Digital Fundamentals

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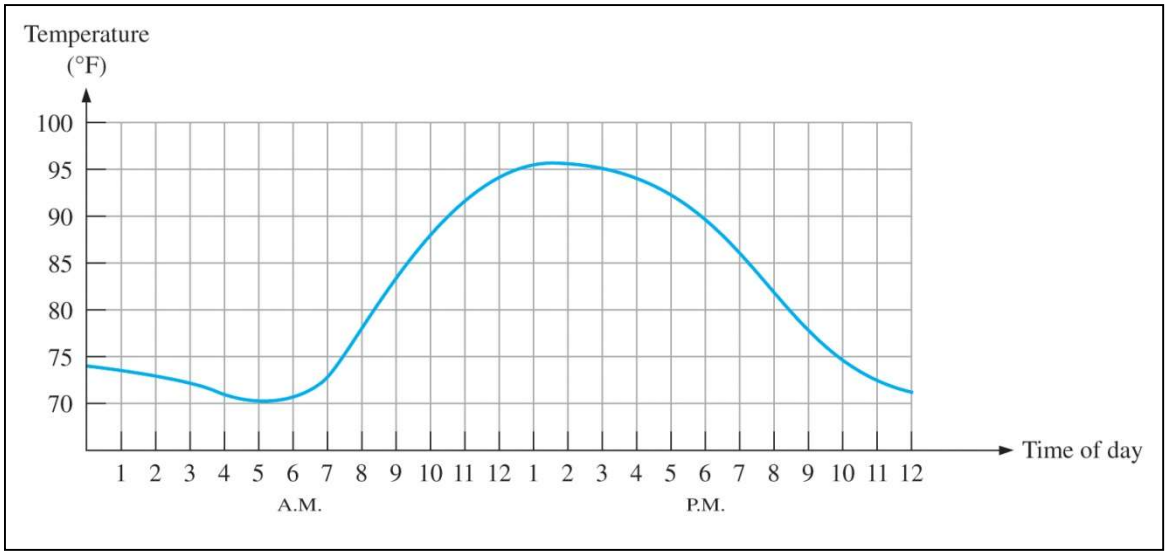
Digital Concepts

Chapter 1

Analog Quantities

Most natural quantities that we see are **analog** and vary continuously. Analog systems can generally handle higher power than digital systems.



Digital systems can process, store, and transmit data more efficiently but can only assign discrete values to each point.

Analog Signals

A waveform that continually varies in a certain manner is classified as an **analog signal**.

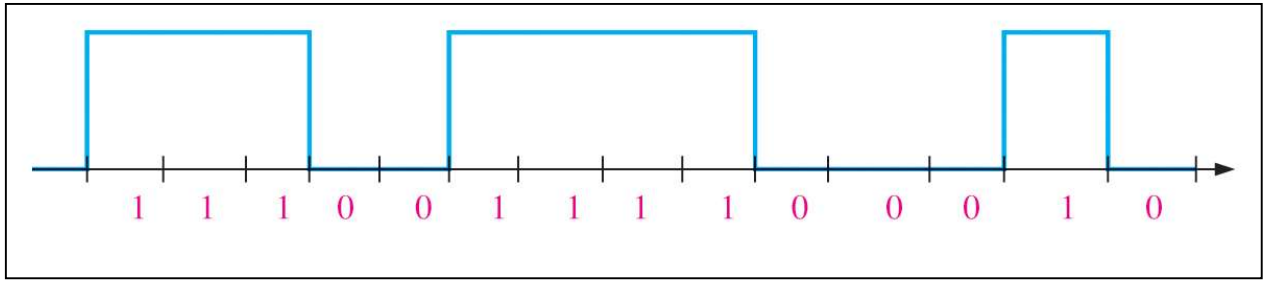
Examples:

- Sine waves
- Audio waves
- Amplitude modulated (AM) signals
- Frequency modulated (FM) signals

Digital Signals

A waveform that represents a sequence of discrete values (1's and 0's) is called a **digital signal**.

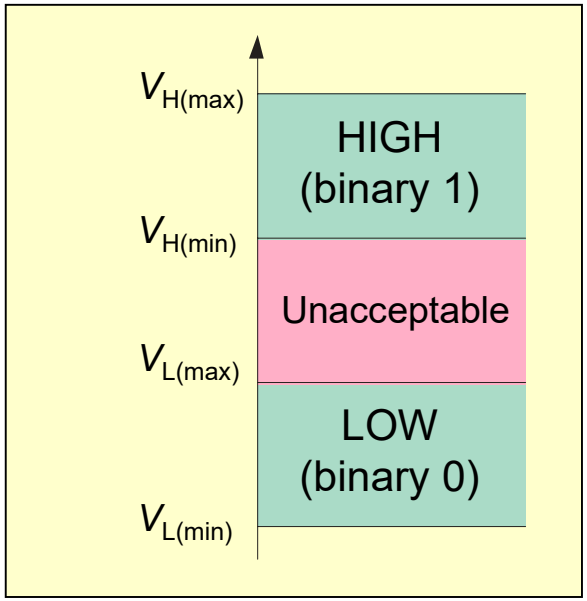
Bit streams are found in telecommunications, computers, and other data system applications.



Binary Digits and Logic Levels

Digital electronics uses circuits that have two states, which are represented by two different voltage levels called HIGH and LOW. The voltages represent numbers in the binary system.

*In binary, a single number is called a **bit** (for **b**inary digi**t**). A bit can have the value of either a 0 or a 1, depending on if the voltage is HIGH or LOW.*

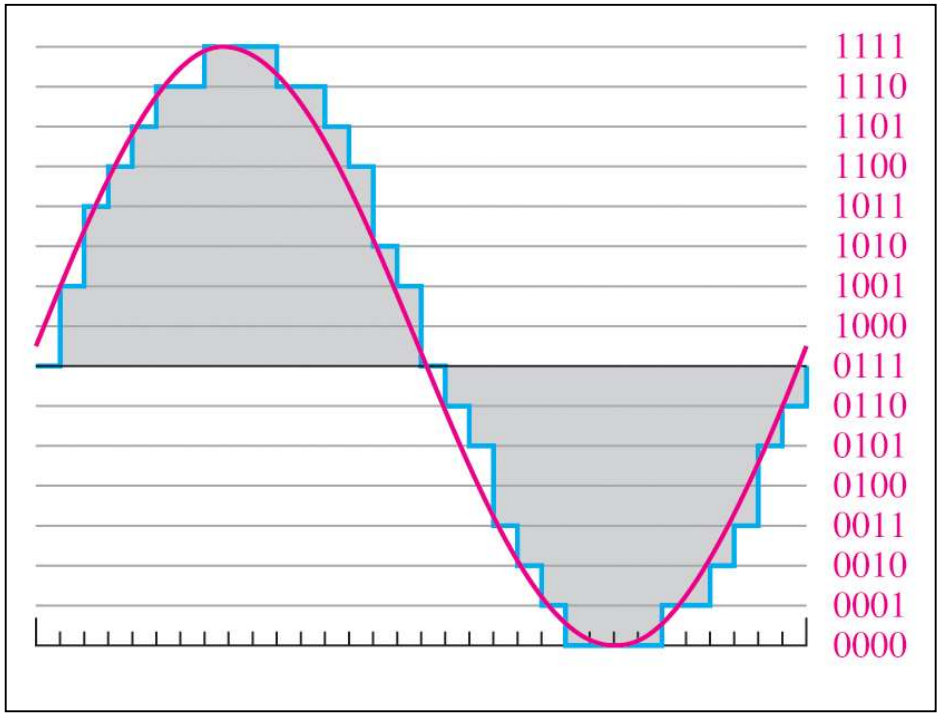


Pulse-code Modulation (PCM)

PCM uses a sequence of digital codes to represent a sampled analog signal.

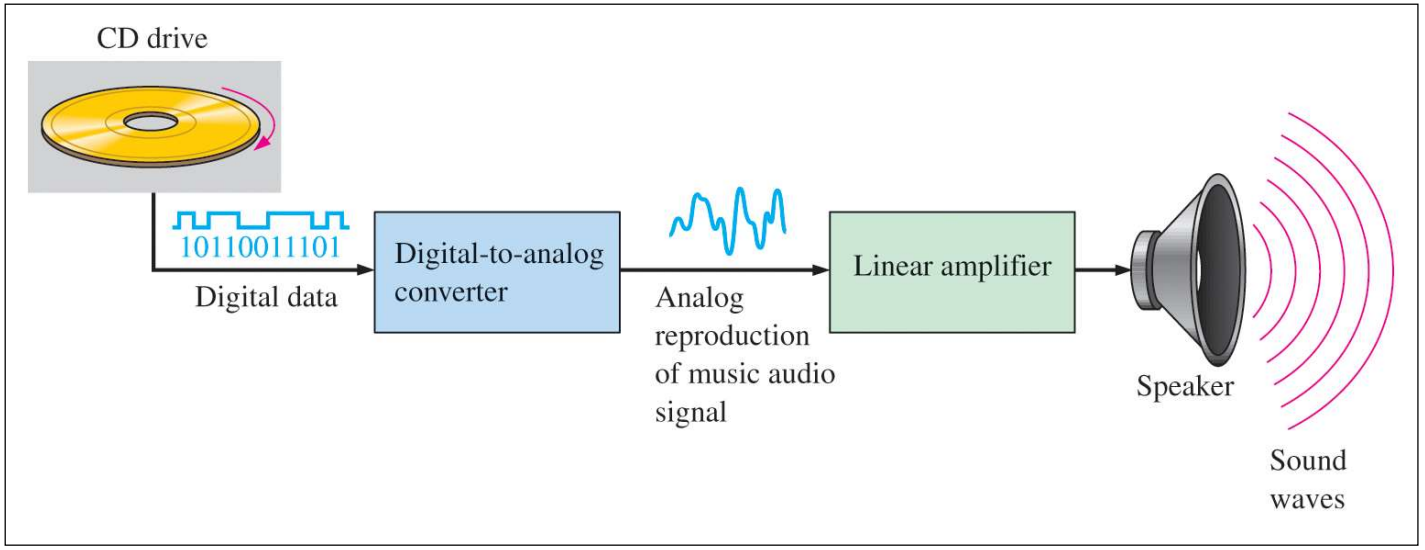
Sampling produces the "stair-step" voltage shown.

The higher the sampling rate, the more accurate the digitized waveform.



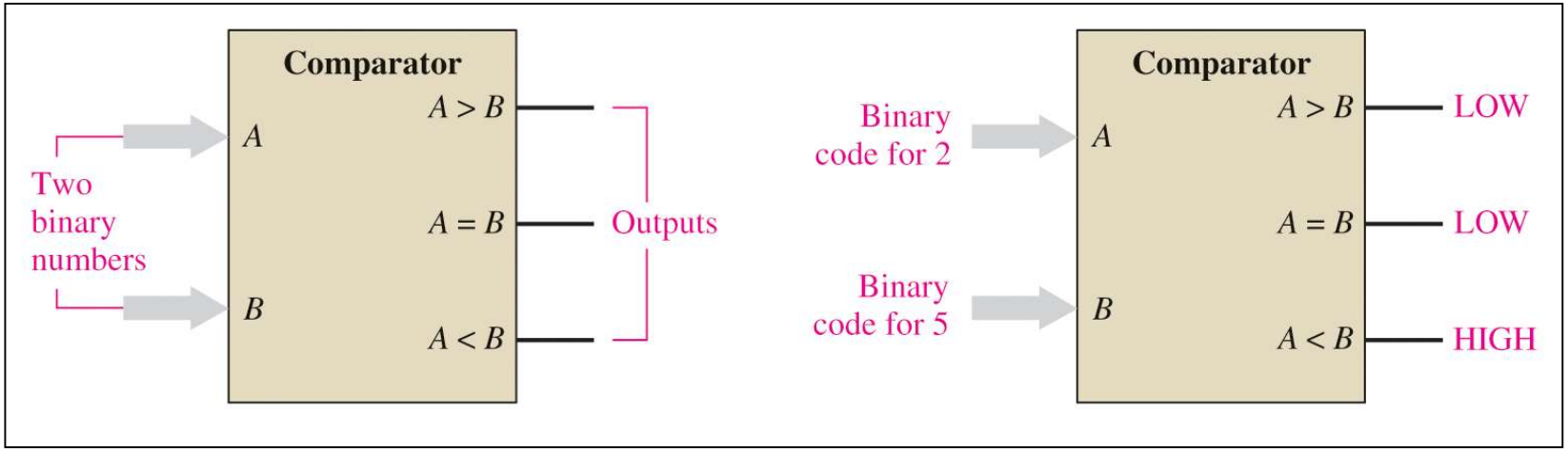
Analog and Digital Systems

Many systems use a mix of analog and digital circuits to utilize the advantages of each. A typical CD player accepts digital data from the CD drive and converts it to an analog signal for amplification.



The Comparison Function

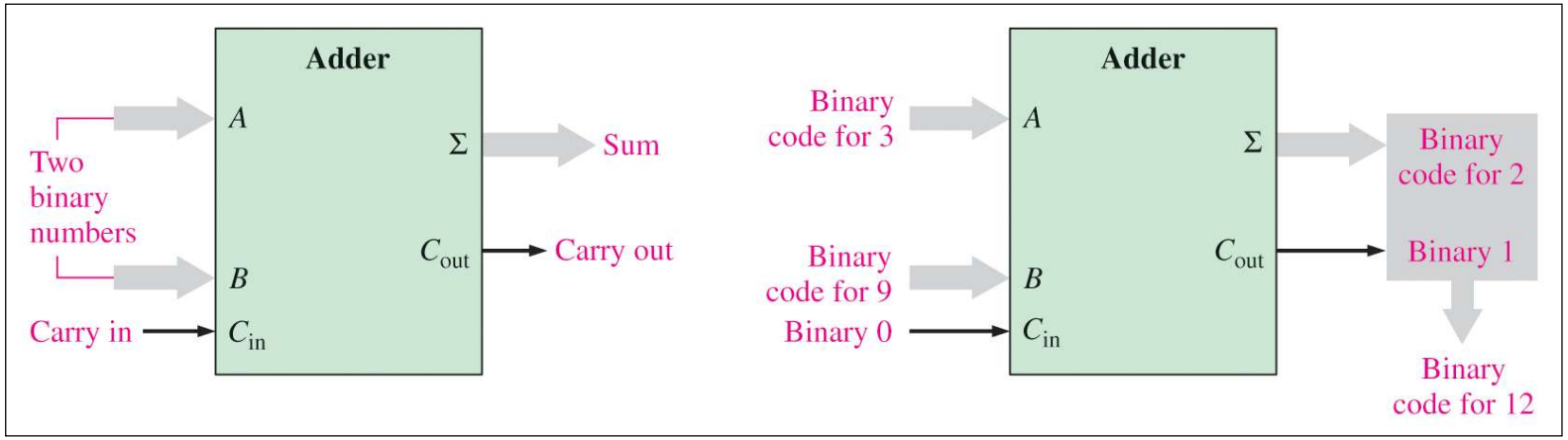
And, **or**, and **not** elements can be combined to form various logic functions. The **comparison function** indicates whether a binary value is greater than, equal to, or less than, another.



The comparison function is performed by a circuit called a **comparator**.

The Arithmetic Functions

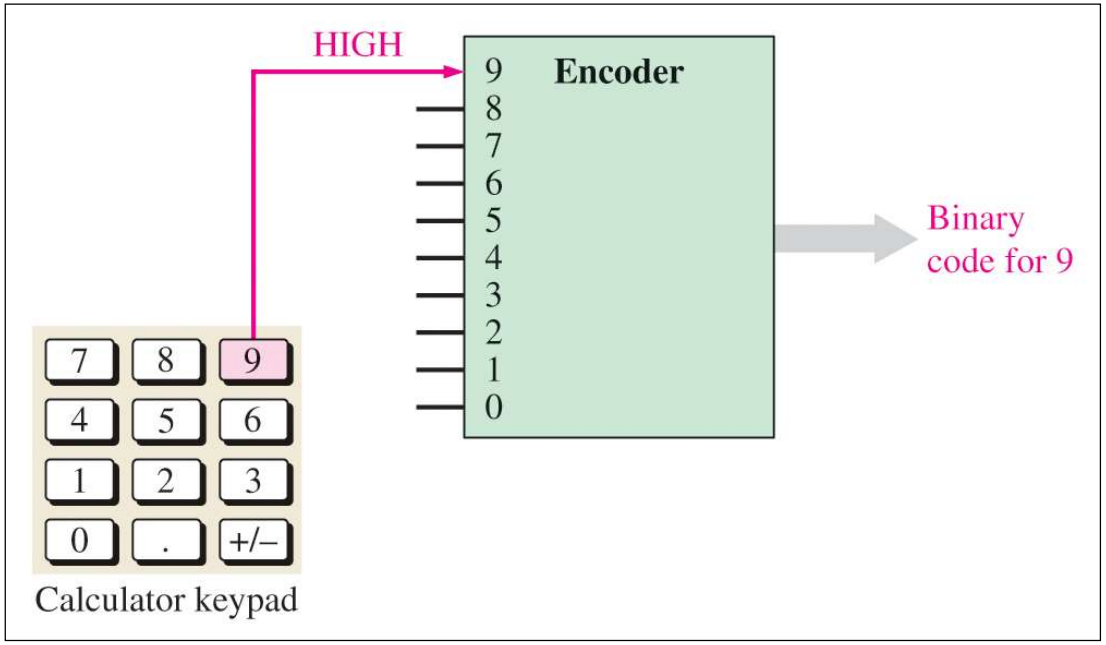
The **arithmetic functions** include addition, subtraction, multiplication, and division.



Addition is performed by an **adder** and subtraction by a **subtracter**. Multiplication and division are performed using circuits that are similar to adders and subtracters.

The Encoder Function

Code: A set of bits arranged in a unique pattern that represents specific information.

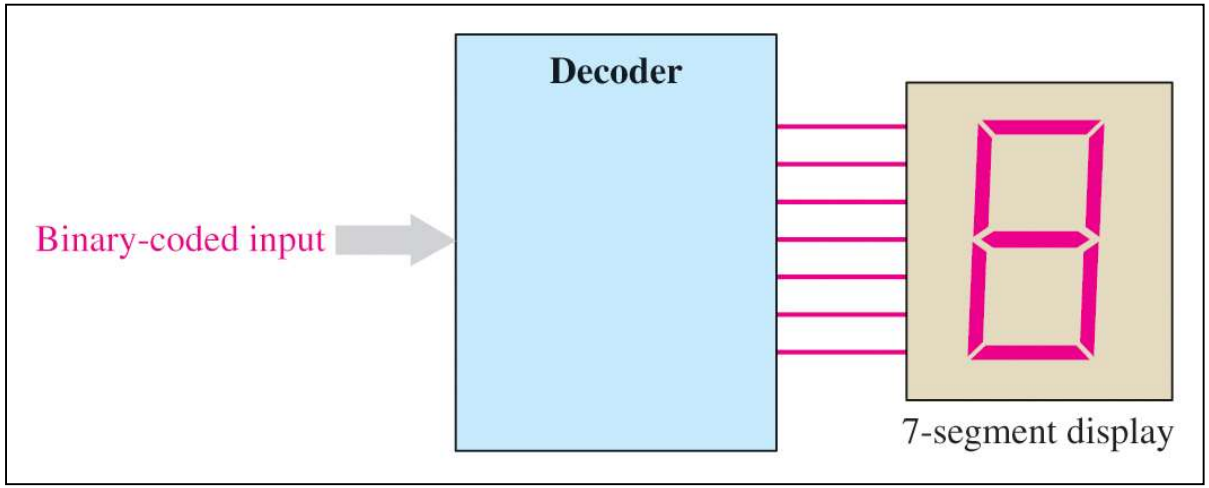


Encoder: A circuit that converts information into a coded form.

The Decoder Function

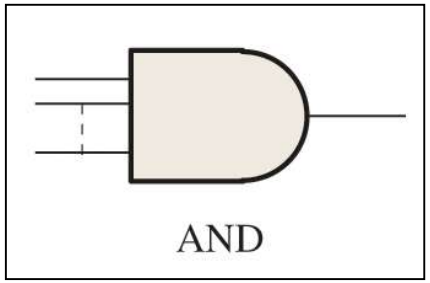
Decoder: A circuit that converts a binary code into a non-binary code of some kind.

Example: The decoder below converts a binary coded input to a form that will light the segments in the 7-segment display required to display a specific character.

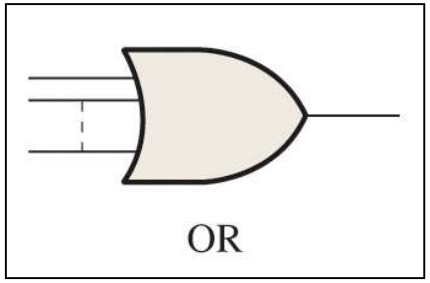


Basic Logic Functions

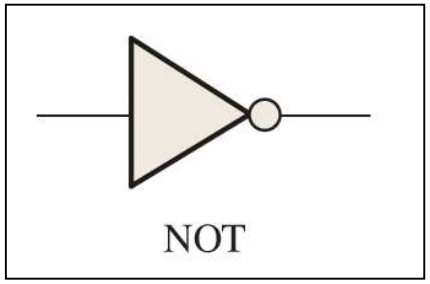
AND Produces a high output only if all inputs are high.



OR Produces a high input if one or more inputs are high.

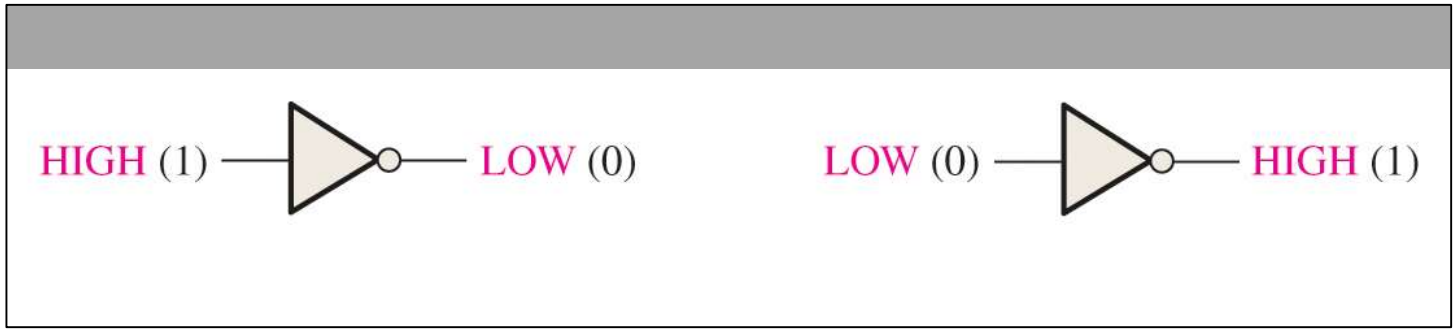


NOT Changes one logic level to the other logic level.



The NOT Operation

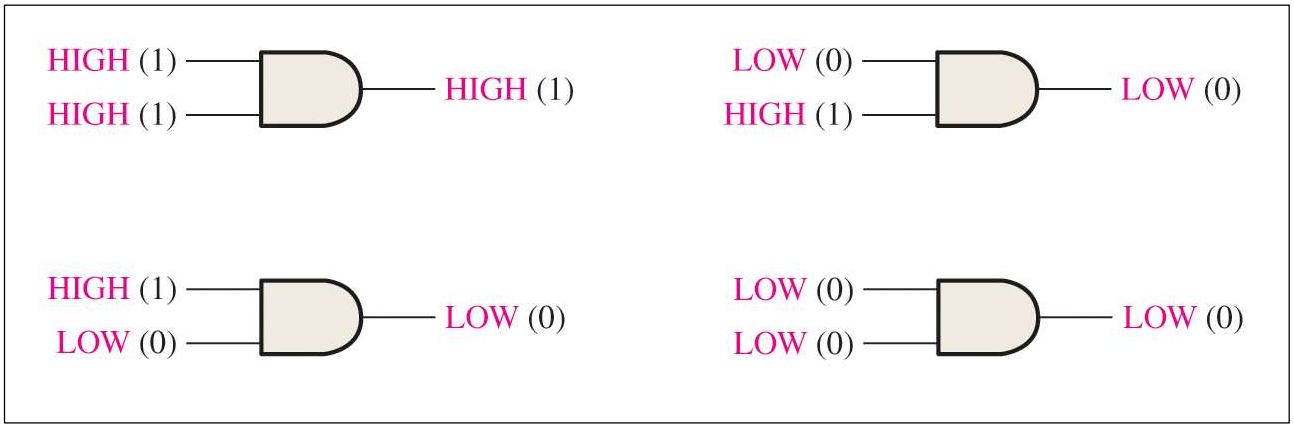
Changes one logic level to the other logic level.



The NOT operation is performed by a circuit called an **inverter**.

The AND Operation

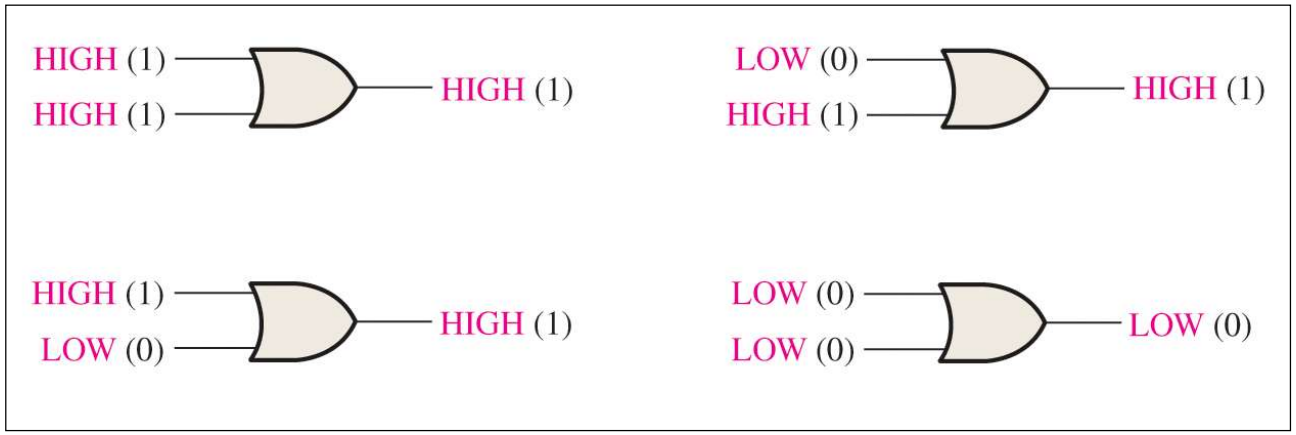
Produces a high output only when ALL inputs are high.



The AND operation is performed by a circuit called an **AND gate**.

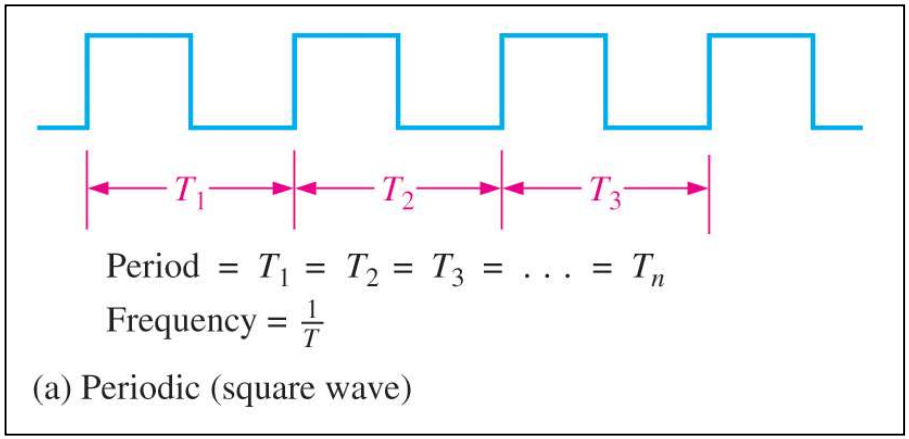
The OR Operation

Produces a high output when one or more inputs are high.

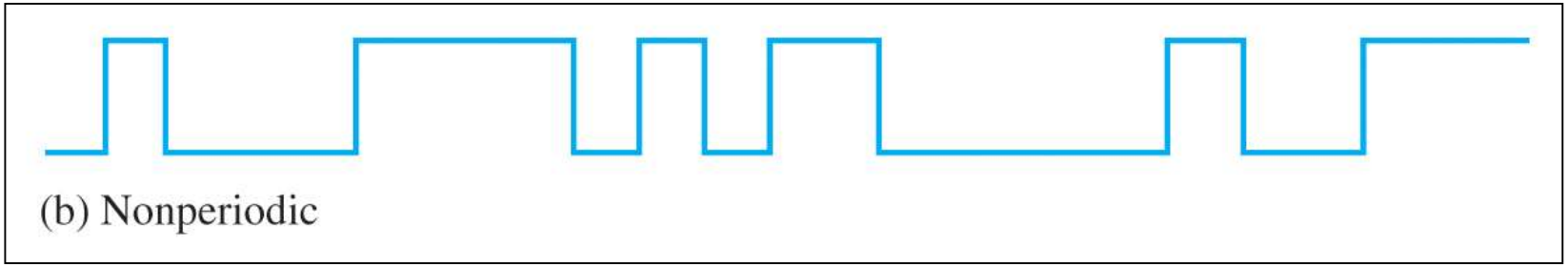


The OR operation is performed by a circuit called an **OR gate**.

Periodic and Nonperiodic Pulse Waveforms



(a) Periodic (square wave)



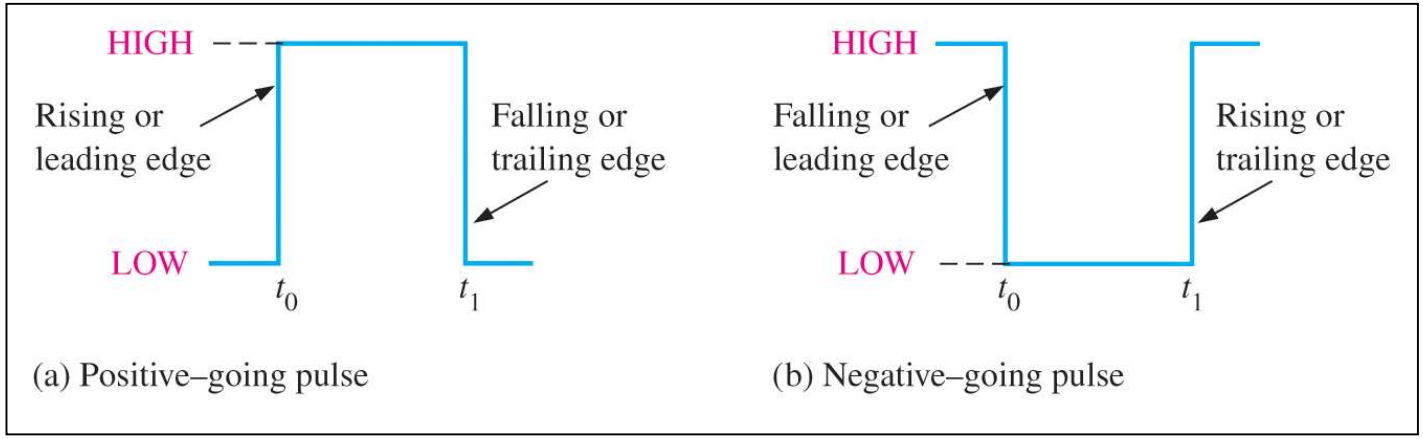
(b) Nonperiodic

Digital Waveforms

Digital waveforms change between the LOW and HIGH levels.

A **positive-going pulse** is one that goes from a normally LOW level to a HIGH level and then back again.

A **negative-going pulse** is one that goes from a normally HIGH level to LOW level and then back again.



Periodic Pulse Waveforms

Periodic pulse waveforms are composed of pulses that repeats in a fixed interval called the **period**. The **frequency** is the rate it repeats and is measured in hertz.

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

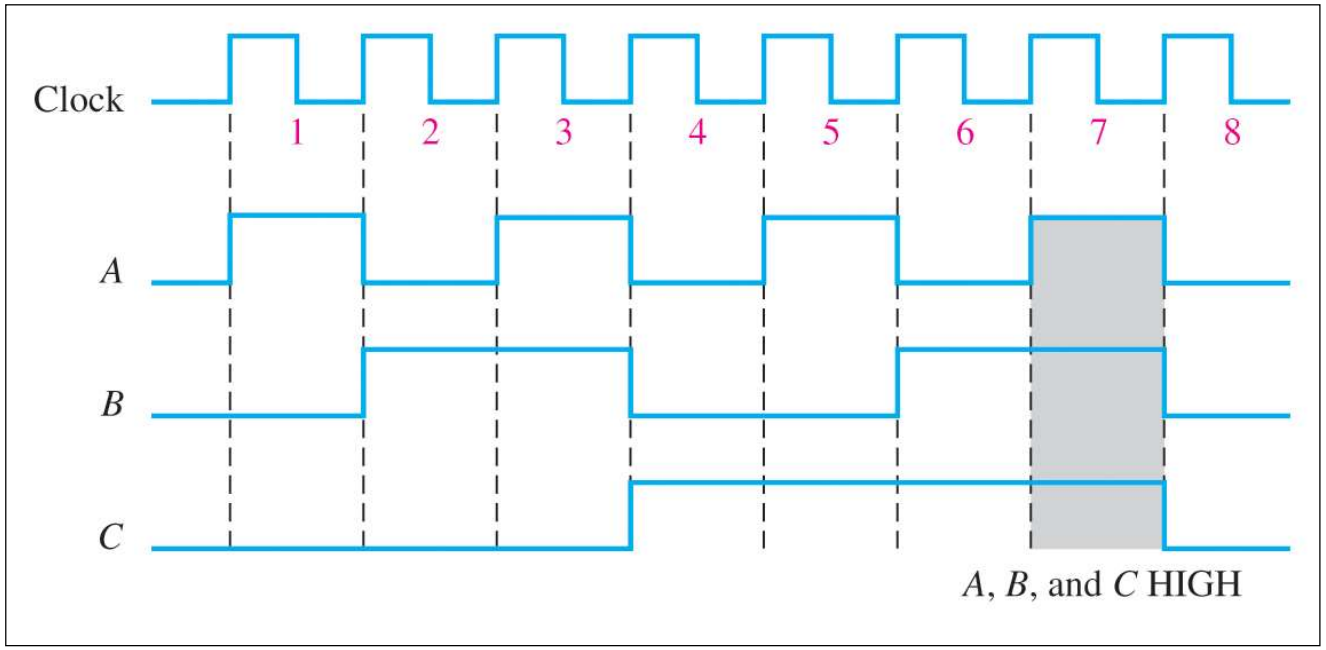
The **clock** is a basic timing signal that is an example of a periodic wave.

What is the period of a repetitive wave if f = 3.2 GHz?

$$T = \frac{1}{f} = \frac{1}{3.2\,\text{GHz}} = \textbf{313 ps}$$

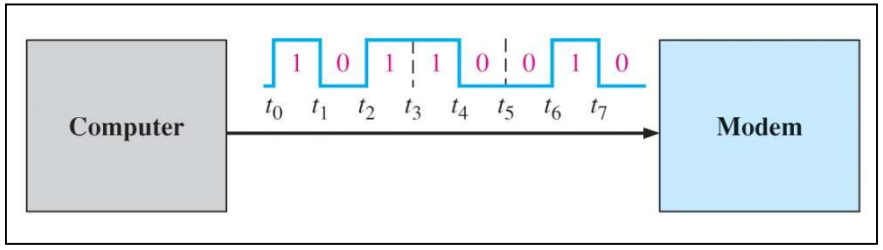
Timing Diagrams

A timing diagram is used to show the relationship between two or more digital waveforms,



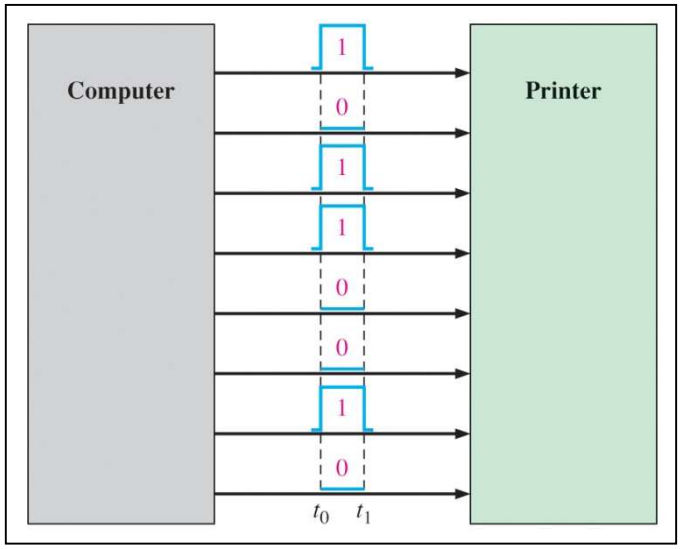
Series and Parallel Data

Data can be transmitted by either serial transfer or parallel transfer.



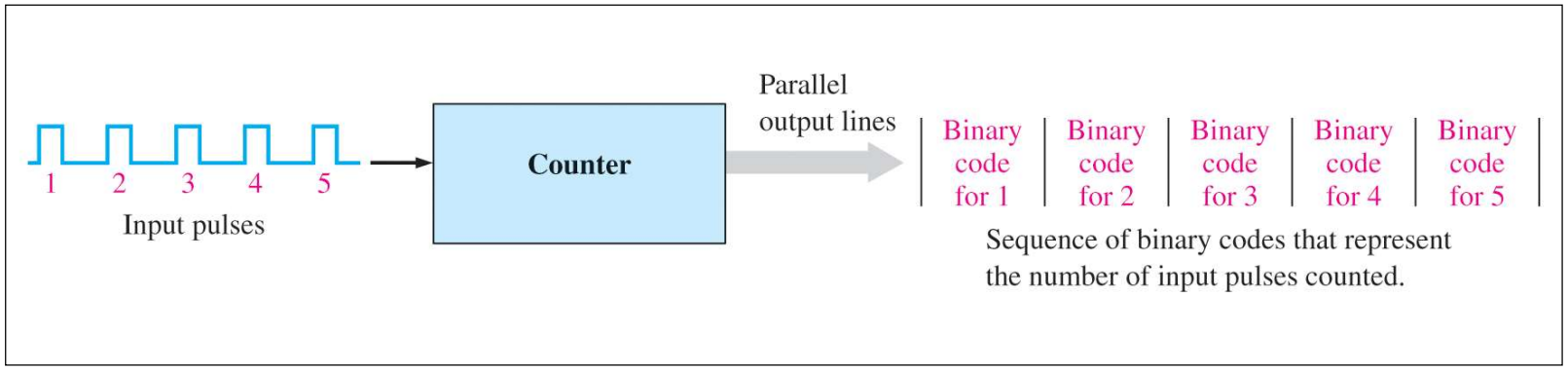
Serial data transfer

Parallel data transfer



The Counting Function

Counter: A sequential device; a **state machine** that has a unique internal sequence of states. Counters are used to count events or to generate output sequences represented by changing levels or pulses.



Pulse Definitions

Actual pulses are not ideal but are described by the rise time, fall time, amplitude, and other characteristics.