Digital Systems:

A Digital System is a combination of devices designed to manipulate logical information or physical quantities that are represented in digital form; that is, the quantities can take only discrete values. Digital systems are used extensively in computation and data processing, control systems, communications, and measurement.

Because digital systems are capable of greater accuracy and reliability than analog systems, many tasks formerly done by analog systems are now being performed digitally. 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.

In a digital system, the physical quantities or signals can assume only discrete values, while in analog systems the physical quantities or signals may vary continuously over a specified range. For example, the output voltage of a digital system might be constrained to take on only two values such as 0 volts and 5 volts, while the output voltage from an analog system might be allowed to assume any value in the range −10 volts to +10 volts.

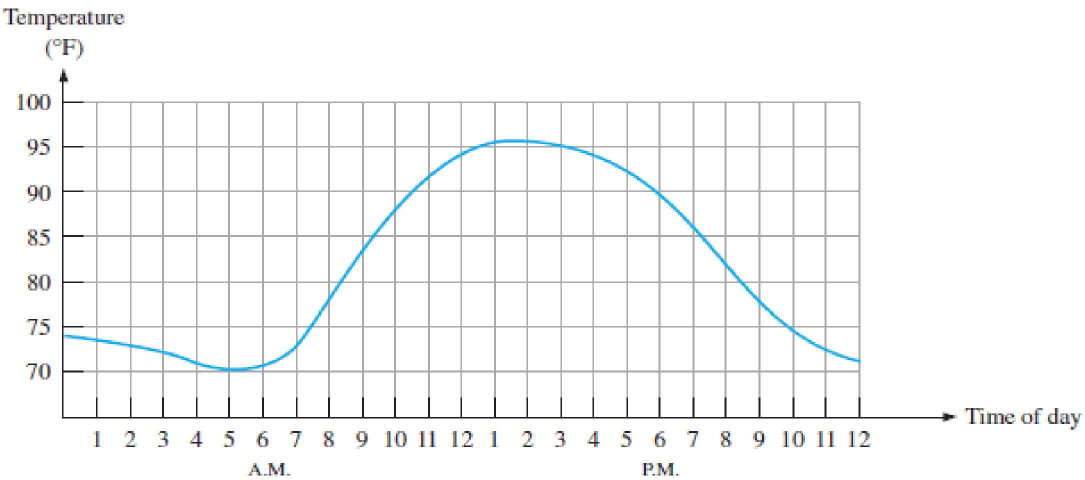
Because digital systems work with discrete quantities, in many cases they can be designed so that for a given input, the output is exactly correct. For example, if we multiply two 5-digit numbers using a digital multiplier, the 10-digit product will be correct in all 10 digits. On the other hand, the output of an analog multiplier might have an error ranging from a fraction of one percent to a few percent depending on the accuracy of the components used in construction of the multiplier.

Digital and Analog Quantities:

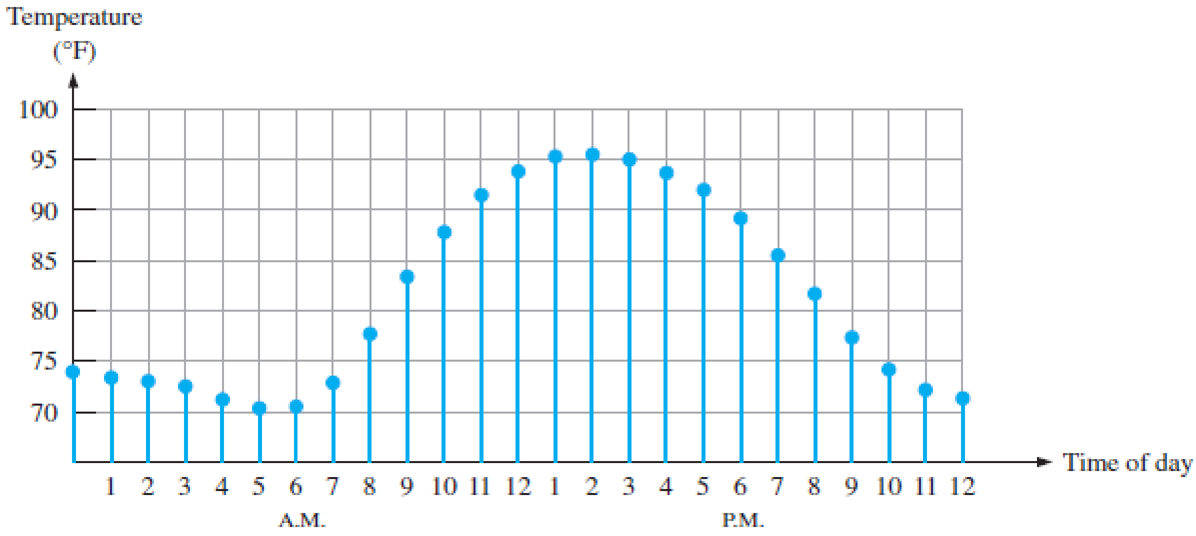
Electronic circuits can be divided into two broad categories, digital and analog. Digital electronics involves quantities with discrete values, and analog electronics involves quantities with continuous values.

An analog quantity is one having continuous values. A digital quantity is one having a discrete set of values. Most things that can be measured quantitatively occur in nature in analog form. For example, the air temperature changes over a continuous range of values.

During a given day, the temperature does not go from, say, 70° to 71° instantaneously; it takes on all the infinite values in between. If you graphed the temperature on a typical summer day, you would have a smooth, continuous curve similar to the curve in Figure below. Other examples of analog quantities are time, pressure, distance, and sound.



Rather than graphing the temperature on a continuous basis, suppose you just take a temperature reading every hour. Now you have sampled values representing the temperature at discrete points in time (every hour) over a 24-hour period, as indicated in Figure below. You have effectively converted an analog quantity to a form that can now be digitized by representing each sampled value by a digital code.



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 such as computers, 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.*

Binary Digits:

Each of the two digits in the binary system, 1 and 0, is called a bit, which is a contraction of the words binary digit. In digital circuits, two different voltage levels are used to represent the two bits. Generally, 1 is represented by the higher voltage, which we will refer to as a HIGH, and a 0 is represented by the lower voltage level, which we will refer to as a LOW.

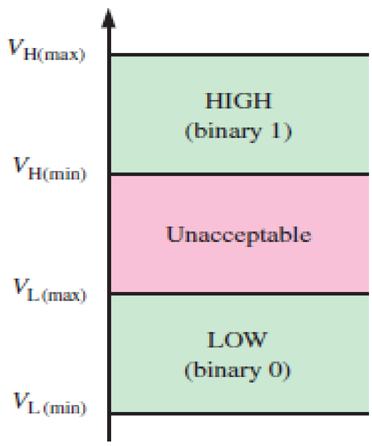
HIGH = 1 and LOW = 0

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, however, 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 specified maximum. There can be no overlap between the accepted range of HIGH levels and the accepted range of LOW levels.

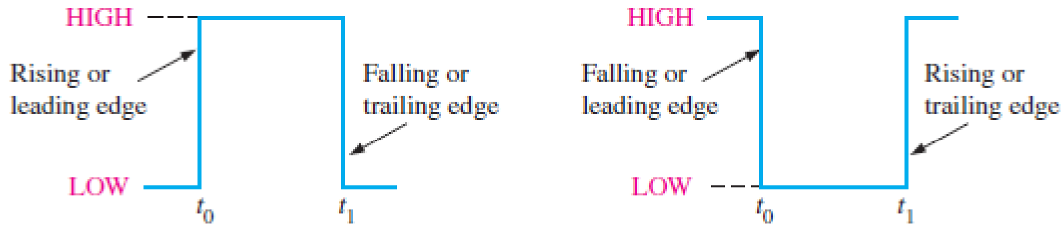
Figure below illustrates the general range of LOWs and HIGHs for a digital circuit. The variable VH(max) represents the maximum HIGH voltage value, and VH(min) represents the minimum HIGH voltage value. The maximum LOW voltage value is represented by VL(max), and the minimum LOW voltage value is represented by VL(min). The voltage values between VL(max) and VH(min) are unacceptable for proper operation.

A voltage in the unacceptable range can appear as either a HIGH or a LOW to a given circuit. For example, the HIGH input values for a certain type of digital circuit technology may range from 2 V to 5 V and the LOW input values may range from 0 V to 0.8 V. If a voltage of 2.5 V is applied, the circuit will accept it as a HIGH or binary 1.



Digital Waveforms:

Digital waveforms consist of voltage levels that are changing back and forth between the HIGH and LOW levels or states. Figure below(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 below(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.



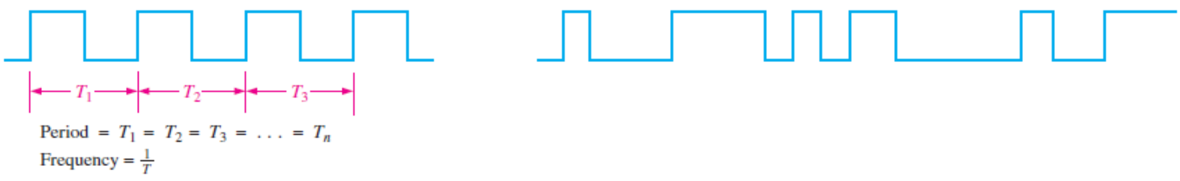
(a) Positive–going pulse

(b) Negative–going pulse

Waveform Characteristics:

Most waveforms 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 period (T). A nonperiodic pulse waveform, of course, 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. An example of each type is shown in Figure below.



(a) Periodic (square wave)

(b) Nonperiodic

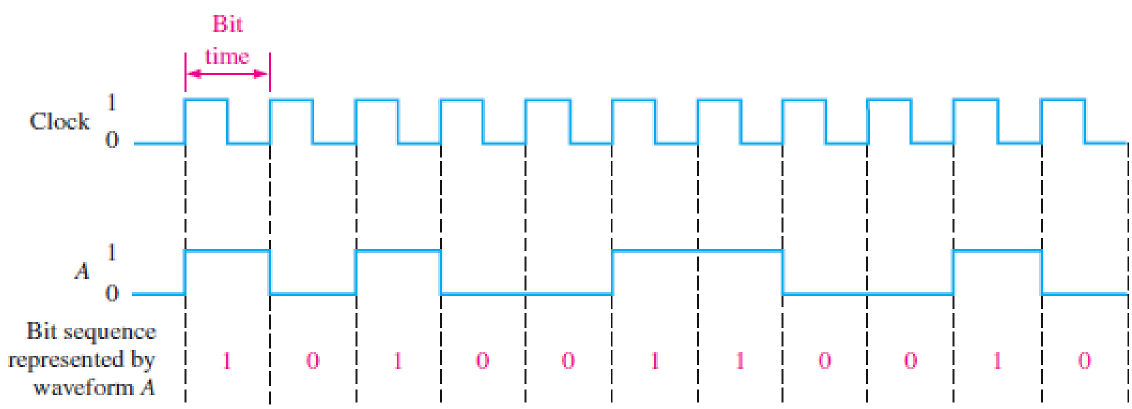
A Digital Waveform Carries Binary Information:

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:

An example of a clock waveform is shown in Figure below. Notice that, in this case, each change in level of waveform *A* occurs at the leading edge of the clock waveform. In other cases, level changes occur at the trailing edge of the clock. During each bit time of the clock, waveform *A* is either HIGH or LOW. These HIGHs and LOWs represent a sequence of bits as indicated. A group of several bits can contain binary information, such as a number or a letter. The clock waveform itself does not carry information.

In digital systems, all waveforms are synchronized with a basic timing waveform called the clock. The clock is a periodic waveform in which each interval between pulses (the period) equals the time for one bit.



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, you 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 below is an example of a timing diagram made up of four waveforms. From this timing diagram you can see, for example, that the three waveforms *A*, *B*, and *C* are HIGH only during bit time 7 (shaded area) and they all change back LOW at the end of bit time 7.