Experiment No.1
Logic Gates

1. Introduction

1.1 Objective:

Study the operation of all logic gates.

1.2 Components:

- TESCA board 38609.
- Set of connecting wires.

1.3 Theory:

There is a computer logic training board has been designed specifically to study simple Logic Functions and Theorems of Boolean Algebra and to compare the truth table with experimental results it's made by TESCA. This training board offers a method of training students in the basic theory of digital circuits and make them familiar with basic experiments in digital circuits. The board is absolutely self-contained and requires no other apparatus.

Figure 1: TESCA Board

A logic gate is an electronic circuit/device which makes the logical decisions. To arrive at this decisions, the most common logic gates used are OR, AND, NOT, NAND, and NOR gates. The NAND and NOR gates are called universal gates. The exclusive-OR gate is another logic gate which can be constructed using AND, OR and NOT gate.

Logic gates have one or more inputs and only one output. The output is active only for certain input combinations. Logic gates are the building blocks of any digital circuit. Logic gates are also called switches. With the advent of integrated circuits, switches have been replaced by TTL (Transistor-Transistor Logic) circuits and CMOS circuits.

AND Gate

The AND gate performs logical multiplication, commonly known as AND function. It has two or more inputs and single output. The output of AND gate is HIGH only when all its inputs are HIGH (i.e. even if one input is LOW, Output will be LOW).

If X and Y are two inputs, then output F can be represented mathematically as F = X.Y, here dot (.) denotes the AND operation sometime X=A & B. The symbol and Truth table of the AND gate are shown in the Figure (2) and Table (1) respectively.
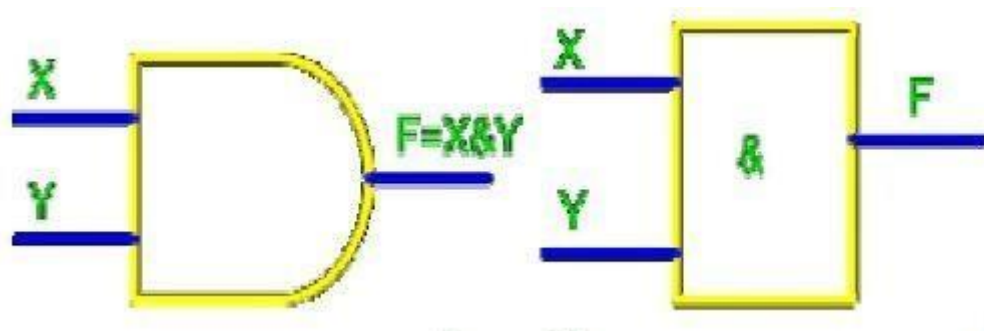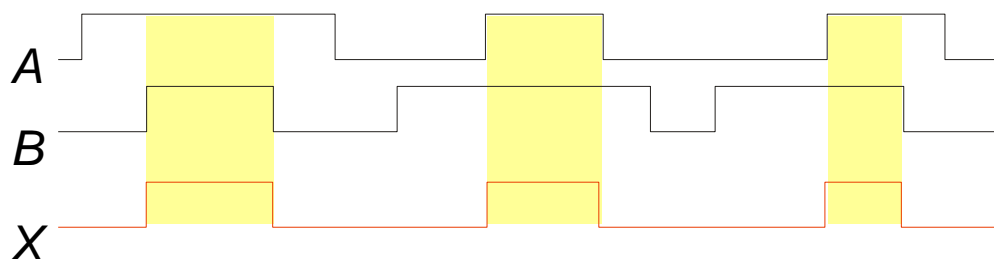

Figure 2: AND Gate Symbol

Inputs		Output
X	**Y**	**F=X.Y**
0	0	0
0	1	0
1	0	0
1	1	1

Table 1: Truth Table of AND Gate

Example waveforms:

OR Gate

The OR gate performs logical addition, commonly known as OR function. It has two or more inputs and single output. The output of OR gate is high only when any one of its inputs are high (i.e. even if one input is high, Output will be high).

If X and Y are two inputs, then output F can be represented mathematically as $F = X+Y$. Here plus sign (+) denotes the OR operation. The symbol and Truth table of the OR gate are shown in the Figure (3) and Table (2) respectively.
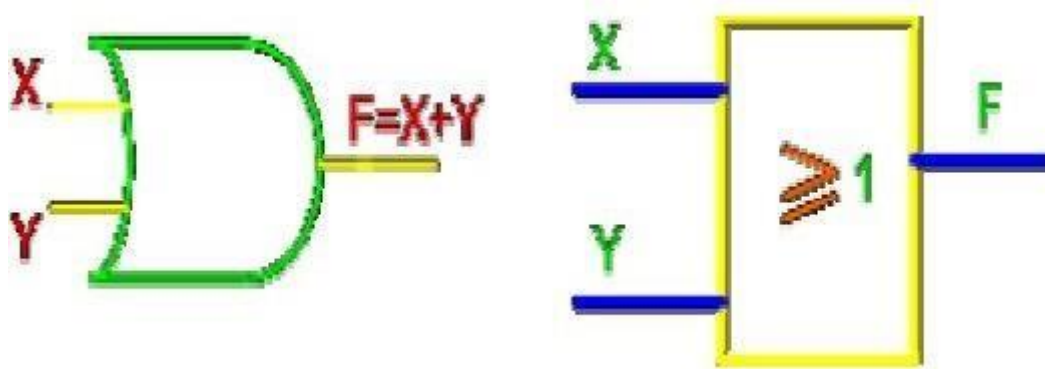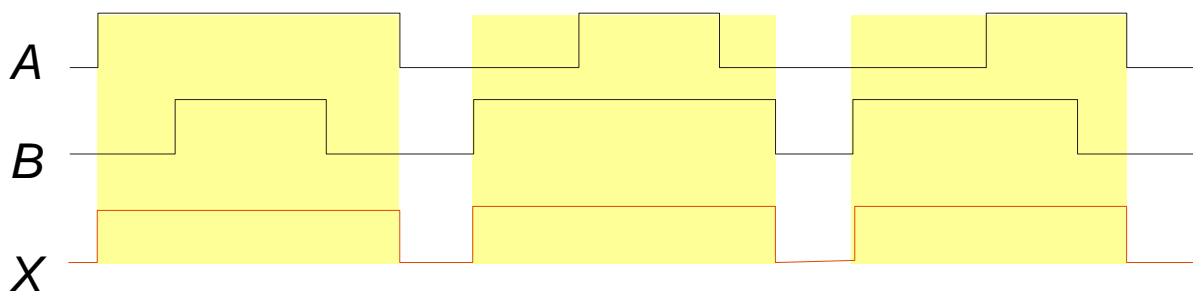

Figure 3: OR Gate Symbol

Inputs		Output
X	**Y**	**F=X+Y**
0	0	0
0	1	1
1	0	1
1	1	1

Table 2: Truth Table of OR Gate

Example waveforms:

The Inventor (NOT Gate)

The NOT gate performs the basic logical function called inversion or complementation. NOT gate is also called inverter. The purpose of this gate is to convert one logic level into the opposite logic level. It has one input and one output. When a high level is applied to an inverter, a low level appears on its output and vice versa.

If X is the input, then output F can be represented mathematically as $F = X'$, Here apostrophe (') denotes the NOT (inversion) operation. There are a couple of other ways to represent inversion,

F=! X, here! Represents inversion. The symbol and Truth table of the NOT gate are shown in the Figure (4) and Table (3) respectively.
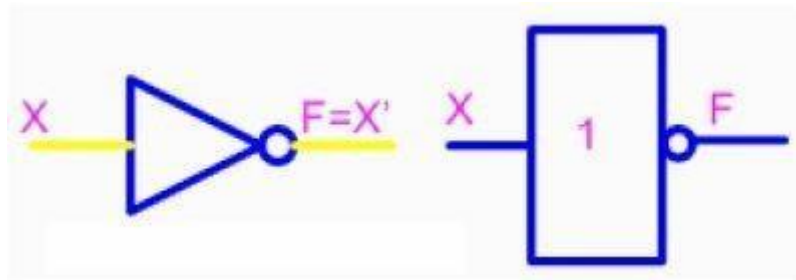

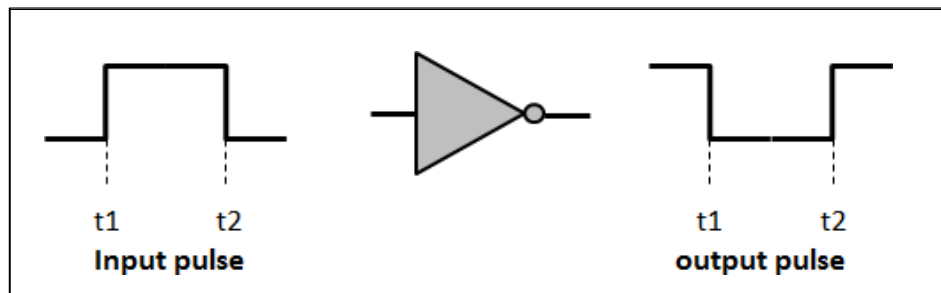*Figure 4: NOT Gate Symbol*

Input	Output
X	F=X'
0	1
1	0

Table 3: Truth Table of NOT Gate

NAND Gate

NAND gate is a cascade of AND gate and NOT gate, as shown in the Figure (5). It has two or more inputs and only one output. The output of NAND gate is high when any one of its input is low (i.e. even if one input is low, Output will be high).
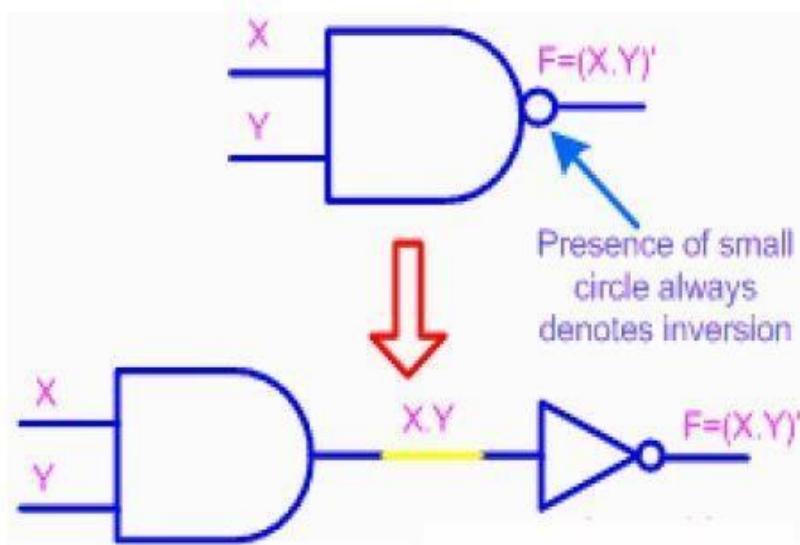

Figure 5: NAND Gate from AND Gate and NOT Gate

If X and Y are two inputs, then output F can be represented mathematically as $F = (X.Y)'$, here dot (.) denotes the AND operation and (') denotes inversion. The symbol and Truth table of the NAND gate are shown in the Figure (6) and Table (4) respectively.
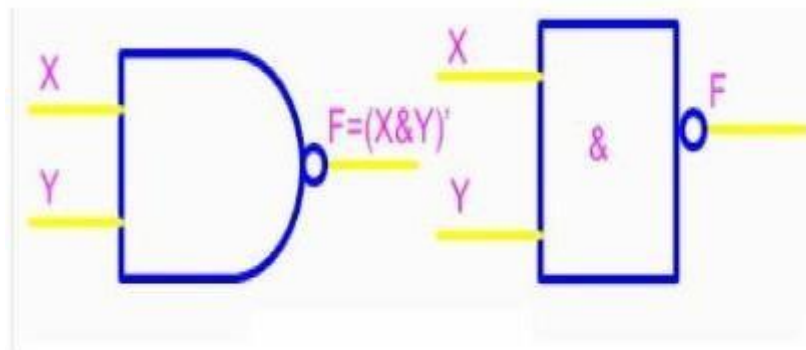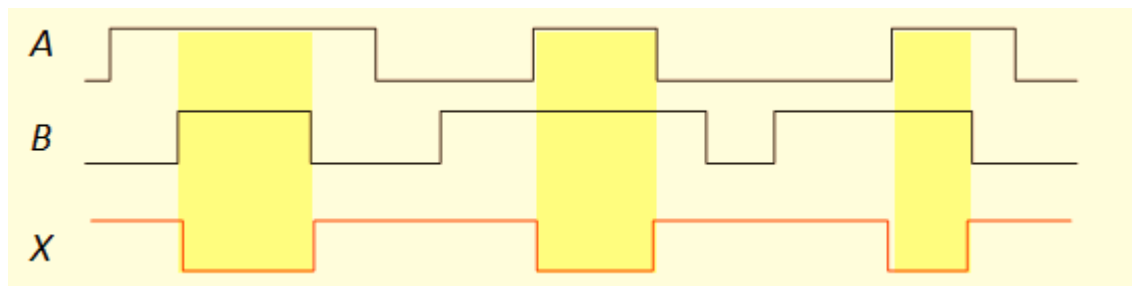

Figure 6: NAND Gate Symbol

Inputs		Output
X	Y	F=(X.Y)'
0	0	1
0	1	1
1	0	1
1	1	0

Table 4: Truth Table of NAND Gate

Example waveforms:

NOR Gate

NOR gate is a cascade of OR gate and NOT gate. It has two or more inputs and only one output. The output of NOR gate is high when any all its inputs are low (i.e. even if one input is high, output will be low).

If X and Y are two inputs, then output F can be represented mathematically as $F = (X+Y)'$; here plus (+) denotes the OR operation and (') denotes inversion. The symbol and Truth table of the NOR gate are shown in the Figure (7) and Table (5) respectively.
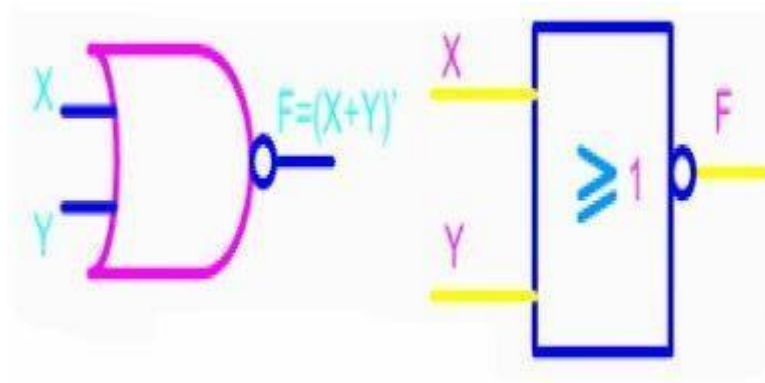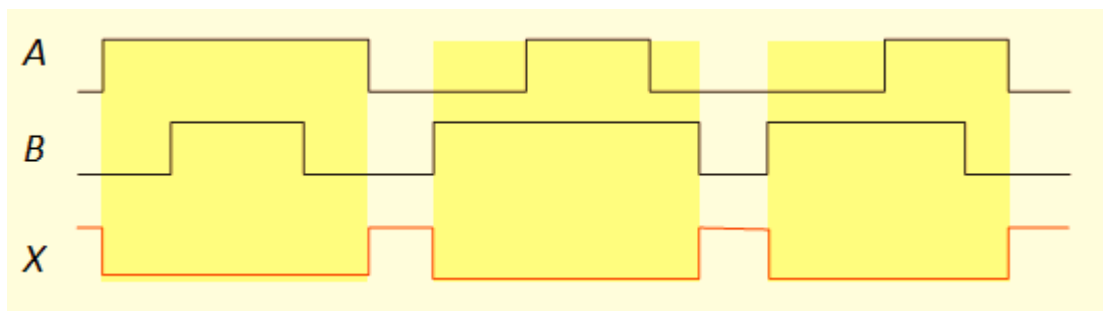
Figure 7: NOR Gate Symbol

Inputs		Output
X	**Y**	**F=(X+Y)'**
0	0	1
0	1	0
1	0	0
1	1	0

Table 5: Truth Table of NOR Gate

Example waveforms:

EX-OR Gate

An Exclusive-OR (EX-OR) gate is gate with two or three or more inputs and one output. The output of a two-input EX-OR gate assumes a high state if one and only one input assumes a HIGH state. This is equivalent to saying that the output is high if either input X or input Y is high exclusively and low when both are 1 or 0 simultaneously.

If X and Y are two inputs, then output F can be represented mathematically as $F = X \oplus Y$, here $\oplus$ denotes the EX-OR operation. $X \oplus Y$ is equivalent to $X.Y' + X'.Y$. The symbol and Truth table of the EX-OR gate are shown in the Figure (8&9) and Table (6) respectively.
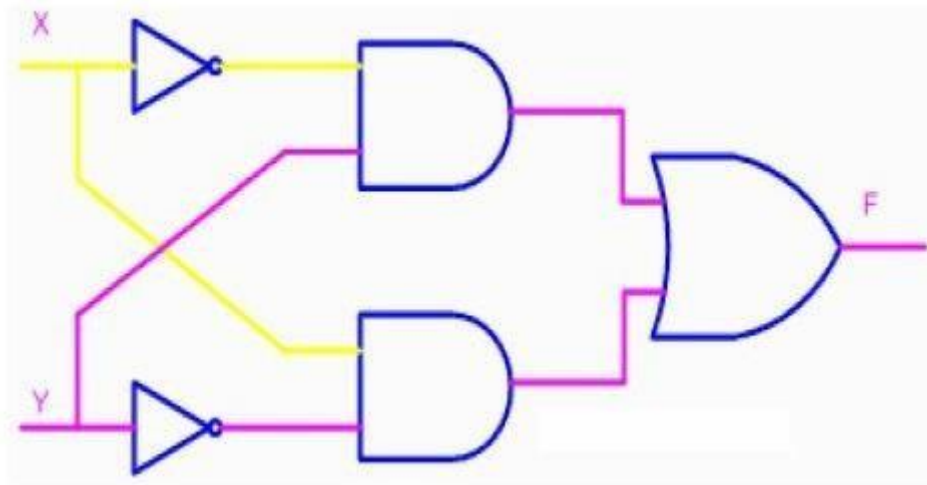
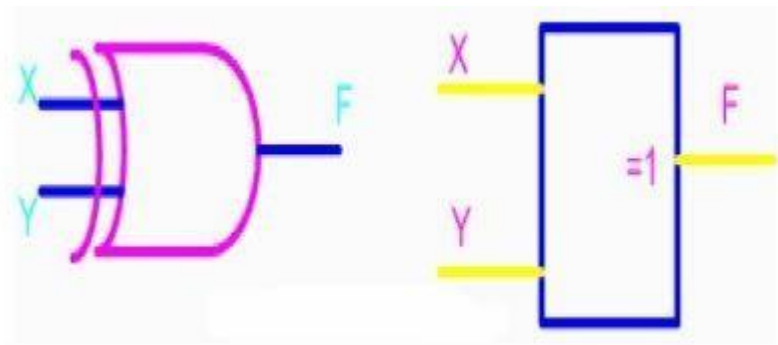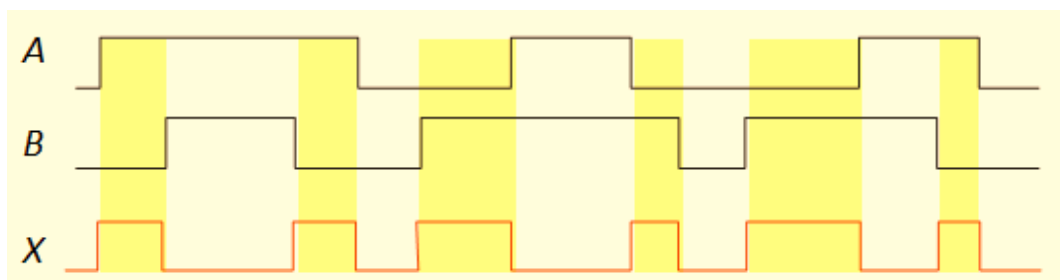Figure 8: EX-OR from Simple Gate

Figure 9: EX-OR Gate Symbol

Inputs		Output
X	**Y**	**F = (X ⊕ Y)**
0	0	0
0	1	1
1	0	1
1	1	0

Table 6: Truth Table of EX-OR Gate

Example waveforms:

EX-NOR Gate

An Exclusive-NOR (EX-NOR) gate is gate with two or three or more inputs and one output. The output of a two-input EX-NOR gate assumes a high state if all the inputs assume same state. This is equivalent to saying that the output is high if both inputs X and input Y is high exclusively or same as input X and input Y is low exclusively and low when both are not same.

If X and Y are two inputs, then output F can be represented mathematically as $F = (X \oplus Y)'$, Here $\oplus$ denotes the EX-OR operation and (') denotes the inversion. $(X \oplus Y)'$ is equivalent to $X.Y + X'.Y'$. The symbol and Truth table of the EX-NOR gate are shown in the Figure (10) and Table (7) respectively.
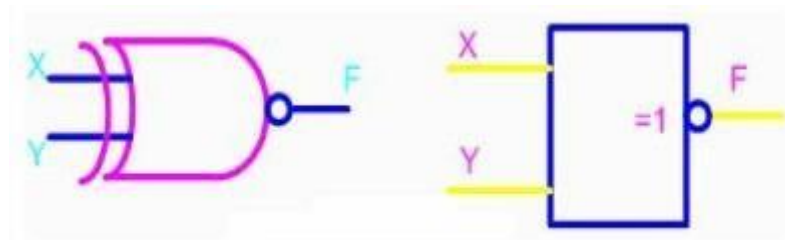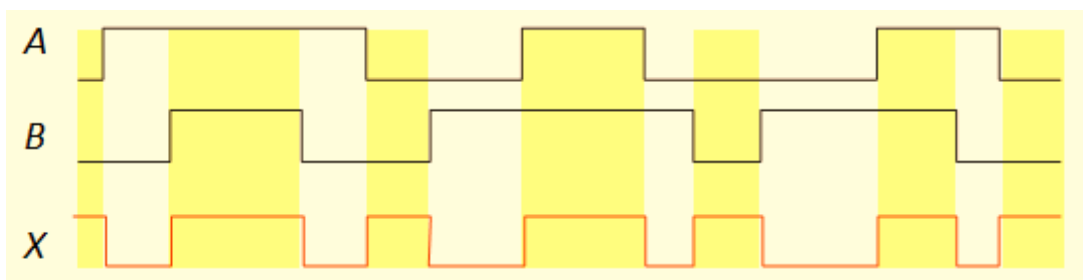

Figure 10: EX-NOR Gate Symbol

Inputs		Output
X	Y	F=(X $\oplus$ Y)'
0	0	1
0	1	0
1	0	0
1	1	1

Table 7: Truth Table of EX-NOR Gate

Example waveforms:

Universal gates are the ones which can be used for implementing any gate like AND, OR and NOT, or any combination of these basic gates; NAND and NOR gates are universal gates. But there are some rules that need to be followed when implementing NAND or NOR based gates.

To facilitate the conversion to NAND and NOR logic, we have two new graphic symbols for these gates.
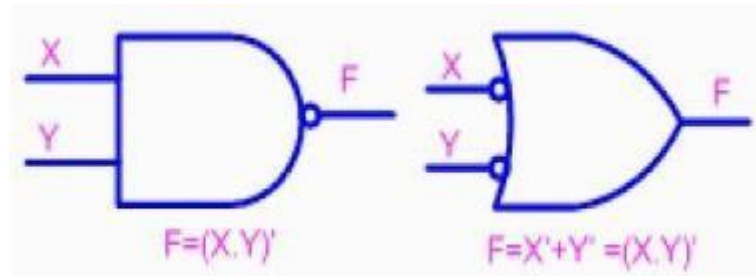

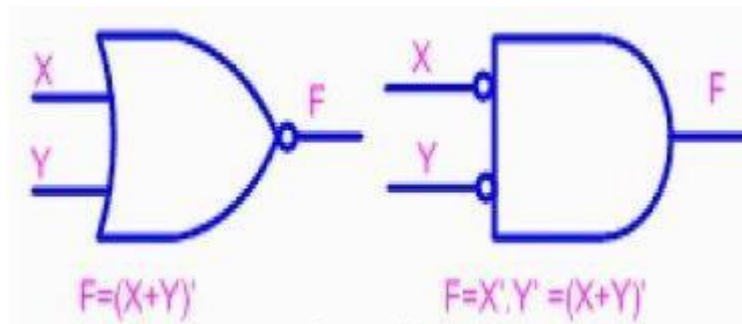Figure 11:Another NAND Gate Symbol

Figure 12: Another NOR Gate Symbol

Now, keep in your mind the shape of the following logic gates because you will use them in the next steps.
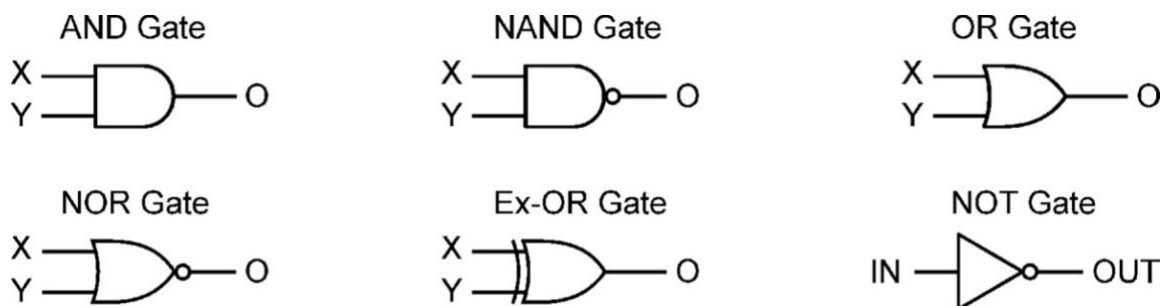

Figure 13: Logic diagrams and IC Pin diagrams

2. Experiments:

2.1 Exercise 1 AND Gate:

1. Provide a power supply for TESCA board by connecting the board cable to a socket switch of 220V AC.

2. Connect the input switches which are pins A, B, C on the bottom of the board to A, B, C input pins of AND gate respectively on the top middle of the TESCA board.

3. Connect the output pin of AND gate of the TESCA board to the output pin L1 LED Display on the middle of the board.

4. Make sure all your connections are right then turn on the power supply from the socket switch.

5. Turn A, B, C switches to position 1 then observe output of AND Gate on the LED display L1.

6. Observe the output for different input combination as shown in truth table of OR gate.

7. Compare the practical results with the truth table of AND gate.

2.2 Exercise 2 OR Gate:

1. Provide a power supply for TESCA board by connecting the board cable to a socket switch of 220V AC.

2. Connect the input switches which are pins A, B, C on the bottom of the board to A, B, C input pins of OR gate respectively on the top left of the TESCA board.

3. Connect the output pin of OR gate of the TESCA board to the output pin L1 LED Display on the middle of the board.

4. Make sure all your connections are right then turn on the power supply from the socket switch.

5. Turn A, B, C switches to position 1 then observe output of OR Gate on the LED display L1.

6. Observe the output for different input combination as shown in truth table of OR gate.

7. Compare the practical results with the truth table of OR gate.

2.3 Exercise 3 NOT Gate:

1. First you should provide a power supply for TESCA board by connecting the board cable to a socket switch of 220V AC.

2. Then, connect the input switch which is pin A on the bottom of the board to A/B/C pin of NOT gate on the top right of the TESCA board.

3. Connect the output pin of NOT gate of the TESCA board to the output pin L1 LED Display on the middle of the board.

4. Make sure all your connections are right then turn on the power supply from the socket switch.

5. Turn A switch to position 0 then observe output of NOT gate.

6. Turn A switch to position 1 then observe output of NOT gate.

7. Compare the practical results with the truth table of NOT gate.

2.4 Exercise 4 NAND Gate:

1. Provide a power supply for TESCA board by connecting the board cable to a socket switch of 220V AC.
2. Connect the input switches which are pins A, B, C on the bottom of the board to A, B, C input pins of NAND gate respectively on the top middle of the TESCA board.
3. Connect the output pin of NAND gate of the TESCA board to the output pin L1 LED Display on the middle of the board.
4. Make sure all your connections are right then turn on the power supply from the socket switch.
5. Turn A, B, C switches to position 1 then observe output of NAND Gate on the LED display L1.
6. Observe the output for different input combination as shown in truth table of NAND gate.
7. Compare the practical results with the truth table of NAND gate.

2.5 Exercise 5 NOR Gate:

1. Provide a power supply for TESCA board by connecting the board cable to a socket switch of 220V AC.
2. Connect the input switches which are pins A, B, C on the bottom of the board to A, B, C input pins of NOR gate respectively on the top left of the TESCA board.
3. Connect the output pin of NOR gate of the TESCA board to the output pin L1 LED Display on the middle of the board.
4. Make sure all your connections are right then turn on the power supply from the socket switch.
5. Turn A, B, C switches to position 1 then observe output of NOR Gate on the LED display L1.
6. Observe the output for different input combination as shown in truth table of NOR gate.
7. Compare the practical results with the truth table of NOR gate.

2.6 Exercise 6 EX-OR Gate:

1. Place the DB02 board on the trainer shown in Figure (14) .
2. Provide power to the board by connecting +5 V pin from the trainer on the left side to +5V pin on the DB03 using a wire.
3. Connect GND pin from the trainer on the left side to ground symbol pin on the DB03.
4. Connect the input switches which are pins no. D1 and D2 of the trainer to X and Y pins of EX-OR gate on the top of the DB03 board.
5. Connect the pin no. Z of EX-OR gate of the DB03 board to the output pin no. 0 of the 8-bit LED Display on the right side of the trainer.
6. Make sure all your connections are right then turn on the power supply.
7. Turn D1 and D2 switches to position 0 then observe output of EX-OR Gate on 8-bit LED display.
8. Observe the output for different input combination as shown in truth table of EX-OR gate.
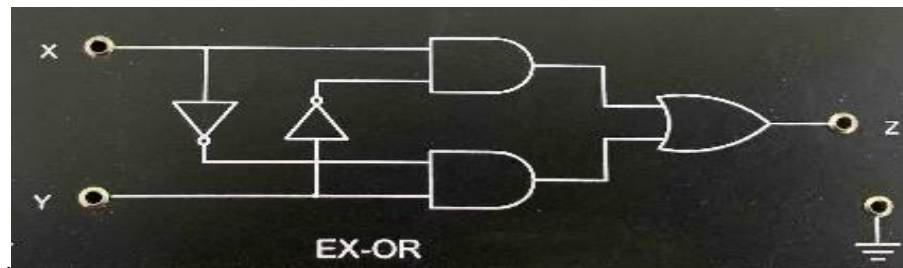
9. Verify Truth Table for EX-OR gate

Figure 14: EX-OR Gate

2.7 Exercise 7 EX-NOR Gate:

1. Place the DB02 board on the trainer .
2. Provide power to the board by connecting +5 V pin from the trainer on the left side to +5V pin on the DB03 using a wire.
3. Connect GND pin from the trainer on the left side to ground symbol pin on the DB03.
4. Connect the input switches which are pins no. D1 and D2 of the trainer to X and Y pins of EX-NOR gate on the top of the DB03 board.
5. Connect the pin no. Z of EX-NOR gate of the DB03 board to the output pin no. 0 of the 8-bit LED Display on the right side of the trainer.
6. Make sure all your connections are right then turn on the power supply.
7. Turn D1 and D2 switches to position 0 then observe output of EX-NOR Gate on 8-bit LED display.
8. Observe the output for different input combination as shown in truth table of EX-NOR gate.
9. Verify Truth Table for EX-NOR gate

3. Discussion:

1. Explain how you can get a logical high output when using OR gate?

2. Explain how you can get a logical low output when using AND gate?

3. How you can distinguish NOT gate from other logic gates introduced in this experiment?

4. Compare the truth table of NOR & AND gates? Explain the similarities & differences?

5. Write the truth table and draw the logical symbol for NAND gate? and Explain how you can get a logical high output when using NAND gate?

6. What is the output F for the circuit shown in Figure (15) ?, consider all the input X possibilities.
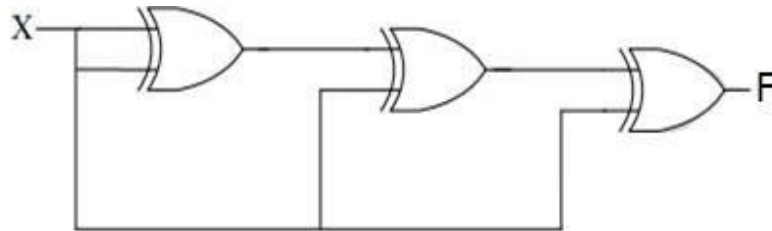

Figure 15: Belong to Question 6.

7. For the logic circuit shown in Figure (16), write the required input condition (A,B,C) to make the output X =1.
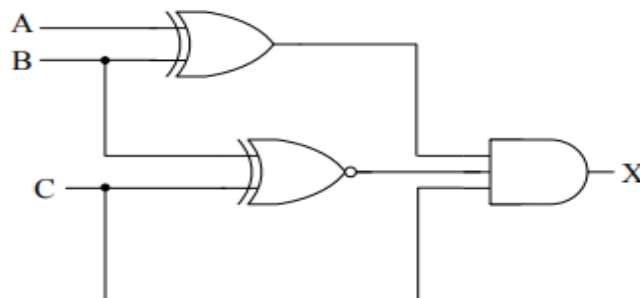

Figure 16: Belong to Question 7.

8. When the output of an X-NOR gate with two inputs, A and B, is HIGH ?

9. What is the gate if a signal passing through it is inhibited by sending a LOW into one of the inputs, and the output is HIGH ?

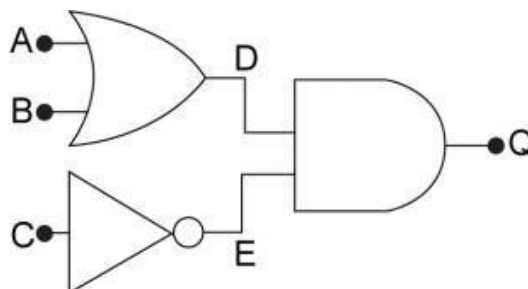10. Create a truth table for the following logic gate circuit shown in Figure (17) ?

Figure 17: Belong to Question 10.