Digital Electronic

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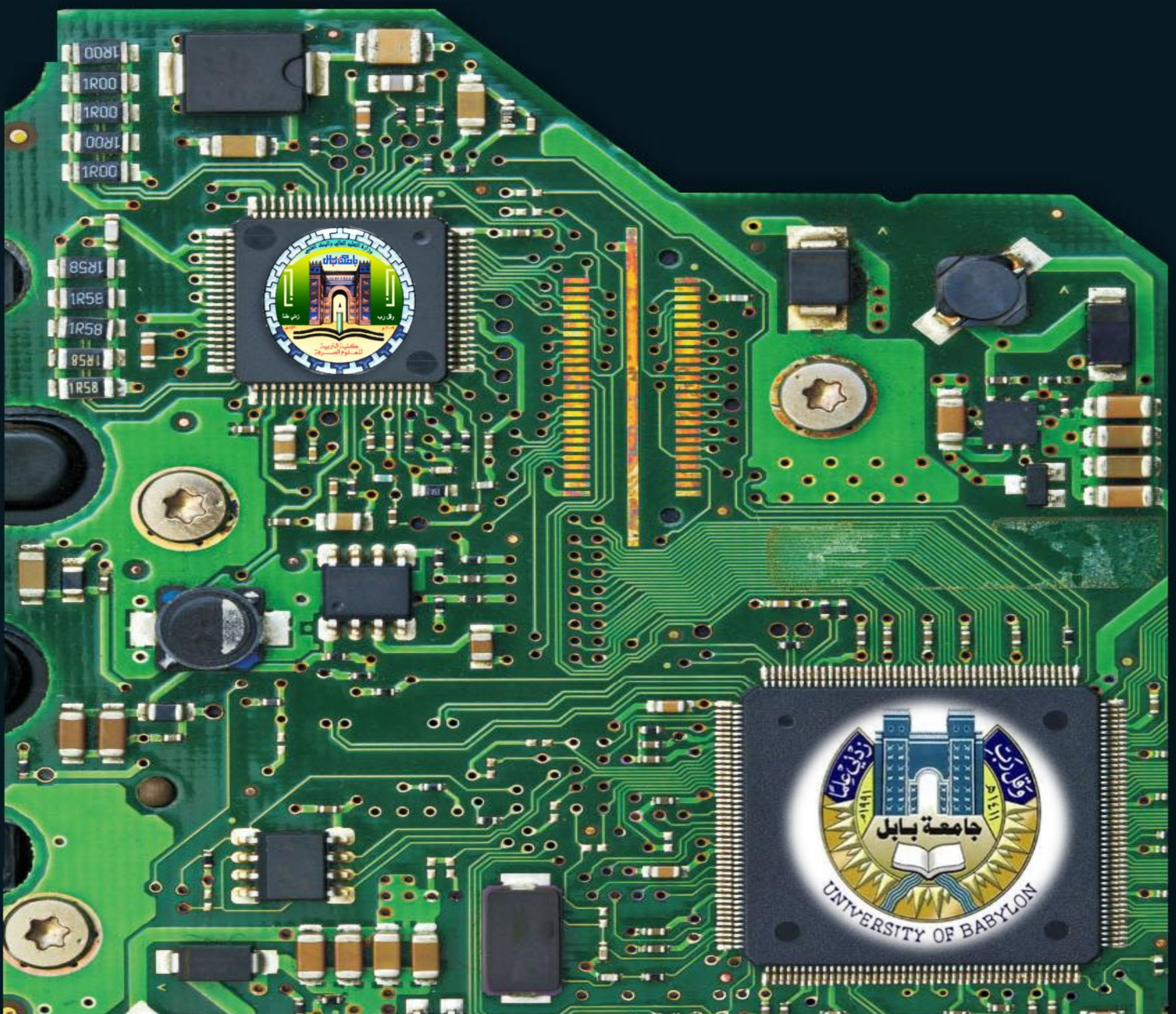


CHAPTER 1

INTRODUCTORY

1.1 Basic Concepts

Digital electronics is a field of electronics involving the study of digital signals and the engineering of devices that use or produce them. This is in contrast to analog electronics and analog signals.

Digital representation has certain advantages over analog representation in electronics applications:

1. Digital data can be processed and transmitted more efficiently and reliably than analog data.
2. Digital data has a great advantage when storage is necessary. For example, audio 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.
3. Noise (unwanted voltage fluctuations) does not affect digital data nearly as much as it does analog signals.
4. Digital circuitry is the foundation of digital computers, home appliances, alarm systems, heating systems, automated machine control, inventory management, medical electronics, etc….

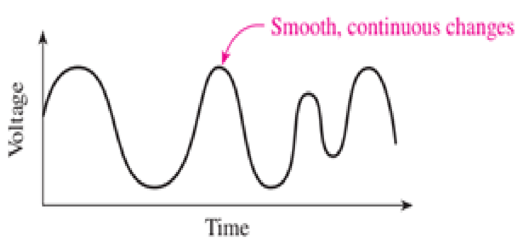
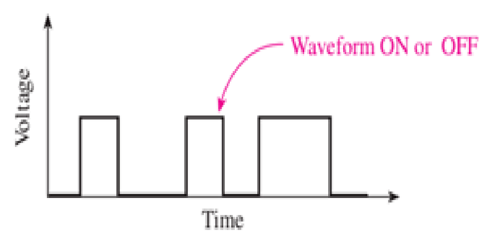
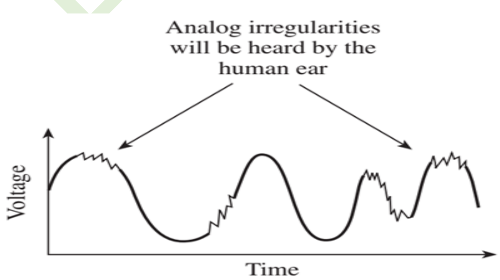
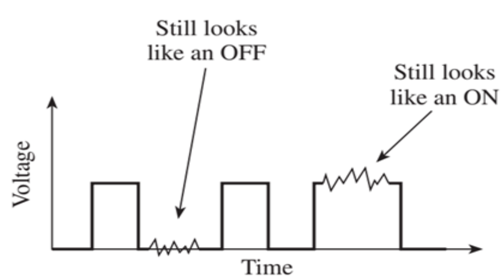
1.1.1 Binary Digits

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, and it is the smallest unit of measurement used to quantify computer data. 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. This is called positive logic.

1.1.2 Analog and Digital Signals

<table>
<tr><th>Analog Signal</th><th>Digital Signal</th></tr>
<tr><td>1. Continuous, an infinite range of values, and more exact values but more difficult to work with.</td><td>1. Discrete, finite range of values (2), and not as exact as analog, but easier to work with.</td></tr>
<tr><td>2. Analog Voltmeter tells you ‘what voltage it is’ (continuous).


</td><td>2. Digital voltmeter tells you voltage to xx.xx digits (countable). Or just ‘on’ and ‘off’


</td></tr>
<tr><td>3. Analog Voltage can be ‘any value’ (Dimmer Switch).</td><td>3. Digital voltage is a limited set of voltages On =1 OR Off = 0.</td></tr>
<tr><td>4. Analog waveform

</td><td>4. Digital waveform

</td></tr>
<tr><td>5. Analog to Digital Conversion (ADC).</td><td>5. Digital to Analog Conversion (DAC).</td></tr>
<tr><td>6. Noises in analog

</td><td>6. Noises in digital

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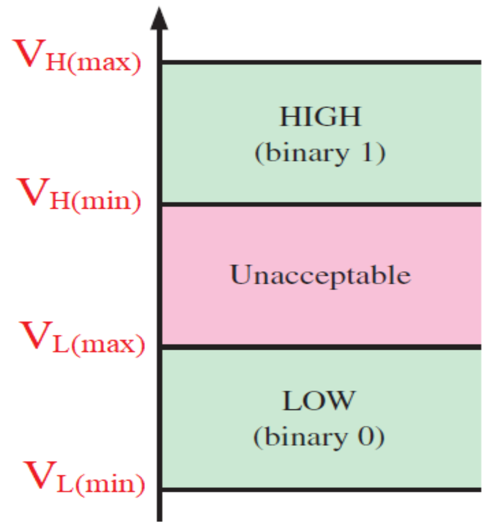
1.1.3 Logic Levels

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

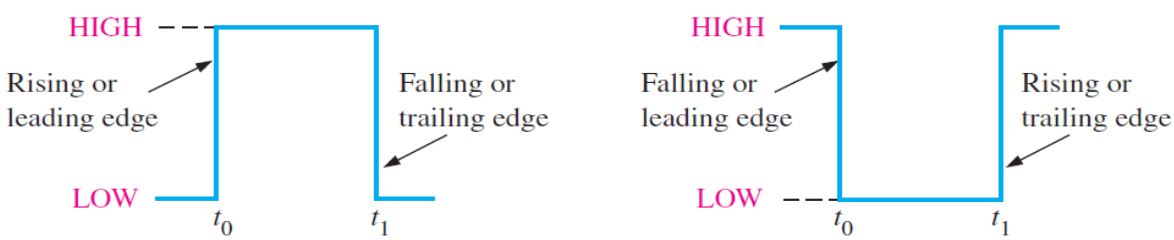


Logic Level	Voltage	True/False	On/Off	0/1
HIGH	5 volts	True	On	1
LOW	0 volts	False	Off	0

The digital is deal strictly with ON and OFF represent by 0s and 1s.

1.1.4 Digital Waveforms and Pulses

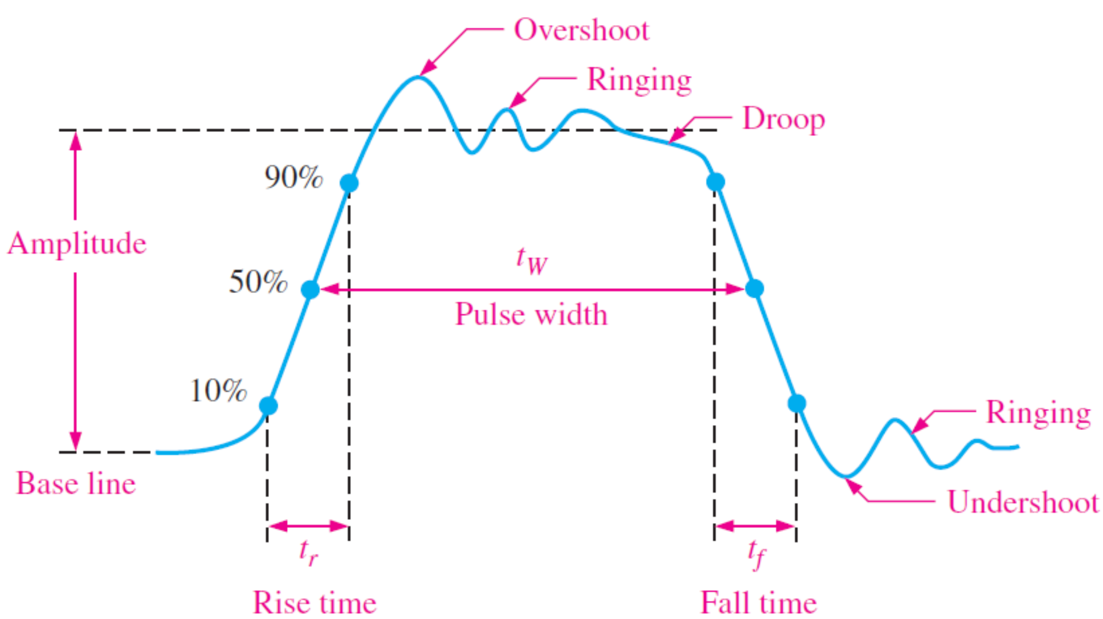
Digital waveforms consist of voltage levels that are changing back and forth between the HIGH and LOW levels or states. Figure (a) shows that a single positive-going pulse is generated when the voltage (or current) goes from its normally LOW level to its HIGH level and then back to its LOW level. The negative-going pulse in Figure (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

As in the figure above the ideal pulse has two edges: a leading-edge that occurs first at time t_0 and a trailing edge that occurs last at time t_1.

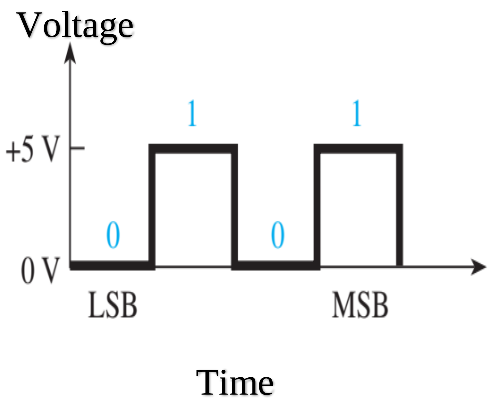
The figure below shows a nonideal pulse. The overshoot and ringing are sometimes produced by stray inductive and capacitive effects. The droop can be caused by stray capacitive and circuit resistance, forming an RC circuit with a low time constant.

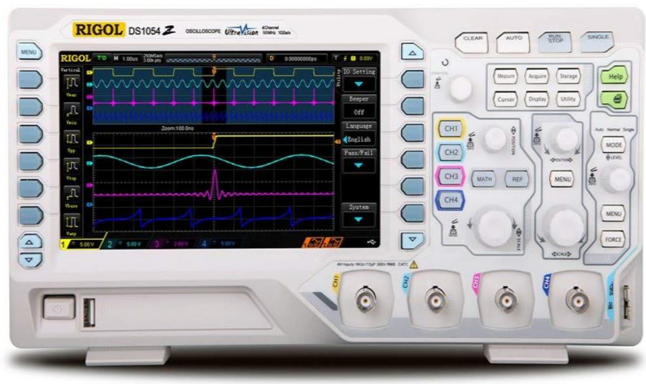


Nonideal pulse characteristics

1.1.5 Digital Signals

The digital signal is being used to represent data as a sequence of discrete values; at any given time it can only take on, at most, one of a finite number of values, and made up of a series of 1s and 0s that represent numbers, letters, symbols, or control signals.

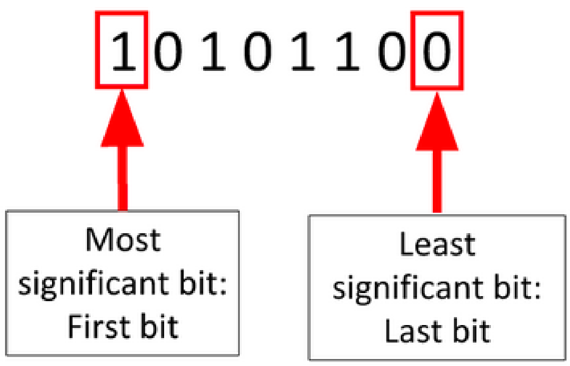




Typical digital signal and oscilloscope displaying the digital waveform, where:

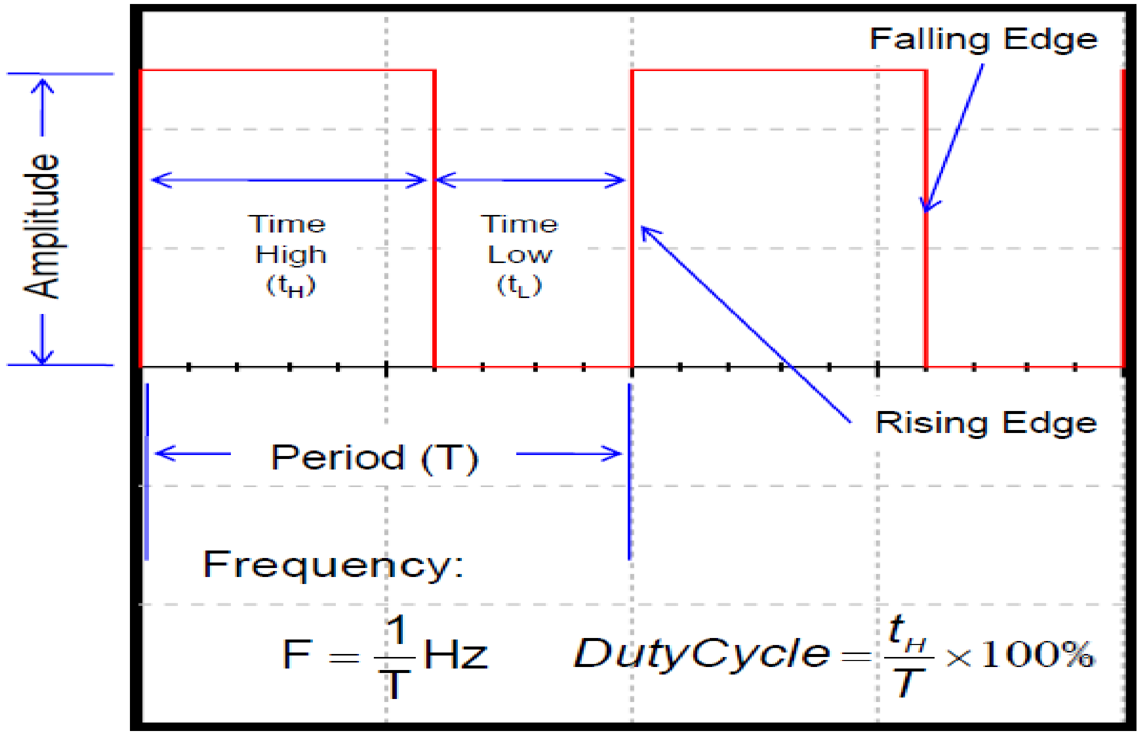
LSB: Least significant bit

MSB: Most significant bit



1.1.6 Parts of a Digital Signal

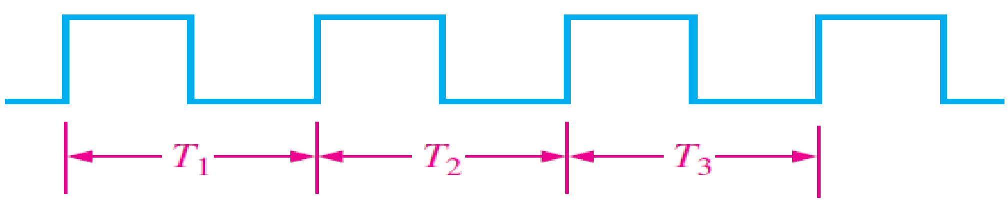
1. Amplitude: For digital signals, this will always be 5 volts.
2. Period: The time (Seconds) it takes for a periodic signal to repeat.
3. Frequency: A measure of the number of occurrences of the signal per second.
4. Time High (t_H): The time the signal is at 5 v.
5. Time Low (t_L): The time the signal is at 0 v.
6. Duty Cycle: The ratio of t_H to the total period (T).
7. Rising Edge: A 0-to-1 transition of the signal.
8. Falling Edge: A 1-to-0 transition of the signal.



1.1.7 Waveform Characteristics

Most waveforms encountered in digital systems are composed of a series of pulses, sometimes called pulse trains, and can be classified:

1. 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).



Periodic (square wave)

2. A nonperiodic pulse waveform does not repeat itself at fixed intervals.

Nonperiodic

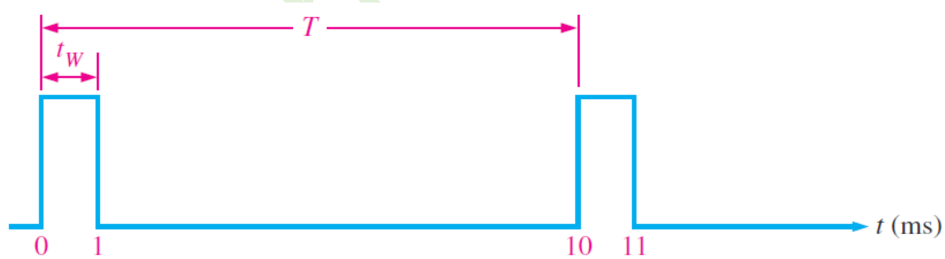
The frequency (f) of a pulse (digital) waveform is the reciprocal of the period. The relationship between frequency and period is expressed as follows:

$f = 1/t$ and $t = 1/f$

Duty cycle is the ratio of the pulse width (t_W) to the period (T). It can be expressed as a percentage.

Duty cycle = (t_W/T) 100%

EXAMPLE: A portion of a periodic digital waveform is shown in the figure below. The measurements are in milliseconds. Determine the following: (a) period (b) frequency (c) duty cycle.



Sol.

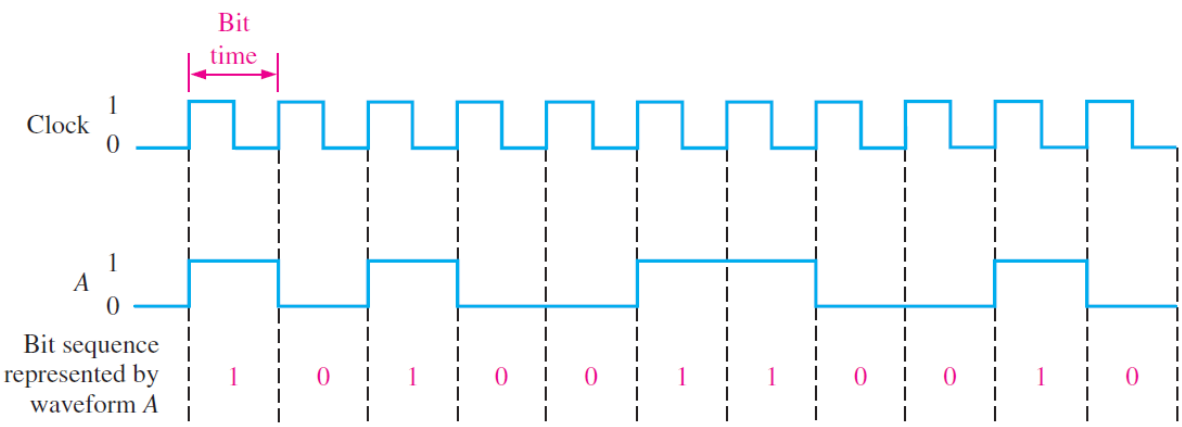
a) The period (T) is measured from the edge of one pulse to the corresponding edge of the next pulse. In this case, T is measured from leading edge to leading edge, as indicated. T equals 10 ms.

b) f = 1/t = 1/10 ms = 100 Hz

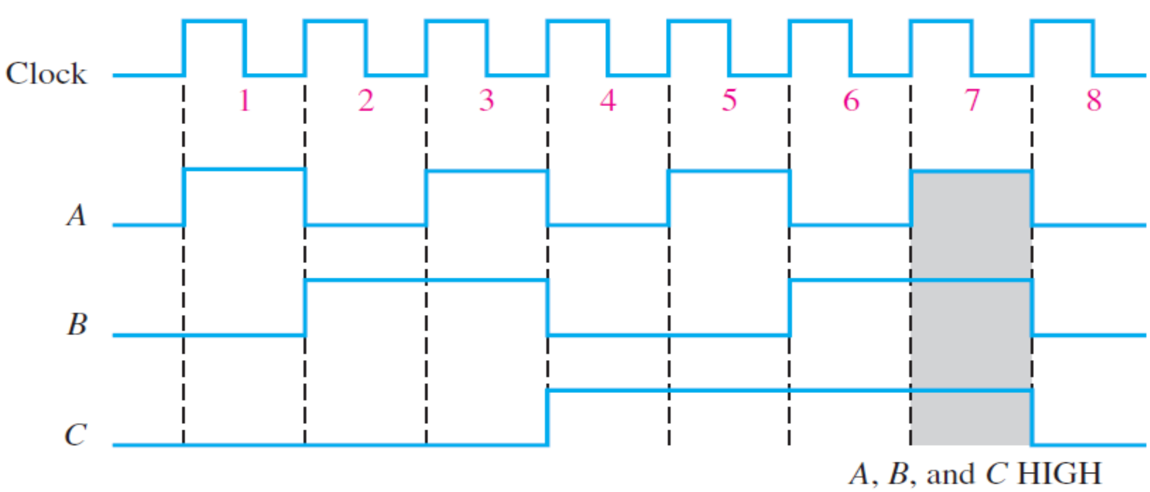
c) Duty cycle = (t_W/T) 100% = (1 ms /10 ms) 100% = 10%

1.2 The Clock and Timing Diagrams

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. The figure below an example of a clock waveform synchronized with a waveform representation of a sequence of bits.



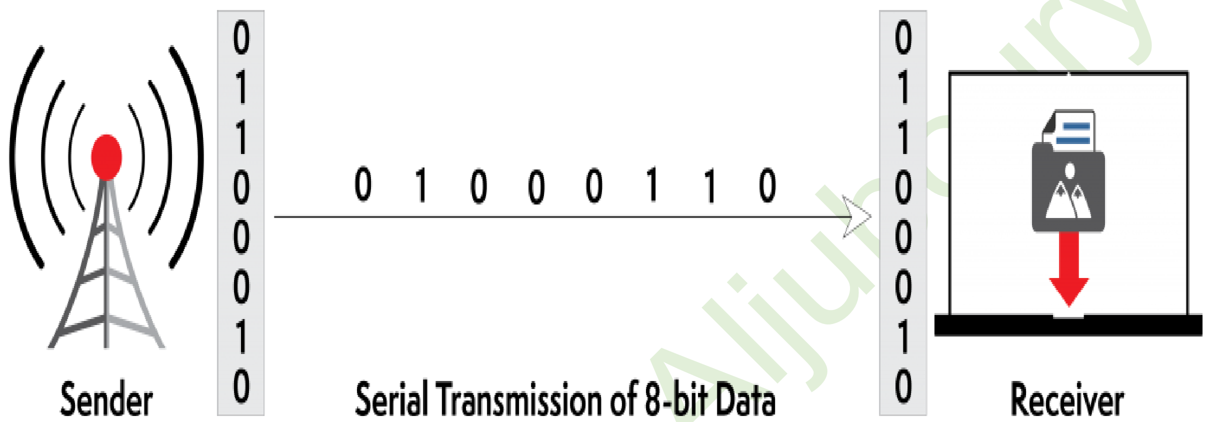
A timing diagram is a graph of digital waveforms showing the actual time relationship of two or more waveforms and how each waveform changes in relation to the others. By looking at a timing diagram, you can determine the states (HIGH or LOW) of all the waveforms at any specified point in time and the exact time that a waveform changes state relative to the other waveforms. The 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.



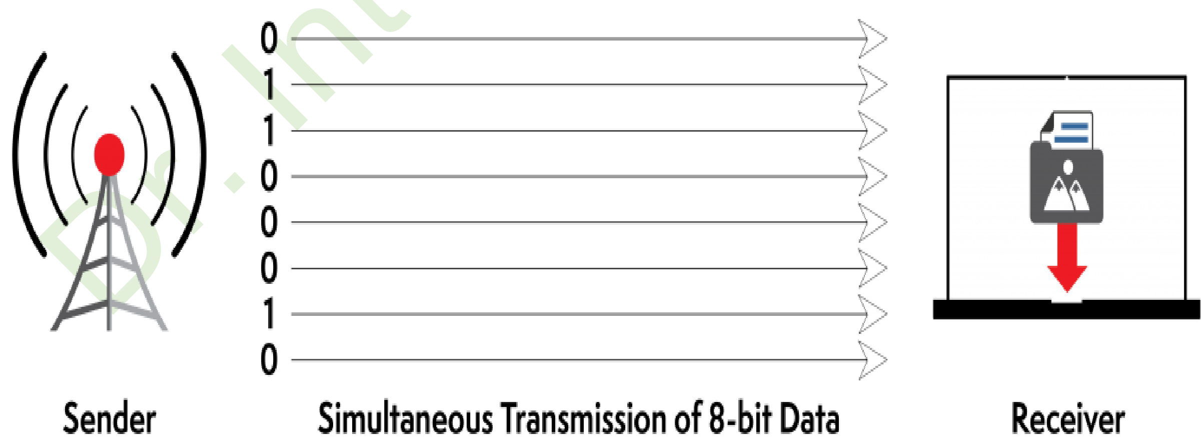
1.3 Data Transmission Digital

Data is transferred in the form of bits between two or more digital devices. There are two methods used to transmit data between digital devices:

1.3.1 Serial data transmission sends data bits one after another over a single channel.



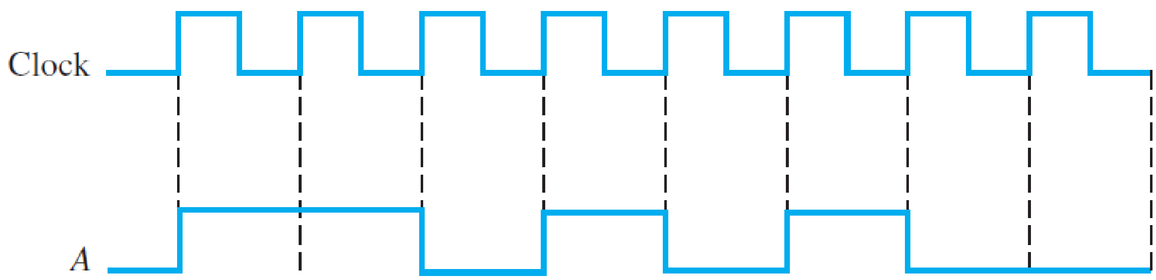
1.3.2 Parallel data transmission sends multiple data bits at the same time over multiple channels.



Example:

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

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



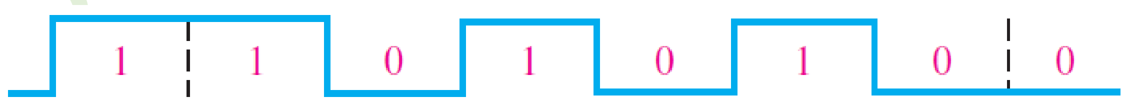
Sol.

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

t = 1/f = 1/1 MHz = 1 μs

It takes 1 ms to transfer each bit in the waveform. The total transfer time for 8 bits is 8 * 1 μs = 8 μs

To determine the sequence of bits, 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 the figure below. The left-most bit is the first to be transferred.



(b) A parallel transfer would take 1 μs for all 8 bit