Logic Gates

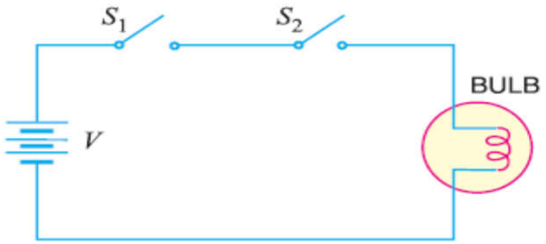
Contents:

- Introduction
- Operation of OR gate
- OR gate using Transistor

Logic Gates

A digital circuit with one or more input signals but only one output signal is called a **logic gate**. Since a logic gate is a switching circuit (*i.e.* a digital circuit), its output can have only one of the two possible states *viz.*, either a high voltage (1) or a low voltage (0) — it is either *ON* or *OFF.* Whether the output voltage of a logic gate is high (1) or low (0) will depend upon the conditions at its input.

Fig. shows the basic idea of a logic gate using switches.



S_1	S_2	Bulb
open	open	OFF
open	closed	OFF
closed	open	OFF
closed	closed	ON

Truth Table

S_1	S_2	Output
0	0	0
0	1	0
1	0	0
1	1	1

(i) When *S*1 and *S*2 are open, the bulb is *OFF*.
(*ii*) When *S*1 is open and *S*2 closed, the bulb is *OFF*.
(*iii*) When *S*2 is open and *S*1 closed, the bulb is *OFF*.
(*iv*) When both *S*1 and *S*2 are closed, the bulb is *ON*.

Note that output (*OFF* or *ON*) depends upon the conditions at the input. It is usual practice to show the conditions at the input and output of a logic gate in the binary form as shown in the table. Such a table is called **truth table**.
The term "logic" is usually used to refer to a decision-making process.
A logic gate makes logical decisions regarding the existence of output depending upon the nature of the input. Hence, such circuits are called logic circuits.

Three Basic Logic Gates:

A logic gate is a circuit that has one or more input signals but only one output signal. All logic gates can be analysed by constructing a truth table. A truth table lists all input possibilities and the corresponding output for each input. The three basic logic gates that make up all digital circuits are **(*i*)** OR gate **(*ii*)** AND gate and **(*iii*)** NOT gate.

OR Gate

An OR gate is a logic gate that has two or more inputs but only one output. However, the output Y of an OR gate is LOW when all inputs are LOW. The output Y of an OR gate is HIGH if any or all the inputs are HIGH.

It is called OR gate because the output is high if any or all the inputs are high. For the same reason, an OR gate is sometimes called **"any or all gate".** For example, consider a 2-input OR gate.

The output Y will be high if either or both inputs are high.

OR gate operation

Fig. (i) shows one way to build a 2-input OR gate while Fig. (ii) shows its simplified schematic diagram. The input voltages are labeled as A and B while the output

voltage is Y. Note that negative terminal of the battery is grounded and corresponds to 0 state (LOW

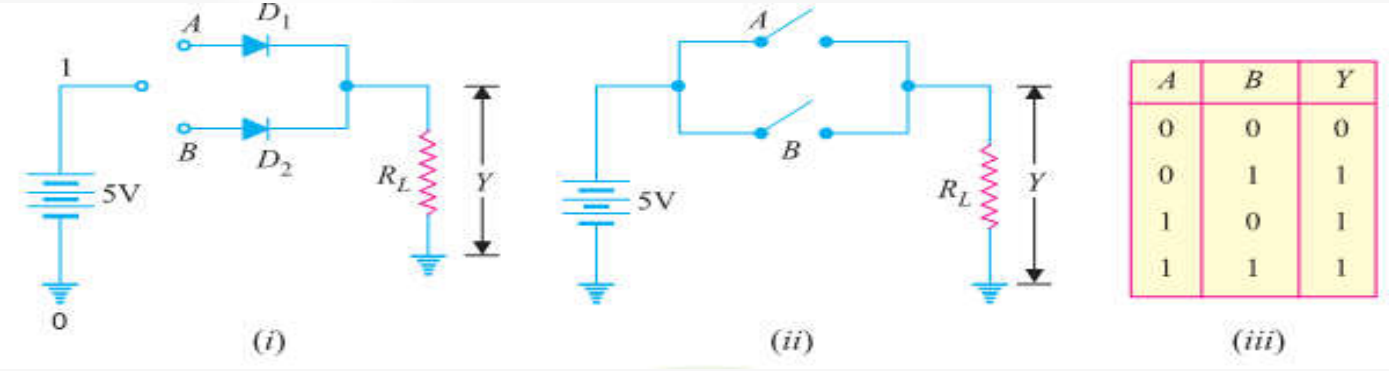
level). The positive terminal of the battery (+5 V) corresponds to 1 state (HIGH level). There are

only four input-output possibilities.

(i) When both A and B are connected to ground, both diodes are non-conducting. Hence, the

output voltage is ideally zero (low voltage). In terms of binary, when A = 0 and B = 0, then Y = 0 as

shown in the truth table in (iii).



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(iii)

OR gate operation

(ii) When A is connected to ground and B connected to the positive terminal of the battery, diode D2 is forward biased and diode D1 is non-conducting. Therefore, diode D2 conducts and the output voltage is ideally +5 V. In terms of binary, when A = 0 and B = 1, then Y = 1 [See Fig. (iii)].

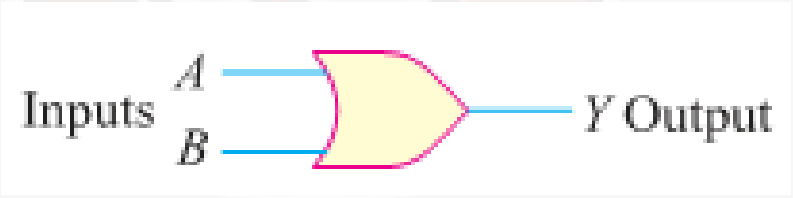
(iii) When A is connected to the positive terminal of the battery and B to the ground, diode D1 is on and diode D2 is off. Again the output voltage is +5 V. In binary terms, when A = 1 and B = 0, then Y = 1 [See Fig. 2 (iii)].

(iv) When both A and B are connected to the positive terminal of the battery, both diodes are on. Since the diodes are in parallel, the output voltage is +5 V. In binary terms, when A = 1 and B = 1, then

Y = 1 [See Fig. (iii)].

Symbol for OR Gate

It is clear from the truth table that for OR gate, the out- put is high if any or all of the inputs are high. The only way to get a low output is by having all inputs low. Fig. shows the logic symbol of OR gate. Note that the symbol has curved line at the input.



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

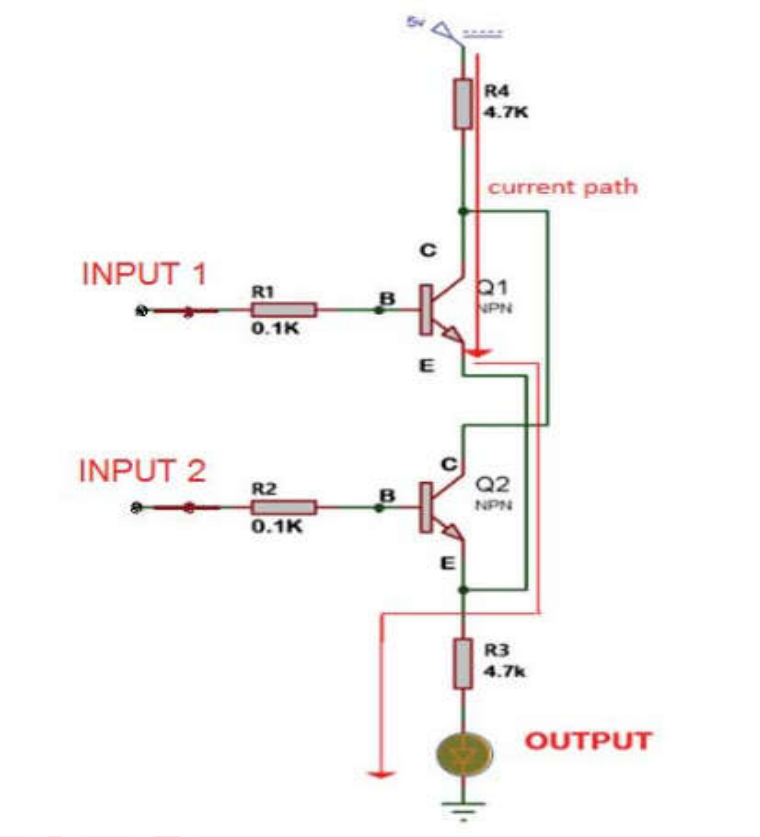
Boolean expression.
The algebra used
to symbolically describe logic functions is called Boolean algebra. The "+" sign in Boolean algebra refers to the logical OR function. The Boolean expression for OR function is
A + B = Y
↑
OR symbol

Two-input OR Gate using transistor

In the common emitter configuration, transistor gives a phase shift of 180 degrees. Due to change in 180 degree in phase shift, it is able to give high at the output when our input is low and vice-versa. The biasing of the transistor is done in a way so that the operating point of the transistor comes closer to the origin in the transfer-characteristic curve of the transistor. This causes an immediate switching of the transistor from its cutoff to saturation state. Hence when we apply enough voltage at the base of the transistor, it immediately reaches into its saturation state and the transistor starts conducting.

Working of OR gate

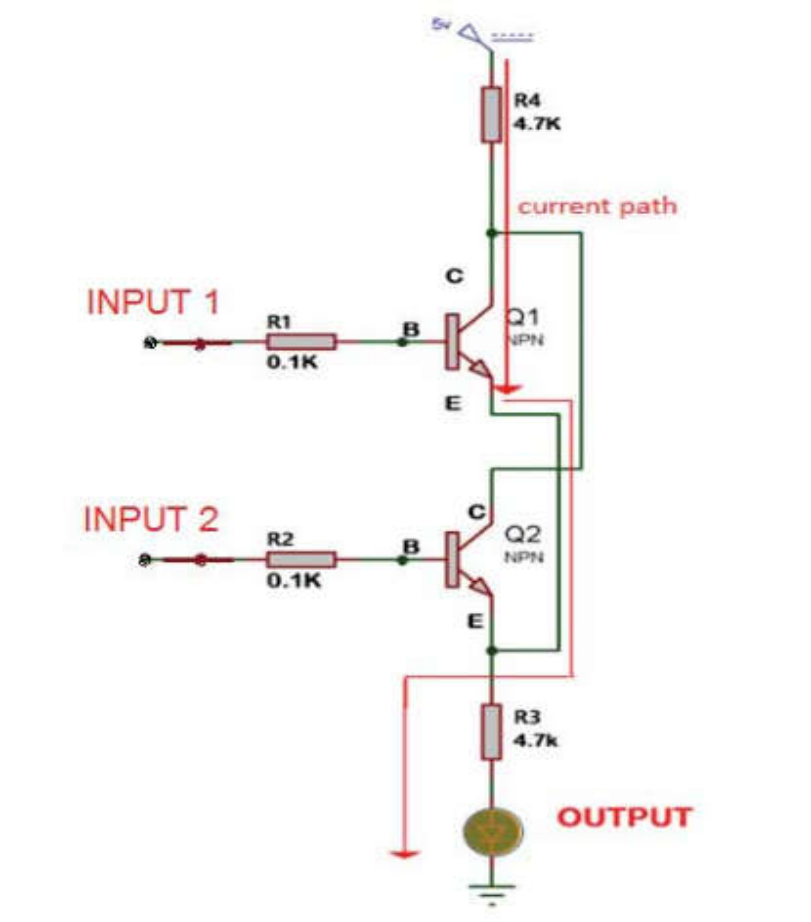
The transistors are connected in parallel and their bases are used as input. The base of both the transistors act like input and one of the emitters of both the transistors is used to derive the output. Initially, both the switches are in OFF state so none of the transistor bases is getting a power supply. The base to emitter junction and base to collector junction of both the transistors have a voltage lower than 0.65V, which is the practical threshold voltage of the diode. Both junctions are in reverse bias hence both the transistors turn off and go into their cutoff state. Therefore the transistors act like an open switch. Since all the current coming from the collector through resistor R4 is blocked by the transistor hence we get a low voltage at the output, which turns off the LED.



Working of OR gate

In next case when we close the switch 1 then the base of the first transistor is getting a positive value of voltage. The base to emitter junction and base to collector junction of the first transistor have a voltage greater than threshold voltage so both junctions are in forward bias. The first transistor reaches into saturation state and acts like a short circuit whereas the second transistor is still in the cutoff state due to no power supply base. Hence all current passes through the first transistor to the output and our LED lights up.

When we close both the switches, the junction of both the transistors has a voltage greater than threshold voltage so both junctions are in forward bias. Therefore both transistors are in saturation state and act like a short circuit. The current now gets a short circuit path and flows from both of the transistors which derive high at the output, thereby lighting up the LED.



References:

- Digital Principles and Applications, A.P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw Hill
- Digital Fundamentals, Thomas L. Floyd, 11th Ed., 2015, Pearson Education Limited
- Modern Digital Electronics, R P Jain, 4th Ed., 2010, Tata McGraw Hill