Lecture 03
Logic Gates

ECE09 – Digital Electronics: Logic Circuit and Switching Theory

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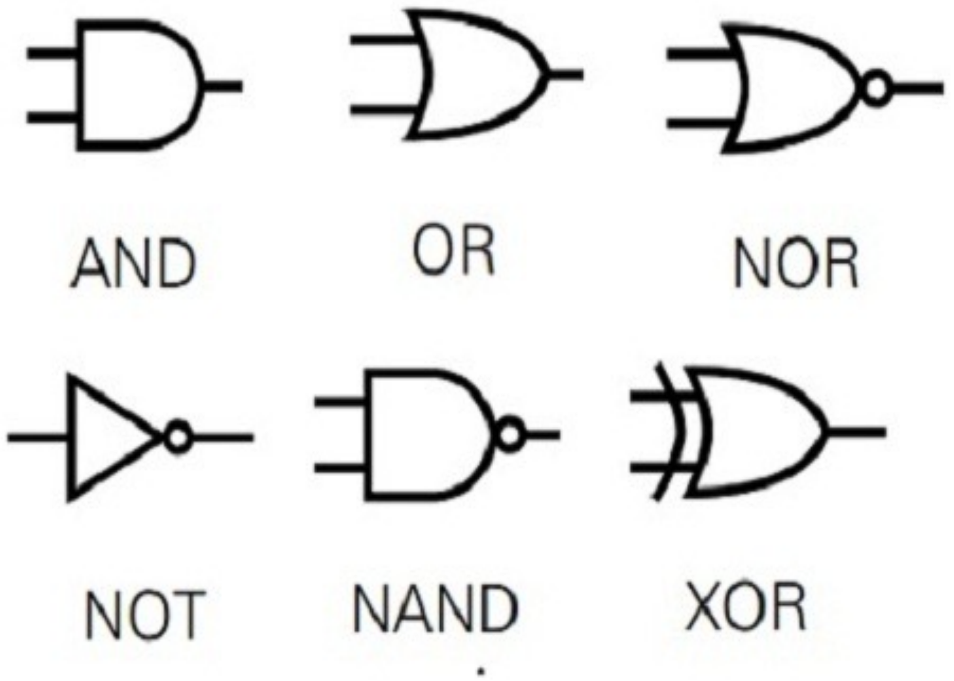
Definition of Logic Gate

- A logic gate is an electronic circuit **which makes logic decision.**
- It has one output and one or more inputs.
- It is the building blocks from which most of the digital systems are made are built up.
- These gates are available today in the form of various IC families. (TTL, ECL, MOS, CMOS)



Positive and Negative Logic

- In computing systems, the number symbols 0 and 1 represent two possible states of a circuit or device.
- The main point is to represent two opposite conditions by 0 and 1.

Positive Logic - the more positive of the two voltage levels represent logic 1.

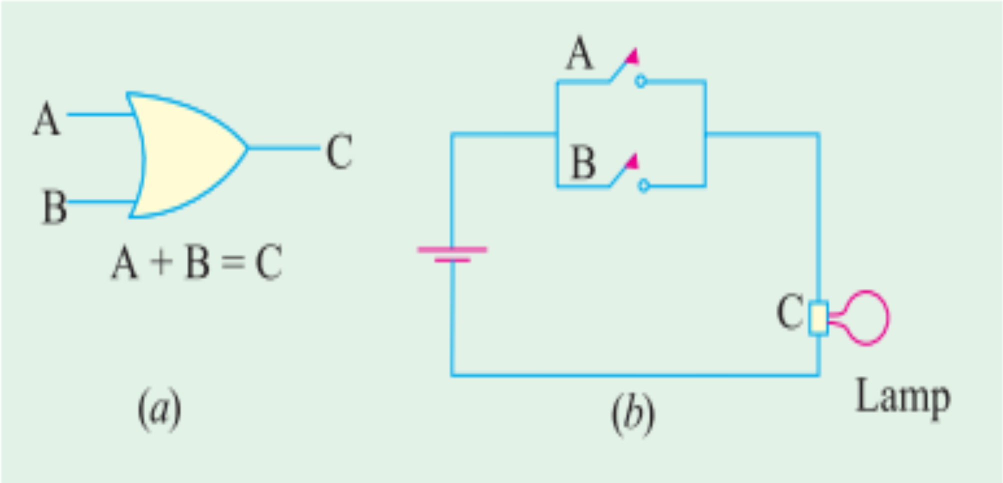
Negative Logic - the more negative of the two voltage levels represent logic 1.

Positive and Negative Logic

- In positive logic, a 1 represents
  - An ON circuit
  - A CLOSED circuit
  - A HIGH voltage
  - A PLUS sign
  - A TRUE statement

- In negative logic, a 1 represents
  - An OFF circuit
  - A OPEN circuit
  - A LOW voltage
  - A MINUS sign
  - A FALSE statement

The OR gate



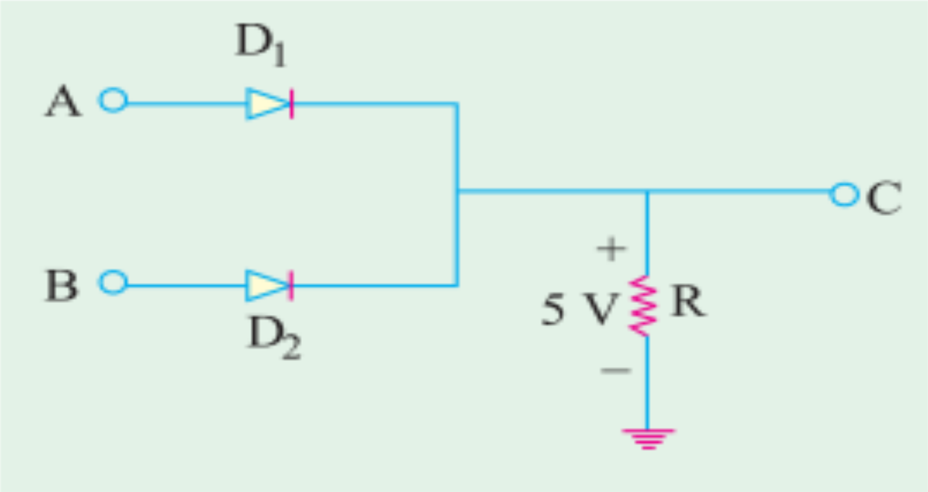
An OR gate is equivalent to a parallel circuit in its logic function.

A truth table may be defined as a table which gives the output state for all possible input combinations.

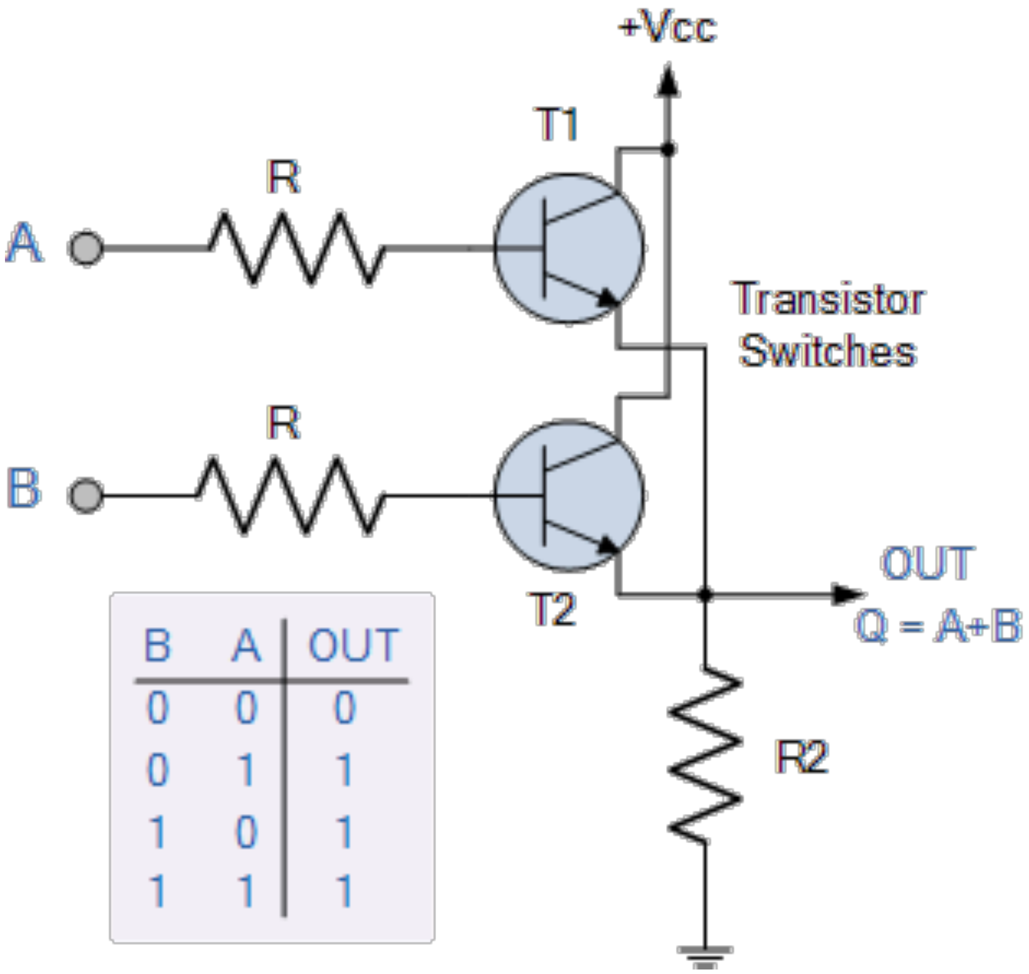
Diode OR gate

1. When A is at +5V, D_1 is forward-biased and hence conducts. The circuit current flows *via* R dropping 5V across it. In this way, point X achieves potential of +5 V.
2. When + 5V is applied to B, D_2 conducts causing point X to go to +5 V.
3. When both A and B are +5V, the drop across R is 5V because voltages of A and B ***are in parallel.***

   Again, point X is driven to +5 V.
4. Obviously, when there is no voltage either at A or B, output X remains 0.



Transistor OR Gate



B	A	OUT
0	0	0
0	1	1
1	0	1
1	1	1

OR gate operation

- OR gate performs logical addition.

$$
\begin{aligned}
0 + 0 &= 0 \\
0 + 1 &= 1 \\
1 + 0 &= 1 \\
1 + 1 &= 1
\end{aligned}
$$

$1+1 = 2$ — decimal addition

$1+1 = 10$ — binary addition

$1+1 = 1$ — *OR* addition

We can put the above *OR* laws in more general terms

$A+1 = 1$

$A+0 = A$

$A+A = A$ — not $2A$

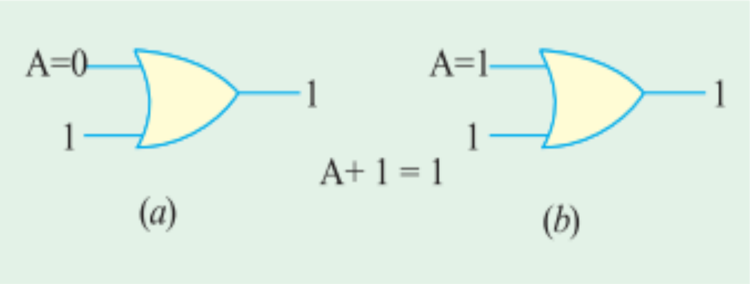


Fig. 70.6

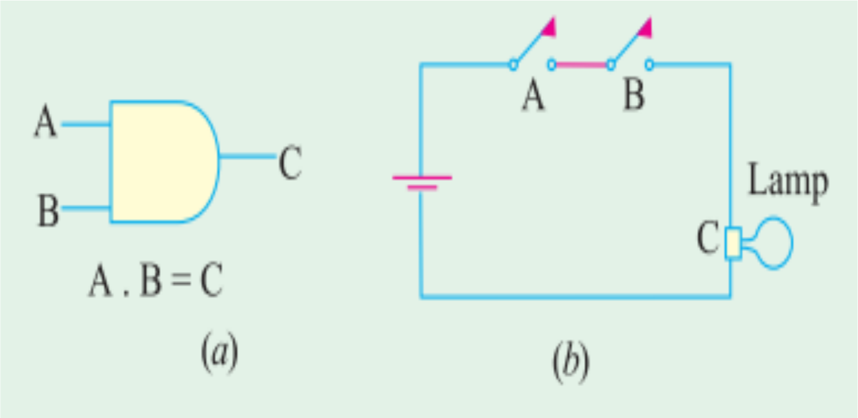
AND gate

Logic Operation

1. The *AND* gate gives an output only **when all its inputs are present**.
2. The *AND* gate has a 1 output when both *A* **and** *B* are 1. Hence, this gate is an **all-or-nothing** gate whose output occurs only when all its inputs are present.
3. In True/False terminology, the output of an *AND* gate will be **true** only if **all its inputs are true**. Its output

would be false if ***any of its inputs is false.***

- The AND gate symbolizes logical multiplication.



A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

Diode AND gate

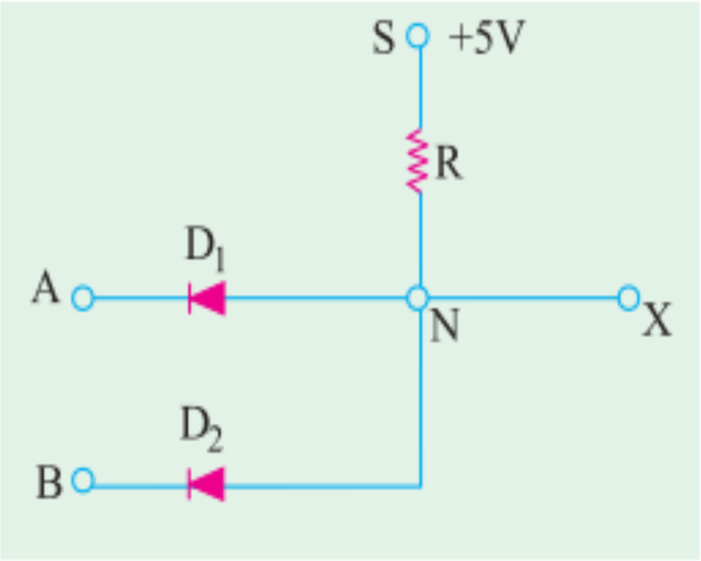
Fig. 70.15

1. When A is at 0 V, diode D_1 conducts and the supply voltage of +5 V drops across R. Consequently, point N and hence point X are driven to 0 V. Therefore, the output C is 0.

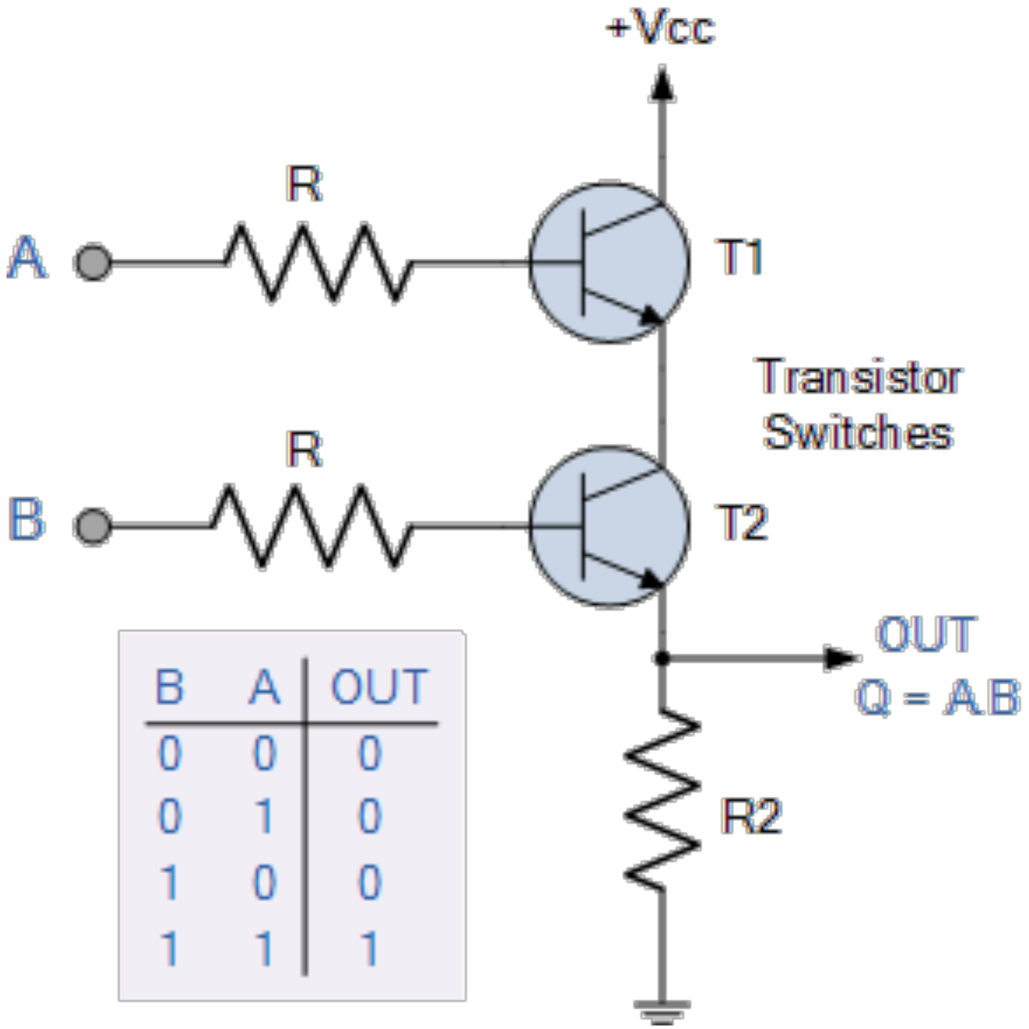
2. Similarly, when B is at 0 V, D_2 conducts thereby driving N and hence X to ground.

3. Obviously, when both A and B are at 0 V, both diodes conduct and, again, the output X is 0.

4. There is no supply current and hence no drop across R ***only when both A and B are at +5 V***. Only in that case, the output X goes to supply voltage of +5 V.



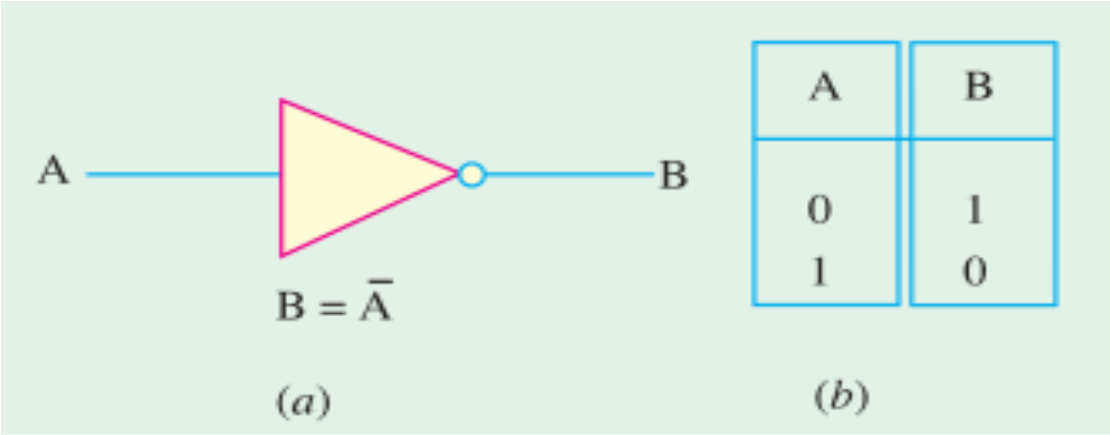
Transistor AND circuit



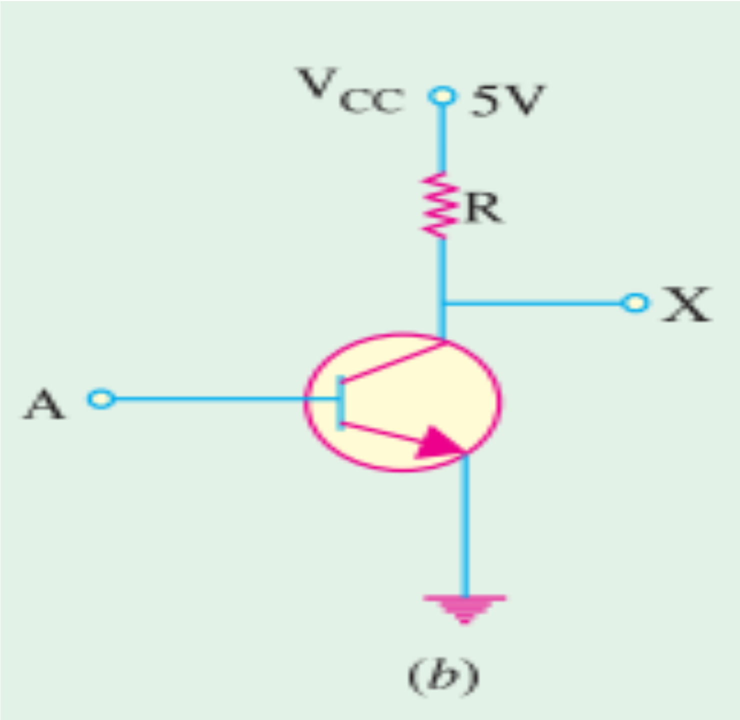
B	A	OUT
0	0	0
0	1	0
1	0	0
1	1	1

NOT gate

- Its output is not the same as its input.
- Also called as *inverter*
- Has one input and one output

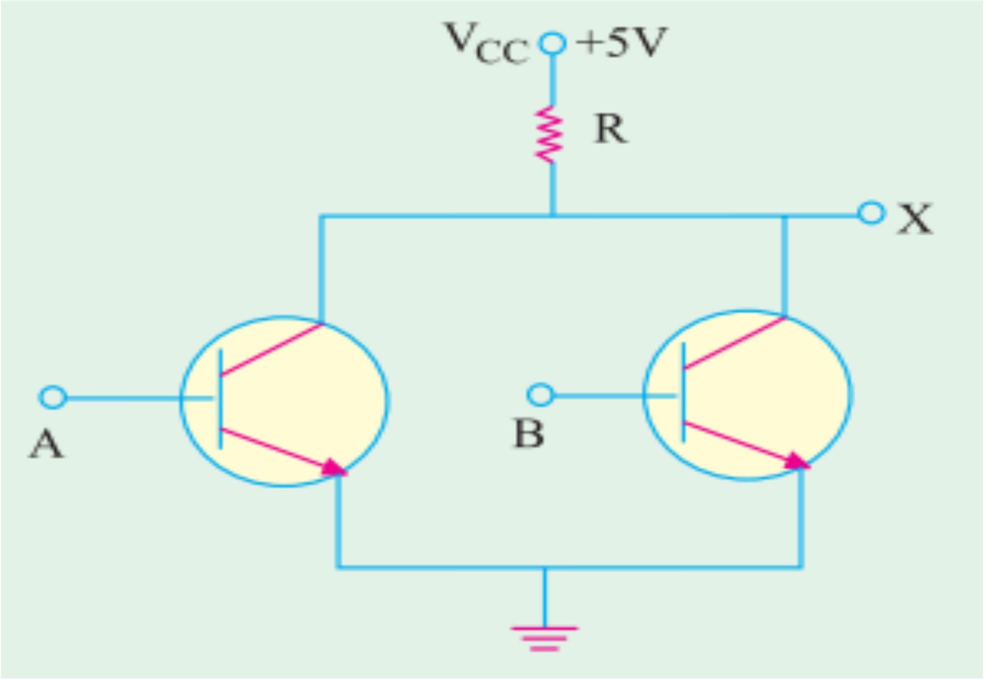


Equivalent Circuit of NOT gate



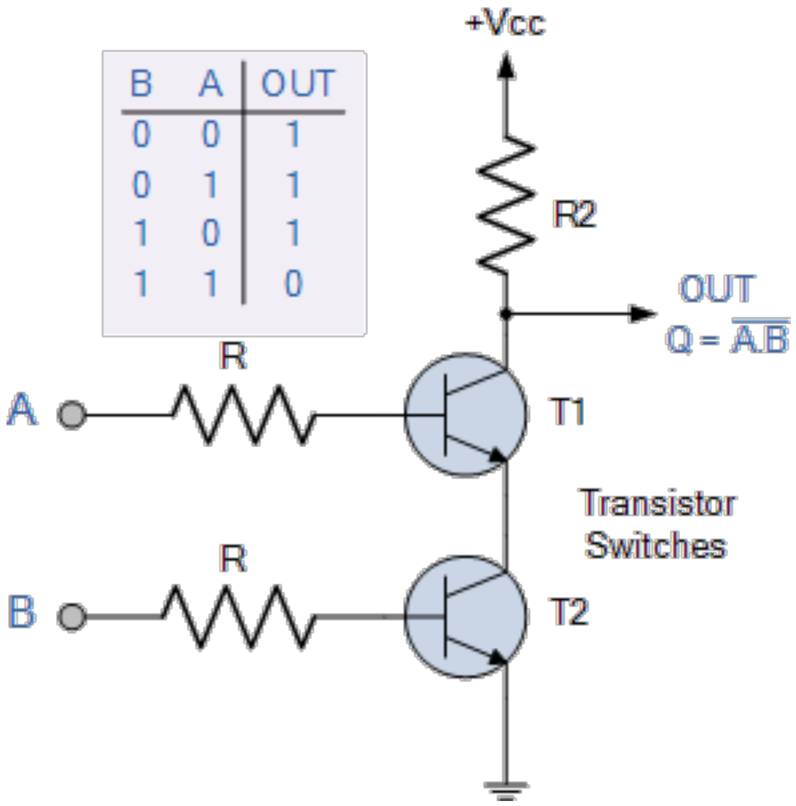
NOR gate

- A NOR gate is the reverse of OR gate.
- Universal gate



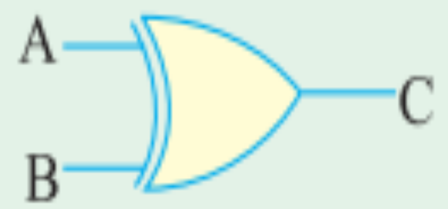
NAND gate

- Gives an output of 1 if its both inputs are not 1.
- Universal gate

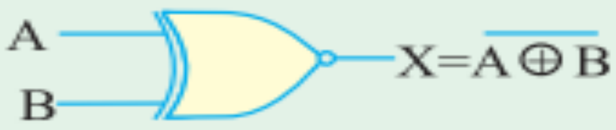


B	A	OUT
0	0	1
0	1	1
1	0	1
1	1	0

XOR and XNOR gate



A	B	C
0	0	0
0	1	1
1	0	1
1	1	0

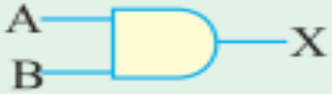


A	B	X
0	0	1
0	1	0
1	0	0
1	1	1

Summary of Logic Gates

$A + B = X$

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1



$AB = X$

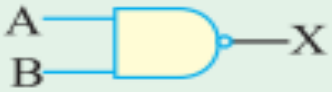
A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

$A \oplus B = X$

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

$\overline{A + B} = X$

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0



$\overline{AB} = X$

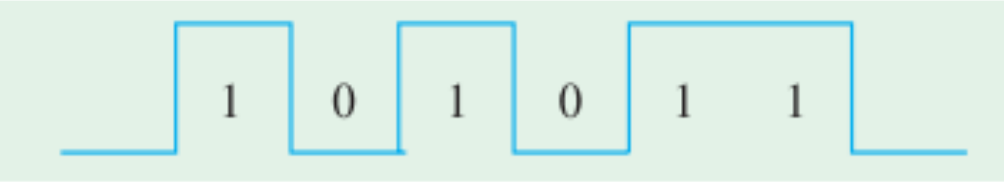
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

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

A	B	X
0	0	1
0	1	0
1	0	0
1	1	1

Sample Problems

1. An electrical signal is expressed as 101011. If the signal is applied to a NOT gate, what would be the output signal?



2. Two electrical signals represented by A = 101101 and B = 110101 are applied to 2-input AND gate. Sketch the output signal and the binary number it represents.

Sample Problems

1. Design a logic hardware based on the Boolean expression $(A + \bar{B}C)$.
2. Design a logic circuit whose output is given by the Boolean expression $(A + B)\overline{AB}$.

Sample Problems

1. Fig. 70.59 shows a 2-input AND gate with waveforms A and B. Sketch the resulting output waveform.

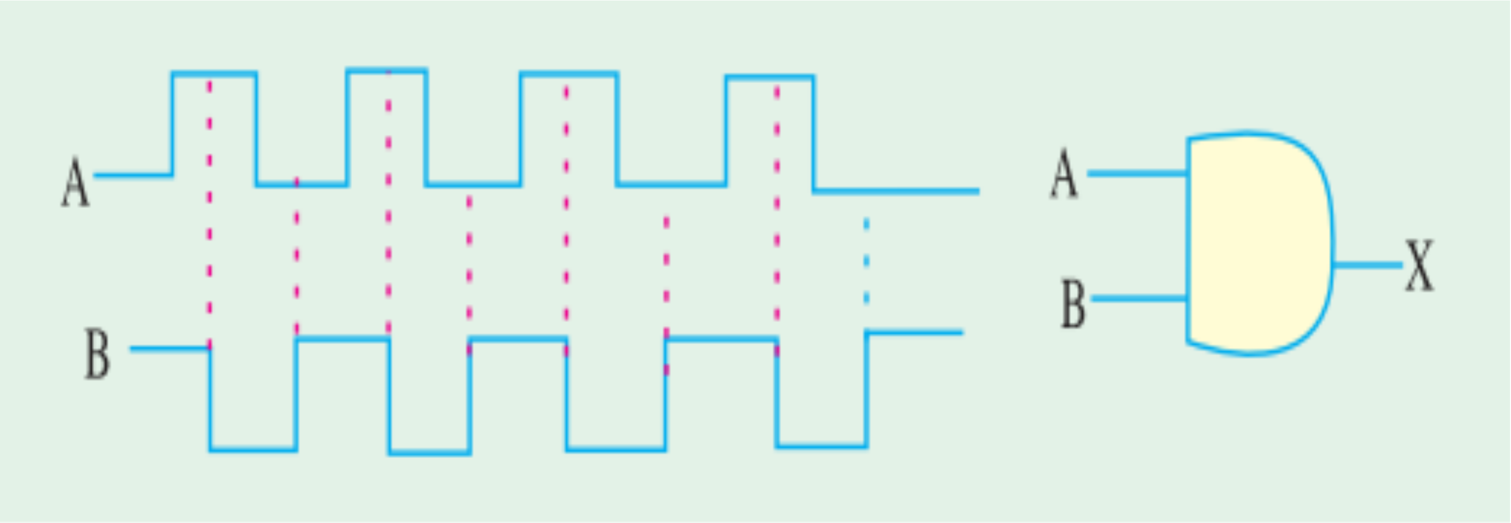


Fig. 70.59

Sample Problems

1. The waveforms A and B are applied as an input to XOR gate and XNOR gate as shown in Fig. 70.71. Determine the output waveforms of these logic gates.

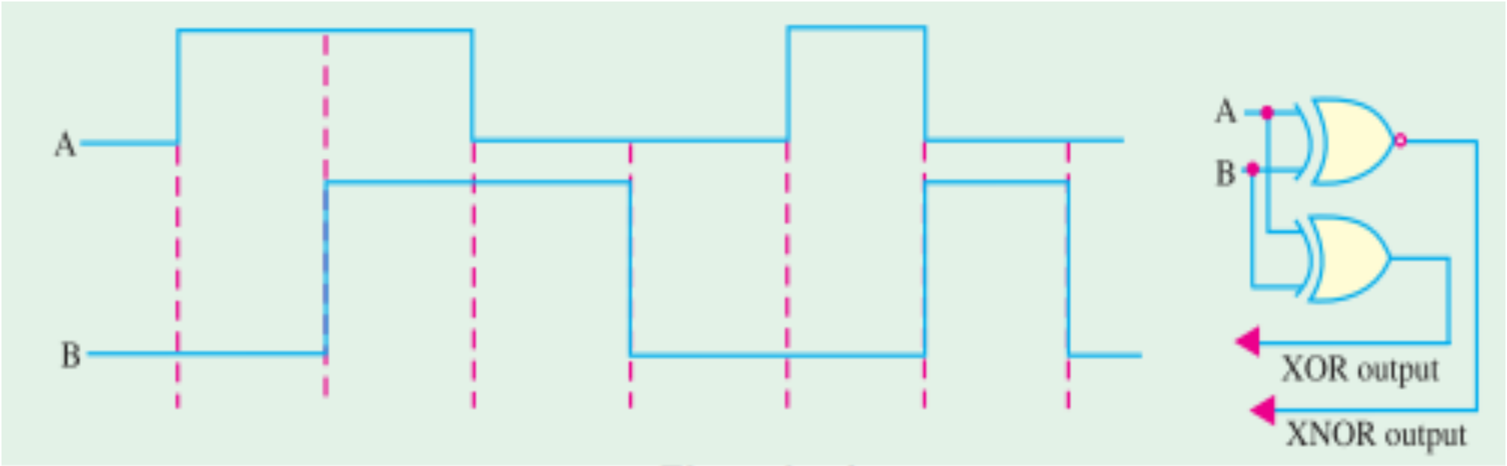


Fig. 70.71