الجامعة السورية الخاصة
SYRIAN PRIVATE UNIVERSITY

كـلـيــة هندسة الحاسوب والمعلوماتية والاتصالات
Faculty of Computer & Informatics
and Communications Engineering

Logic Circuits

Dr. Eng.

Hassan M. Ahmad

Hassan.Ahmad@spu.edu.sy, istamo48@mail.ru

Chapter_ 1
Digital Concepts

Lecture _01
Digital Basics

Syllabus Outline

№_Ch	Title	Contents
Ch_1	Introductory Concepts	Digital and Analog Quantities, Binary Digits, Logic Levels, Digital Waveforms, Basic Logic Functions
Ch_2	Number Systems, Operations, and Codes	Decimal, Binary, Complements, Hexadecimal, Octal, Binary Coded Decimal (BCD) and Digital Codes
Ch_3	Logic Gates	AND, OR, NAND, NOR, Exclusive-OR and Exclusive-NOR
Ch_4	Boolean Algebra and Logic Simplification	Operations and Expressions, Laws and Rules, DeMorgan's Theorems, Truth Tables and Karnaugh Map
Ch_5	Combinational Circuit Analysis	Basic Combinational Logic Circuits, Implementing Combinational Logic, Combinational Logic Using NAND and NOR Gates, Pulse Waveform Operation
Ch_6	Functions of Combinational Logic	Adders, Comparators, Decoders, Encoders, Multiplexers and Demultiplexers.
Ch_7	Sequential circuit analysis	Latches, Flip-Flops, and Timers. Shift Registers. Counters

Intended Learning Outcomes

After completing the course, the student will be able to:

- Understand number systems, codes, and binary arithmetic.
- Produce the truth table, timing diagram.
- Use Boolean Algebra, recognize Operator precedence.
- Use standard forms and simplify of Boolean functions.
- Construct Karnaugh Maps.
- Design combinational circuits.
- Build and trace the logic of circuits composed of simple gates.
- Describe the behavior of the following circuits: Adders, comparators, Decoder, Encoder, Multiplexer, Flip-Flops, registers, and Counters.
- Analyze synchronous sequential circuits.

Assessment

Coursework:	**50%**
Activity	10%
2 Tests	20% (10% each)
Practice	20%
Examination:	**50%**

To pass the course, at least 25% of coursework AND examination marks are required.

Text book

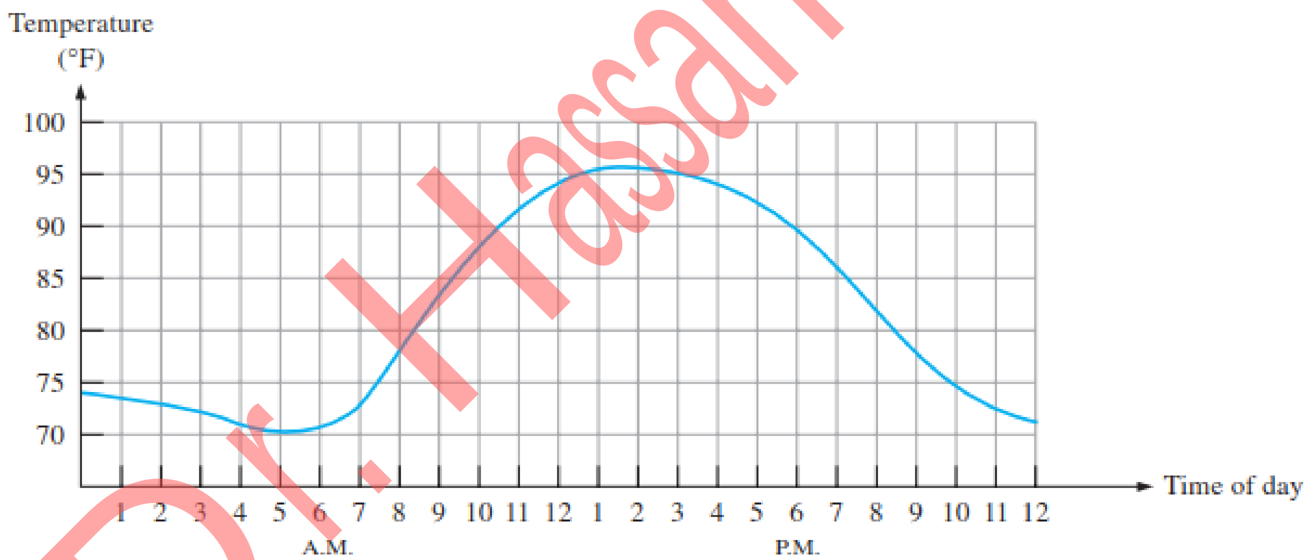
1. Thomas L. Floyd. Digital Fundamentals, (9,10) 11-th Edition, Pearson Education Limited 2015.

References

1. Morris Mano. Digital design, 4-th edition, Pearson Education, 2007.
2. Fundamentals of Digital Logic Design with Verilog Design, S. Brown and Z. Vranesic, McGraw Hill Ed., 2003.
3. أ. د. محمد ابراهيم العدوي. الدوائر المنطقية. قسم الإلكترونيات والاتصالات والحاسبات، كلية الهندسة – جامعة حلوان.

1-1. Digital and Analog Quantities (الكميات الرقمية والتماثلية)

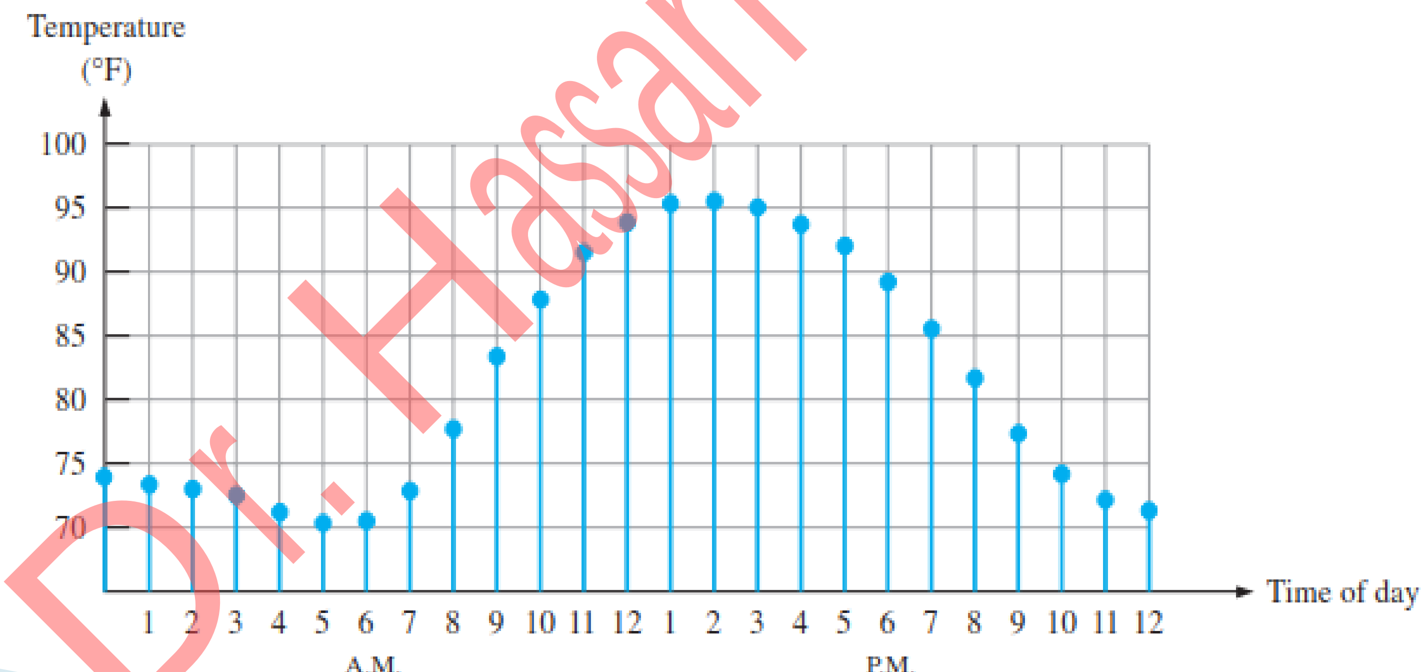
- An **analog** quantity is one having continuous values.
- A **digital** quantity is one having a discrete set of values.
- Most natural quantities that we see are analog and vary continuously.
- For example, the air temperature changes over a continuous range of values as shown in Fig.



Graph of an analog quantity (temperature versus time).

Digital and Analog Quantities

- **Analog systems** can generally handle (تتعامل) higher power than digital systems.
- **Digital systems** can process, store, and transmit data more efficiently but can only assign (تُخصص) discrete values to each point.
- For example, have sampled values (قيم متقطعة=عينات) representing the temperature at discrete points in time (every hour) over a 24-hour period, as indicated in Fig.



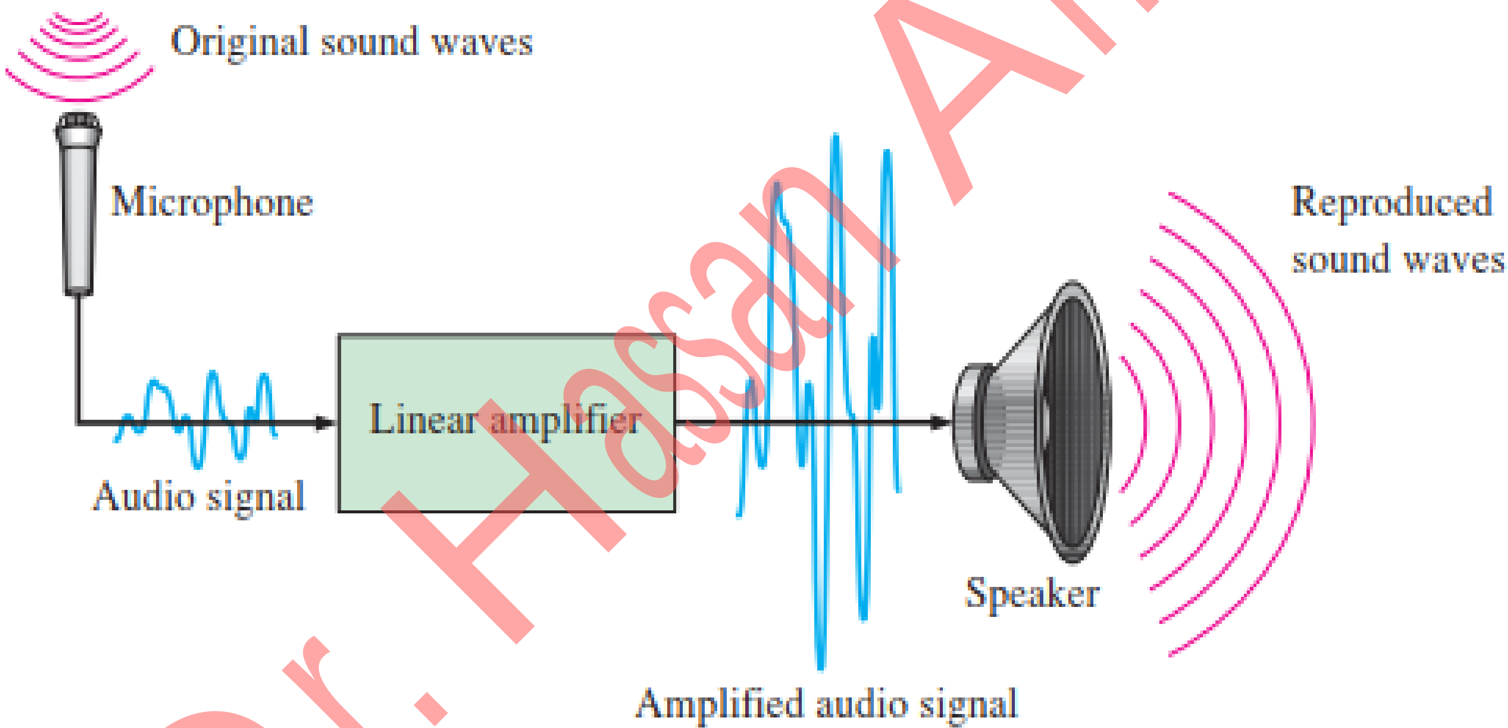
Sampled-value representation (quantization) of the analog quantity

The digital advantage (مميزات التمثيل الرقمي)

- Digital data can be processed and transmitted more efficiently (أكثر كفاءة) and reliable (موثوقية) than analog data.
- 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 (دقة) and clarity than is possible when it is in analog form.
  - Noise (unwanted voltage fluctuations (تقلبات)) does not affect digital data nearly as much as it does analog signals.

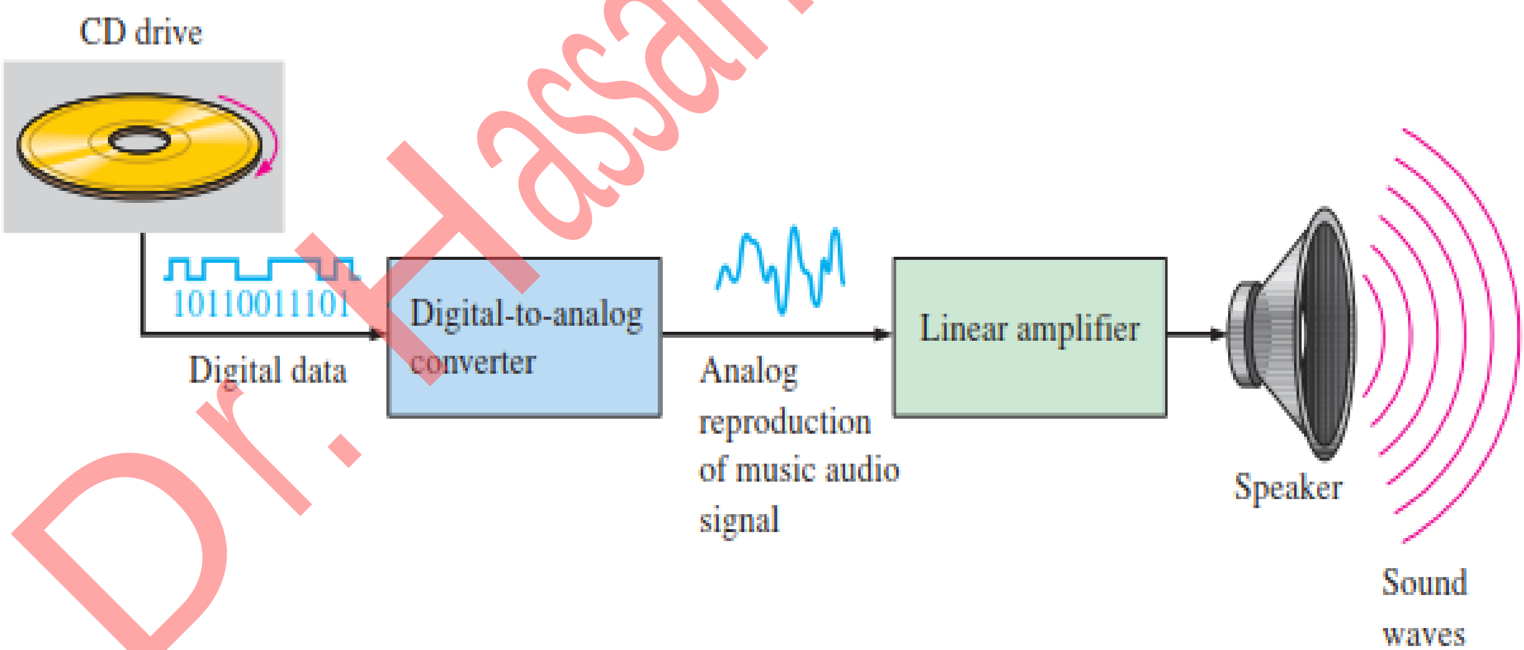
Analog System

- A public address system, used to amplify sound, is one simple example of an application of analog electronics, shown in Fig.



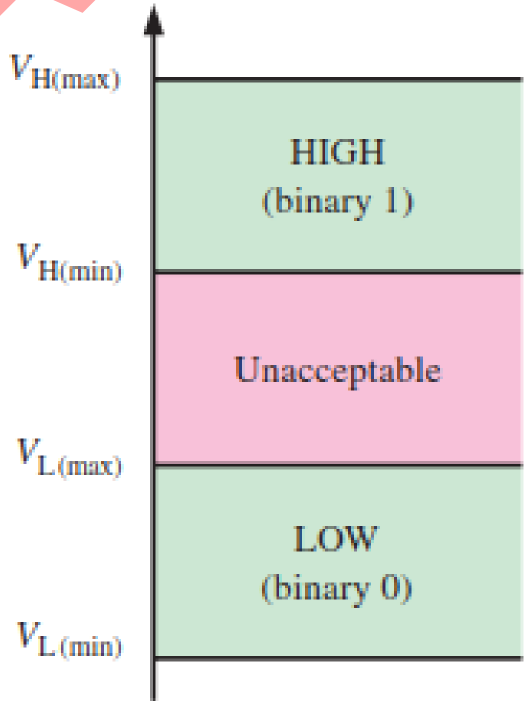
A System Using Digital and Analog Methods

- The compact disk (CD) player is an example of a system in which both digital and analog circuits are used, shown in Fig.
  - A laser diode optical system picks up the digital data from the rotating disk and transfers it to the digital-to-analog converter (**DAC**).
- When the music was originally recorded on the CD, a process, essentially the reverse of the one described here, using an analog-to-digital converter (**ADC**) was used.



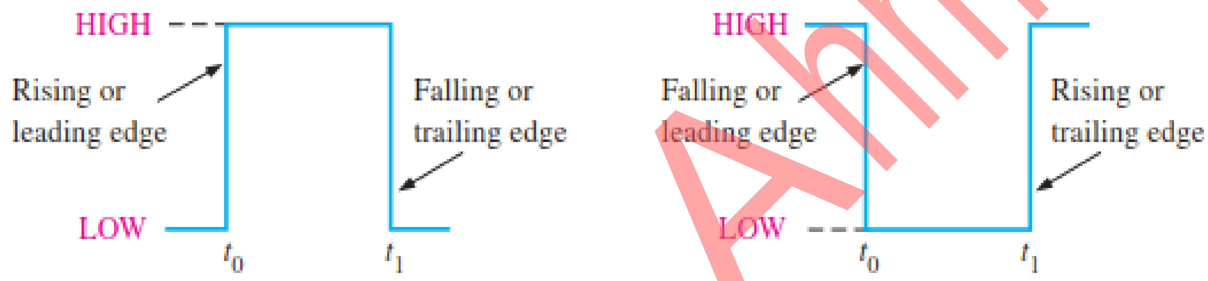
1-2. Binary Digits, Logic Levels and Digital Waveforms

- 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 dig*it*).
- A bit can have the value of either a **0** or a **1**, depending on if the voltage is HIGH or LOW.



Digital Waveforms (الموجات الرقمية)

- **Digital waveforms** change between the **LOW** and **HIGH** levels, as shown in Fig.

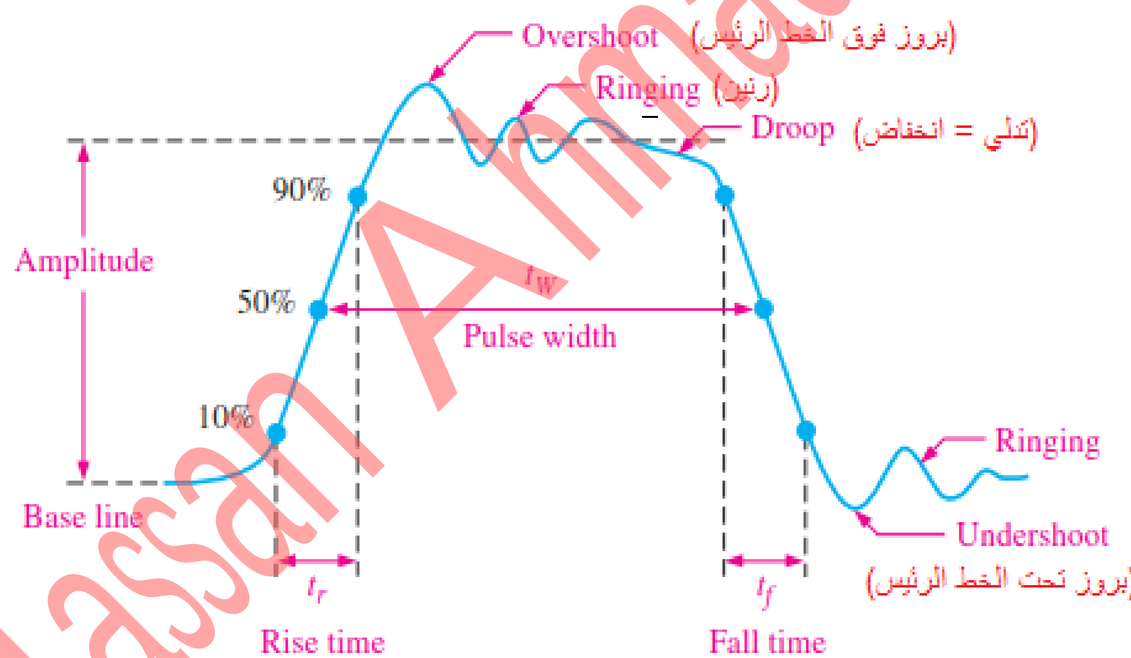


(a) Positive–going pulse (b) Negative–going pulse

1) A **positive-going pulse (نبضة موجبة الاتجاه)** is one that goes from a normally LOW logic level to a HIGH level and then back again.
2) A **negative-going pulse (نبضة سالبة الاتجاه)** is one that goes from a normally HIGH logic level to a LOW level and then back again.
   - Digital waveforms are made up of a series of pulses.
   - Pulse has **tow edges**: a leading edge (حافة أمامية) that occurs first at time t_0 and a trailing edge (حافة خلفية) that occurs last at time t_1.
   - The pulses in Fig. are **ideal** because the rising (صاعدة) and falling (هابطة) edges are assumed to change in zero time (instantaneously (لحظي)).

Pulse Definitions (تفاصيل النبضة)

Actual pulses are not ideal but are described by:



1) **Rise time (t_r) (زمن الصعود):** the time required for a pulse to go from its LOW level to its HIGH level. (from 10% of the **pulse amplitude (مطال = ارتفاع)** (height from baseline) to 90%).

2) **Fall time (t_f) (زمن الهبوط):** the time required for the transition from the HIGH level to the LOW level. (from 90% to 10% of the pulse amplitude).

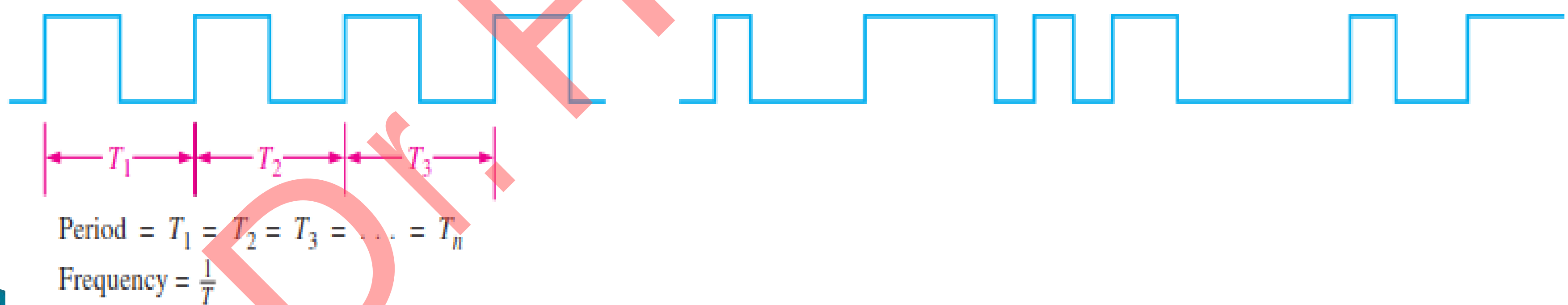
3) **Pulse width (t_W) (عرض النبضة)** or (*pulse active time*) is a measure of the duration of the pulse and is often defined as the time interval between the 50% points on the rising and falling edges.

Waveforms characteristics (خصائص الموجات)

- Most waveforms encountered in digital systems are composed of series of pulses, sometimes called ***pulse train*** (قطار النبضة), and can be classified as either periodic or nonperiodic.
  - **A periodic pulse** waveform is one that repeat itself at a fixed interval, called a ***period*** (***T***). The ***frequency*** (***f***) is the rate (المعدل/النسبة) at which a pulse repeats itself and measured in hertz (**Hz**).

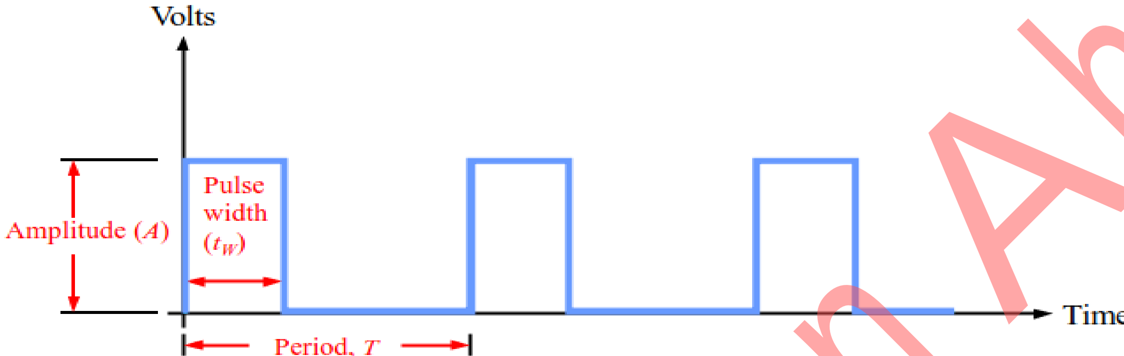
$$f = \frac{1}{T} \quad \text{or} \quad T = \frac{1}{f}$$

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



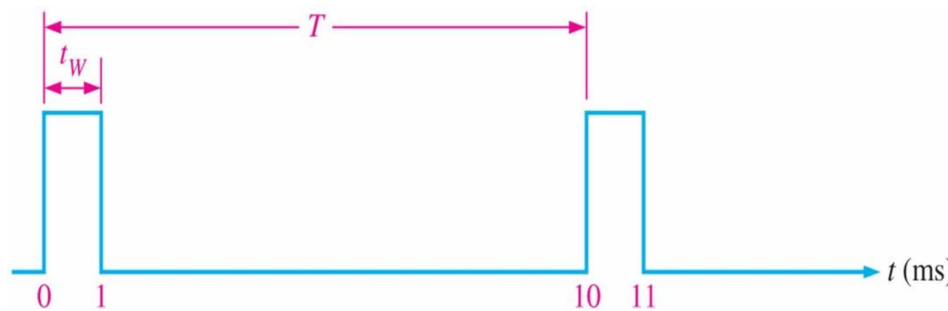
(a) Periodic (square wave) (b) Nonperiodic

- In addition to frequency and period, repetitive pulse waveforms are described by the ***amplitude*** (A), ***pulse width*** (t_W) and ***duty cycle*** (دورة العمل).
- **Duty cycle** is the ratio of t_W to T. It can be represents as percentage.



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

Example 1-1 A portion of periodic digital waveform is shown in Fig. The measurements are in milliseconds. Determine the following: period, frequency and duty cycle.



Solution

$T = 10\text{ms};$

$$f = \frac{1}{T} = \frac{1}{10\,\text{ms}} = 100\,\text{Hz}$$

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

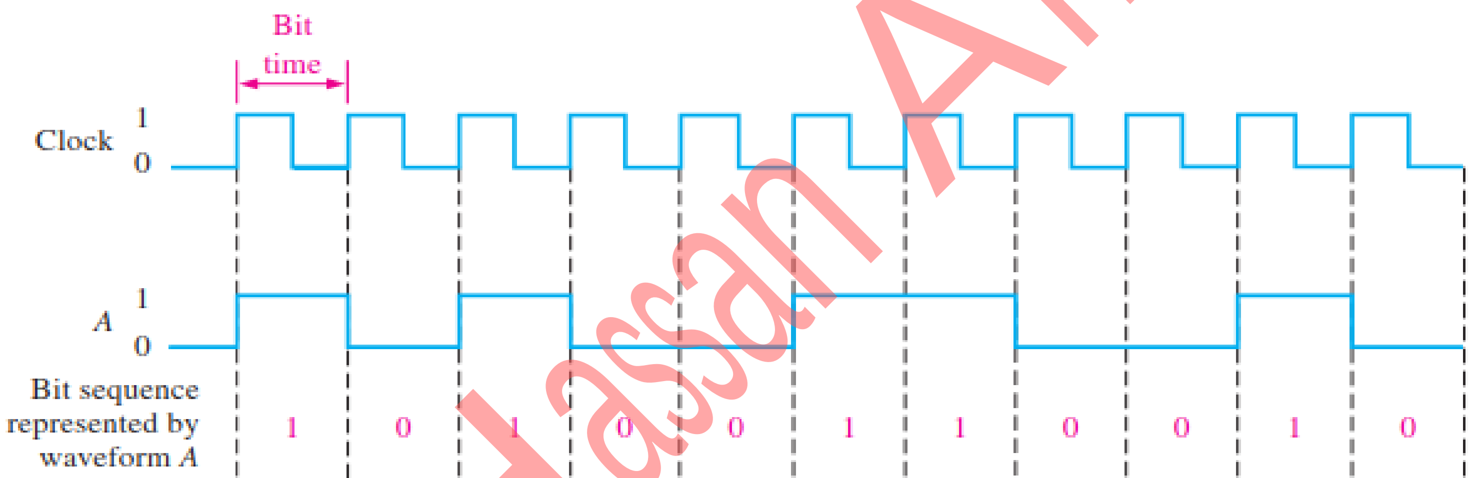
نسبة الدورة الواحدة من الإشارة 10% من إجمالي الإشارة
الذي قد يكون ثانية ، أو يوما ، أو حتي أسبوع

A digital waveforms Carries Binary Information

The clock

- In digital systems, all waveforms are synchronized with a basic timing waveform called the **clock**, that is a periodic waveform, and **itself does not carry information.**

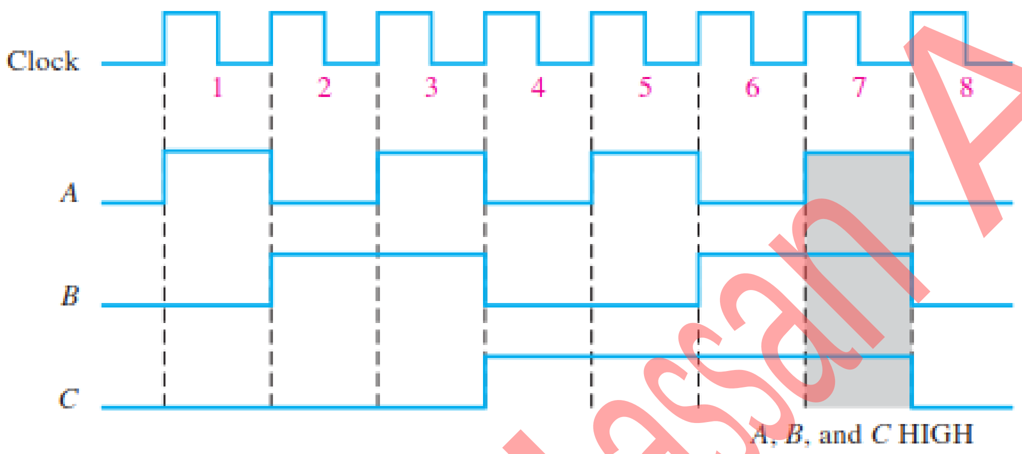
An example of clock is shown in Fig.



- 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 clock.
- During each bit time of the clock, waveform *A* is either HIGH or LOW.
- These HIGHs and LOWs represent a sequence of bits.
- A group of several bits can be used as piece of binary information, such as a **number** or a **letter**.

Timing Diagrams

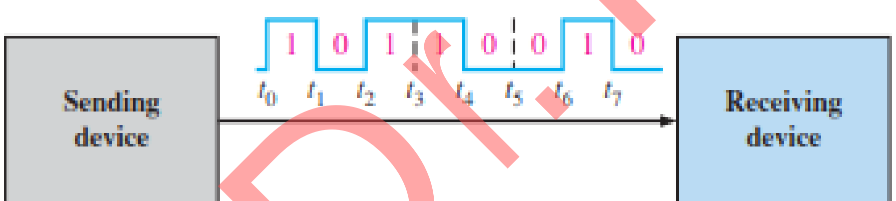
- A **timing diagram** is used to show the relationship between two or more digital waveforms, and how each waveform changes in relation to the others.



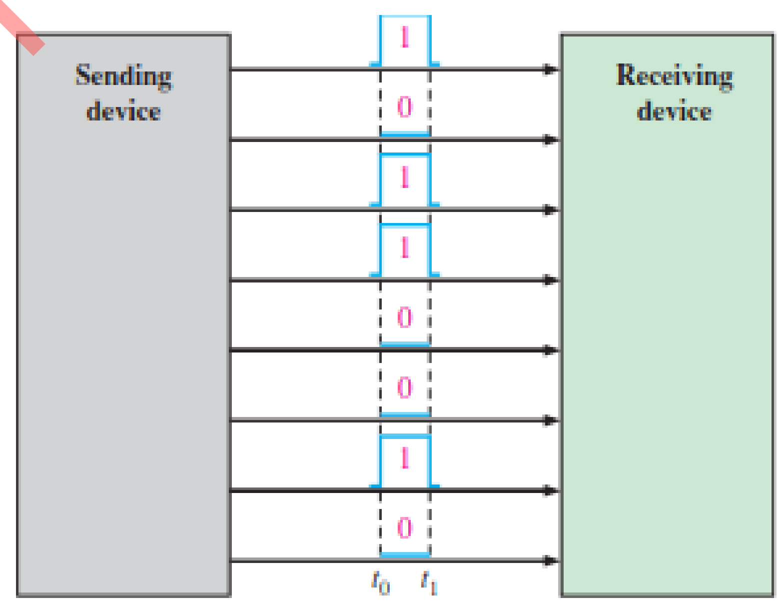
- From this timing diagram you can see, for example, that the three waveforms *A*, *B*, and *C* are HIGH only during bit time 7 (shaded area) and they all change back LOW at the end of bit time 7.
- A diagram like this can be observed directly on a logic analyzer.

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 to another within a digital system or from one system to another.
  - **For example**, numbers stored in binary form in the memory of a computer must be transferred to the computer's central processing unit in order to be added.
    - The sum of the addition must then be transferred to a monitor for display and/or transferred back to the memory.
  - Binary data are transferred in two ways: **serial** and **parallel**, as shown in Fig.



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



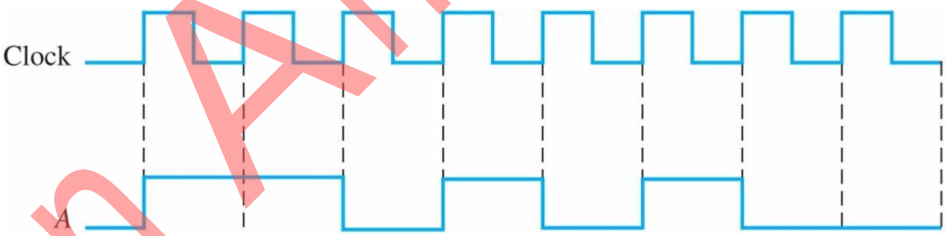
(b) Parallel transfer of 8 bits of binary data. The beginning time is t_0

Example 1-2

a) Determine the total time required to serially transfer the *eight bits* contained in waveform ***A*** of Fig., 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?

Solution



a) The period is: $T = \frac{1}{f} = \frac{1}{100kHz} = 10\mu s$

It takes $10\mu s$ to transfer each bit in the waveform.

The total transfer time for eight bits is $8 \times 10\mu s = 80\mu s$

To determine the sequence of bits, examine the wave form during each bit time.

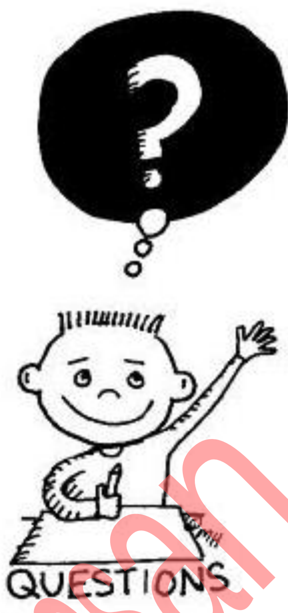
If waveform *A* is HIGH during the bit time, a 1 is transferred.

If waveform *A* is LOW during the bit time, a 0 is transferred.

The bit sequence is

The left-most bit is the first to be transferred

b) A parallel transfer would take $10\mu s$ for all eight bits.



The end of Lecture_01, chapter 1

Problems & Solutions

Problem 1-1

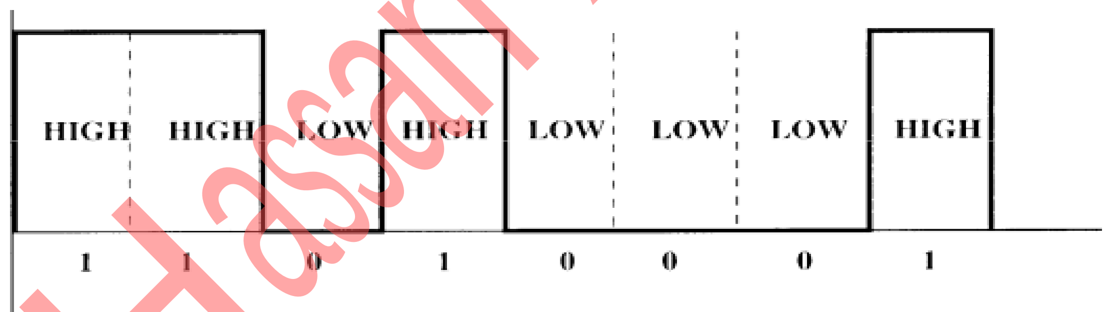
Define the sequence of bits (1s and 0s) represented by each of the following sequences of levels:

(a) HIGH, HIGH, LOW, HIGH, LOW, LOW, LOW, HIGH

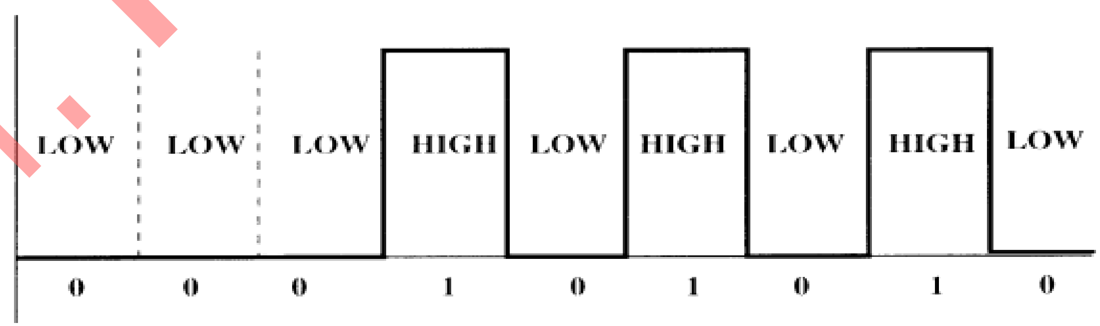
(b) LOW, LOW, LOW, HIGH, LOW, HIGH, LOW, HIGH, LOW

Solution

HIGH = 1; LOW = 0. See Figure

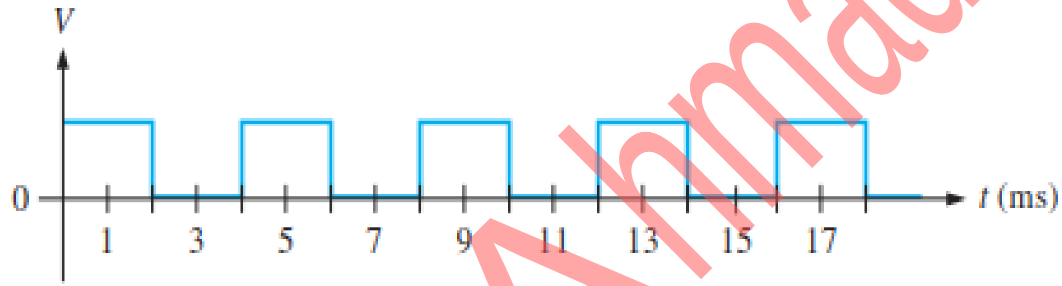


(a)



Problem 1-2

Determine the duty cycle of the waveform in Fig.



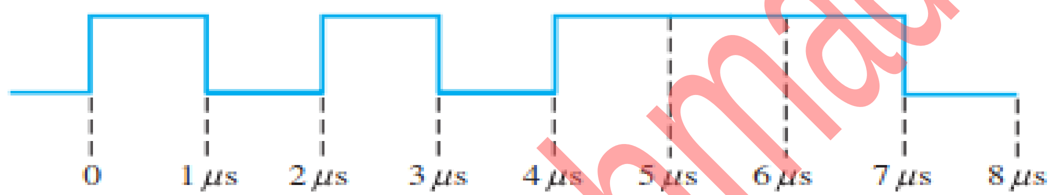
Solution

$t_W = 2\text{ ms};\ T = 4\text{ ms}$

$$\text{Duty cycle} = \left(\frac{t_W}{T}\right)100\% = \left(\frac{2\text{ms}}{4\text{ms}}\right)100\% = 50\%$$

Problem 1-3

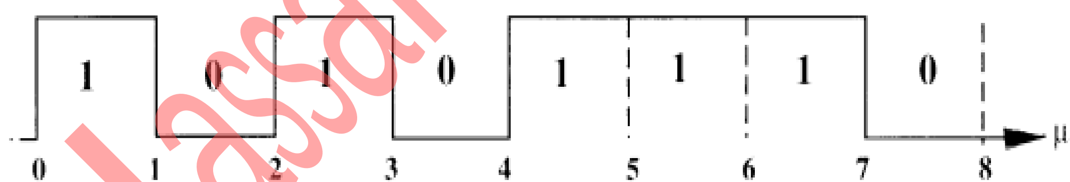
Given the waveform in Fig.



1. Determine the bit sequence represented by A bit time is 1 μs in this case
2. What is the total serial transfer time for the eight bits in Fig.? What is the total parallel transfer time?
3. What is the period if the clock frequency is 4 kHz?

Solution

- The bit sequence is:



- Each bit time = 1 μs , → Serial transfer time = (8 bits)(1 μs/bit) = 8 μs; Parallel transfer time = 1 bit time = 1 μs
- The period:

$$T = \frac{1}{f} = \frac{1}{4\text{kHz}} = 0.25\text{ms}$$