الجامعة السورية الخاصة
SYRIAN PRIVATE UNIVERSITY

كـلـيـــة هندسة الحاسوب والمعلوماتية والاتصالات
Faculty of Computer & Informatics
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Logic Circuits

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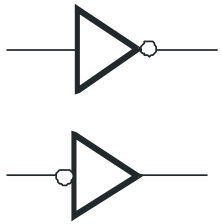
Chapter_ 1
Digital Concepts

Lecture _02
Basic Logic Functions

2-1. Basic Logic Functions

NOT

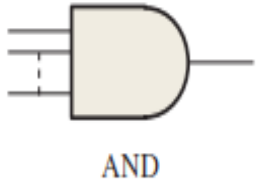
Indicates the ***opposite*** condition (بوابة النفي أو العكس)
The basic logic functions and symbols are shown.



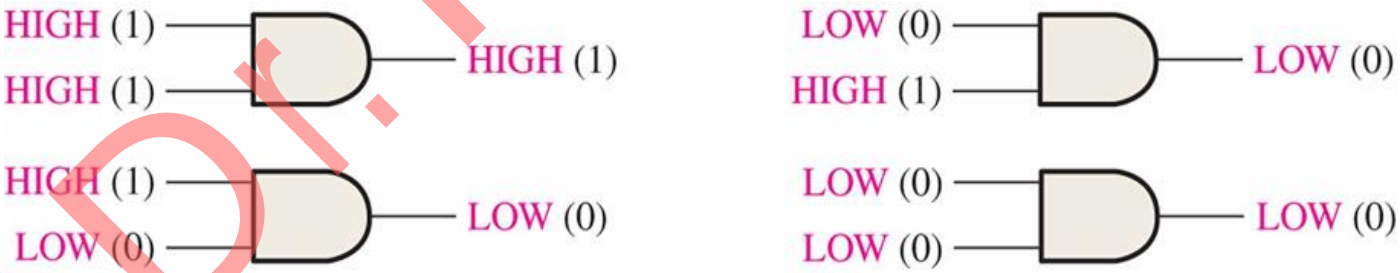
The NOT operation is implemented by a logic circuit known as an **invertor**.

AND

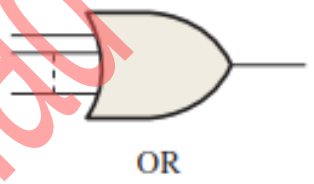
True only if ***all*** input conditions are **true**. (بوابة « و»)
The basic logic functions and symbols are shown.



The AND operation is implemented by a logic circuit known as an **AND Gate**.

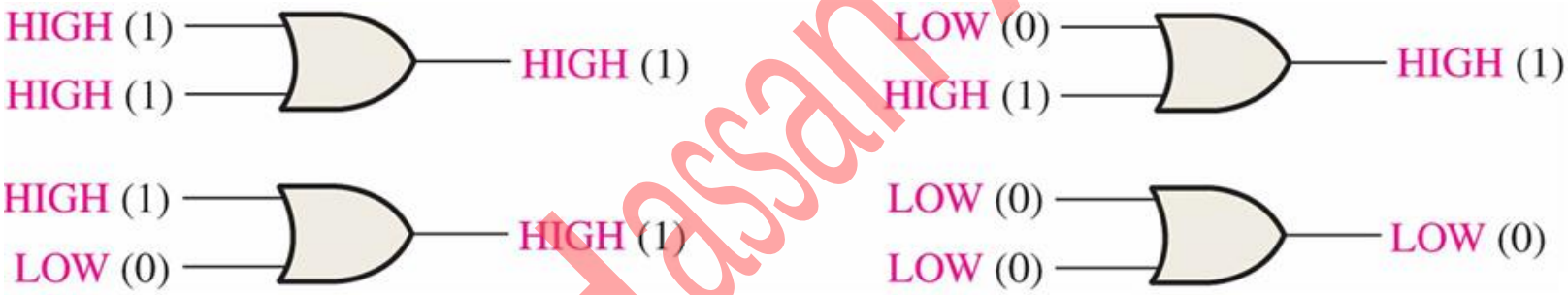


OR



True only if ***one or more*** input conditions are **true**. (بوابة «أو»)
The basic logic functions and symbols are shown.

The OR operation is implemented by a logic circuit known as an **OR Gate**.

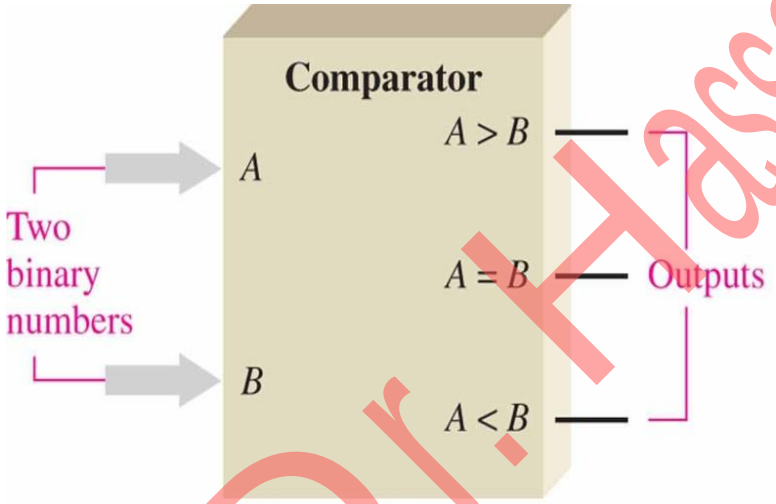


2-2. Combinational and Sequential Logic Functions
(التوابع المنطقية التوافقية والمتعاقبة/التتابعية)

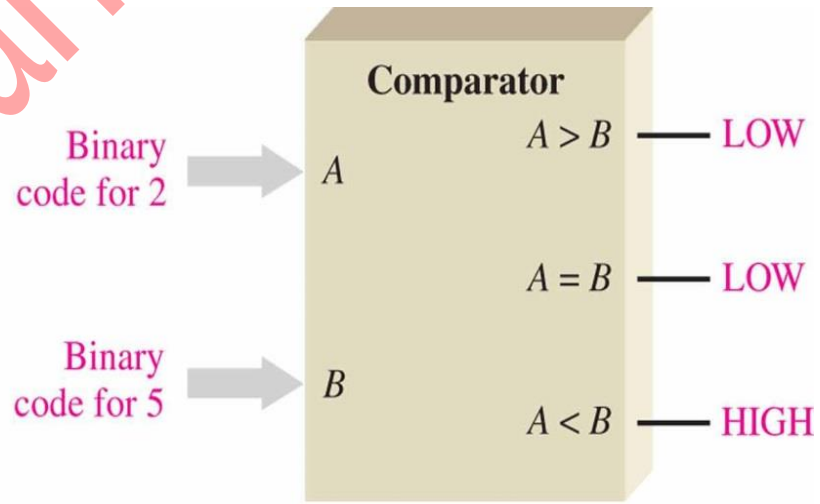
AND, **OR**, and **NOT** elements can be combined to form various *logic functions*.

1. Comparison Function (تابع المقارنة):

- Magnitude comparison is performed by a logic circuit called a **comparator (مقارن)**.
- A comparator compares two quantities and indicates whether or not they are equal.
- **For example**, suppose you have two numbers and wish to know if they are equal or not equal and, if not equal, which is greater.



(a) Basic magnitude comparator



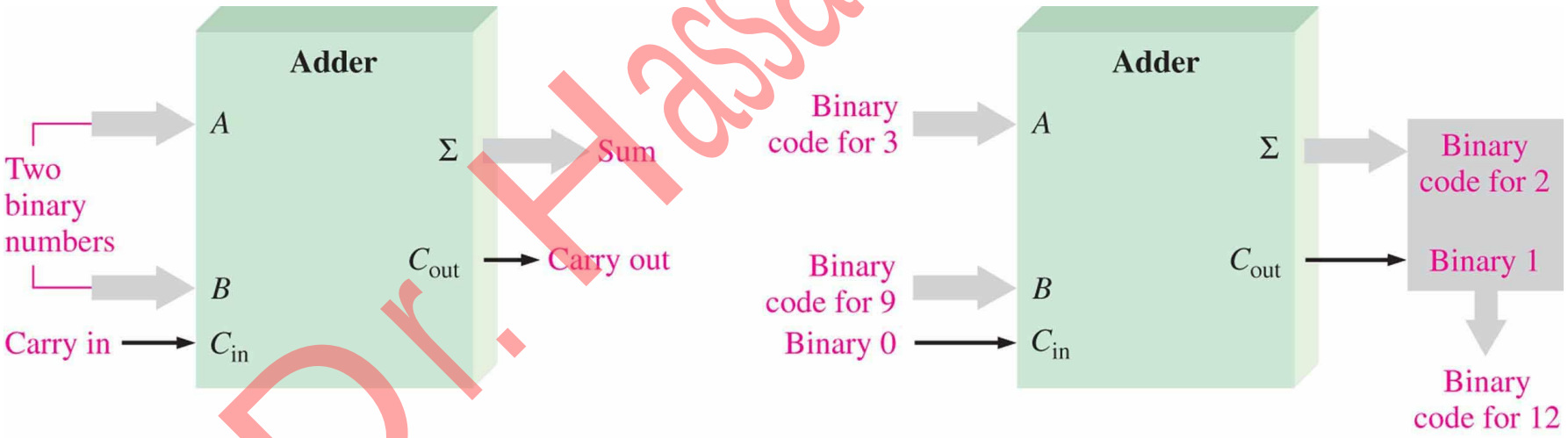
(b) Example: A is less than B ($2 < 5$) as indicated by the HIGH output ($A < B$)

2. Arithmetic Functions (التوابع الحسابية):

Addition. Addition is performed by a logic circuit called an **adder (الجامع)**.

- An adder adds two binary numbers (on inputs A and B with a carry C_{in}) and generates a **sum** ($\sum$) and a **carry output** (C_{out}), as shown in Fig.

For example, suppose you wish to add 3 and 9. We know that the sum is 12; the adder indicates this result by producing 2 on the sum output and 1 on the carry output. Assume that the carry input in this example is 0.



(a) Basic adder

(b) Example: A plus B (3 + 9 = 12)

Subtraction.

- Subtraction is performed by a logic circuit called an **subtractor (الطارح)**.
- A subtractor requires three inputs: the two numbers that are to be subtracted and a borrow input (دخل الاستعارة).
- The two outputs are the difference (الفرق=حاصل الطرح) and the borrow output.
- **For example**, when, 5 is subtracted from 8 with no borrow input, the difference is 3 with no borrow output.

Multiplication.

- Multiplication is performed by a logic circuit called **multiplier (الضارب)**.
- Numbers are always multiplied two at a time, so two inputs are required.
- The output of multiplier is the product (حاصل الضرب).
- Because multiplication is simply a series of additions with shifts in the positions of the partial products (نواتج جزئية), it can be performed by using an adder in conjunction (ربط/اتصال) with other circuits.

Division.

- Division can be performed by a series of subtraction, comparisons, and shifts, and thus it can also be done using an adder in conjunction with other circuits.
- **Two inputs** to the **divider** are required, and the outputs generated are the **quotient (ناتج القسمة)** and the **remainder (باقي القسمة)**.

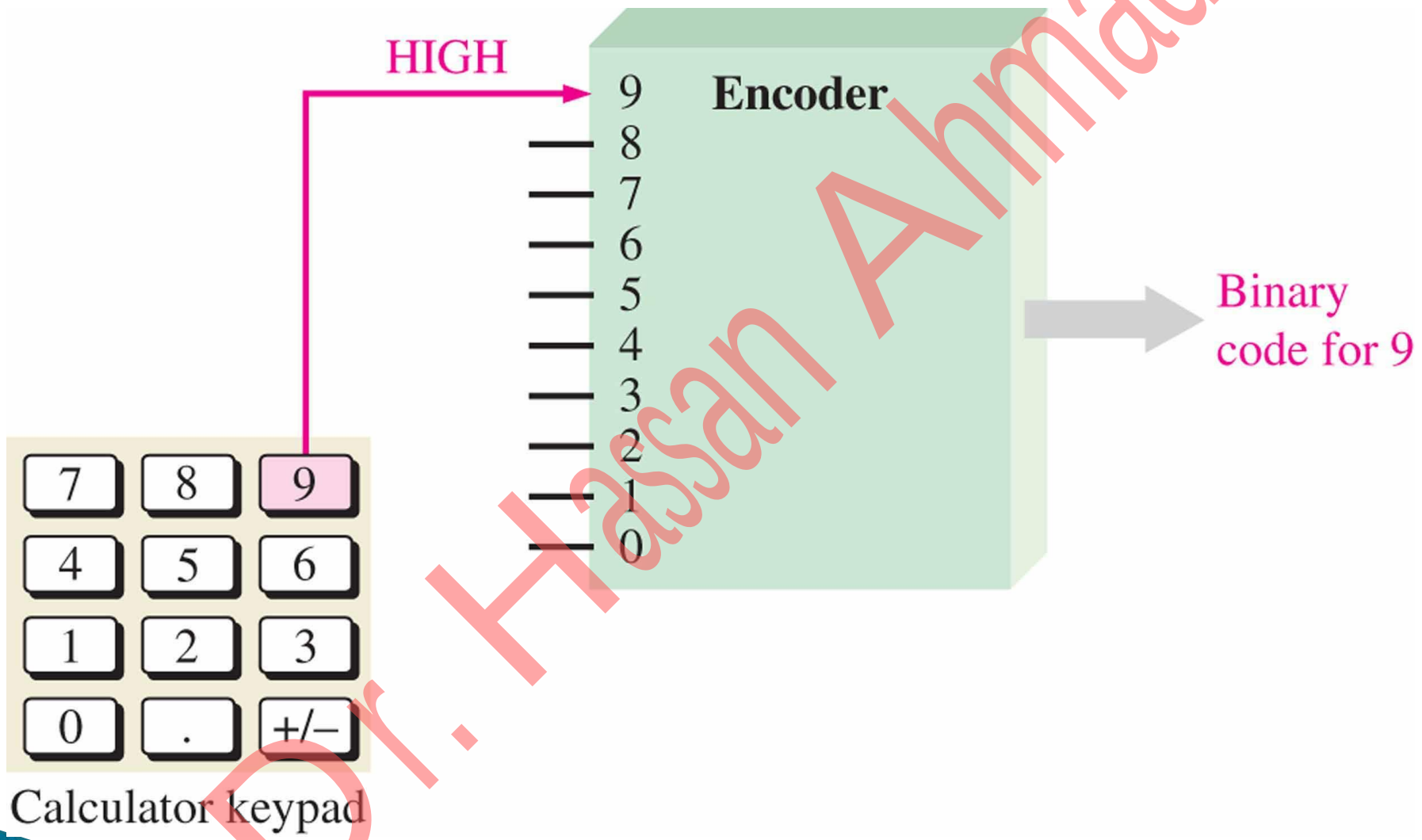
3. Code Conversion Function ((تابع تحويل رموز البيانات (الشيفرة/الترميز)

- A **code** is a set of bits arranged in a unique pattern (نمط فريد) and used to represent specified information.
- A **code convertor (محوّل الرموز)** changes one form of coded information into another coded form.
- Examples are conversion between binary and other codes such as the binary coded decimal (BCD) (عشري مرمَّز ثنائياً) and Gray code (ترميز غراي) [also known as reflected binary code (RBC) (الترميز الثنائي المنعكس)].

4. Encoding Function (تابع التشفير).

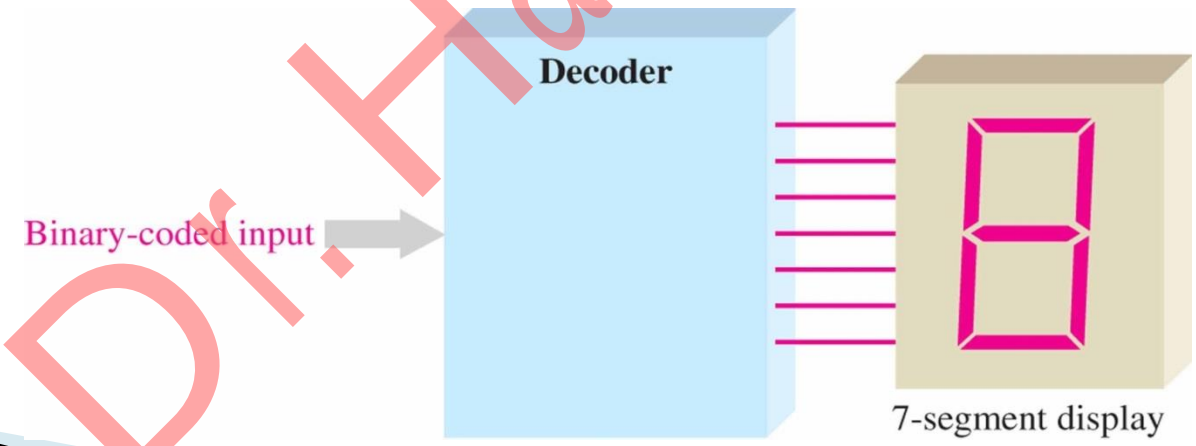
- The encoding function is performed by a logic circuit called an **encoder (المشفّر)**.
- The encoder converts information, such as a decimal number and an alphabetic character, into some coded form.
- For example, on certain type of encoder converts each of the decimal digits, 0 through 9, to a binary code.

Example for the encoding function



5. Decoding Function (تابع فك التشفير).

- The decoding function is performed by the logic circuit called a **decoder (مفكك/محلل الشيفرة)**.
- The decoder converts coded information, such as a binary number, into a non-coded form, such as a decimal form.
- For example, one particular type of decoder converts a 4-bit binary code into the appropriate decimal digit.
- Fig. show a decoder used to convert a special binary code into a 7-segment decimal readout.



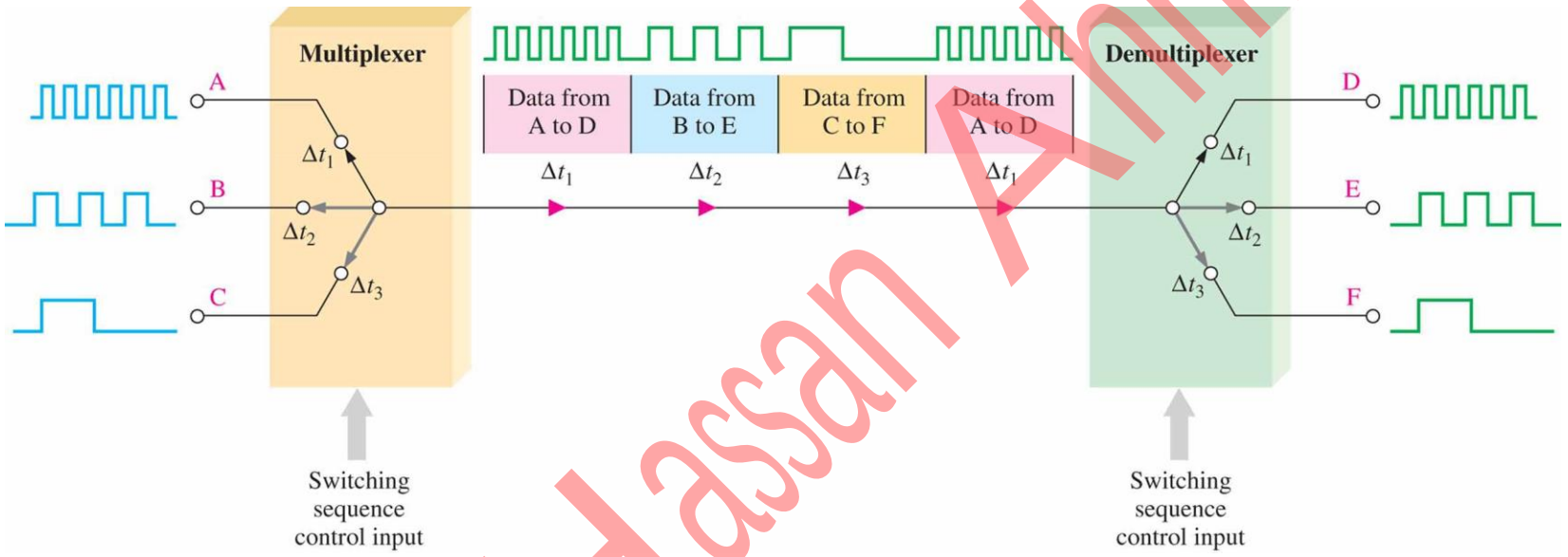
6. Data Selection Function (تابع اختيار البيانات).

Two types of circuits that select data are the multiplexer and the demultiplexer.

- The **multiplexer** (**mux**) (الناخب) is a logic circuit that switches digital data from **several** input lines onto a **single** output line in a specified time sequence.
- The **demultiplexer** (**demux**) (موزع البيانات) is a logic circuit that switches digital data from **one** input line to **several** lines in a specified time sequence.
- Multiplexing and Demultiplexing are used when data from several sources are to be transmitted over one line to distant location and redistributed to several destinations (اتجاهات).

Illustration of a basic multiplexing/demultiplexing application.

Fig. illustrates the type of application where digital data from three sources are sent out along a single line to three terminals at another location.



- Data from input *A* are connected to the output line during time interval Δt_1 and transmitted to the **demux** that connects them to output *D*.
- During interval Δt_2, the **mux** switches to input *B* and the **demux** switches to output *E*.
- During interval Δt_3, the **mux** switches to input *C* and the **demux** switches to output *F*.

Because the time is divided up among several sources and destinations where each has its **turn to send and receive data**, this process is called **time division multiplexing (TDM)** (تعدد الإرسال بتقسيم الزمن).

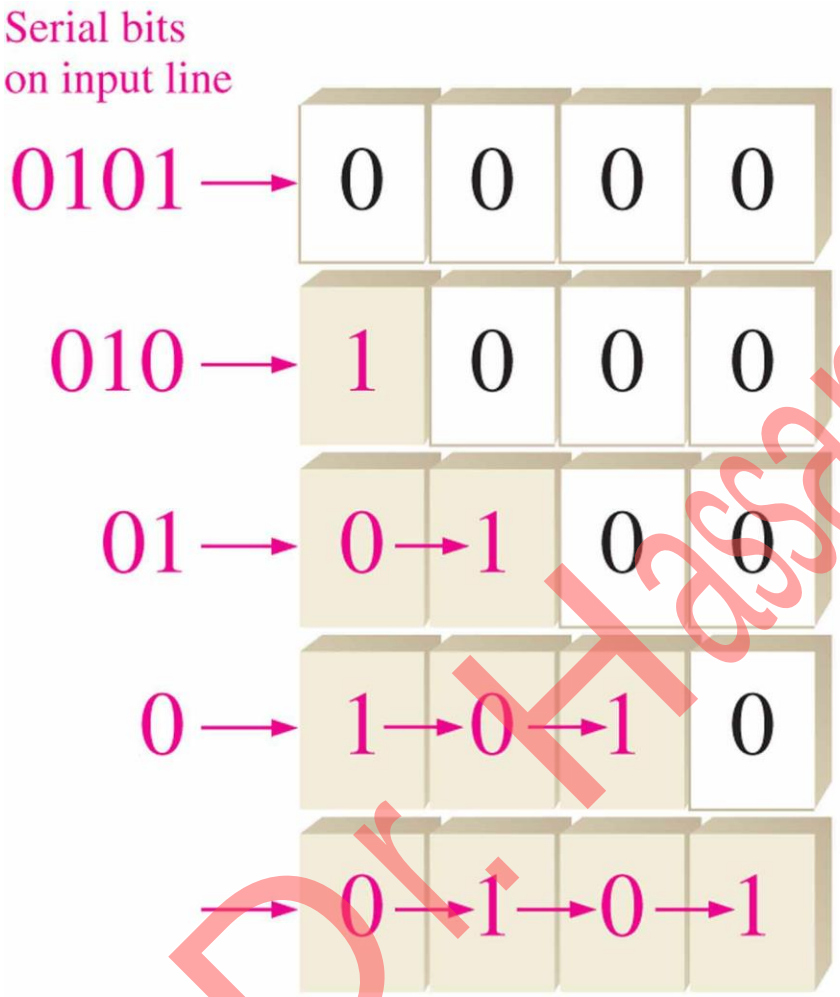
7. Storage Function (تابع التخزين)

- **Storage** is a function that is required in most digital systems, and its purpose is to retain (الاحتفاظ) binary data for a period of time.

Common types of storage devices:

1) **Flip-flops (القلابات)**. A flip-flop is a bistable (two stable states=ثنائي الاستقرار) logic circuit that can store only **one bit** at a time, either a **1 (HIGH)** or a **0 (LOW)**. The output of a flip-flop indicates which bit it is storing.
2) **Registers (المسجلات)**. A register is formed by combining several flip-flops so that groups of bits can be stored.
   - For example, an 8-bit register is constructed from eight flip-flops.
   - Registers can be used to shift the bits from one position to another within the register or out of the register to another circuit, therefore, these devices are known as **shift registers** (مسجلات الإزاحة).
3) **Semiconductor Memories (ذواكر شبه ناقلة)**. Semiconductor memories are devices typically used for storing large numbers of bits. For example, **ROM** and **RAM**.
4) **Magnetic Memories (ذواكر مغناطيسية)**. Magnetic disk memories are used for mass storage of binary data. For example, floppy disks, hard disks, flash disks…….

Example of the operation of a 4-bit **serial shift register**. Each block represents one storage "cell" or flip-flop.



Initially, the register contains only *invalid* data or all zeros as shown here.

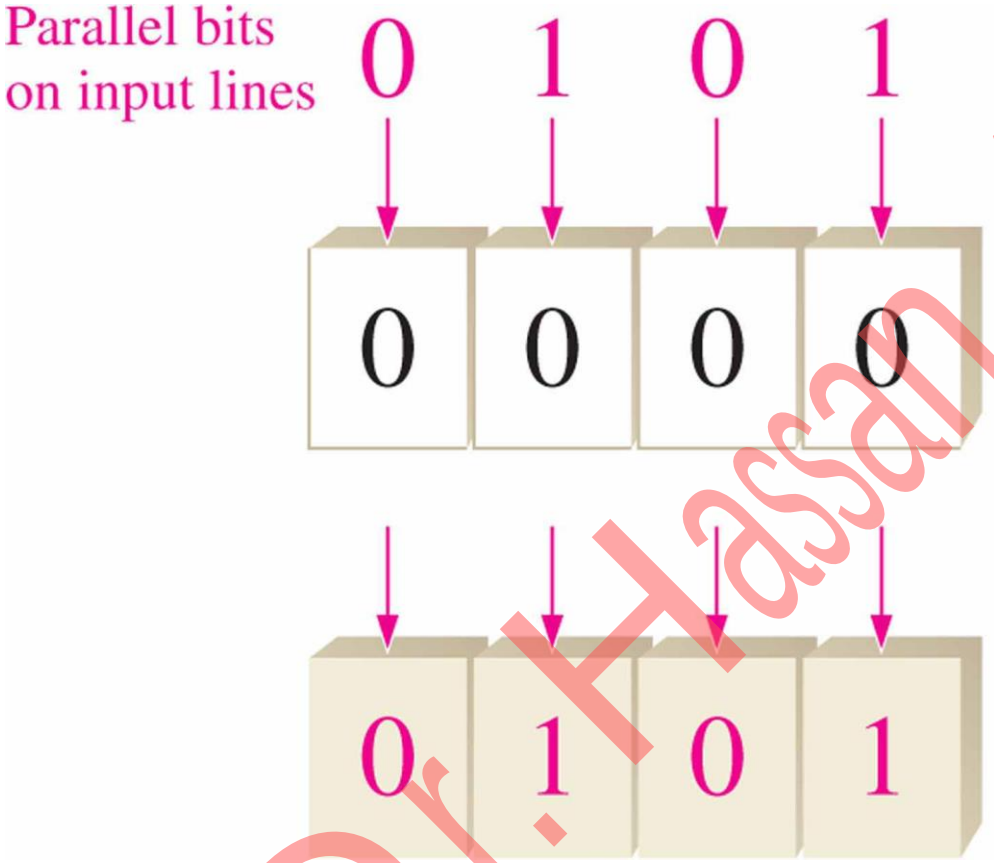
First bit (1) is shifted serially into the register.

Second bit (0) is shifted serially into register and first bit is shifted right.

Third bit (1) is shifted into register and the first and second bits are shifted right.

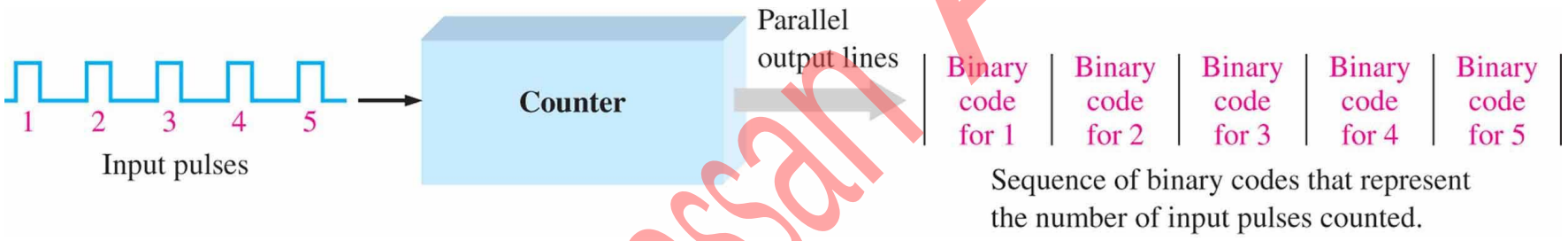
Fourth bit (0) is shifted into register and the first, second, and third bits are shifted right. The register now stores all four bits and is full.

Example of the operation of a 4-bit **parallel shift register**. Each block represents one storage "cell" or flip-flop.



8. Counting Function (تابع العد).

- The **counting function** is important in digital systems.
- There are many types of digital counters (العدادات), but their basic purpose is to count events represented by changing levels or pulses.
- Fig. illustrates the basic idea of counter operation.



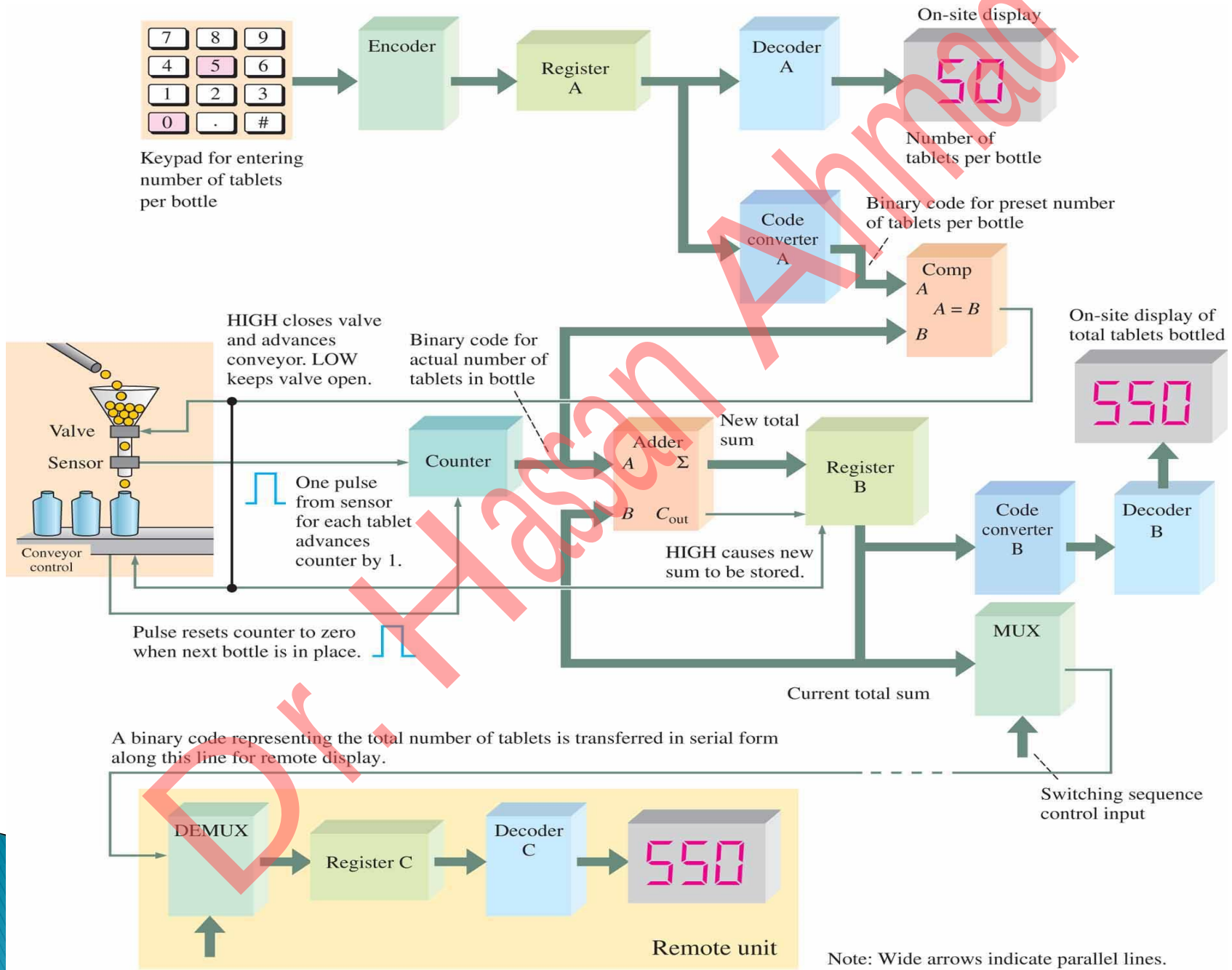
Sequence of binary codes that represent the number of input pulses counted.

- The number of counted pulses (N_p) is defined as: $N_p = \frac{t}{T}$

where: T – period of the input waveform

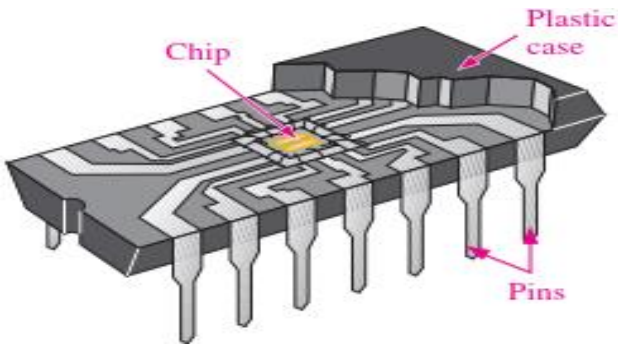
t – total time for counting.

Digital system application: Block diagram of a tablet-bottling system (نظام تعبأة أقراص)



2-3. Fixed-Function Logic Devices (الأجهزة المنطقية ثابتة الوظيفة)

- All the logic elements and functions that have been discussed are generally available in **integrated circuit (IC)** form.
- Integrated circuit (IC) is an electronic circuit that is constructed entirely on a single small chip of silicon.
  - All the components that make up the circuit (transistors, diodes, resistors, and capacitors) are an integral part of that single chip.
- Fixed-function logic and programmable logic are two broad categories of digital ICs.
  - In fixed-function logic devices, the logic functions are set by the manufacturer (الشركة المصنعة) and cannot be altered (تغيير).
    - Fig. shows a cutaway view of one type of fixed-function IC package with the circuit chip shown within the package.
    - Points on the chip are connected to the package pins to allow input and output connections to the outside world.



2-4. Programmable Logic Devices (PLDs) (الأجهزة المنطقية القابلة للبرمجة)

- Many types of programmable logic are available, ranging from small devices that can replace a few fixed-function devices to complex high-density devices that can replace thousands of fixed-function devices.
- Two major categories of user-programmable logic are:

1) **PLD** (programmable logic device). PLDs are either SPLDs (simple PLDs) or CPLDs (complex PLDs).
2) **FPGA** (field-programmable gate array= مصفوفة منطقية ذات حقل قابل للبرمجة).

Selected Key Terms

Analog	Being continuous or having continuous values.
AND	A basic logic operation in which a true (HIGH) output occurs only when all input conditions are true (HIGH).
Binary	Having two values or states; describes a number system that has a base of two and utilizes 1 and 0 as its digits.
Bit	A binary digit, which can be a 1 or a 0.
Clock	A basic timing signal in a digital system; a periodic waveform used to synchronize actions.
Compiler	A program that controls the design flow process and translates source code into object code in a format that can be logically tested or downloaded to a target device.
Data	Information in numeric, alphabetic, or other form.
Digital	Related to digits or discrete quantities; having a set of discrete values.
Duty cycle	The ratio of the pulse width to the period of a digital waveform, expressed as a percentage.

Selected Key Terms

Fixed-function logic	A category of digital integrated circuits having functions that cannot be altered.
Gate	A logic circuit that performs a basic logic operations such as AND or OR.
Input	The signal or line going into a circuit.
Integrated circuit (IC)	A type of circuit in which all of the components are integrated on a single chip of semiconductive material of extremely small size.
Inverter	A NOT circuit; a circuit that changes a HIGH to a LOW or vice versa.
Logic	In digital electronics, the decision-making capability of gate circuits, in which a HIGH represents a true statement and a LOW represents a false one.
NOT	A basic logic function that performs inversion.
OR	A basic logic operation in which a true (HIGH) output occurs when one or more of the input conditions are true (HIGH).
Output	The signal or line coming out of a circuit.
Parallel	In digital systems, data occurring simultaneously on several lines; the transfer or processing of several bits simultaneously.

Selected Key Terms

Programmable logic	**A category of digital integrated circuits capable of being programmed to perform specified functions.**
Pulse	A sudden change from one level to another, followed after a time, called the pulse width, by a sudden change back to the original level.
Serial	Having one element following another, as in a serial transfer of bits; occurring in sequence rather than simultaneously.
Timing diagram	A graph of digital waveforms showing the time relationship of two or more waveforms.

True/False Quiz

1. An analog quantity is one having continuous values.
2. A digital quantity has no discrete values.
3. There are two digits in the binary system.
4. The term bit is short for binary digit.
5. In positive logic, a LOW level represents a binary 1.
6. A periodic wave repeats itself at a fixed interval.
7. A timing diagram shows the timing relationship of two or more digital waveforms.
8. An AND function is implemented by a logic circuit known as an inverter.
9. A flip-flop is a bistable logic circuit that can store only two bits at a time.
10. Two broad types of digital integrated circuits are fixed- function and programmable.

1. T 2. F 3. T 4. T 5. F 6. T 7. T 8. F 9. F 10. T

SELF-TEST

1. A quantity having discrete numerical values is
   (a) an analog quantity (b) a digital quantity
   (c) a binary quantity (d) a natural quantity

2. The term *bit* means
   (a) a small amount of data (b) a 1 or a 0
   (c) binary digit (d) both answers (b) and (c)

3. The time interval between the 50% points on the rising and falling edges is
   (a) rise time (b) fall time
   (c) pulse width (d) period

4. A pulse in a certain waveform has a frequency of 50 Hz. It repeats itself every
   (a) 1 ms (b) 20 ms (c) 50 ms (d) 100 ms

5. In a certain digital waveform, the period is four times the pulse width. The duty cycle is
   (a) 25% (b) 50% (c) 75% (d) 100%

SELF-TEST

6. An inverter
- **(a)** performs the NOT operation
- **(b)** changes a HIGH to a LOW
- **(c)** changes a LOW to a HIGH
- **(d)** does all of the above

7. The output of an OR gate is LOW when
- **(a)** any input is HIGH
- **(b)** all inputs are HIGH
- **(c)** no inputs are HIGH
- **(d)** Both (a) and (b)

8. The output of an AND gate is LOW when
- **(a)** any input is LOW
- **(b)** all inputs are HIGH
- **(c)** no inputs are HIGH
- **(d)** Both (a) and (c)

9. The device used to convert a binary number to a 7-segment display format is the
- **(a)** multiplexer
- **(b)** encoder
- **(c)** decoder
- **(d)** register

10. An example of a data storage device is
- **(a)** the logic gate
- **(b)** the flip-flop
- **(c)** the comparator
- **(d)** the register
- **(e)** both answers (b) and (d)

Quiz

1. Compared to analog systems, digital systems
   a. **are less prone to noise** (هي أقل عرضة للضوضاء)
   b. can represent an infinite number of values
   c. can handle much higher power
   d. all of the above
2. The number of values that can be assigned (المُسندة) to a bit are
   a. one
   b. **two**
   c. three
   d. ten
3. The time measurement between the 50% point on the leading edge of a pulse to the 50% point on the trailing edge of the pulse is called the
   a. rise time
   b. fall time
   c. period
   d. **pulse width**

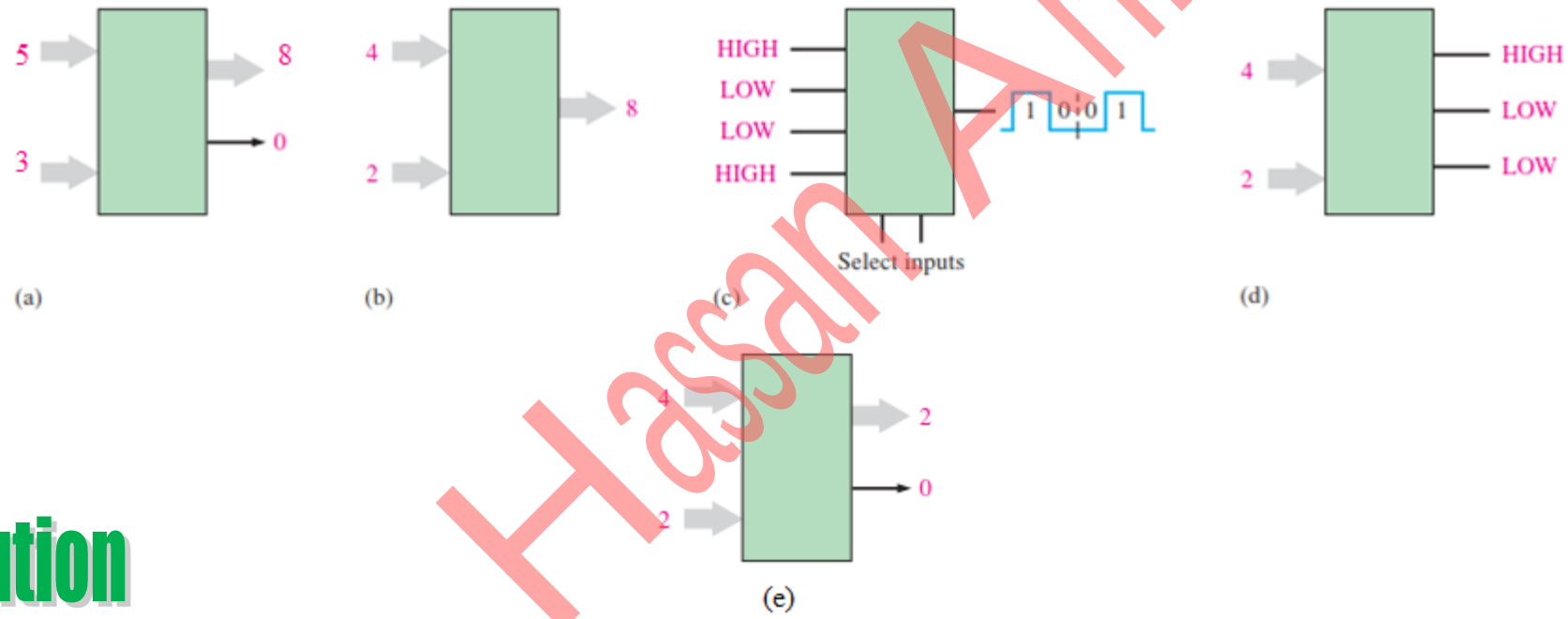
4. The time measurement between the 90% point on the trailing edge of a pulse to the 10% point on the trailing edge of the pulse is called the
    a. rise time
    b. **fall time**
    c. period
    d. pulse width
5. The reciprocal of the frequency of a clock signal is the
    a. rise time
    b. fall time
    c. **period**
    d. pulse width
6. If the period of a clock signal is 500 ps, the frequency is
    a. 20 MHz
    b. 200 MHz
    c. **2 GHz**
    d. 20 GHz

7. AND, OR, and NOT gates can be used to form
    a. storage devices
    b. comparators
    c. data selectors
    d. **all of the above**
8. A shift register is an example of a
    a. **storage device**
    b. comparator
    c. data selector
    d. counter
9. A device that is used to switch one of several input lines to a single output line is called a
    a. comparator
    b. decoder
    c. counter
    d. **multiplexer**

Problems & Solutions

Problem 2-1

Name the logic function of each block in Fig. based on your observation of the inputs.



Solution

(a) Adder; (b) Multiplier; (c) Multiplexer; (d) Comparator, (e) Subtractor.

Problem 2-2

A pulse waveform with a frequency of 10 kHz is applied to the input of a counter. During 100 ms, how many pulses are counted?

Solution

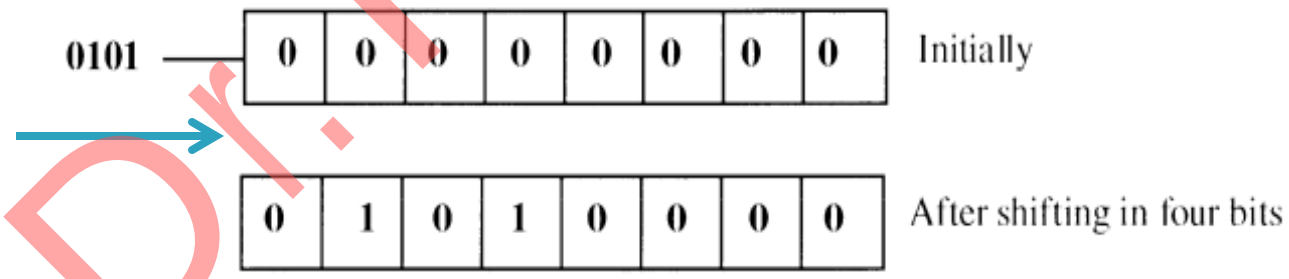
$$T = \frac{1}{f} = \frac{1}{10\,\text{kHz}} = 100\,\mu s \Rightarrow \text{Pulses counted} = \frac{100\text{ ms}}{100\ \mu\text{s}} = 1000$$

****

Problem 2-3

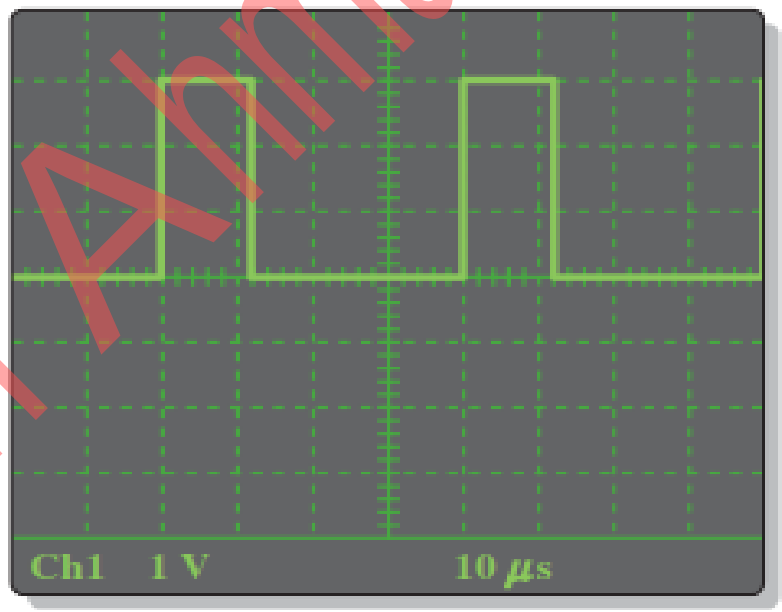
Consider a register that can store eight bits. Assume that it has been reset so that it contains zeros in all positions. If you transfer four alternating bits (0101) serially into the register, beginning with a 1 and shifting to the right, what will the total content of the register be as soon as the fourth bit is stored?

Solution



Problem 2-4

Based on the readouts, determine the amplitude and the period of the pulse waveform on the screen of a digital oscilloscope as shown in Fig. Also, calculate the frequency.



Solution

The volts/div setting is 1 V.
The pulses are three divisions high.
Since each division represents 1 V,
the pulse amplitude is:

Amplitude = (3 div)(1 V/div) = 3 V

The sec/div setting is 10 µs. A full cycle of the waveform (from beginning of one pulse to the beginning of the next) covers four divisions; therefore, the period is

Period = (4 div)(10 µs/div) = 40 µs

The frequency is calculated as $f = 1 / T = 1 / 40\ \mu s = 25$ kHz.

The end of Lecture_02, chapter 1