CME 2003
Digital Logic

Introductory Digital Concepts

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Books

Text Book:

Digital Fundamentals with VHDL Thomas L. FLOYD, Prentice Hall,0-13-099527-4,2003
http://www.prenhall.com/floyd

Reference books:

- Logic Computer Design Fundamentals (2nd ed), M.Morris Mano, Charles R. Kime, Prentice Hall,0-13-031486-2, 2001
- Digital Principles and Design, Donald D. Givone, McGraw-Hill,0-07-119521-1, 2003
- Introduction to Logic Design, Alan B. Marcovitz, McGraw-Hill,0-07-111162-X, 2005

Contents

- Digital and analog quantities, Binary Digits, Logic Levels, Digital waveforms, Basic Logic Operations and Functions.
- Number Systems, Operations, Codes and Conversions
- Logic Gates, Boolean Algebra and Logic Simplification
- Implementing combinational logic, the universal property of NAND and NOR gates, operation with pulse waveforms
- Functions of Combinational Logic: Basic adders, parallel binary adders, comparators, decoders, encoders, code converters.
- Multiplexers, demultiplexers, parity generators/checkers
- Latches, Flip-Flops and operation characteristics of Flip-Flops

… Contents

- Flip-Flops applications
- Asynchronous and synchronous counter operation, Up/Down synchronous counters
- Design of synchronous counters, cascaded counters, counter decoding and applications
- Shift registers and applications
- Interfacing the digital and analog worlds, digital-to-analog (D/A) conversion, analog-to-digital (A/D) conversion.
- Algorithmic State Machines: ASM charts, State assignments, ASM tables
- Synchronous Sequential Networks

Introductory Digital Concepts

- Digital and Analog Quantities
- Binary Digits, Logic Levels, and Digital Waveforms
- Basic Logic Operations
- Overview of Basic Logic Functions
- Fixed-Function Integrated Circuits
- Introduction to Programmable Logic
- Test and Measurement Instruments

Digital

Digital technology applications

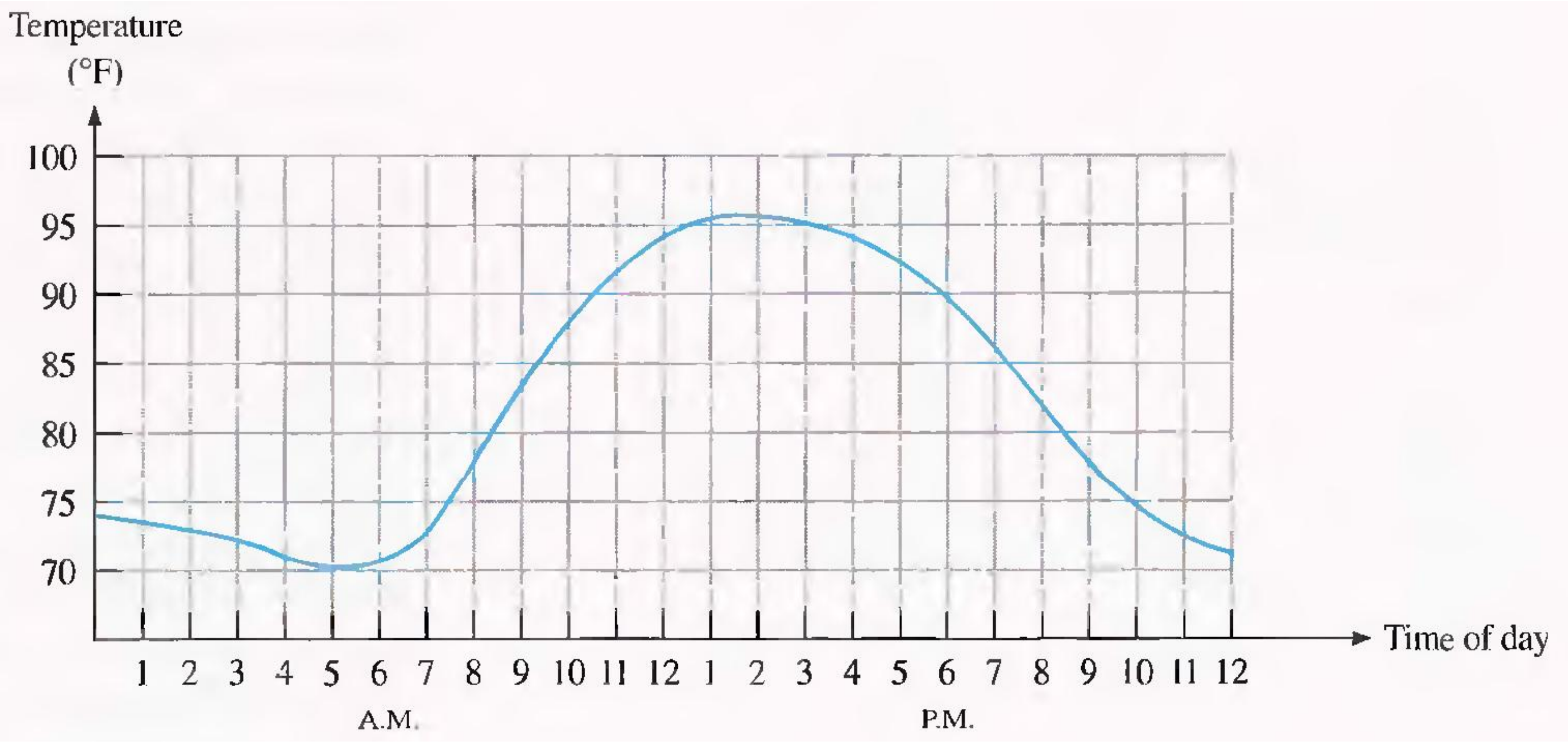
- television,
- communication systems : radar, navigation and guidance systems
- military systems
- medical instrumentation
- industrial process control
- consumer electronics

vacuum-tube → **transistor** → **integrated circuit**

Digital and Analog Quantities

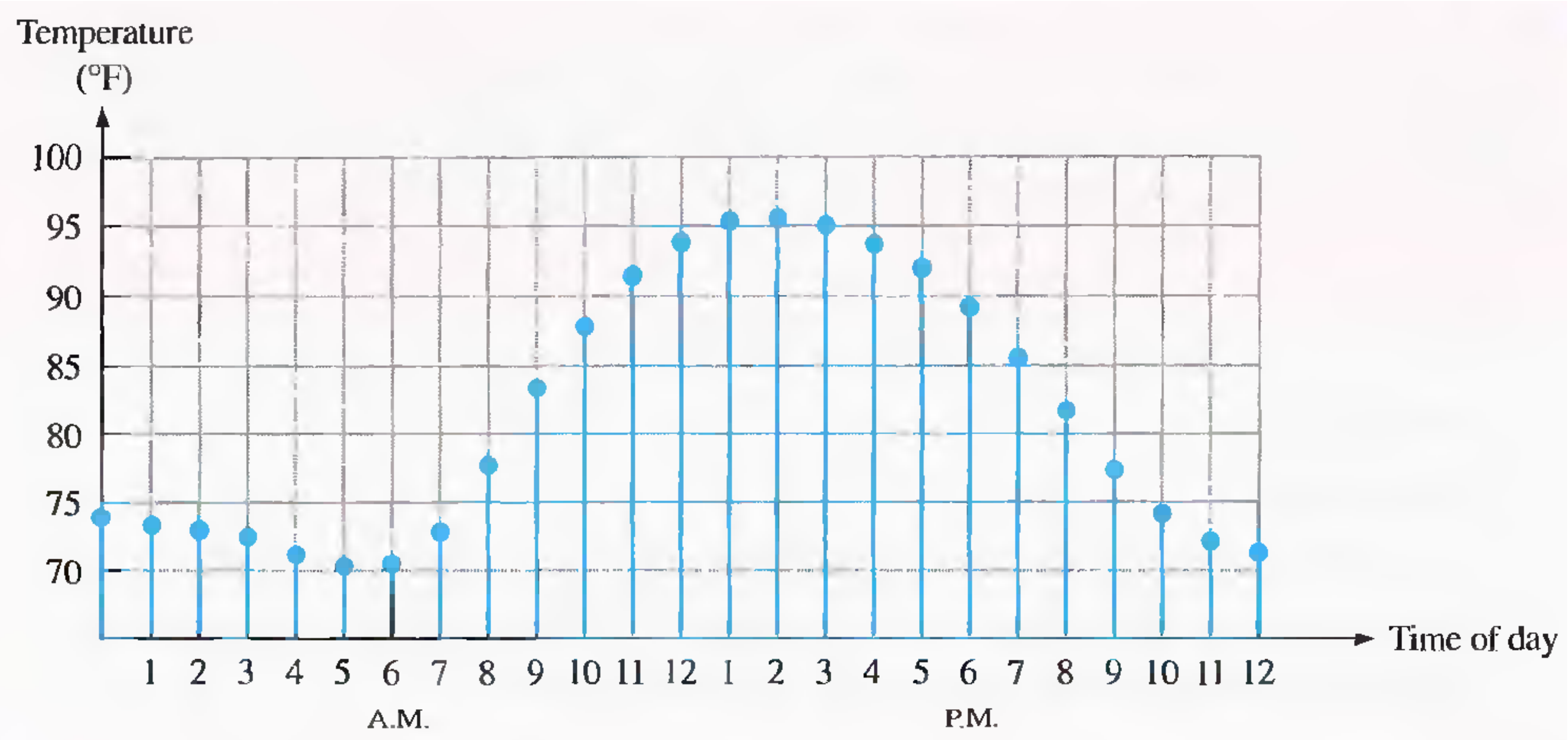
- Electronic Circuits:
  - Digital - discrete values
  - Analog - continuous values

Example – Analog quantity



The temperature on a typical summer day

Quantization of the analog quantity



Sampled-value representation(quantization) of the analog quantity in figure. Each value represented by a dot can be digitized by representing it as a digital code that consists of a series of 1‘s and 0’s.

The advantage of digital data

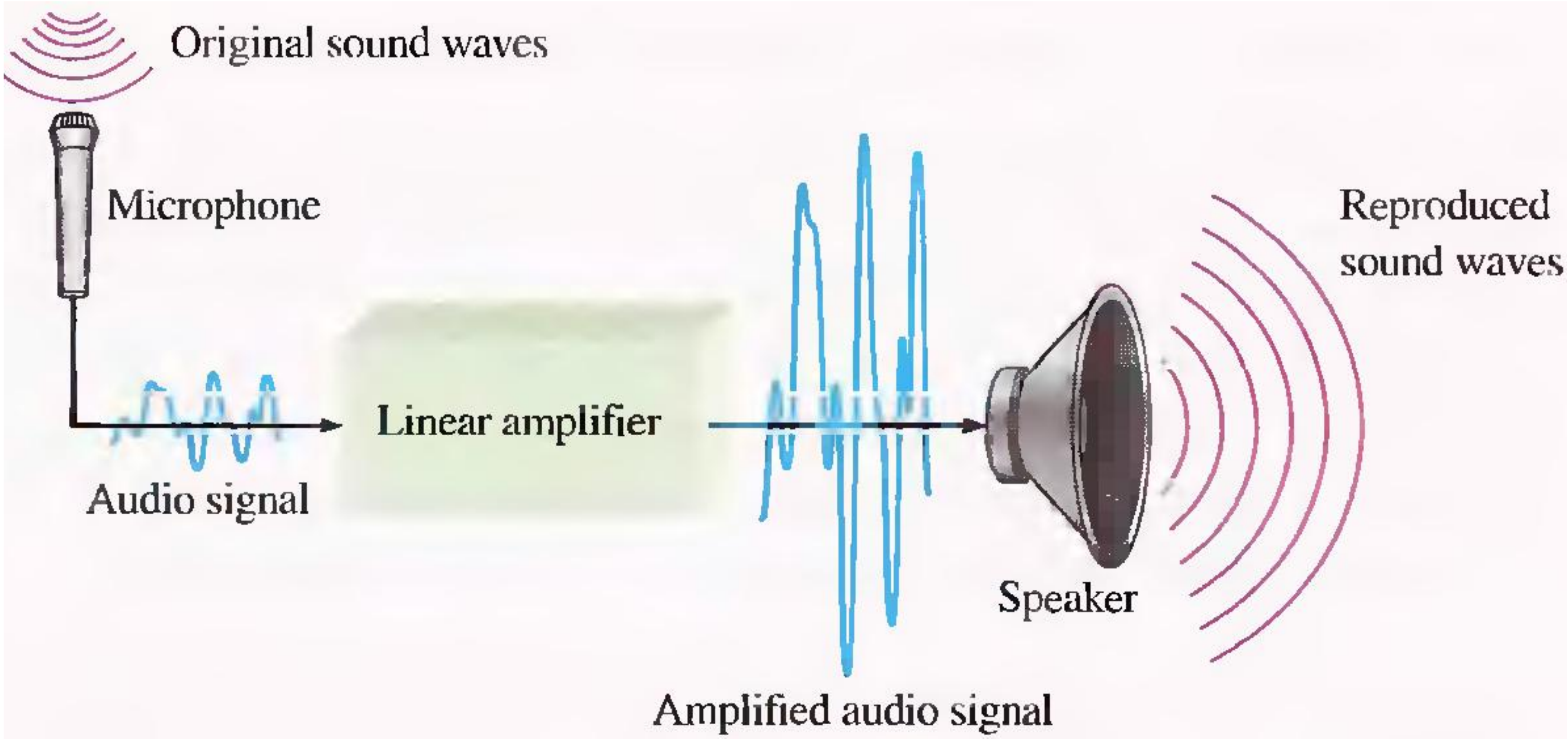
- Digital data can be processed and transmitted more **<u>efficiently</u>** and **<u>reliably</u>** than analog data.
- Storage advantage

Compact storage

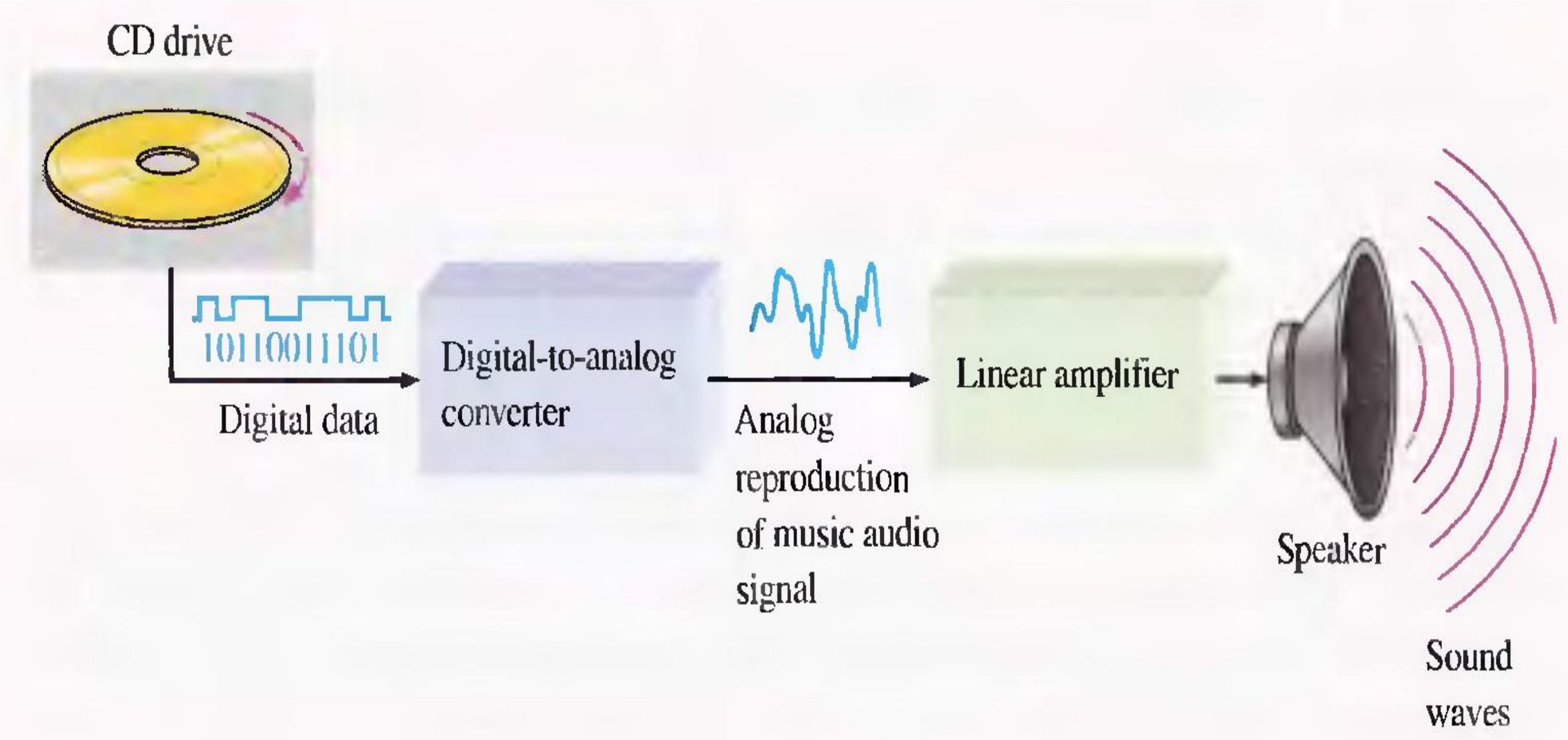
Noise (unwanted voltage fluctuations

reproduction with greater accuracy and clarity

A basic audio public address system



Basic block diagram of a CD player



Binary Digits

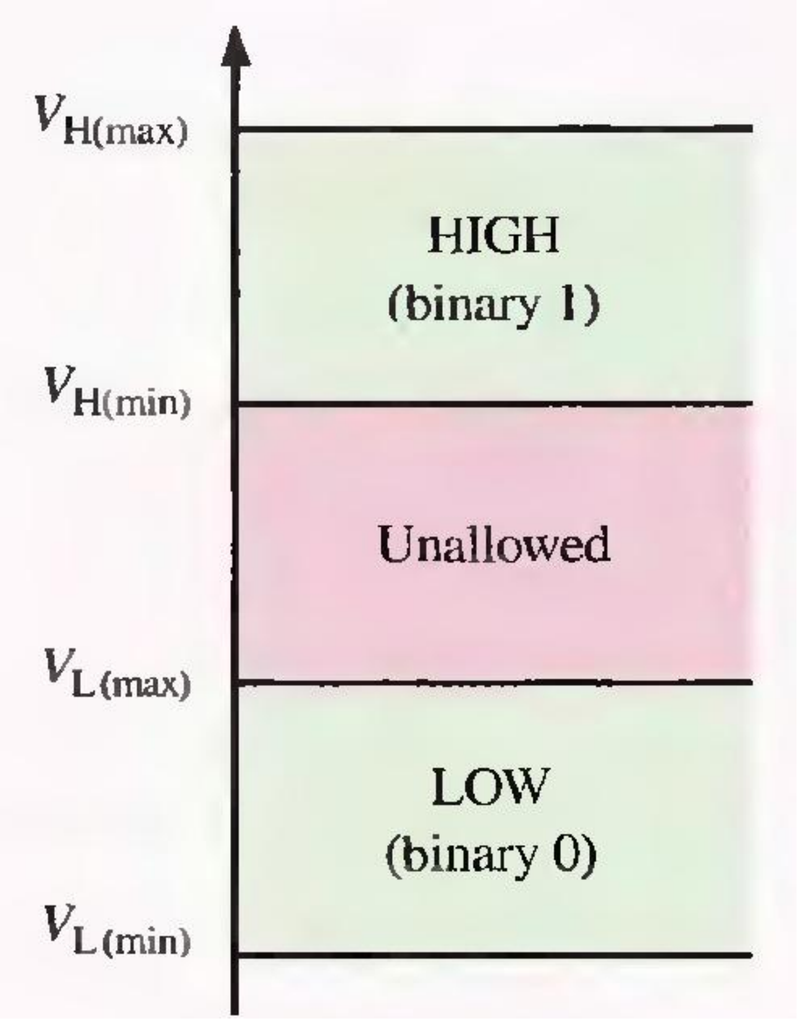
- Digital electronics involves circuits and systems in which there are only two possible states:

HIGH = 1 and LOW = 0

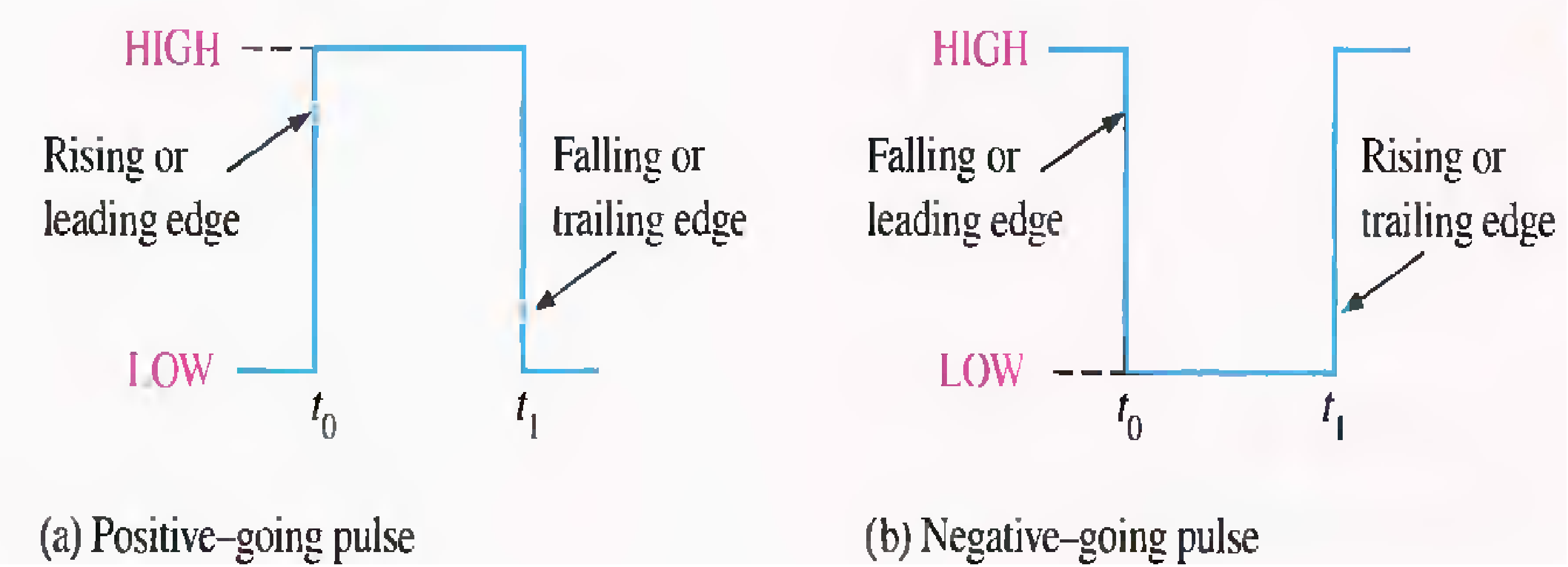
- Binary: the two-state number system
  - its two digits are 0 and 1.
- **Bit** : binary digit
- Code:
  - combination of the two states
  - combinations of 1s and 0s
  - groups of bits
  - Codes are used to represent numbers, letters, symbols, instructions, and anything else required in a given application.

Logic Levels

- Logic levels are the voltages used to represent a 1 and a 0.

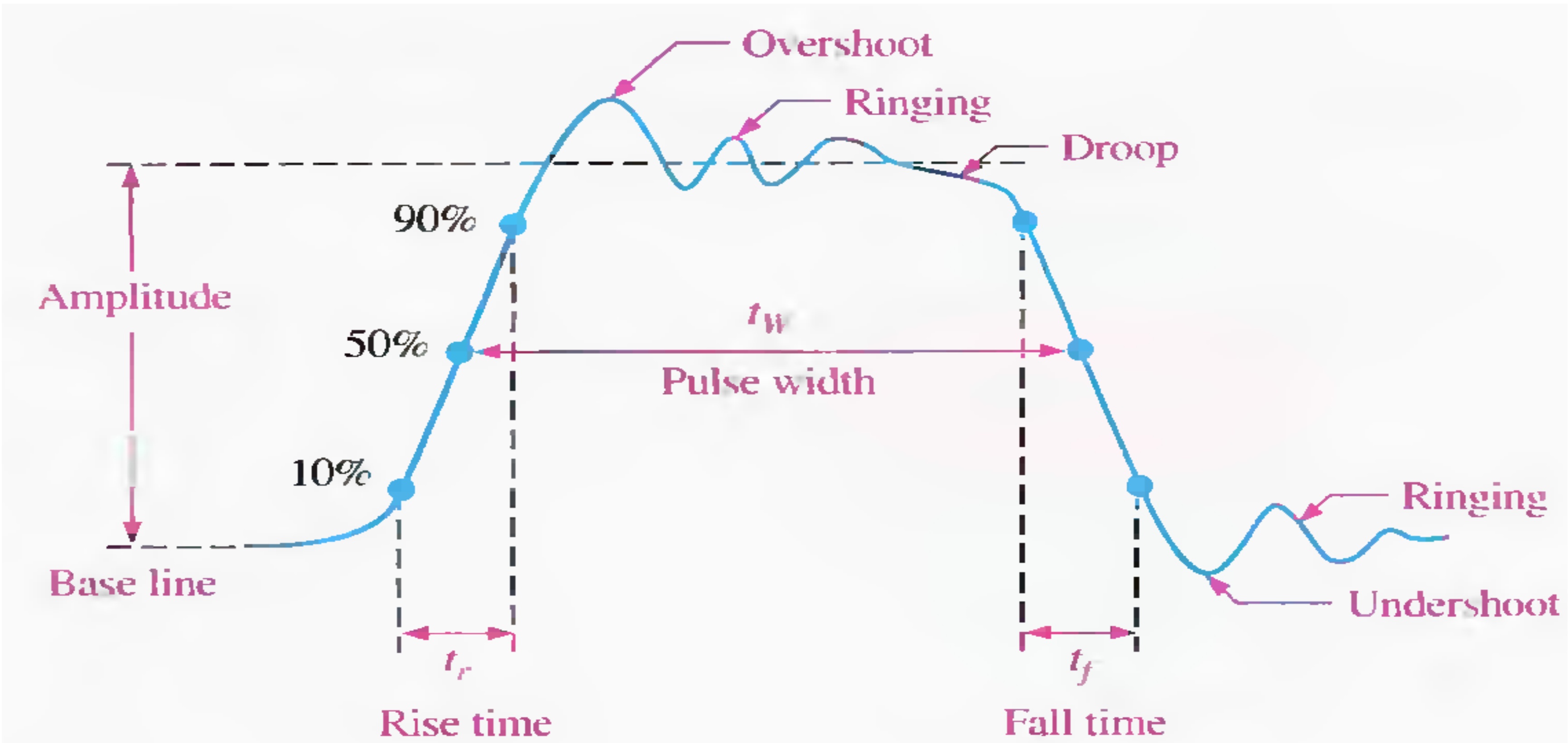


Digital Waveforms



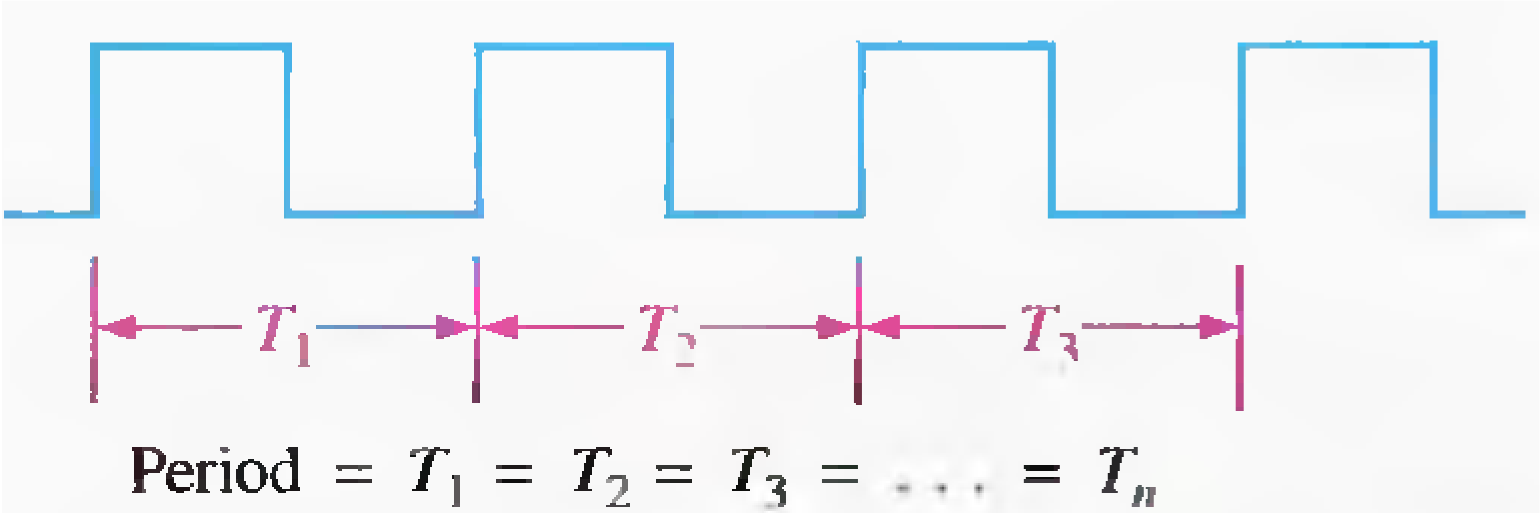
Ideal pulses.

Nonideal pulse characteristics



Waveform Characteristics

- A periodic pulse waveform repeats itself at a fixed interval, called a **period** (***T***)



Square wave (Periodic)

… Waveform Characteristics

- The **frequency** (***f***) is the rate at which it repeats itself and is measured in **hertz** (Hz).

$$f = \frac{1}{T} \qquad T = \frac{1}{f}$$

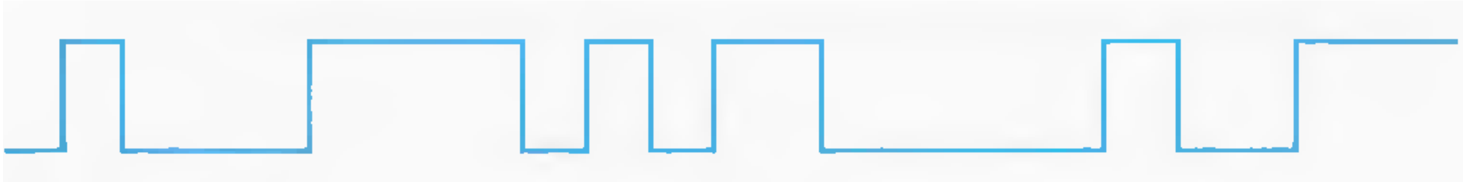
… Waveform Characteristics

- In addition to frequency and period, repetitive pulse waveforms are described by the **amplitude (*A*)**, **pulse width (t_W)** and **duty cycle**.
- **Duty cycle** is the ratio of t_W to T.

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

… Waveform Characteristics

- A **nonperiodic pulse** waveform **does not** repeat itself at fixed intervals and may be composed of pulses of randomly differing pulse widths and/or randomly *differing time intervals* between the pulses.



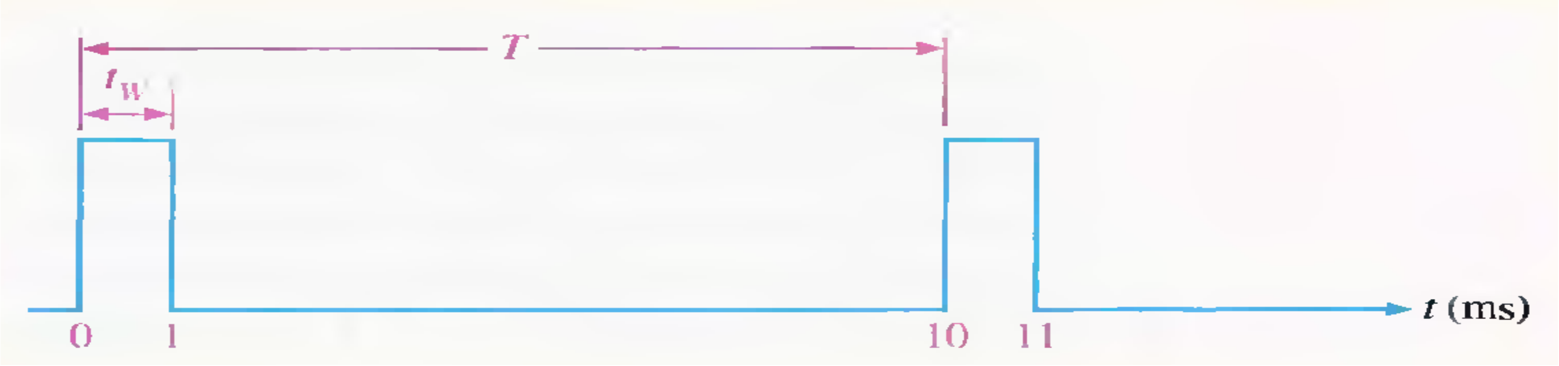
Nonperiodic

Example

- A portion of a periodic digital waveform is shown in the following Figure. The measurements are in milliseconds.

  Determine the following:

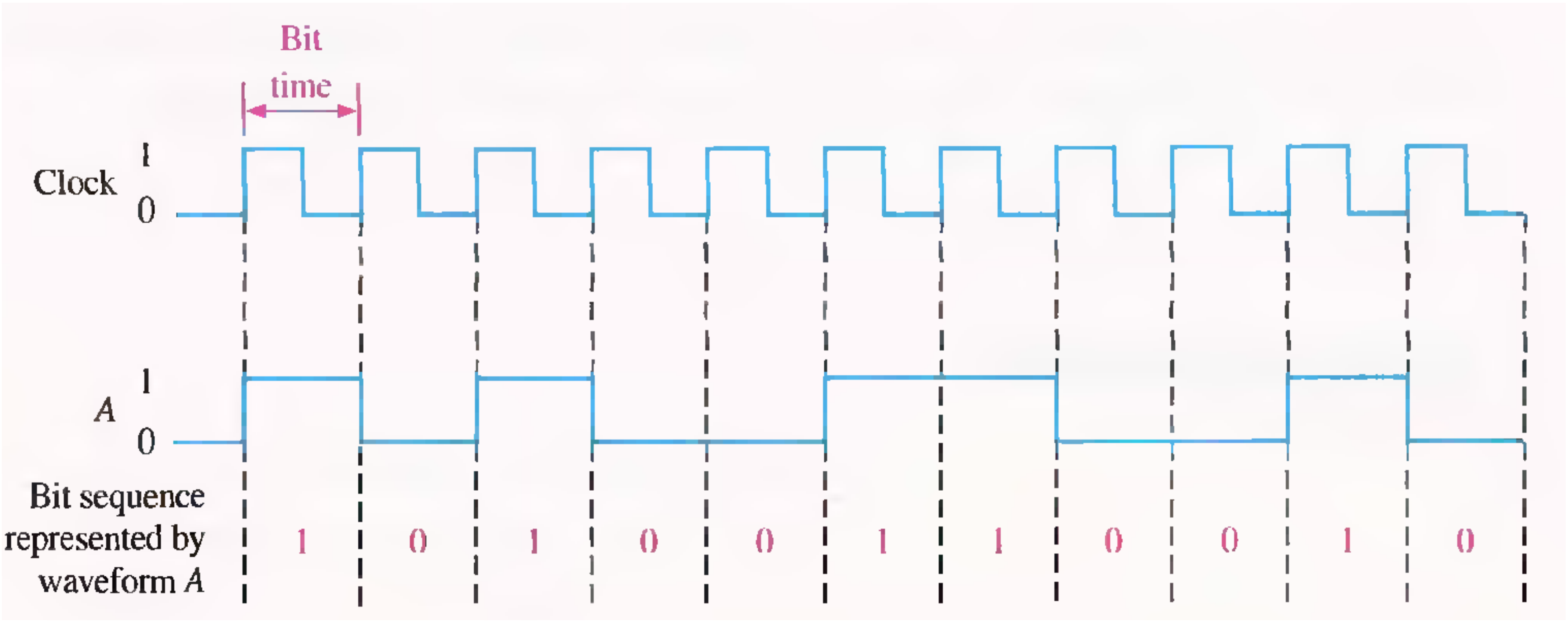
  (a) period
  (b) frequency
  (c) duty cycle



Clock

- a basic timing wave,
- a periodic waveform,
- synchronizes all waveforms in digital systems

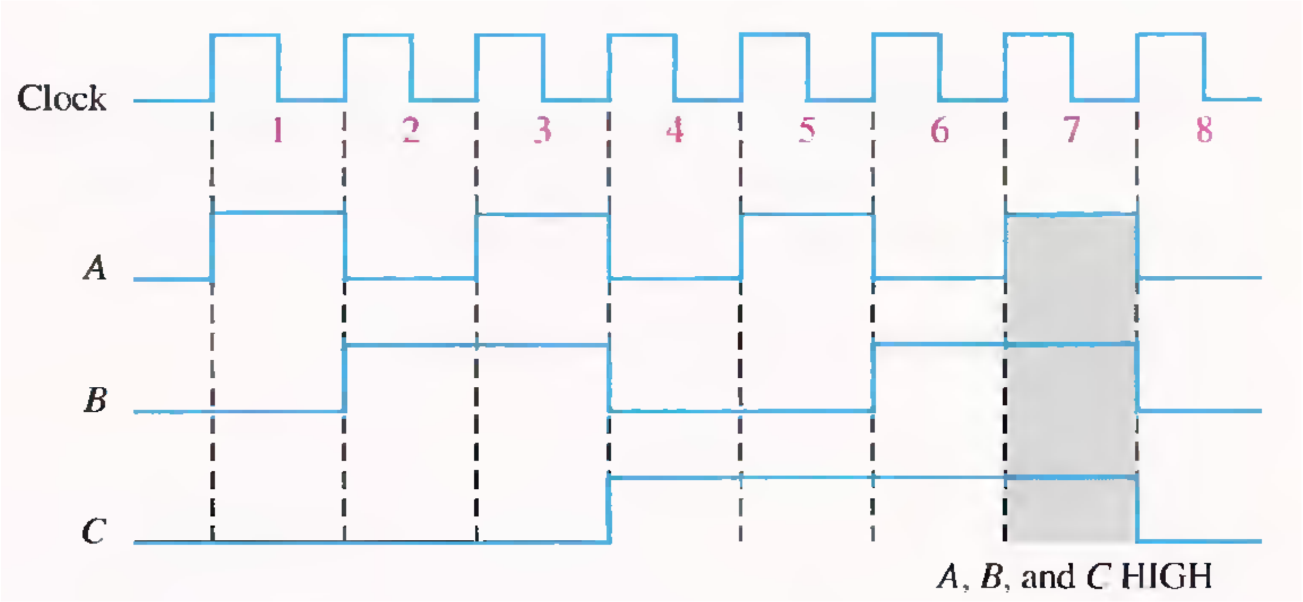
...Clock



Example of a clock waveform synchronized with a waveform representation of a sequence of bits.

Timing Diagrams

- *A* ***timing diagram*** is a graph of digital waveforms showing the actual time relationship of two or more waveforms and how each waveform changes in relation to the others.

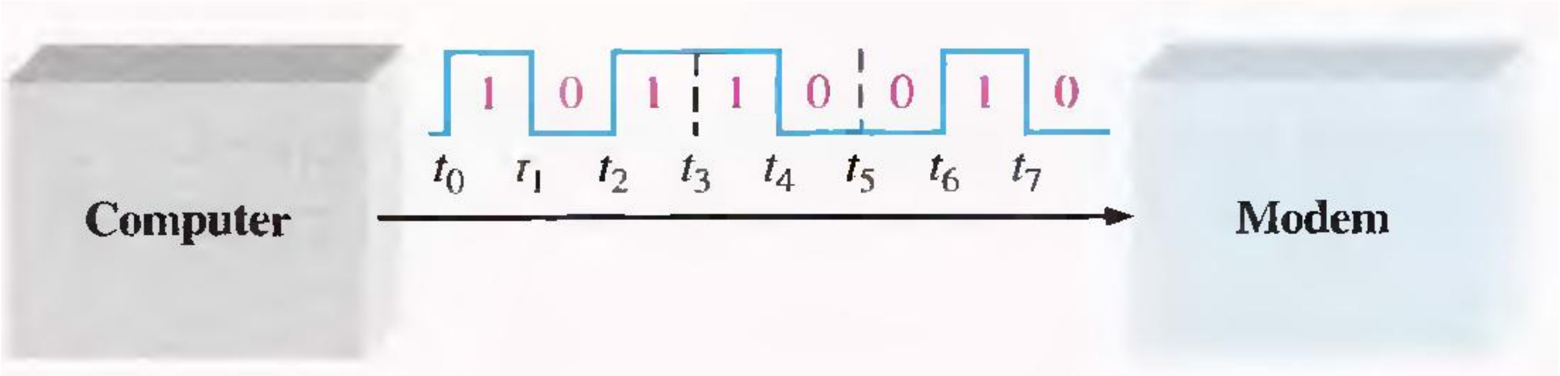


Data Transfer

- ***Data***: groups of bits that convey some type of information.
- ***Binary data***:
  - represented by digital waveforms,
  - must be transferred from one circuit to another within a digital system or from one system to another in order to accomplish a given purpose.
  - binary data are transferred in two ways:
    - Serial : single line
    - Parallel : one line for each bit of the group

Example: Serial transfer of binary data

- Serial transfer of 8 bits of binary data from computer to modem. Interval t_o to t_1 is first.



+ CHEAP :only one line is required

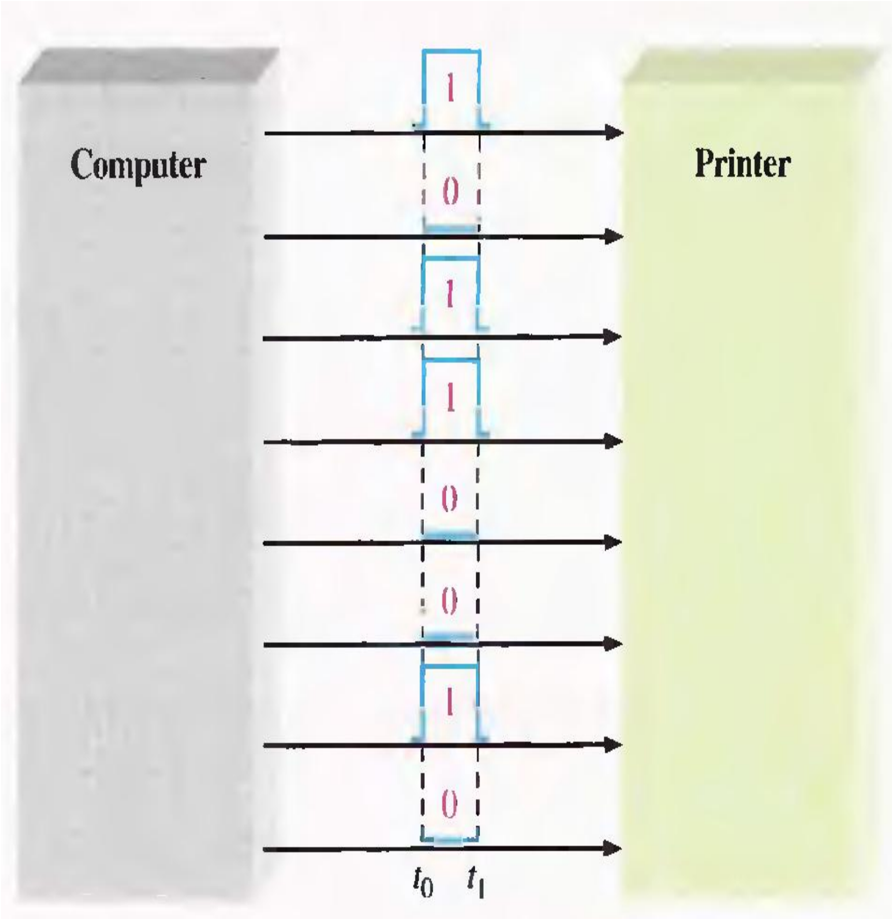
— SLOW : longer transfer time

Example: Parallel transfer of binary data

- Parallel transfer of 8 bits of binary data from computer to printer.
- The beginning time is t_o

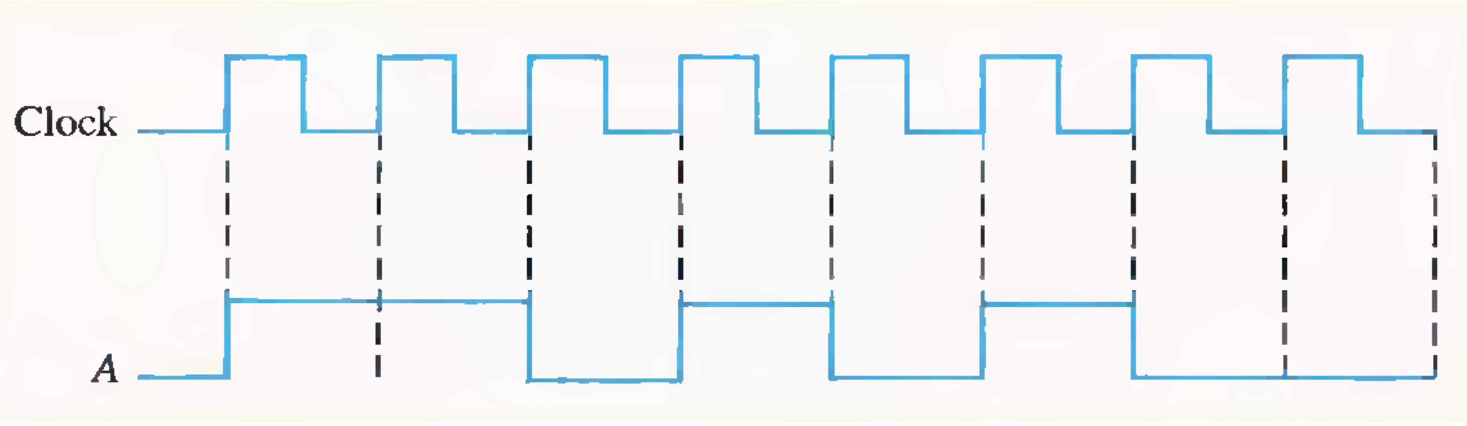
✚ FAST : short transfer time

— EXPENSIVE :a number of lines equal to the number of bits



Example

- 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 100 kHz clock is used as reference.
- (b) What is the total time to transfer the same eight bits **in parallel**?



… Example

Since the frequency of the clock is 100 kHz. the period is

$$T = \frac{1}{f} = \frac{1}{100\ \text{kHz}} = 10\ \mu\text{s}$$

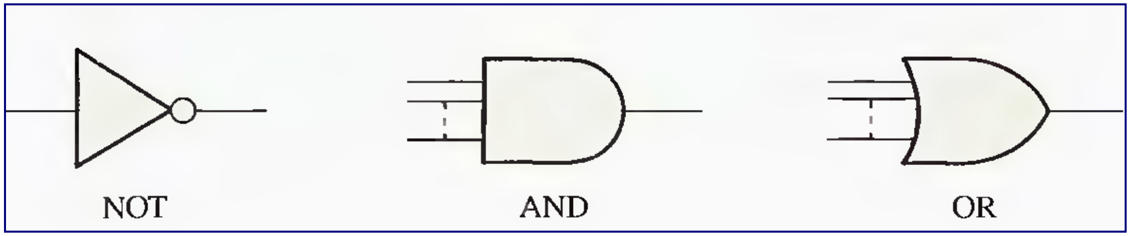
It takes 10 μs to transfer each bit in the waveform. The total transfer time for 8 bits is

$$8 \times 10\ \mu\text{s} = \mathbf{80\ \mu s}$$

(b) A parallel transfer would take **10 μs** for all eight bits.

Basic Logic Oparations

- **Logic** is the realm of human reasoning that tells you a *certain proposition* (declarative statement) is true if certain conditions are true.
- Propositions can be classified as **true** or **false**.
- The term logic is applied to digital circuits used to implement logic functions.
- Three basic logic operations
  - NOT
  - AND
  - OR



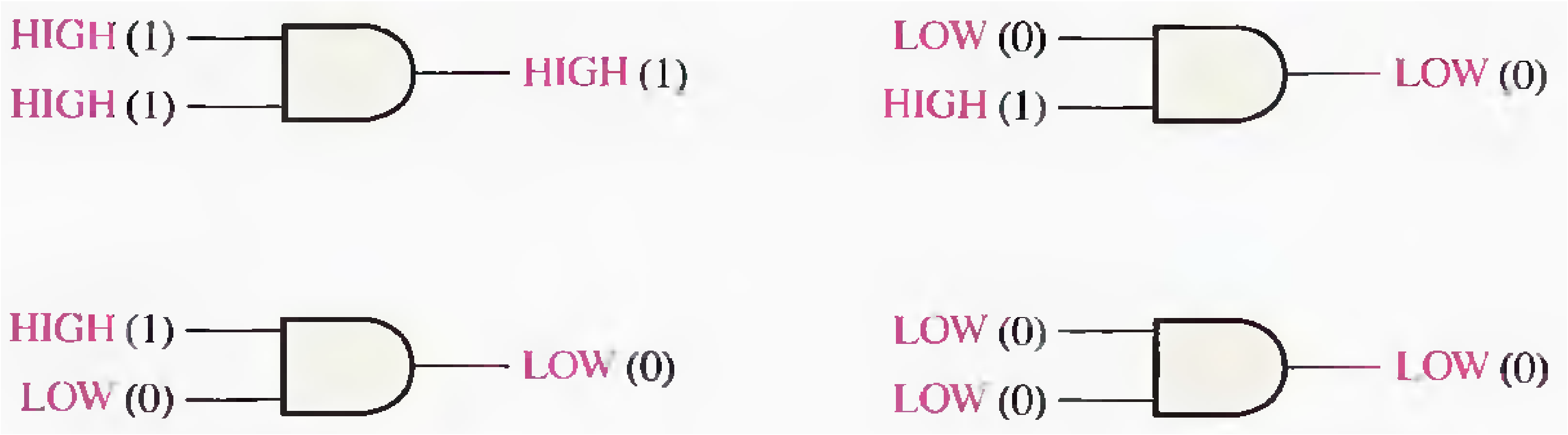
The symbols of the basic logic operations

NOT Operation

- The **NOT** operation
  - changes one logic level to the opposite logic level
  - implemented by a logic circuit known as an **inverter**.

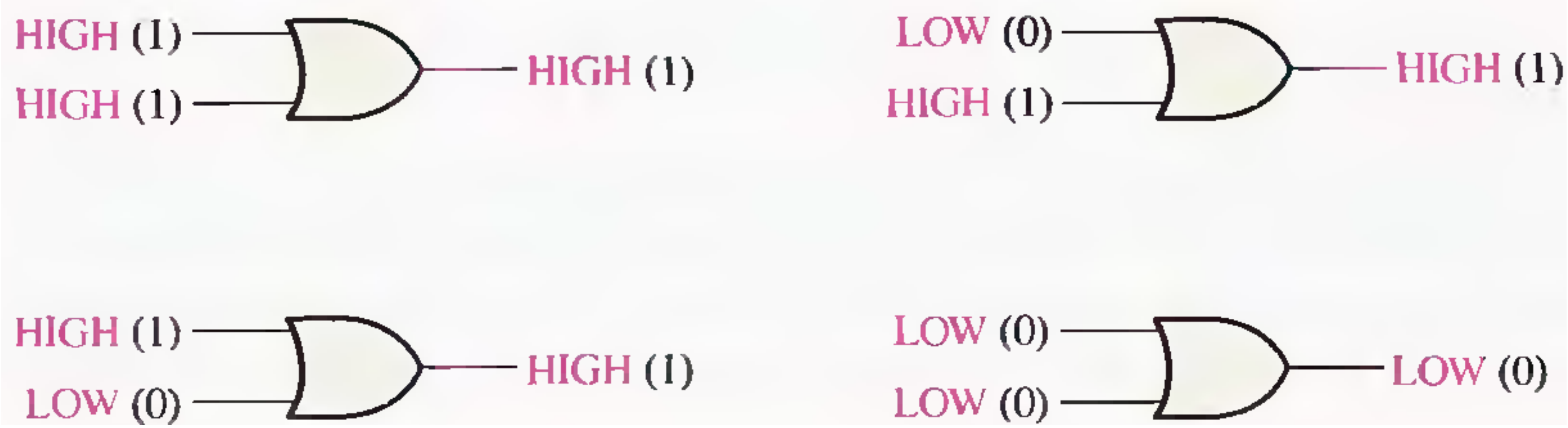
AND Operation

- The **AND** operation
  - produces a HIGH output **only when all the inputs are** HIGH
  - When any or all inputs are LOW, the output is LOW.
  - implemented by a logic circuit known as an **AND Gate**.



OR Operation

- The **OR** operation
  - produces a HIGH output **when one or more inputs are** HIGH,
  - When both inputs are LOW, the output is LOW.
  - implemented by a logic circuit known as an **OR Gate**.



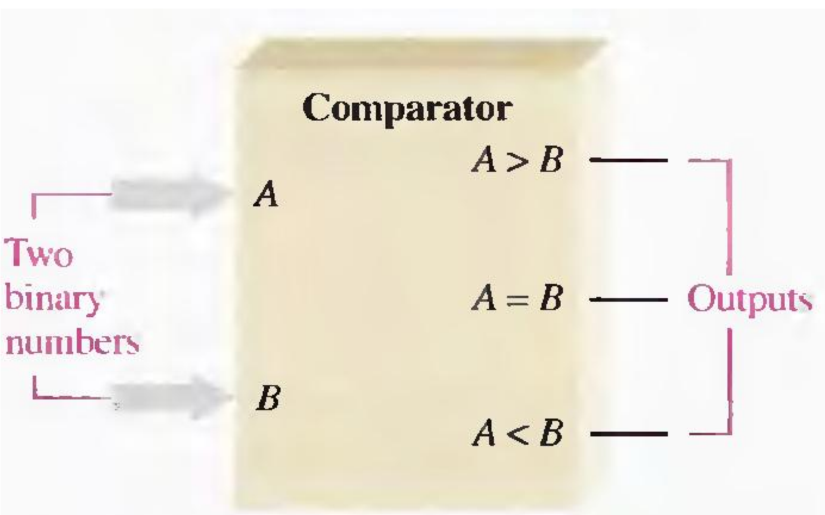
Basic Logic Functions

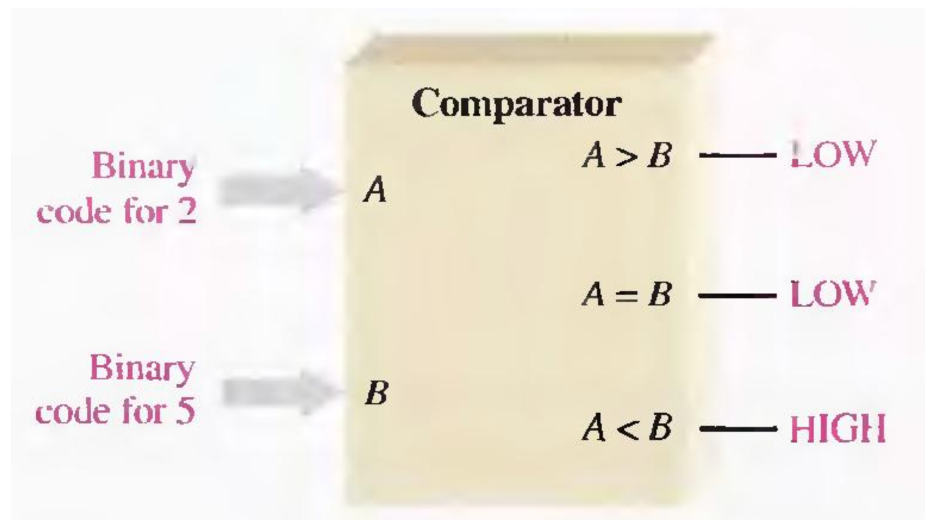
- The three basic logic elements AND, OR, and NOT can be combined to form more **complex logic circuits** that perform many useful operations and that are used to build complete digital systems.

- Some of the **common logic functions** are
  - comparison,
  - arithmetic,
  - code conversion,
  - encoding,
  - decoding,
  - data selection,
  - storage,
  - counting.

The Comparison Function

- Basic magnitude **comparator**

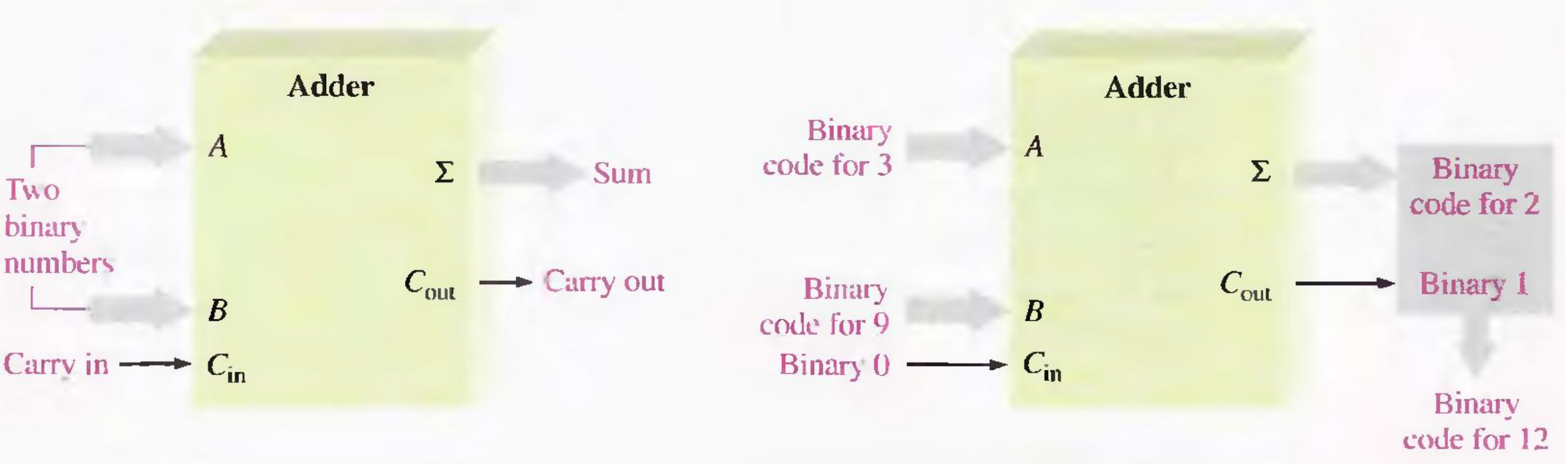




Example: A is less than B (2 < 5) as indicated by the HIGH output (A < B)

The Arithmetic Functions

- **Addition** is performed by a logic circuit called an **adder**.



(a) Basic adder

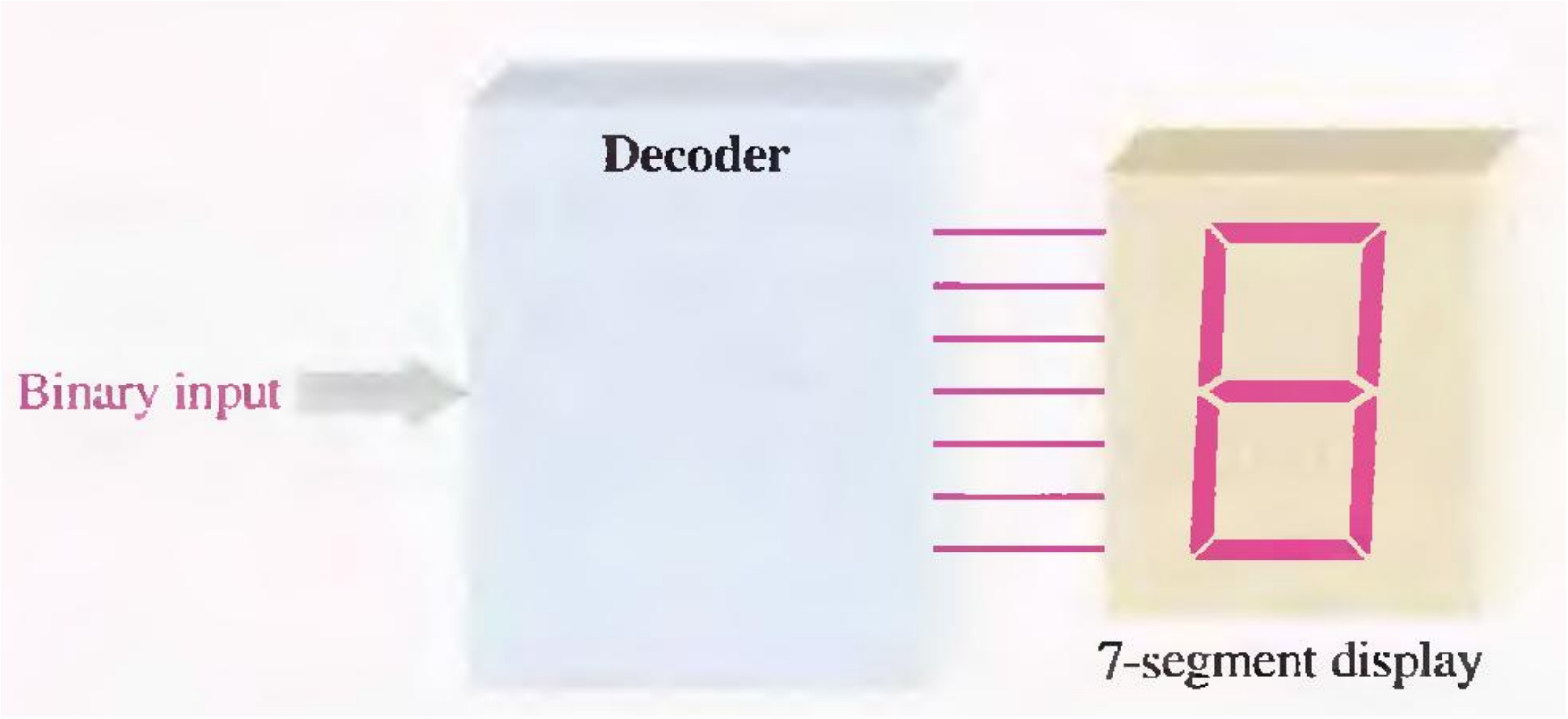
(b) Example: A plus B $(3 + 9 = 12)$

The Encoding Function

- The **encoding** function is performed by a logic circuit called an **encoder**.

The Decoding Function

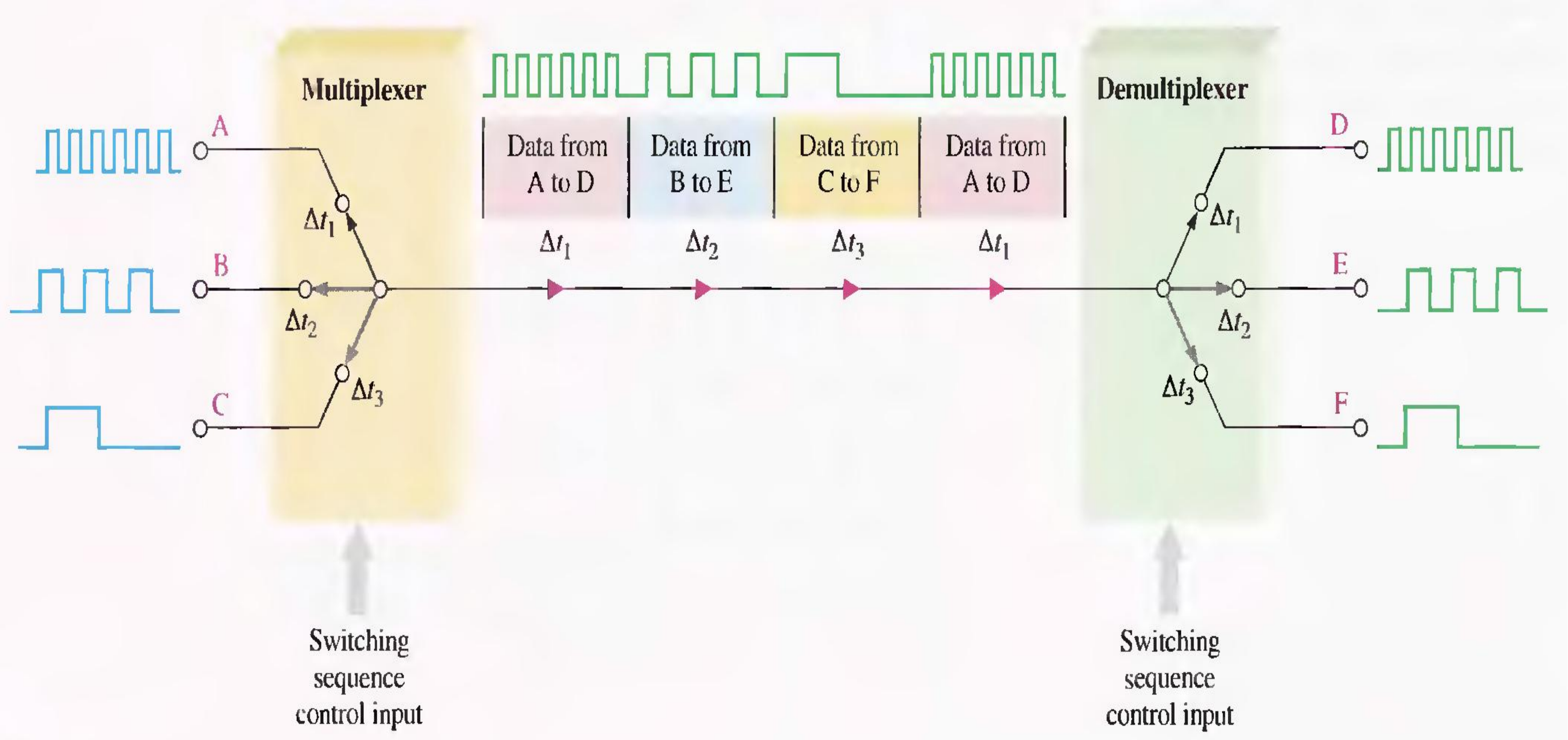
- The **decoding** function is performed by a logic circuit called a **decoder**:



The Data Selection Function

- Two types of circuits that select data
  - **Multiplexer (mux)**: switches digital data from several input lines **onto a single output line** in a specified time sequence.
  - **Demultiplexer (demux)** :switches digital data from one input line **to several output lines** in a specified time.
- The **demux** is a **mux** in <u>reverse</u>.

Example : Data Selection



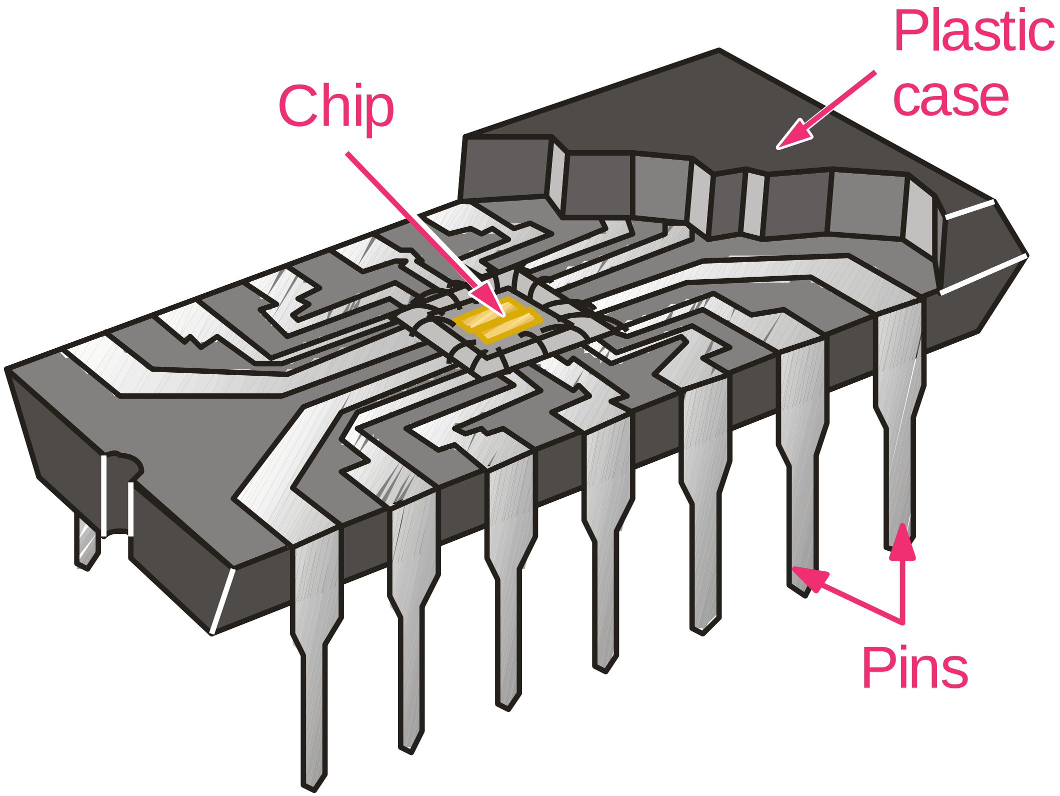
Integrated Circuits (IC)

- All the logic elements and functions that have been discussed generally available in integrated circuit (IC) form.

- Digital systems have incorporated ICs for many years because of
  - small size,
  - high reliability,
  - low cost,
  - low power consumption.

- It is important to be able to recognize the IC packages and to know how the pin connections are numbered, as well as to be familiar with the way in which circuit complexities and circuit technologies determine the various IC classifications.

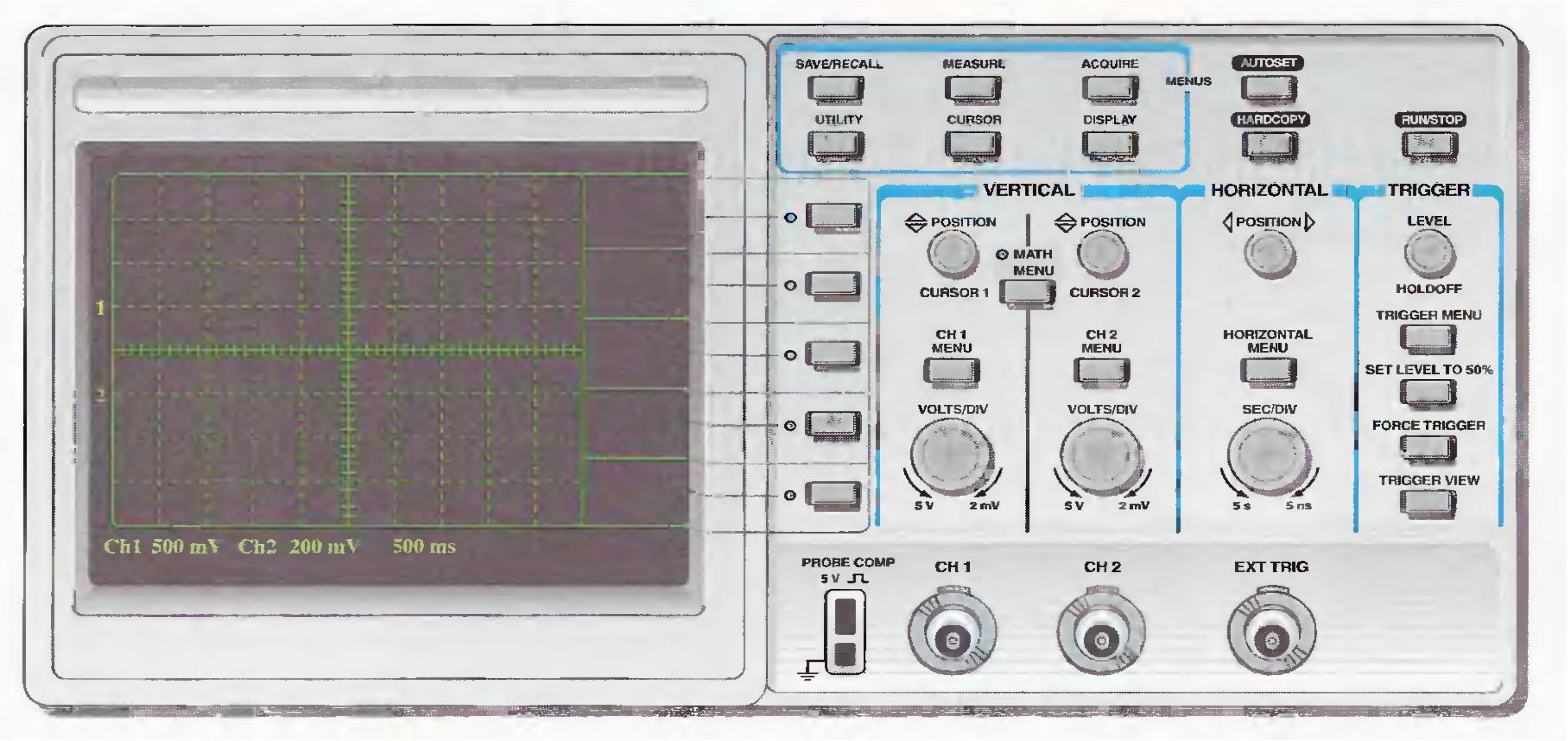
Cutaway view of an IC package



Pin Numbering

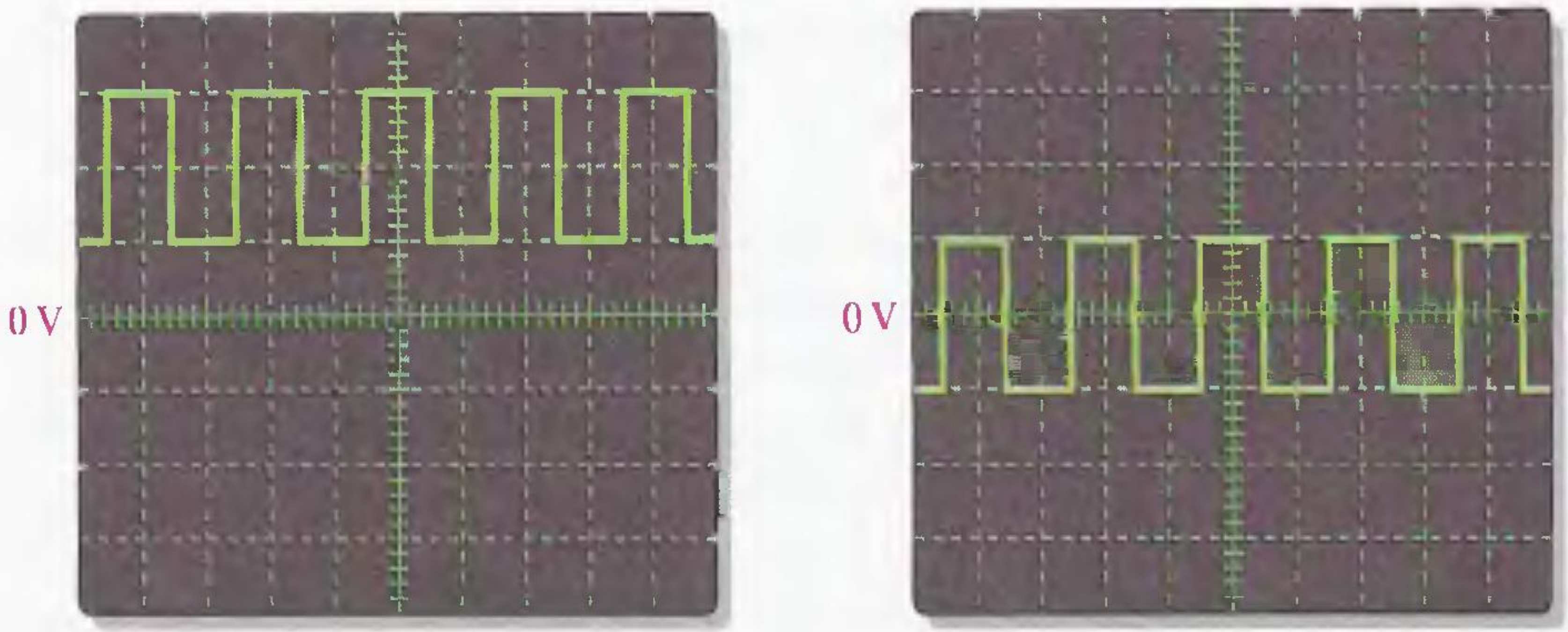
- All IC packages have a standard format for numbering the pins.

Test and Measurement Instruments



A typical dual-channel oscilloscope.

The Oscilloscope



(a) DC coupled waveform (b) AC coupled waveform

… The Oscilloscope

- An oscilloscope voltage probe.

… The Oscilloscope

- Based on the readouts, determine the amplitude and the period of the pulse waveform on the screen of a digital oscilloscope. Also, calculate the frequency.
- V /div setting is 1V.
- time/div 10 μS.