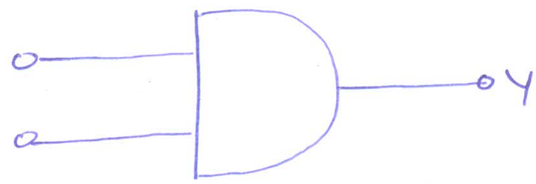
Logic Gates

A logic gate is a physical device or circuit implementing a Boolean function. It performs a logical operation on one or more binary inputs and produces a single binary output.
Logic gates are primarily implemented using diodes or transistors. Logic gates can be cascaded in the same way that Boolean function can be composed, allowing the construction of a physical model of all of Boolean logic.
There are three basic gates; AND, OR and NOT. from these three gates, two more gates have been formed, called NOR and NAND gate. These two gates also called 'Universal Gates', because by using universal gates we can make any gate or we can realize any Boolean expression. Two special logic circuits that occur quite often in digital systemare the exclusive-OR (XOR) and exclusive-NOR (XNOR) circuits.

AND Gate

The AND gate performs logical multiplication, more commonly known as AND function. The AND gate has two ore more inputs and a single output, as shown in figure1. The AND gate provides high output only when all inputs are high. The AND function can be represented by the equation

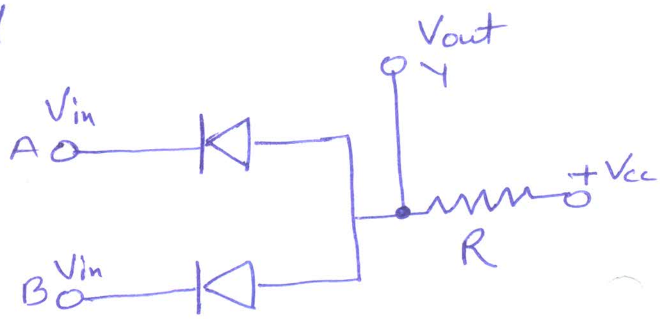


$Y = A.B$

Fig1: Symbol of AND Gate.

$$\boxed{Y = A.B}$$

Figure 2 shows simplified circuit of AND gate. The inputs are A and B, while the output is Y. When Voltage of both inputs are high, both the diodes are non-conducting because the diodes are in reverse biased. Since the diodes are off, no current flows through resistor R, and the output is pulled up to the supply voltage V_{cc}. Thus for both inputs high; output is high. But when input voltage of either



or both terminals are low. Cathod of the diode Connected to low input terminals and the diode become forward biased, resulting in flow of current through resistor R. So in such condition Voltage of the output terminal becomes low. The complete truth table for 2-input AND gate is shown table.

Truth Table

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

OR Gate

The OR gate performs logical addition, more commonly known as the OR function. An OR gate has two or more inputs signals with only one output signal. Figure 1 shows the symbol of OR gate and the OR function expressed as

$$\boxed{Y = A + B}$$

Fig1

In OR gate output voltage is high if any or all of the input voltages are high.

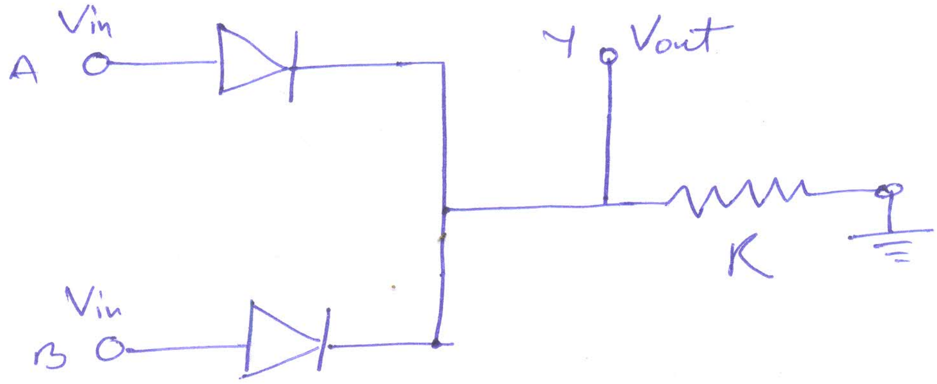


fig2:

Figure 2 shows a circuit to build a 2-input OR gate. The input voltages are labelled A and B, while the output voltage Y, when voltage of any input is high, the diode corresponding to that voltage is conducting because diode is in forward biased. Since the diode is on, current flows through Resistor R and get the output high. But when the input terminals connected to low, anode of the diode connected to low input terminal in this condition both the diodes are in off condition and get the output low.

The logical operation of the two input OR gate is described in truth table shown below. ~~The~~

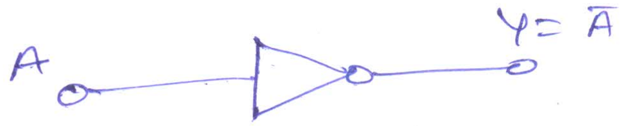
Truth Table : OR Gate

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

NOT Gate :

The NOT gate (Inverter) performs a basic logic function called inversion or complimentation. A NOT gate is called inverter because output state is always opposite to the input state, so when the input is low, output is high and vice-versa. Figure 1 shows the symbol of NOT gate and the expression for NOT gate is

$$\boxed{Y = \overline{A}}$$



This gate has only one input and output. Transistor may be used as an inverter as shown in figure 2. When input terminal (base of the transistor) Vin is zero, base current of transistor is zero, so no current flows in collector circuit and the potential of Vout remains equal to Vcc. On the other hand when Vin is high, base current flows through the transistor resulting in flow of saturation current in collector circuit. This results low output at output terminal.

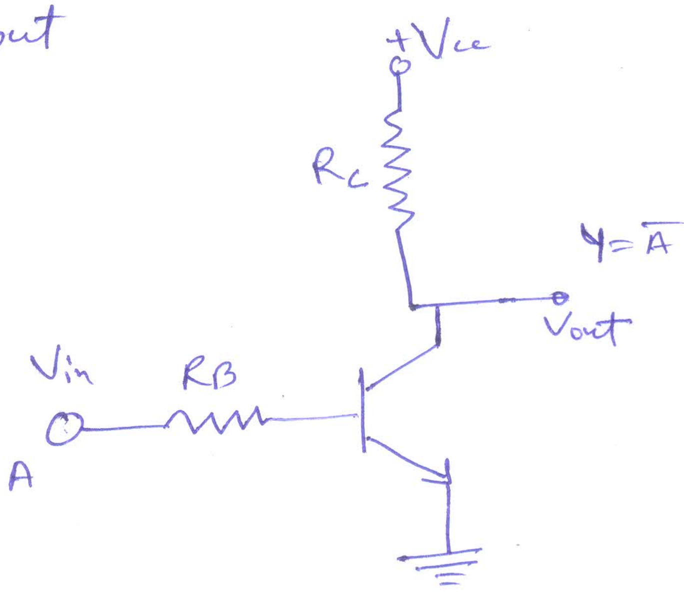


Fig: 2

The truth table for NOT gate is

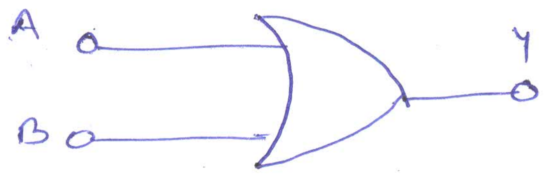
A	$Y = \bar{A}$
0	1
1	0

Universal Gates

NOR and NAND gates have become very popular and are extensively used in digital circuitry. The reason is that these gates actually combine the basic operations AND, OR and NOT, which makes it relatively easy to describe them using the Boolean algebraic operations. Because of this reason NOR and NAND gates are also called Universal Gates.

NOR Gate

The term NOR is a contraction of NOT-OR and implies an OR function with an inverted output. The output of this gate is high, only when all inputs are low. The standard symbol for the NOR gate is the same as the OR gate symbol except that it has a small circle on the output. This small circle represent the inversion operation.



$$\boxed{Y = \overline{A+B}}$$

The circuit of NOR gate is shown in figure. The output Y is 1 only when both transistors are in cut off i.e. when A=0 and B=0. For any other condition of input such as A=1, B=0 or A=0, B=1 or A=1, B=1 one or both transistors operate in saturation and as a result the output Y is low.

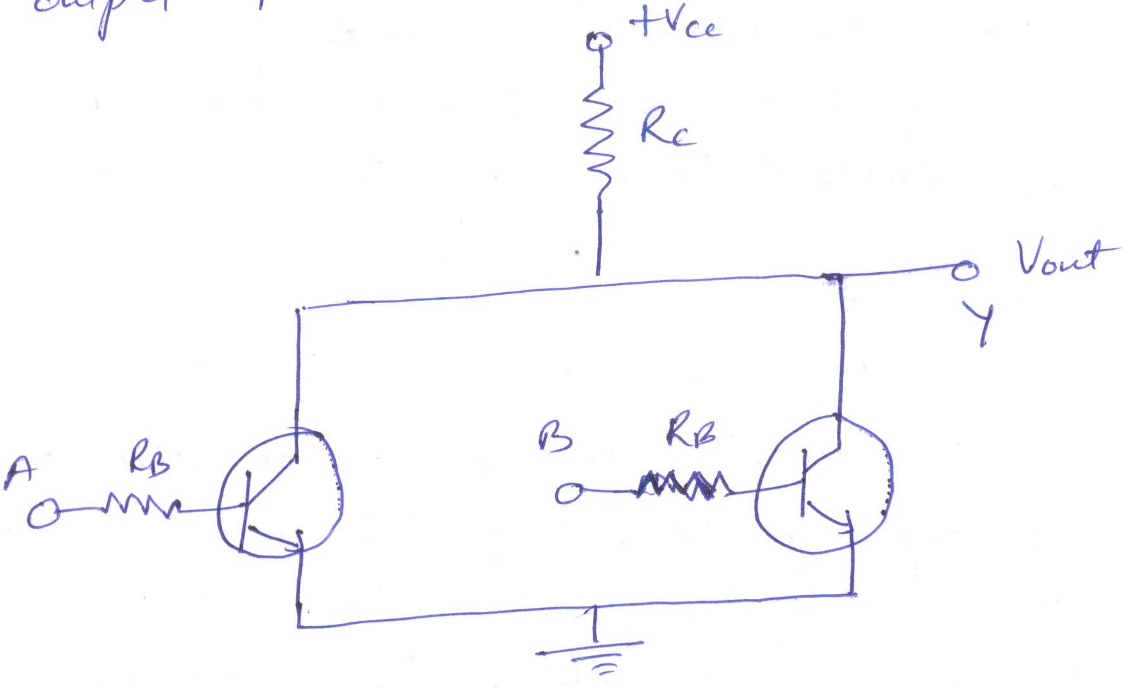


Fig: Circuit for NOR gate.

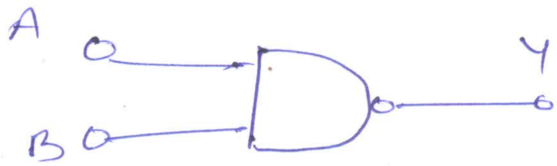
The truth table for 2-input NOR gate is given in Table. From tabe we find that NOR gate output is the exact inverse of the OR gate output.

Truth Table

A	B	$Y=\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

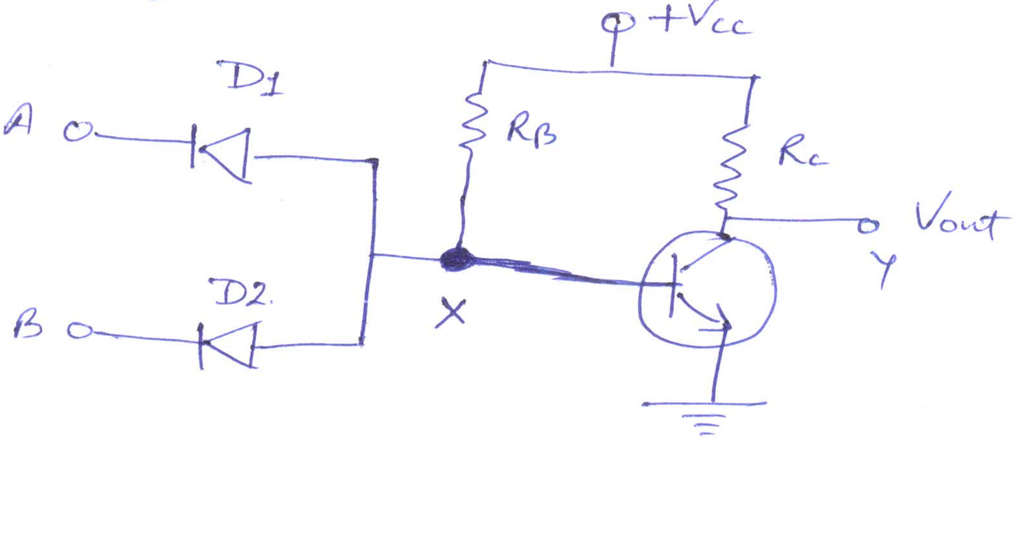
NAND Gate

The term NAND is a contraction of NOT-AND and implies an AND function with inverted output. In this gate, output is low only when all inputs are high. A standard logic symbol for NAND gate is the same as the AND gate except for small circle on its output. This small circle denotes the inverse operation.



$$\boxed{Y = \overline{A \cdot B}}$$

The circuit of NAND gate is shown in figure. Here a ~~diode~~ AND circuit using diodes are connected to NOT circuit using transistor, that gives the NAND circuit.



It can be seen from the figure that the point X could be driven to ground when either of the diodes D1 or D2 or both D1 and D2 conducts. Under such conditions, the transistor is in cutoff and output goes high. output is low only when both input voltages are high so that X is at +Vcc and transistors operates in saturation.

The truth table for 2 input NAND gate is given in Table. from the table it is clear that NAND gate output is the exact inverse of AND gate.

Table: Truth Table

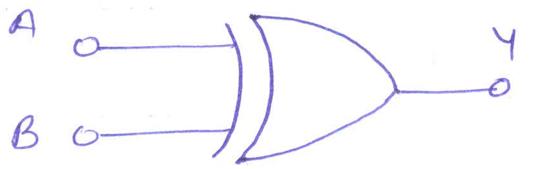
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

Special Logic Circuits

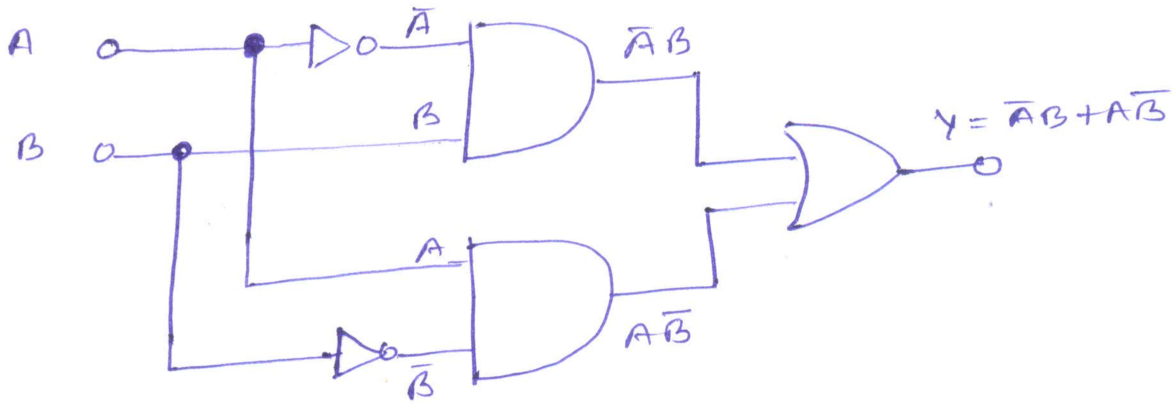
Two special logic circuits that occur quite often in digital systems are the exclusive-OR (XOR) and exclusive-NOR (XNOR) circuits.

Exclusive-OR (XOR) Gate:

The symbol and equivalent switching circuit of a XOR gate are shown in figures 1 and 2 respectively.



$$\boxed{\begin{aligned} Y &= A \oplus B \\ Y &= \bar{A}B + A\bar{B} \end{aligned}}$$



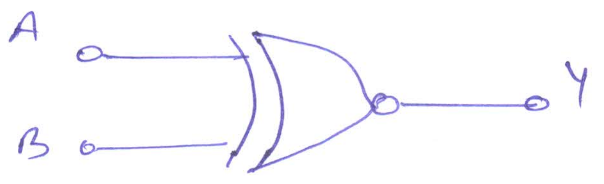
It is observed that output of the XOR gate is high if its either input but not both, is high. It means that when the two inputs are different, the output is high and when the two inputs are the same the output is low.

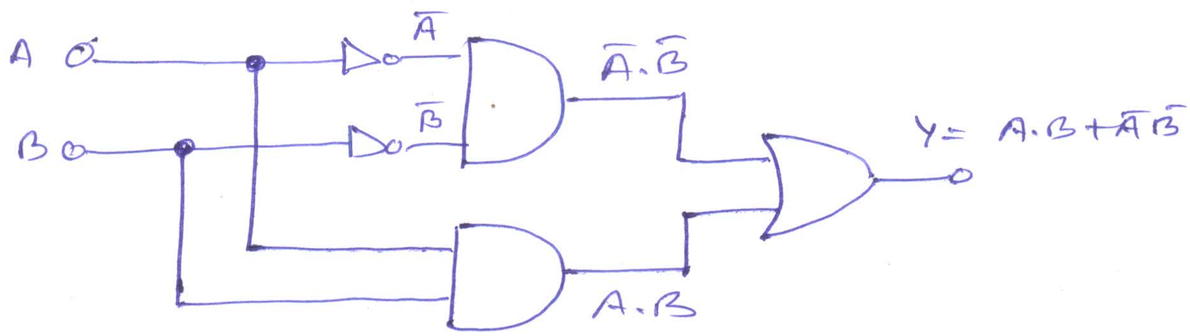
The truth table for XOR gate is shown in Table I.

A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive-NOR (XNOR):

The XNOR circuit operates just opposite to the XOR circuit. The circuit symbol and equivalent switching circuit are shown in figures 1 and 2.





The expression for the output of the XNOR circuit is given as

$$Y = AB + \bar{A}\,\bar{B}$$

$$Y = \overline{A \oplus B}$$

This gate has high output if and only if its both inputs are same and its output is low if input are different.

Truth table for XNOR gate is shown in table.

A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1