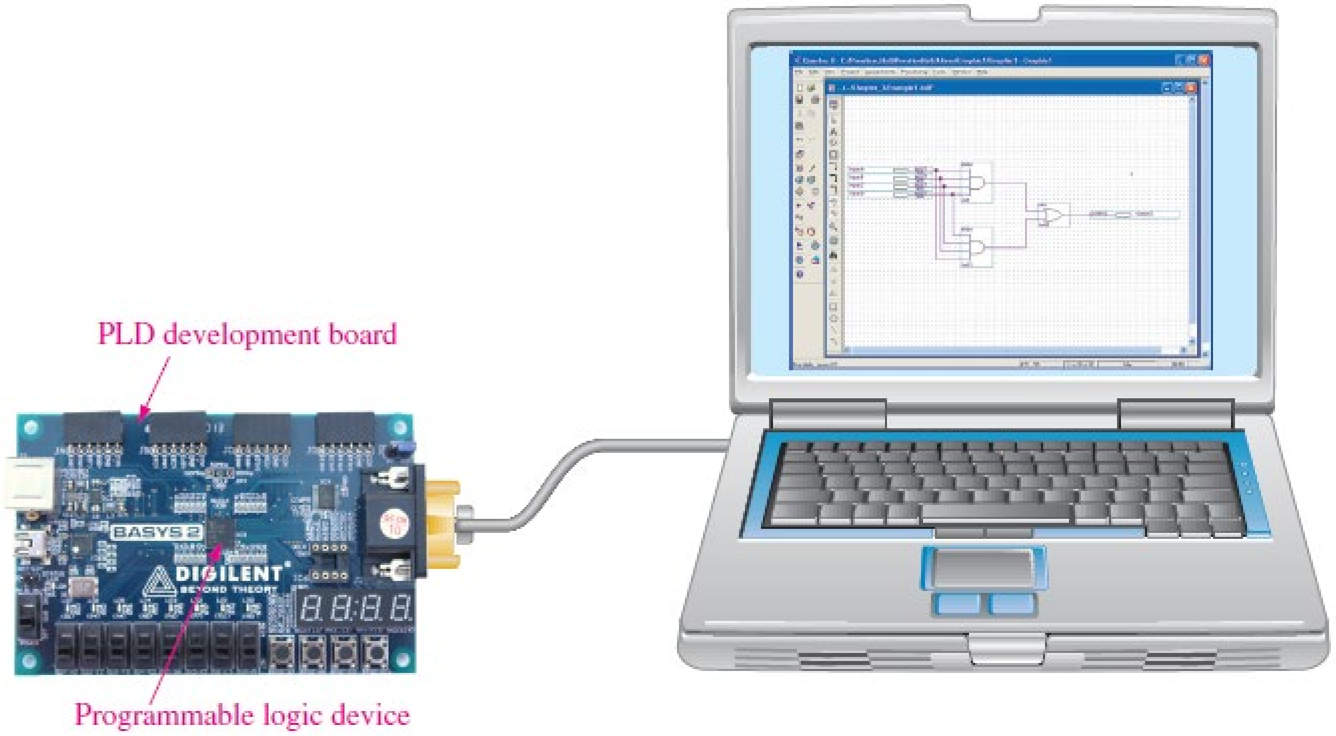


FIGURE 1–36 Basic setup for programming a PLD or FPGA. Graphic entry of a logic circuit is shown for illustration. Text entry such as VHDL can also be used. (Photo courtesy of Digilent, Inc.)

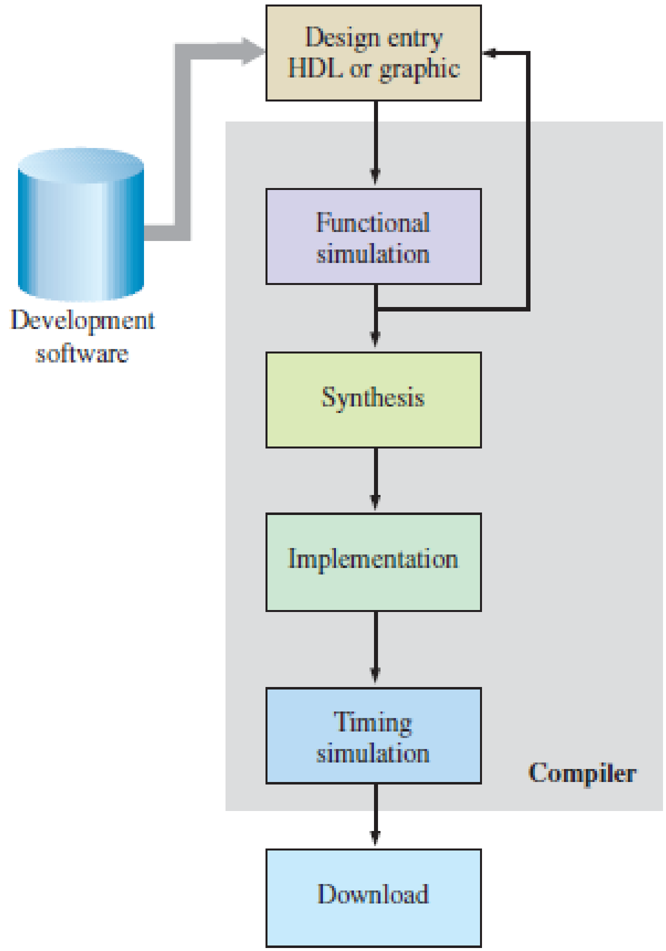


FIGURE 1–37 Basic programmable logic design flow block diagram.

Fixed function logic devices

- An **integrated circuit (IC)** is an electronic circuit that is constructed entirely on a single small chip of silicon.
- All the components that make up the circuit—transistors, diodes, resistors, and capacitors—are an integral part of that single chip.
- Fixed-function logic and programmable logic are two broad categories of digital ICs.
- In **fixed-function logic** devices, the logic functions are set by the manufacturer and cannot be altered.

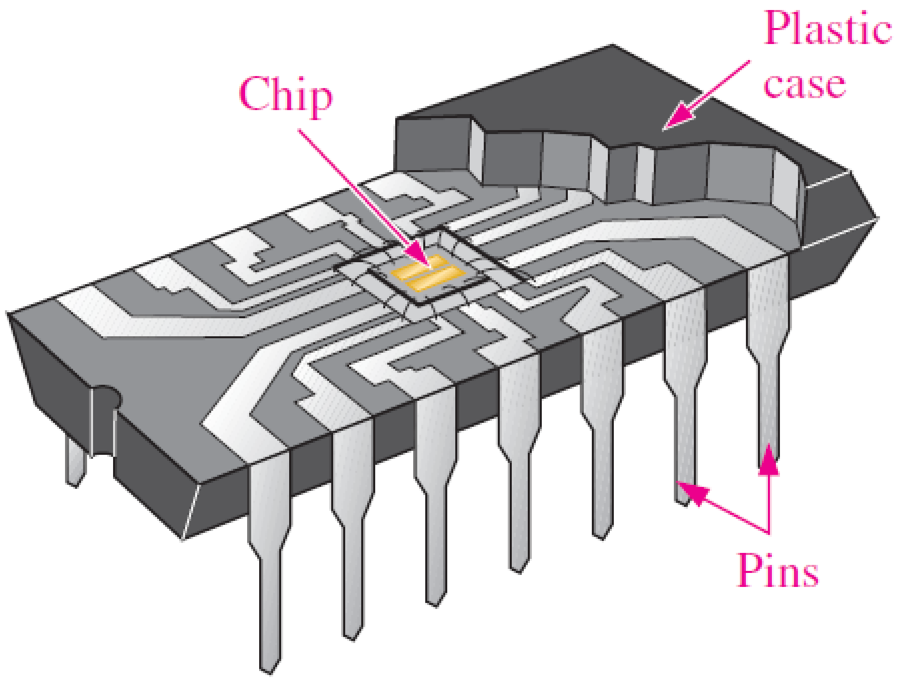
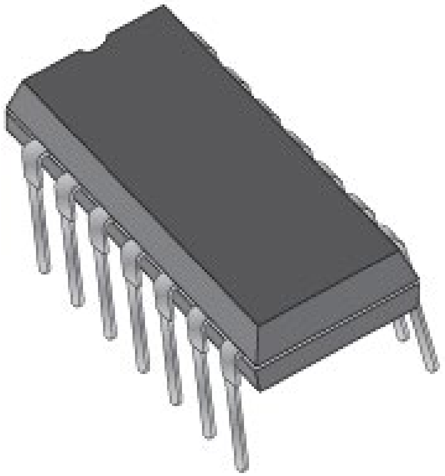


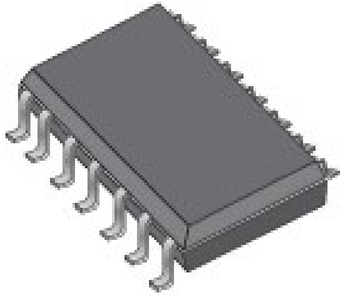
FIGURE Cutaway view of one type of fixed-function IC package (dual in-line package) showing the chip mounted inside, with connections to input and output pins

Fixed function logic devices

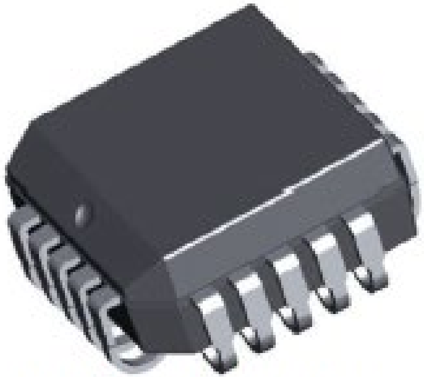
- Integrated circuit (IC) packages are classified according to the way they are mounted on printed circuit boards (PCBs) as either through-hole mounted or surface mounted
  - ✓ Dual in-line packages (DIP)
  - ✓ Small-outline integrated circuit packages (SOIC)
  - ✓ Plastic leaded chip carrier packages (PLCC)
  - ✓ Leadless ceramic chip carrier packages (LCC)



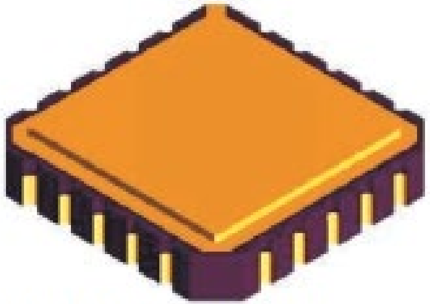
(a) Dual in-line package (DIP)



(b) Small-outline IC (SOIC)



(b) PLCC (350 × 350 mils)



(c) LCC (350 × 350 mils)

Fixed function logic devices

- **Fixed-function digital ICs are classified according to their complexity.**
  - ✓ **Small-scale integration (SSI)** describes fixed-function ICs that have up to ten equivalent gate circuits on a single chip, and they include basic gates and flip-flops.
  - ✓ **Medium-scale integration (MSI)** describes integrated circuits that have from 10 to 100 equivalent gates on a chip. They include logic functions such as encoders, decoders, counters, registers, multiplexers, arithmetic circuits, small memories, and others.
  - ✓ **Large-scale integration (LSI)** is a classification of ICs with complexities of from more than 100 to 10,000 equivalent gates per chip, including memories.
  - ✓ **Very large-scale integration (VLSI)** describes integrated circuits with complexities of from more than 10,000 to 100,000 equivalent gates per chip.
  - ✓ **Ultra large-scale integration (ULSI)** describes very large memories, larger **microprocessors**, and larger single-chip computers. Complexities of more than 100,000 equivalent gates per chip are classified as ULS.

Measurement instruments - digital oscilloscope

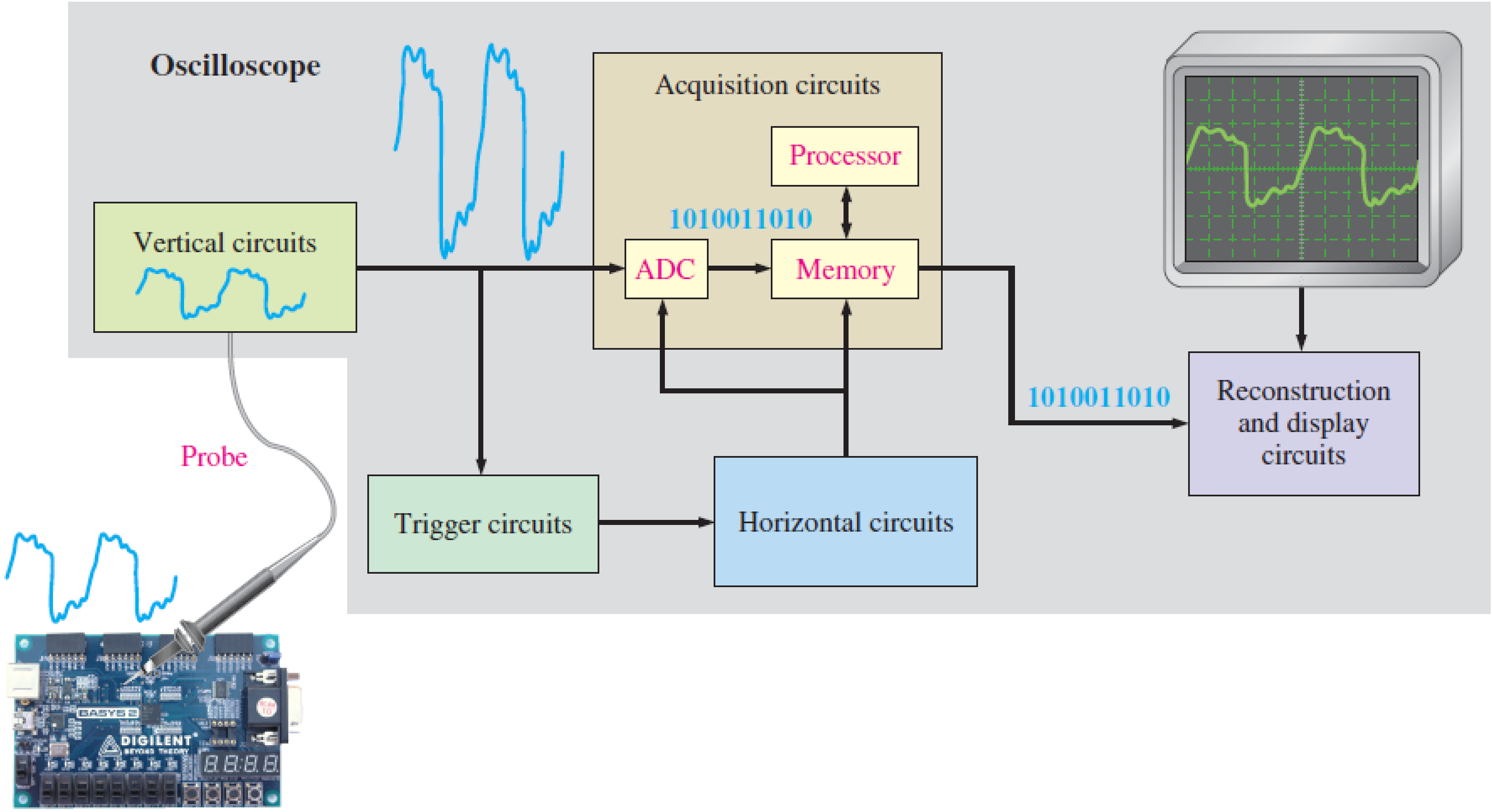


FIGURE 1–43 Block diagram of a digital oscilloscope. (Photo courtesy of Digilent, Inc.)

References

1. ***Digital Fundamentals*** by Thomas Floyd, Pearson International Edition, 11th Edition, Chapter 1, Page 16-54.

Next class

Number Systems and Operations