Digital Logic Design
Week No. 01

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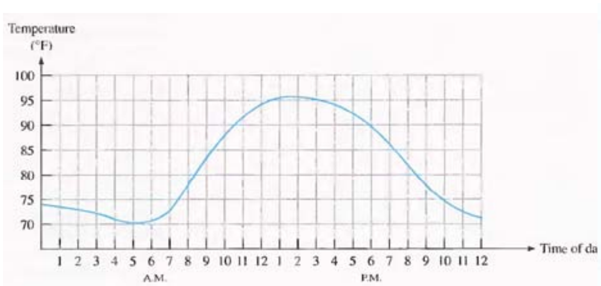
Digital

- The term digital is derived from the way computers perform operations, by counting digits.
- Today, digital technology is applied in a wide range of areas such as computers, television, communications systems, radar, navigation and guidance systems, military systems, medical instrumentation, industrial process control.

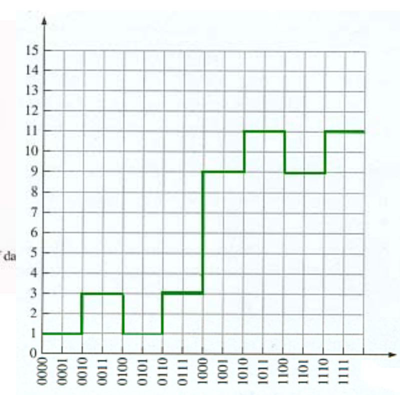
ANALOG QUANTITIES

- An analog quantity is one having continuous values.
  - For example, the air temperature changes over a continuous range of values.
  - During a given day, the temperature does not go from, say, 70°F to 71 °F instantaneously; it takes on all the infinite values in between.
  - If we graphed the temperature we would have a smooth, continuous curve.
  - Other examples of analog quantities are time, pressure, distance, and sound.

Digital and Analog Quantities



Analog quantities have continuous values



Digital quantities have discrete sets of values

DIGITAL QUANTITIES

- A digital quantity is one having a discrete set of values.
  - Digital data can be processed and transmitted more efficiently and reliably than ,analog data.
  - Also, digital data has a great advantage when storage is necessary. For example. music when converted to digital form can be stored more compactly and reproduced with greater accuracy and clarity than is possible when it is in analog form.
  - Noise (unwanted voltage fluctuations) does not affect digital data nearly as much as it does analog signals.

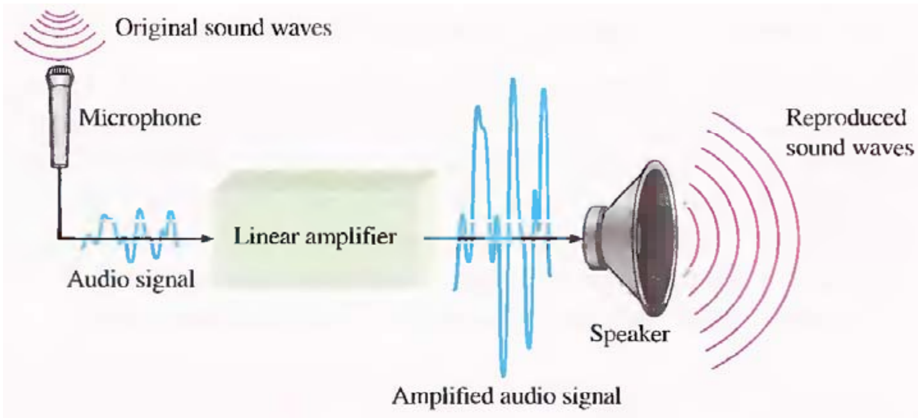
An Analog Electronic System

A public address system, used to amplify sound so that it can be heard by a large audience, is an example of analog electronics.

Sound waves, which are analog in nature, are picked up by a microphone and converted to a small analog voltage called the audio signal.

This voltage varies continuously as the volume and frequency of the sound changes and is applied to the input of a linear amplifier.

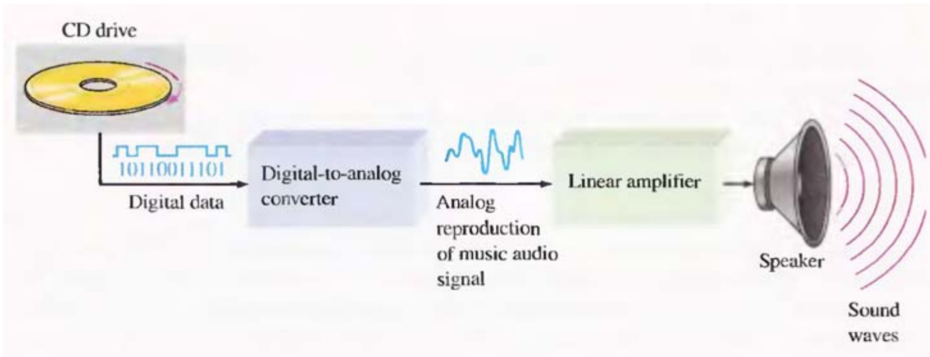
The output of the amplifier, which is an increased reproduction of input voltage, goes to the speaker(s). The speaker changes the amplified audio signal back to sound waves that have a much greater volume than the original sound waves picked up by the microphone.



A basic audio public address system.

A System Using Digital and Analog Methods

- The compact disk (CD) player is an example of a system in which both digital and analog circuits are used.
- Music in digital form is stored on the compact disk. A laser diode optical system picks up the digital data from the rotating disk and transfers it to the digital-to-analog converter (DAC).
- The DAC changes the digital data into an analog signal that is an electrical reproduction of the original music. This signal is amplified and sent to the speaker.



Basic block diagram of a CD player. Only one channel is shown.

BINARY DIGITS, LOGIC LEVELS, AND DIGITAL WAVEFORMS

- Digital electronics involves circuits and systems in which there are only two possible states. These states are represented by two different voltage levels: A HIGH and a LOW.
- In digital systems, combinations of the two states, called codes, are used to represent numbers, symbols, alphabetic characters, and other types of information.
- The two-state number system is called binary, and its two digits are 0 and 1. A binary digit is called a bit.
- 1 is represented by the higher voltage, and a 0 is represented by the lower voltage level.

  HIGH = 1 and LOW = 0

Logic Levels :

The voltages used to represent a 1 and a 0 are called logic levels. Ideally, one voltage level represents a HIGH and another voltage level represents a LOW.

In a practical digital circuit, a HIGH can be any voltage between a specified minimum value and a specified maximum value. Likewise, a LOW can be any voltage between a specified minimum and a specified maximum.

There can be no overlap between the accepted range of HIGH levels and the accepted range of LOW levels.

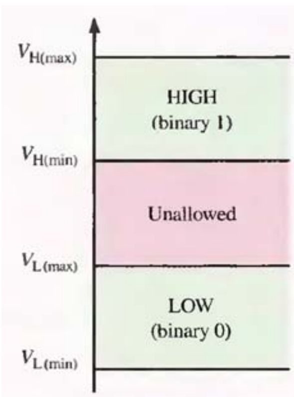


FIGURE 1–5

Logic level ranges of voltage for a digital circuit.

For example, the HIGH values for a certain type of digital circuit called CMOS may range from 2 V to 3.3 V and the LOW values may range from o V to 0.8 V.

For example, if a voltage of 2.5 V is applied, the circuit will accept it as a HIGH or binary 1.

If a voltage of 0.5 V is applied, the circuit will accept it as a LOW or binary O.

For this type of circuit, voltages between 0.8 V and 2 V are unacceptable.

Digital Waveforms

- Digital waveforms consist of voltage levels that are changing back and forth between the HIGH and LOW levels or states.
- Figure l-6(a) shows that a single positive-going pulse is generated when the voltage (or current) goes from its normally LOW level to its HIGH level and then back to its LOW level.
- The negative-going pulse in Figure 1-6(b) is generated when the voltage goes from its normally HIGH level to its LOW level and back to its HIGH level. A digital waveform is made up of a series of pulses.

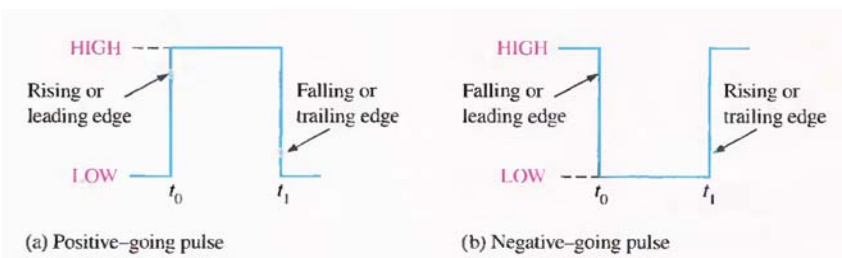


FIGURE 1–6 Ideal pulses.

As indicated in Figure 1-6, a pulse has two edges: a leading edge that occurs first at time to and a trailing edge that occurs last at time t 1 .

For a positive-going pulse, the leading edge is a rising edge, and the trailing edge is a falling edge.

Waveform Characteristics

- Most Wave forms encountered in digital systems are composed of series of pulses, sometimes called pulse trains, and can be classified as either periodic or nonperiodic.

- A periodic pulse waveform is one that repeats itself at a fixed interval, called a period (T).
  - The frequency (f) is the rate at which it repeats itself and is measured in hertz (Hz).

- 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.

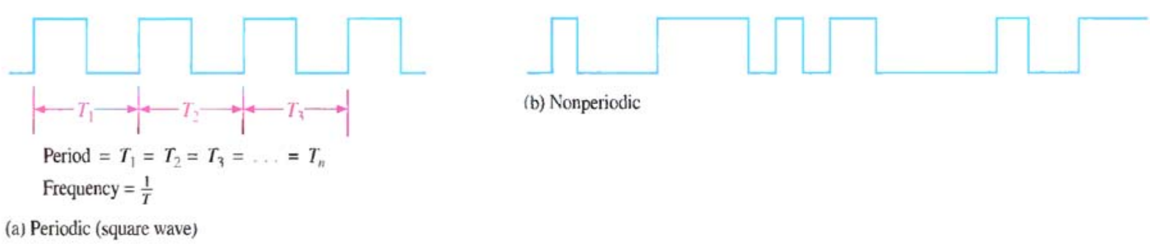


FIGURE 1–8

Examples of digital waveforms.

The frequency (f) of a pulse (digital) waveform is the reciprocal of the period. The relationship between frequency and period is expressed as follows:

Equation 1–1
$$f = \frac{1}{T}$$

Equation 1–2
$$T = \frac{1}{f}$$

An important characteristic of a periodic digital waveform is its **duty cycle,** which is the ratio of the pulse width (t_W) to the period (T). It can be expressed as a percentage.

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

Equation 1–3

EXAMPLE 1–1

A portion of a periodic digital waveform is shown in Figure 1–9. The measurements are in milliseconds. Determine the following:

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

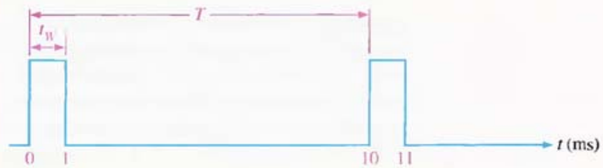


FIGURE 1–9

Solution **(a)** The period is measured from the edge of one pulse to the corresponding edge of the next pulse. In this case T is measured from leading edge to leading edge, as indicated. T equals **10 ms.**

(b) $f = \frac{1}{T} = \frac{1}{10\text{ ms}} = \mathbf{100\ Hz}$

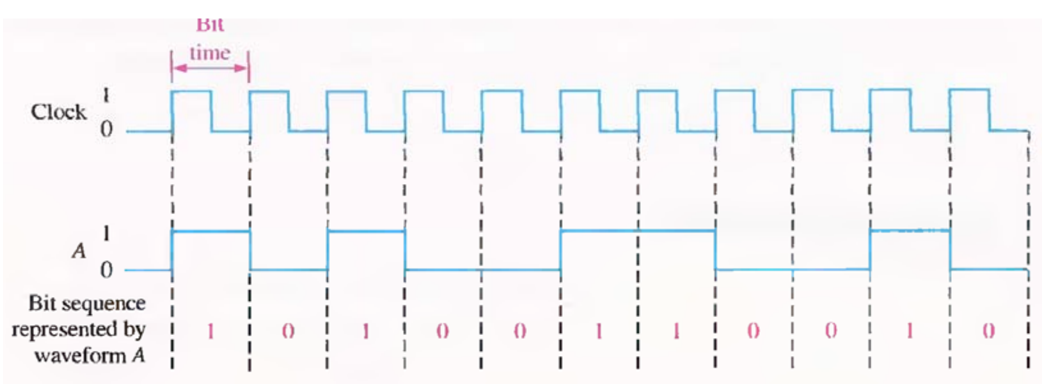
(c) Duty cycle $= \left(\frac{t_W}{T}\right)100\% = \left(\frac{1\text{ ms}}{10\text{ ms}}\right)100\% = \mathbf{10\%}$

*Related Problem** A periodic digital waveform has a pulse width of 25 μs and a period of 150 μs. Determine the frequency and the duty cycle.

A Digital Waveform Carries Binary Information

Binary information that is handled by digital systems appears as waveforms that represent sequences of bits. When the waveform is HIGH, a binary 1 is present; when the waveform is LOW, a binary 0 is present. Each bit in a sequence occupies a defined time interval called a **bit time.**

The Clock: In digital systems, all waveforms are synchronized with a basic timing waveform called the clock.



Timing Diagrams

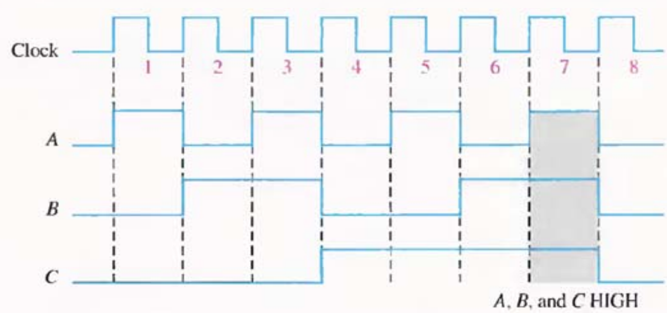
- A timing diagram is a graph of digital waveforms showing the actual time relationship of two or more waveforms and how each waveform changes in relation to the others.

- By looking at a timing diagram, we can determine the states (HIGH or LOW) of all the waveforms at any specified point in time and the exact time that a waveform changes state relative to the other waveforms.

- Figure 1.11 is an example of a timing diagram made up of four waveforms.

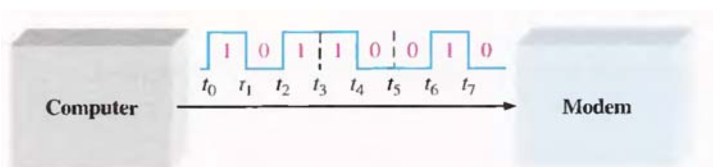
FIGURE 1–11

Example of a timing diagram.



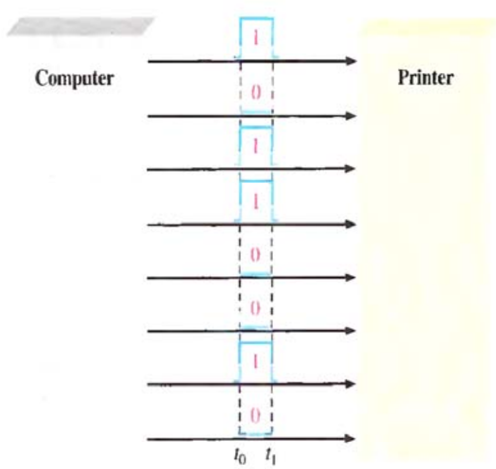
Data Transfer

- Data refers to groups of bits that convey some type of information.
- Binary data, which are 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.
- When bits are transferred in serial form from one point to another, they are sent one bit at a time along a single line, as illustrated in Figure 1-12(a) for the case of a computer-to- modem transfer.
  - During the time interval from to to t" the first bit is transferred. During the time interval from t, to t 2 , the second bit is transferred, and so on.
  - To transfer eight bits in series, it takes eight time intervals.



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

FIGURE 1–12



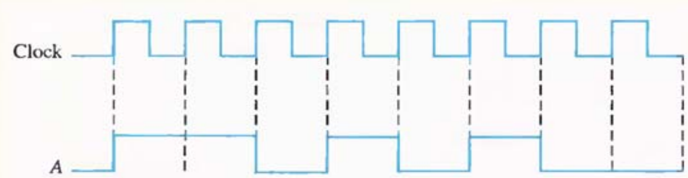
(b) Parallel transfer of 8 bits of binary data from computer to printer. The beginning time is t_0.

- When bits are transferred in parallel form, all the bits in a group are sent out on separate lines at the same time. There is one line for each bit, as shown in Figure 1-12(b) for the example of eight bits being transferred from a computer to a printer.

- To transfer eight bits in parallel, it takes one time interval compared to eight time intervals for the serial transfer.

(a) Determine the total time required to serially transfer the eight bits contained in waveform A of Figure 1–13, 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?



▲ **FIGURE 1–13**

Solution **(a)** 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

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

To determine the sequence of bits, examine the waveform in Figure 1–13 during each bit time. If waveform A is HIGH during the bit time, a 1 is transferred. If waveform A is LOW during the bit time, a 0 is transferred. The bit sequence is illustrated in Figure 1–14. The left-most bit is the first to be transferred.

▲ FIGURE 1–14

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