Logic Gates

Objectives:

At the end of the lecture students may learn:

1- Basic logic gates

2- NOT gate

3- AND gate

4- OR gate

5- NAND gate

6- NOR gate

7- Exclusive –OR (X-OR)

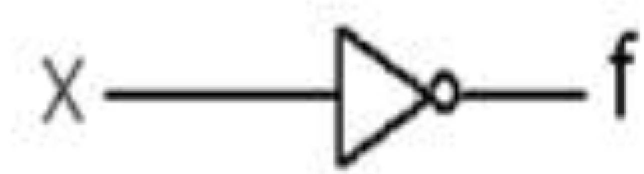
8- Exclusive- NOR (X-NOR)

1-Basic logic gates

- Logic gate is a device used to control the signal.
- For basic logic functions (NOT , AND, OR), The inputs variables are on the left of each symbol and the outputs variables are on the right.
- The total number of possible combinations of binary inputs to the gate is determined by the following formula: $N=2^n$ (where N is number of possible input combinations and n is the number of input variables).

2- NOT(Invertor) gate

The NOT circuit performs the operation called complementation. The NOT (invertor) circuit changes the logic 1 in the input to logic zero in the out put and change logic 0 in the input to logic 1 in the output.

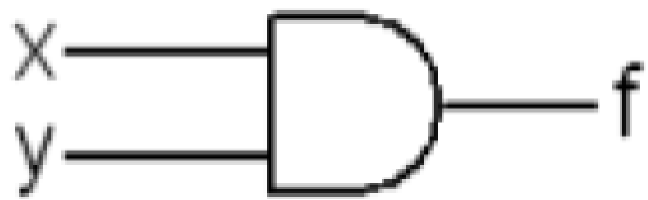


$$F = \overline{X}$$

X	F
0	1
1	0

3- AND gate

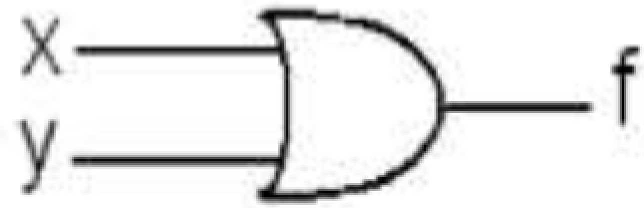
- If all inputs to AND gate are at logic 1 (high), the output is at logic 1(high) otherwise the output is at logic zero (low).



X	Y	F= X .Y
0	0	0
0	1	0
1	0	0
1	1	1

4- OR gate

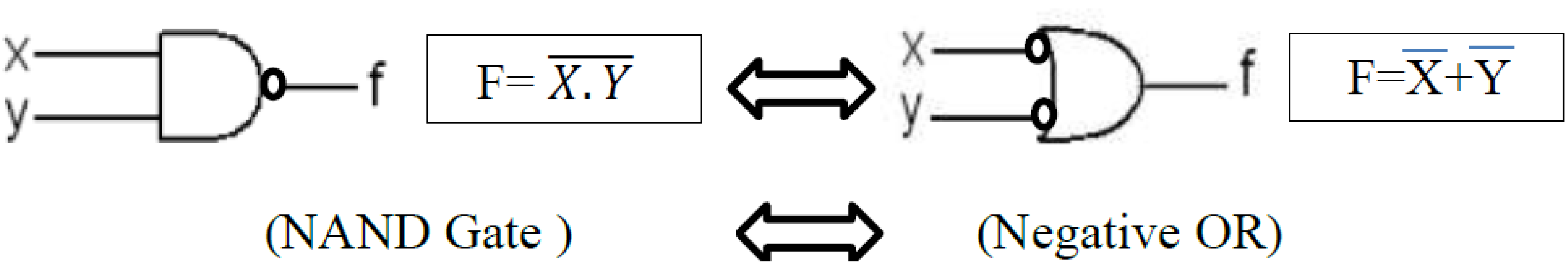
- The output of OR gate is at logic 1 (high) if any one or more inputs are at logic 1 otherwise the output is at logic zero (low).



X	Y	F= X+Y
0	0	0
0	1	1
1	0	1
1	1	1

5-NAND gate

- This gate performs a negative OR operation.
- output F is high (1) when either input X or input Y is low (0) or when both X and Y are low (0).

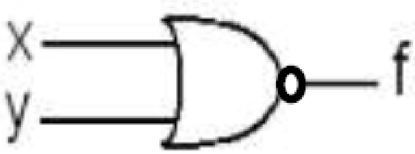


X	Y	$F = \overline{X.Y}$
0	0	1
0	1	1
1	0	1
1	1	0

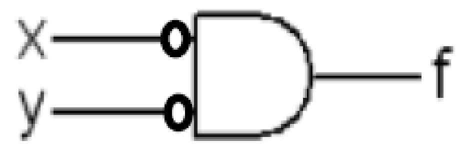
$$F = \overline{X.Y} \Longleftrightarrow F = \overline{X} + \overline{Y}$$

6- NOR gate

- This gate perform negative AND operation
- Output F is low (0) when either input X or input Y is high (1), or when both X and Y is high (1). F is high (1) only when both X and Y are low (0)



$F = \overline{X + Y}$ $\Leftrightarrow$



$F = \overline{X} . \overline{Y}$

(NOR Gate) $\Leftrightarrow$ (Negative AND)

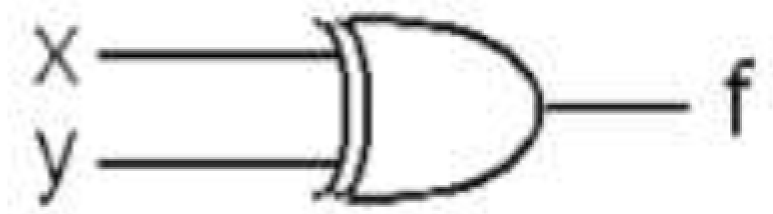
X	Y	$F = \overline{X + Y}$
0	0	1
0	1	0
1	0	0
1	1	0

$$F = \overline{X + Y} \Longleftrightarrow F = \overline{X} \cdot \overline{Y}$$

7- Exclusive-OR (X-OR)

- For this gate, output F is high (1) when input X is low (0) and input Y is high (1) or when input X is high (1) and input Y is low (0)
- F is low (0) when X and Y are both high (1) 0r both low (0).

$$F = X \oplus Y = \bar{X}Y + X\bar{Y}$$

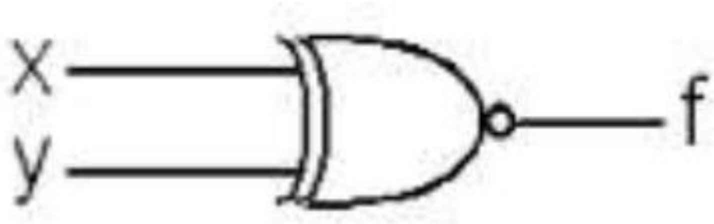


X	Y	$F = X \oplus Y$
0	0	0
0	1	1
1	0	1
1	1	0

8- Exclusive-NOR (X-NOR)

- For this gate, output F is low (0) when input X is low (0) and input Y is high (1), or when X is high (1) and input Y is low.
- F is high (1) when X and Y are both high (1) or both low (0).

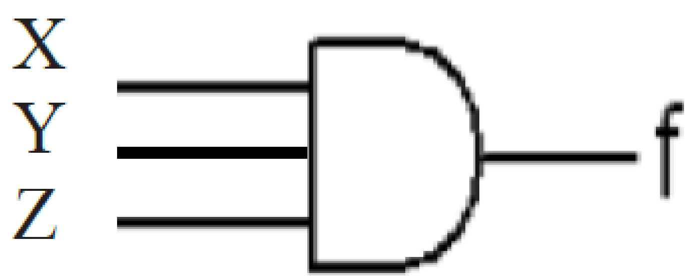
$$F=\overline{X \oplus Y}=\overline{X}\overline{Y}+XY$$

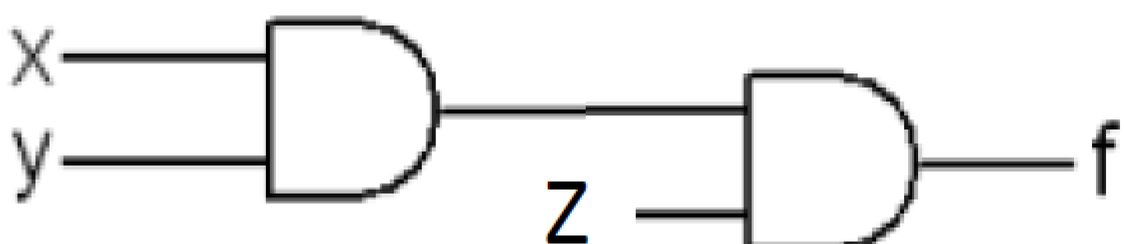


X	Y	$F = \overline{X \oplus Y}$
0	0	1
0	1	0
1	0	0
1	1	1

Example-1: Develop the truth table for a 3-inputs AND gate.

Solution: There are eight possible combinations ($2^3 = 8$) for a 3-input AND gate. The output F is (0) except when all three input bits are (1).

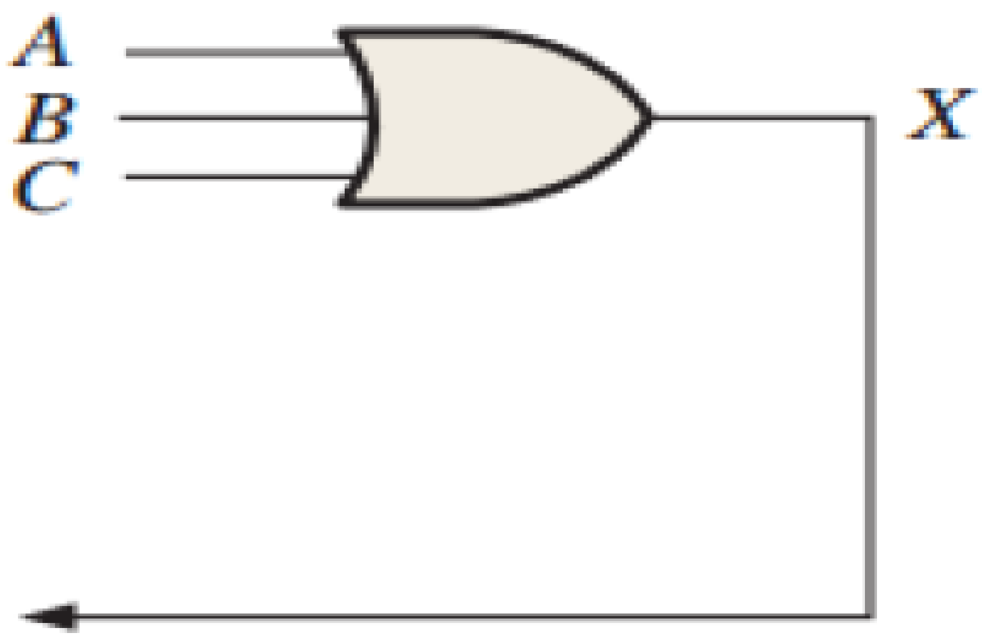


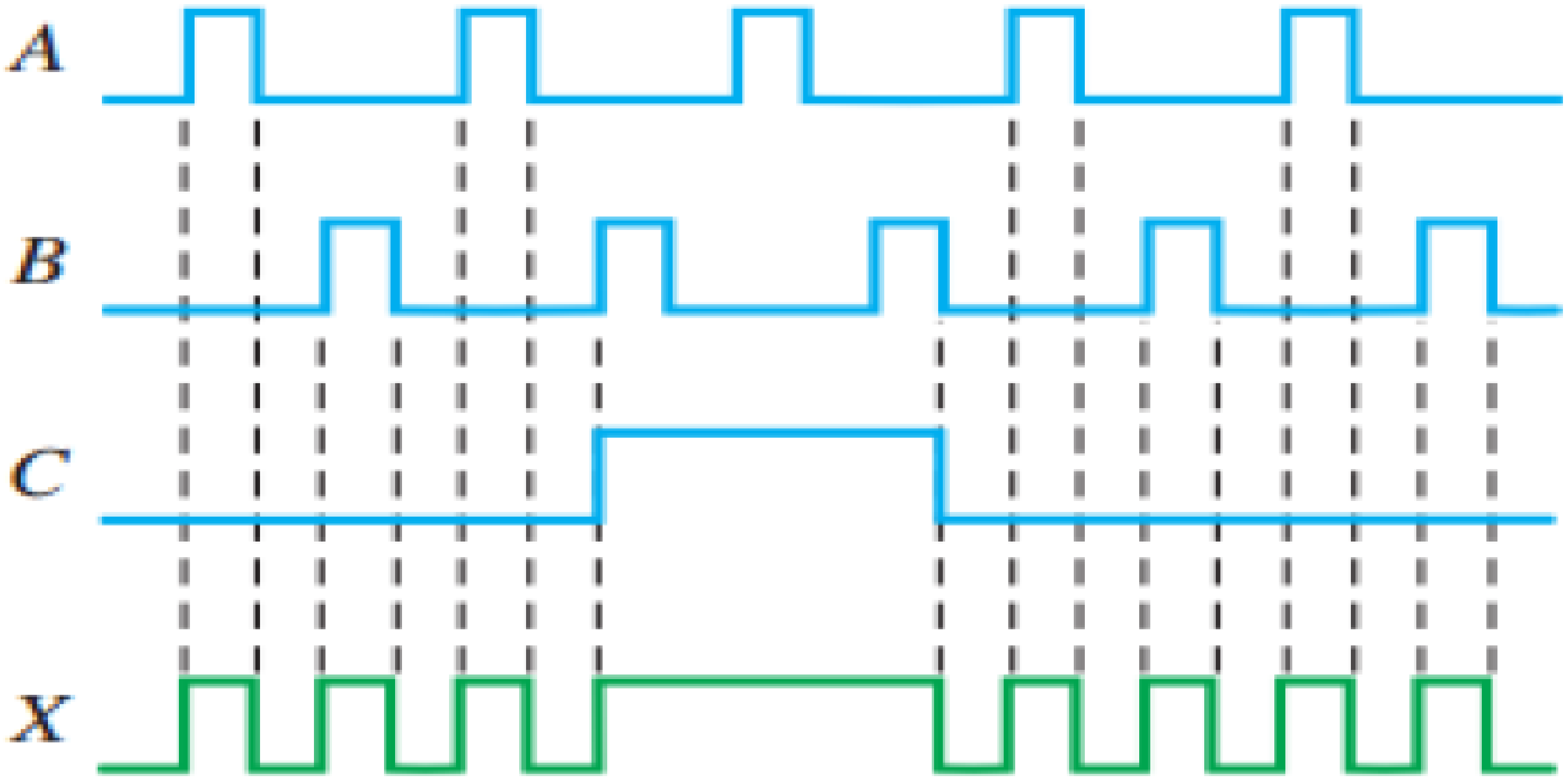


X	Y	Z	F= X .Y.Z
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Example-2: Determine the output waveforms for OR gate and for the given input waveforms A,B and C in figure below.

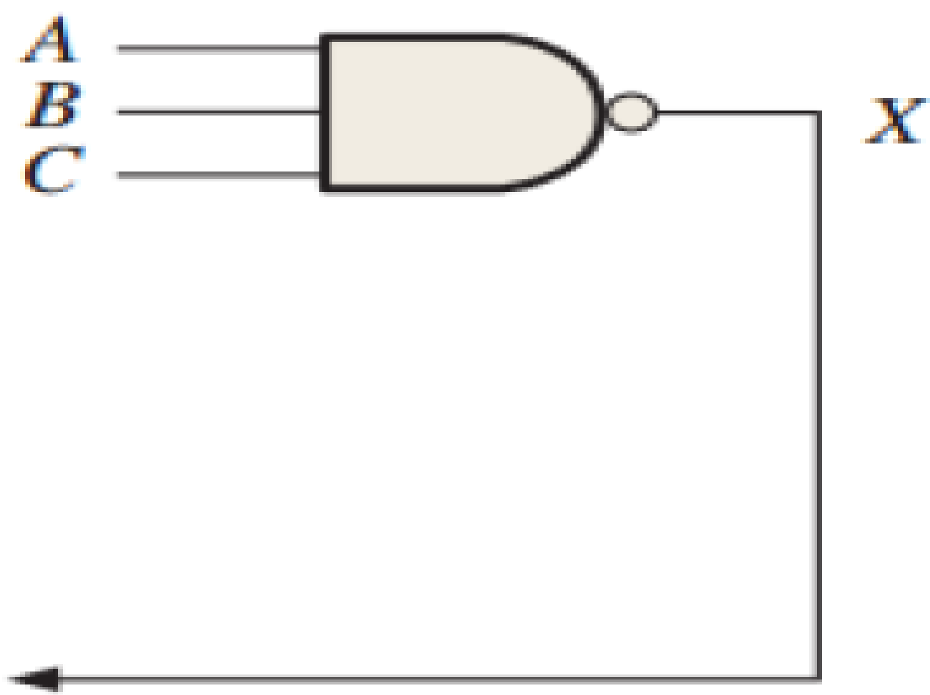
Solution: The output (X) is high (1) when one or more of the input waveform (A,B,C) are high (1) as indicated by the output waveform (X) in the timing diagram.

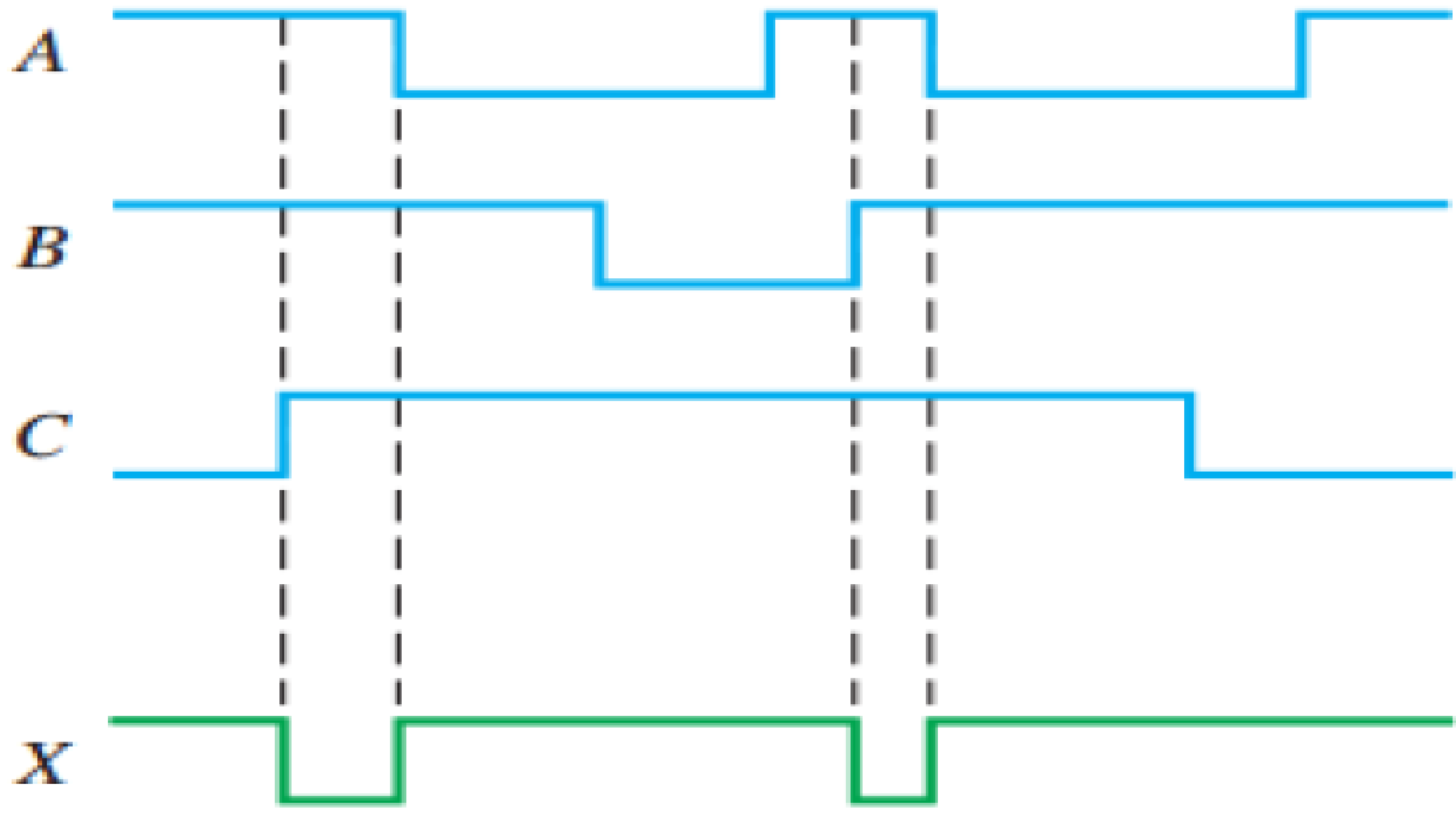



A
B
C
X

Example-3: Determine the output waveforms for the NAND gate and for the given input waveforms A,B and C in figure below.

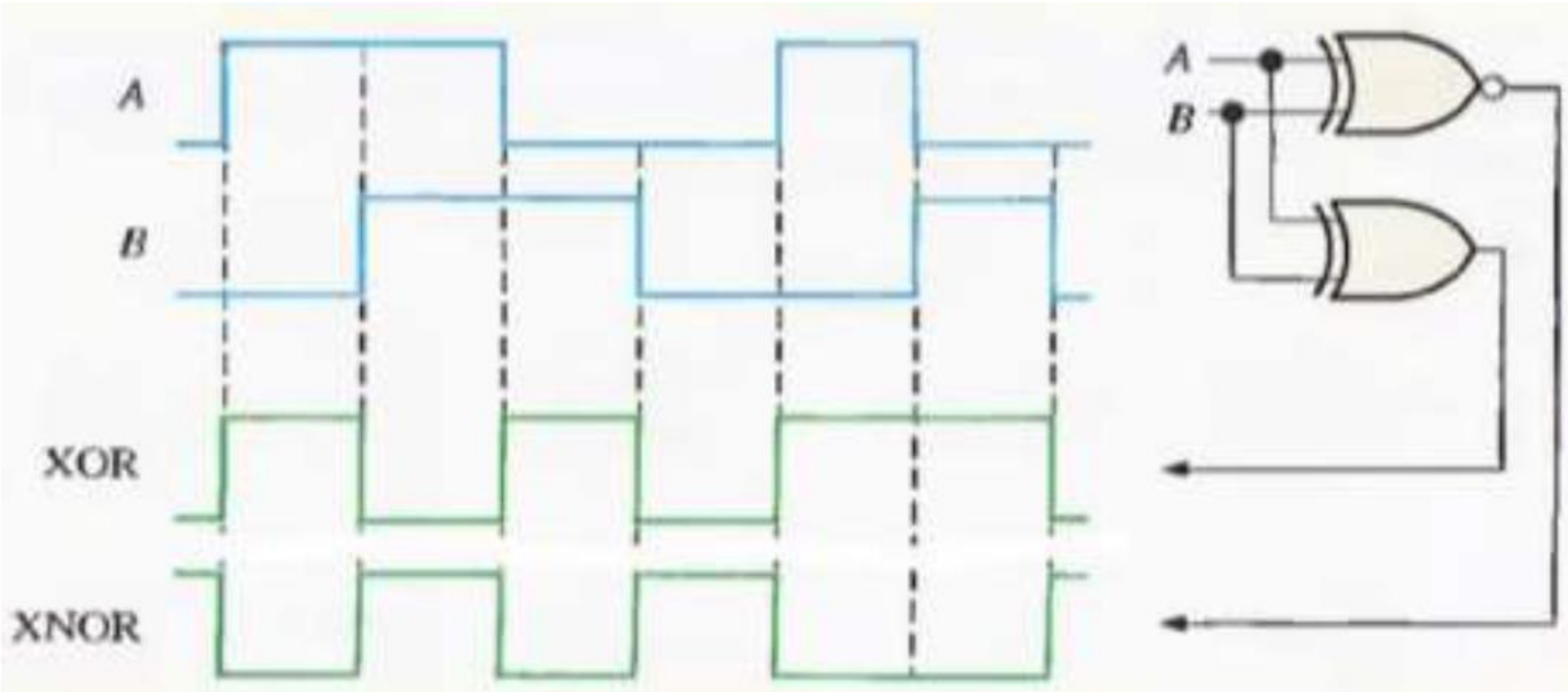
Solution: The output waveform is low (0) only when all the three input waveforms are high (1) as shown in the timing diagram.




A
B
C
X

Example-4: Determine the output for XOR gate and for XNOR gate, given the input waveforms, A and B in figure below:

Solution:

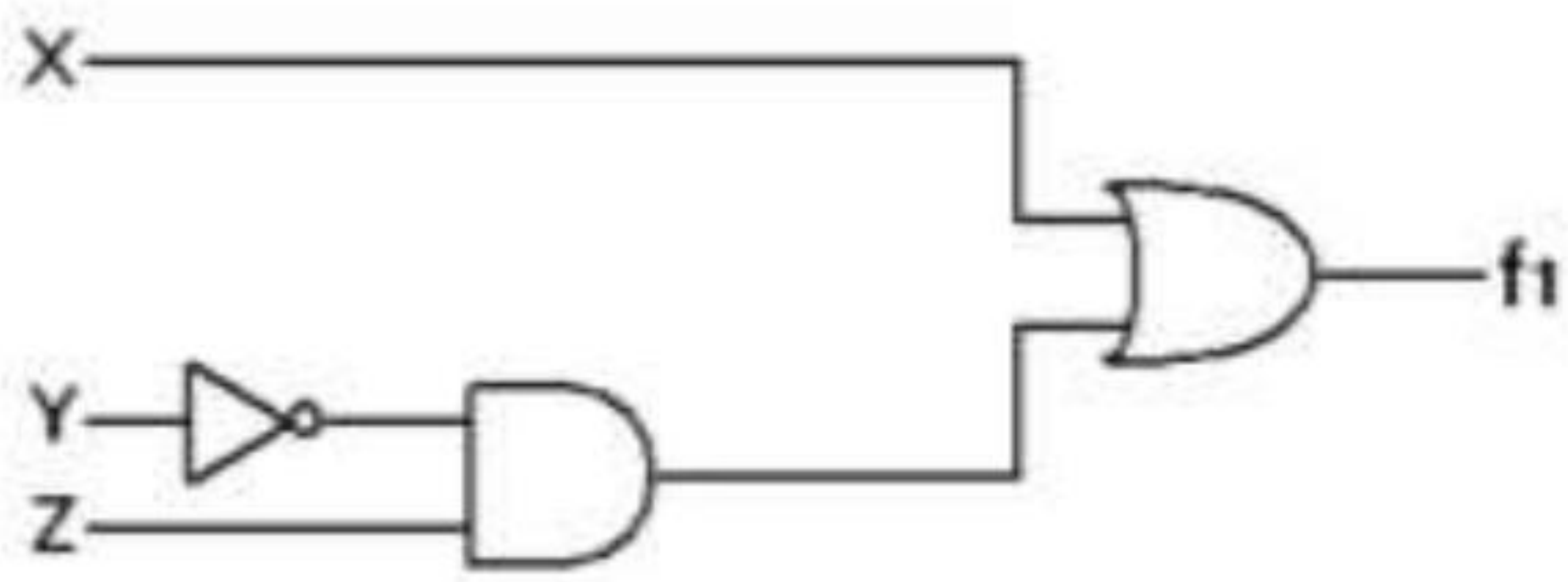


Dr. Adnan Allawi
N.U.S.T

Example-5: Draw the logic diagrams for the following Boolean expressions

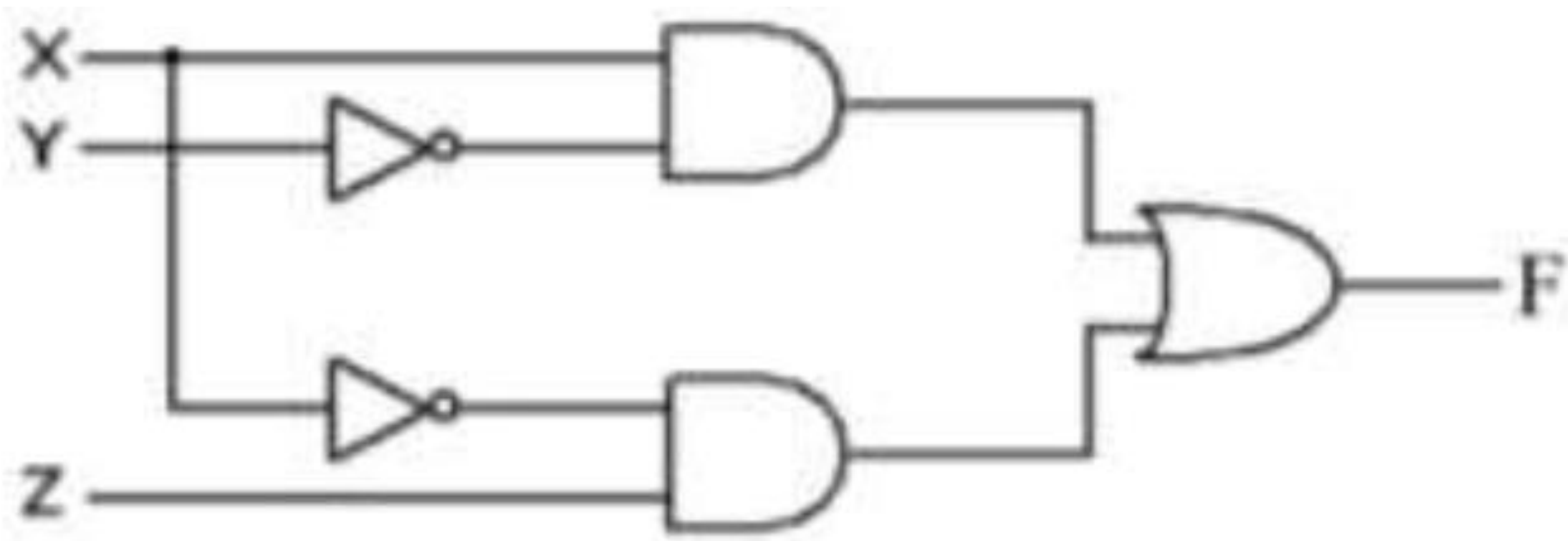
1- $F1= X + \bar{Y}Z$

Solution:



$F2 = X\bar{Y} + \bar{X}Z$

Solution:



References:

1-Digital Fundamental, Thomas L. Floyd, Eleventh Edition, 2015, pearson.

2- Digital design, M .Morris Mano and Michael D. Ciletti, Fifth Edition, 2013, Pearson.

Thank you
With best wishes