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Digital Circuits: A Study on Logical Gates

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Abstract: The Digital electronic circuits operate with voltages of **two logic levels** known as Logic Low and Logic High. The voltages of Logic Low are represented with '0' & Similarly, The voltages of Logic High are represented with '1'. These digital electronic circuits have one or more inputs with the single output known as ***Logic gate***. They are the building blocks of any digital system.

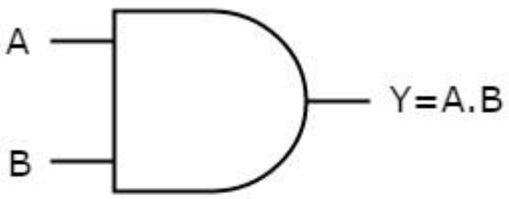
Introduction

The Boolean functions can be represented either in the form of sum of products or in the form of product of sums form based on the user requirement. The basic gates are AND, OR & NOT gates.

AND gate
The AND gate is a digital circuit which has two or more inputs and produce an output, which is known the **Logical AND** of all the inputs and they are represented with the symbol **'.'**.
The following **truth table** shows the 2-input AND gate.

A	**B**	**Y = A.B**
0	0	0
0	1	0
1	0	0
1	1	1

Here the A, B are the inputs and Y is the output of 2 input AND gate. If both inputs are '1', then only the output, Y is '1'. For remaining combinations of inputs, the output, Y is '0'.
The following figure shows the **symbol** of an AND gate, which is having two inputs A, B and one output, Y.

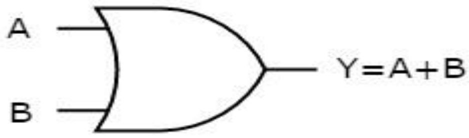


This AND gate produces an output *Y*, which is the **logical AND** of two inputs A, B. Similarly, if there are 'n' inputs, then the AND gate produces an output, which is the **logical AND** of all those inputs. This means, the output of AND gate will be '1', when all the inputs are '1'.
OR gate An OR gate is a digital circuit that has two or more inputs thus producing an output, which is the **logical OR** of all those inputs. This **logical OR** is represented with the symbol '+'.

The following table shows the **truth table** of 2-input OR gate.

A	B	Y = A + B
0	0	0
0	1	1
1	0	1
1	1	1

Here A, B are the inputs and Y is the output of two input **OR gate**. If both inputs are '0', then only the output, Y is '0'. For remaining combinations of inputs, the output, Y is '1'.
The following figure shows the **symbol** of an OR gate, which is having two inputs A, B and one output, Y.



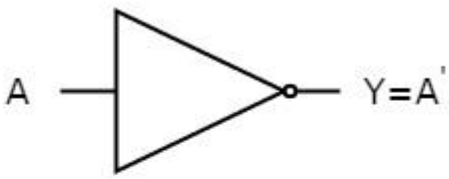
This **OR gate** produces an output known as 'Y', which is the **logical OR** of the two inputs A & B. Similarly, if there are 'n' inputs, then the OR gate produces an output, which is the logical OR of all those inputs which means, the output of an OR gate will be '1', when in least possible case one of those inputs is '1'.

NOT gate

A **NOT gate** is a digital circuit that has single input and single output. The output of **NOT gate** is the **logical inversion** of input. Hence, the NOT gate is also called as inverter.
The following table shows the **truth table** of NOT gate.

A	Y = A'
0	1
1	0

Here A and Y are the input and output of NOT gate respectively. If the input, A is '0', then, the output, Y is '1'. Similarly, if the input, A is '1', then the output, Y is '0'.
The following figure shows the symbol of **NOT gate**, which is having one input A and one output Y.



This **NOT** gate produces an output Y, which is the **complement** of input, A.

Universal gates

The NAND & The NOR gates are called as **universal gates**. As they help the user in implementing any Boolean function, which is in sum of products format by using NAND gates alone. Similarly, we can implement any Boolean function, which is in product of sums format by using NOR gates alone.

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NAND gate

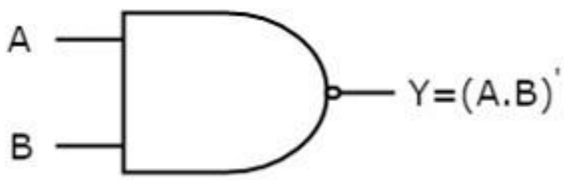
NAND gate is a digital circuit that has two or more inputs and produces an output which is the inversion of **logical AND** of all those inputs.

The following table shows the **truth table** of 2-input NAND gate.

A	**B**	**Y = *A*.*B***
’		
0	0	1
0	1	1
1	0	1
1	1	0

Here A and B are the inputs and Y is the output of two input NAND gate. When both inputs are ‘1’ the output Y is ‘0’. If at least one of the input is zero, then the output Y is ‘1’. This is just opposite to that of two input **AND** gate operation.

The following image shows the **symbol** of NAND gate, which is having two inputs A and B and one output ie Y.



NAND gate operation is same as that of AND gate followed by an inverter. That’s why the NAND gate symbol is represented like that.

NOR gate

NOR gate is a digital circuit that has two or more inputs and produces an output, which is the inversion of **logical OR** of all those inputs.

The following table shows the **truth table** of 2-input NOR gate

A	**B**	**Y = *A*+*B***
’		
0	0	1
0	1	0
1	0	0
1	1	0

Here A and B are the inputs and Y is the output. If both inputs are ‘0’, then the output, Y is ‘1’. If at least one of the input is ‘1’, then the output, Y is ‘0’. This is just opposite to that of two input OR gate operation.

The following figure shows the **symbol** of NOR gate, which is having two inputs A and B and one output, Y.

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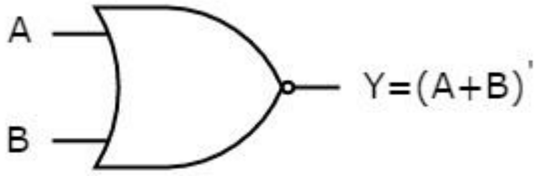


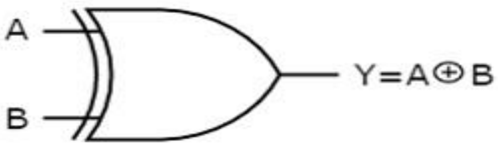
NOR gate operation is same as that of OR gate followed by an inverter. That's why the NOR gate symbol is represented like that.

Special Gates
Ex-OR & Ex-NOR gates are called as special gates. As these two gates are special cases of OR & NOR gates.

Ex-OR gate
The full form of Ex-OR gate is **Exclusive-OR** gate. Its function is same as that of OR gate except for some cases, when the inputs having even number of ones.
The following table shows the **truth table** of 2-input Ex-OR gate.

A	B	Y = A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

Here A & B are the inputs and Y is the output of two input Ex-OR gate. The truth table of Ex-OR gate is same as that of OR gate for first three rows. The only modification is in the fourth row. Which says the output *Y* is zero instead of one, when both the inputs are one as the inputs having even number of ones. Therefore the output of Ex-OR gate is '1' when only one of the two inputs is '1'. And it is zero, when both inputs are same.
Below figure shows the **symbol** of Ex-OR gate, which is having two inputs A, B and one output, Y.

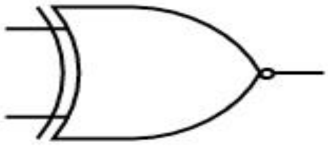


Ex-OR gate operation is similar to that of OR gate except for a few combinations of inputs & that's why the Ex-OR gate symbol is represented like that. The output of Ex-OR gate is '1' when the odd number of ones present at the inputs. Hence, the output of Ex-OR gate is also called as an **odd function**.

Ex-NOR gate
The full form of Ex-NOR gate is **Exclusive-NOR** gate. Its function is same as that of NOR gate except for certain cases when the inputs having even number of ones. The following table shows the **truth table** of 2-input Ex-NOR gate.

A	**B**	**Y = A⊙B**
0	0	1
0	1	0
1	0	0
1	1	1

Here A and B are the inputs and Y is the output. The truth table of Ex-NOR gate is same as that of NOR gate for first three rows. The only modification is in the fourth row which says the output is one instead of zero, when both the inputs are one. Therefore, the output of Ex-NOR gate is '1' when both inputs are same. And it is zero when both the inputs are different. The following figure shows the **symbol** of Ex-NOR gate, which is having two inputs A & B and one output, Y.



Ex-NOR gate operation is similar to that of NOR gate, except for few combinations of inputs. That's why the Ex-NOR gate symbol is represented like that. The output of Ex-NOR gate is '1' when even number of ones present at the inputs. Hence, the output of Ex-NOR gate is also called as an *even function*. From the above truth tables of Ex-OR & Ex-NOR logic gates, we can easily notice that the Ex-NOR operation is just the logical inversion of Ex-OR operation.

Application of Logic Gates

Wherever the existence of, any one or more than one incident is needed to be observed or some behavior are to be taken after their existence, then in all those instances **OR** gates can be used. **AND** gates are used as Enable gate and Inhibit gate. Enable gate means acceptance of data through a pathway while Inhibit gate is the opposite of that process which means rejection of data through a pathway. **XOR** and **XNOR** gates are used in identity generation and identity check operation. **NOT** gates are also called inverter because they switch the output given to them and show the reverse outcome.

Advantages of Logic Gates

- They are quick and low energy consumptive.
- They don't get overworked.
- They can lessen the prescribed number of I/O ports needed by a microcontroller.
- They can bring about straightforward data encryption and decryption.

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