Logic gates-AND & NOT Gate

Contents:

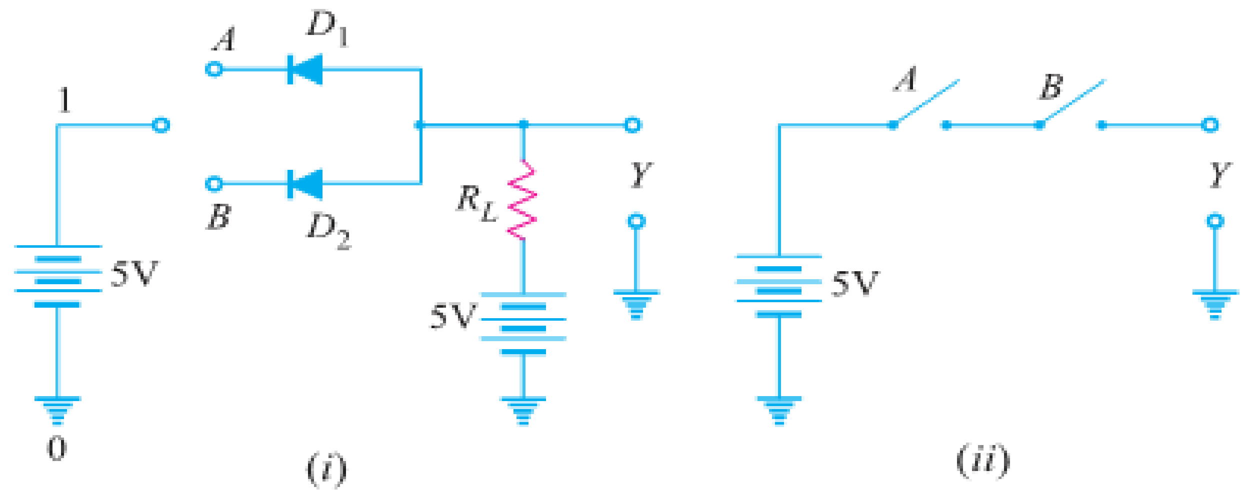
- Introduction
- Operation of AND gate
- AND gate using Transistor
- Operation of NOT gate
- NOT gate using Transistor

AND Gate

The AND gate is a logic gate that has two or more inputs but only one output. The output Y of AND gate is HIGH when all inputs are HIGH. However, the output Y of AND gate is LOW if any or all inputs are LOW It is called AND gate because output is HIGH only when all the inputs are HIGH. For this reason, the AND gate is sometimes called "all or nothing gate". For example, consider a 2-input AND gate. The output will be HIGH when both the inputs are HIGH.

AND gate operation

Fig. (i) shows one way to build a 2-input AND gate while Fig. (ii) shows its simplified schematic diagram. There are only four input-output possibilities.



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

(iii)

AND gate operation

(i) When both A and B are connected to ground, both the diodes (D1 and D2) are forward biased and hence they conduct current. Consequently, the two diodes are grounded and output voltage is zero. In terms of binary, when A = 0 and B = 0, then Y = 0 as shown in truth table in Fig. (iii).

(ii) When A is connected to the ground and B connected to the positive terminal of the battery, diode D1 is forward biased while diode D2 will not conduct. Therefore, diode D1 conducts and is grounded. Again output voltage will be zero. In binary terms, when A = 0 and B = 1, then Y = 0. This fact is shown in the truth table.

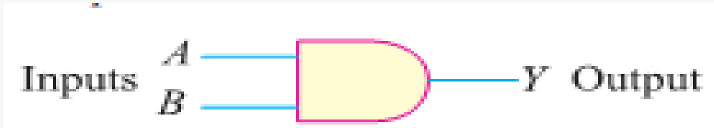
(iii) When B is connected to the ground and A connected to the positive terminal of the battery, the roles of diodes are interchanged. Now diode D2 will conduct while diode D1 does not conduct. As a result, diode D2 is grounded and again output voltage is zero. In binary terms, when A = 1 and B = 0, then Y = 0. This fact is indicated in the truth table.

(iv) When both A and B are connected to the positive terminal of the battery, both the diodes do not conduct. Now, the output voltage is +5 V because there is no current through RL.

It is clear from the truth table that for AND gate, the output is high if all the inputs are high.

However, the output is low if any or all inputs are low.

Fig. shows the logic symbol of AND gate.
This is the symbol you should memorize and use from now on for AND gates.



logic symbol

Boolean expression.

The Boolean expression for AND function is

$$A \cdot B = Y$$

↑

AND symbol

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

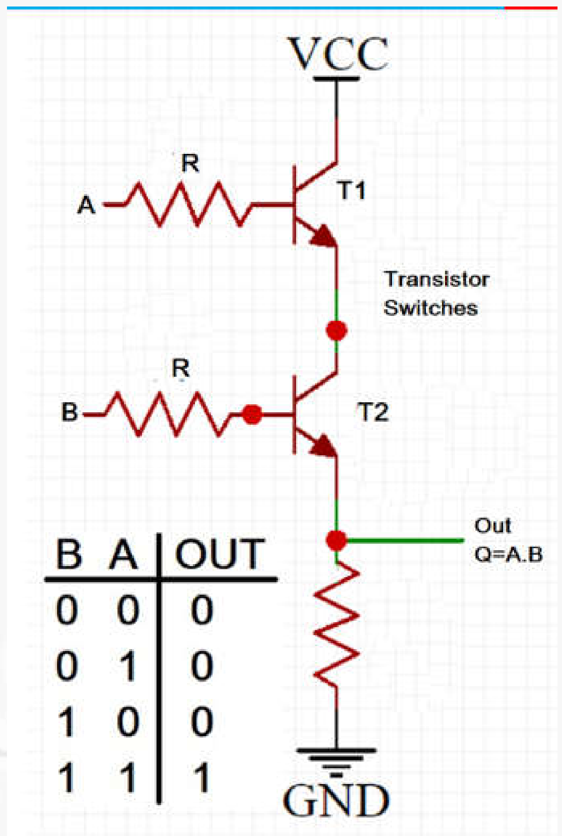
Truth Table

where the multiplication 'dot' stands for the AND operation. The adjoining table shows the possibilities for the inputs. Table tells us that 0 ANDed with any variable equals 0.

Also, 1 ANDed with 1 equals one.

Two-input AND Gate using transistor

The circuit represents both the inputs A & B for the AND gate and Output, Q which also has a +5V supply to the collector of the first transistor which is connected in series to the second transistor and an LED is connected to the emitter terminal of the second transistor. The inputs A & B are connected to the base terminal of Transistor 1 and Transistor 2, respectively and the output Q goes to the positive terminal LED. The below diagram represents the above-explained circuit to build an AND gate using NPN Transistor.



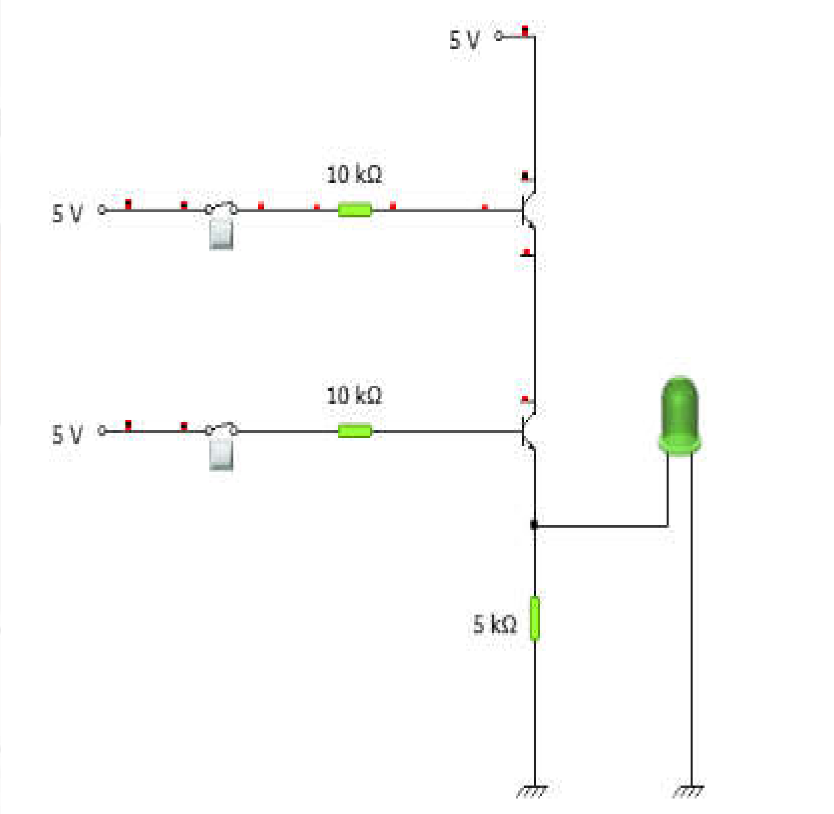
Working of AND Gate using Transistor

Here we will be using the transistor as a switch and so, when a voltage is applied through a Collector terminal of the NPN transistor, the voltage reaches the Emitter Junction only when the Base Junction is having a voltage supply between 0V and Collector Voltage. Similarly, the circuit above would make the LED glow i.e. the output is 1 (High) only when both the inputs are 1 (High) i.e. when there is a voltage supply at the base terminal of both the transistors. Meaning, there will be a straight line current path from VCC (+5V power supply) to the LED and further to the ground. Rest in all the cases, the output will be **0** (Low) and the LED will be OFF. These all can be explained in more detail by understanding each case one by one.

Working of AND Gate using Transistor

Case 1. When both the inputs A & B are 0

you need not press any of the pushbuttons in this case. If you are not using the push buttons then remove the wires connected with, the pushbuttons and the base terminal of both the transistors. So, we got both inputs A & B as 0 and now we need to check for the output, which also should be 0 according to the AND gate truth table.

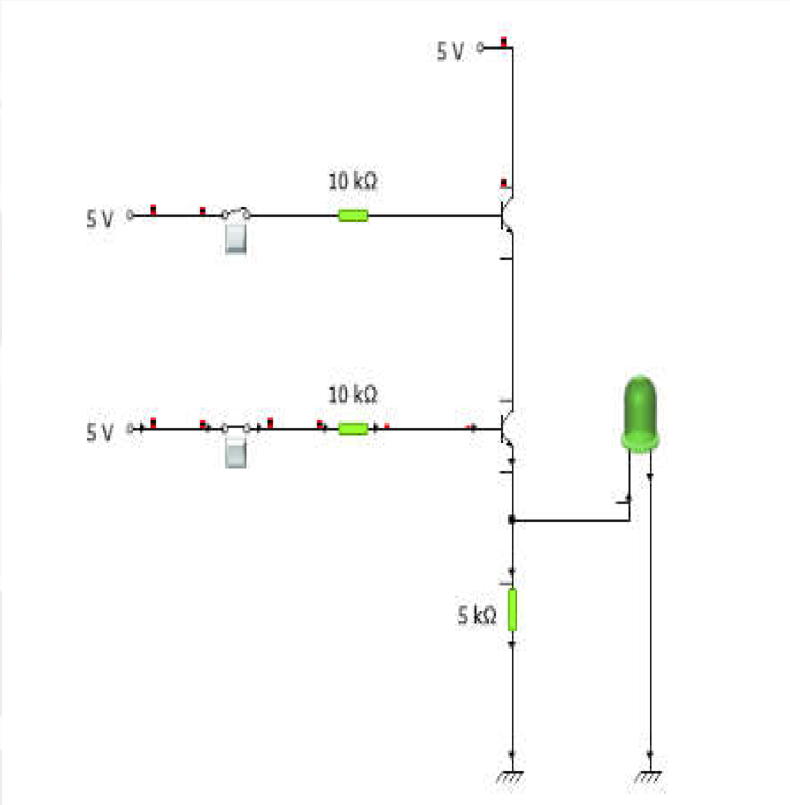


Now, when a voltage is supplied through the collector terminal of Transistor 1, the emitter doesn't receive any input because the base terminal value is 0. Similarly, the emitter of transistor 1 which is connected to the collector of Transistor 2, supplies no current or voltage and also the base terminal value of transistor 2 is 0. So, the 2nd transistor's emitter outputs the value 0 and as a result, the LED would be OFF.

Working of AND Gate using Transistor

Case 2: When the inputs are : **A = 0 & B = 1**

In the second case, when the inputs are A = 0 & B = 1, the circuit has first input as 0 (Low) and the second input as 1 (High) to the base of transistor 1 & 2, respectively. Now, when a 5V supply is passed to the collector of the first transistor, then there is no change in the phase shift of transistor since that the base terminal has 0 input. Which passes 0 value to the emitter and the emitter of first transistor is connected to the collector of the second transistor in series, so 0 value goes into the collector of second transistor.



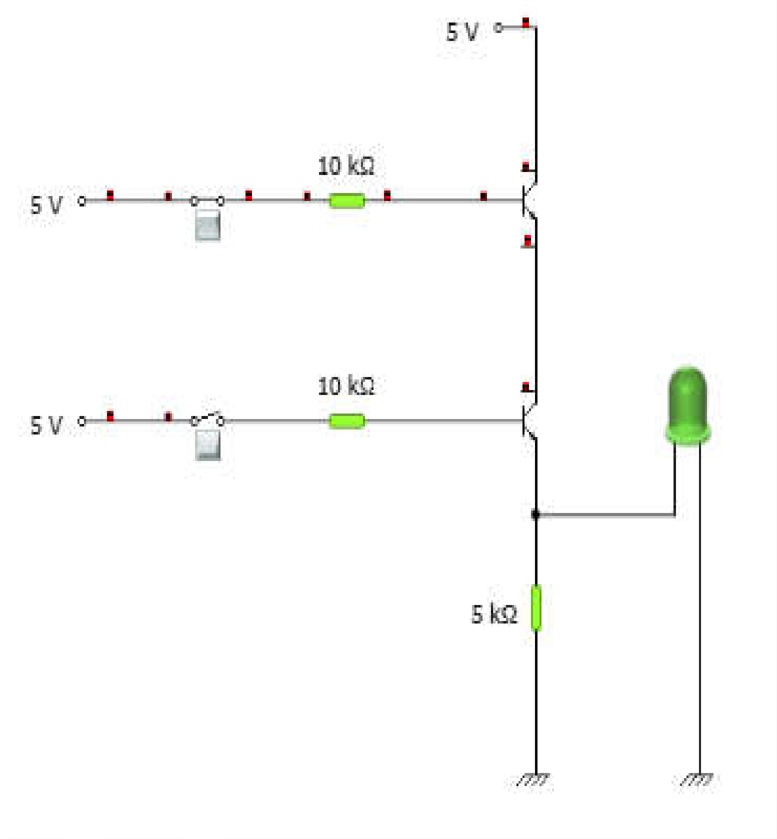
Now, the second transistor has a high value in the base, so it would allow the same value received in the collector to pass to the emitter. But since the value is 0 in the collector terminal of the second transistor, that's why the emitter will also be 0 and the LED connected to the emitter would not glow.

Working of AND Gate using Transistor

Case 3: When the inputs are – **A = 1 & B = 0**.

Here, the input is 1 (high) for the first transistor base and low for the second transistor base. So, the current path will start from 5V power supply to the collector of the second transistor passing through the collector and emitter of the first transistor since the base terminal value is high for the first transistor.

But in the second transistor, the base terminal value is 0 and so, no current passes from collector to the emitter of the second transistor and as a result, the led would still be OFF only.

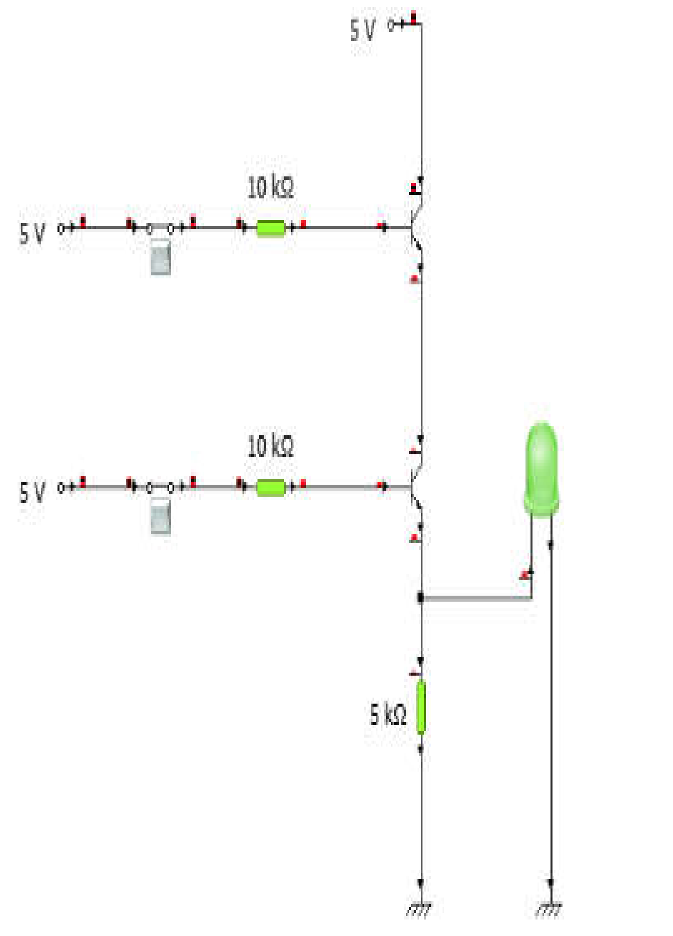


Working of AND Gate using Transistor

Case 4: When both inputs are one – **A = 1 & B = 1**.

The last case and here both the inputs are supposed to be high which are connected to the base terminals of both the transistors. This means whenever a current or voltage passes through the collector of both the transistors, the base reaches its saturation and the transistor conducts.

Practically explaining, when a +5V supply is provided to the collector terminal of transistor 1 and also the base terminal is saturated then, the emitter terminal would receive a high output since the transistor is forward biased. This high output at the emitter goes directly to the collector of 2nd transistor through a series connection. Now, similarly at the second transistor, the input at the collector is high and in this case, the base terminal is also high, meaning the second transistor is also in a saturated state and the high input would pass from the collector to the emitter. This high output at the emitter goes to the LED which turns the LED ON.



NOT Gate or Inverter

The NOT gate or inverter is the simplest of all logic gates. It has only one input and one output, where the output is opposite of the input. The NOT gate is often called inverter because it inverts the input

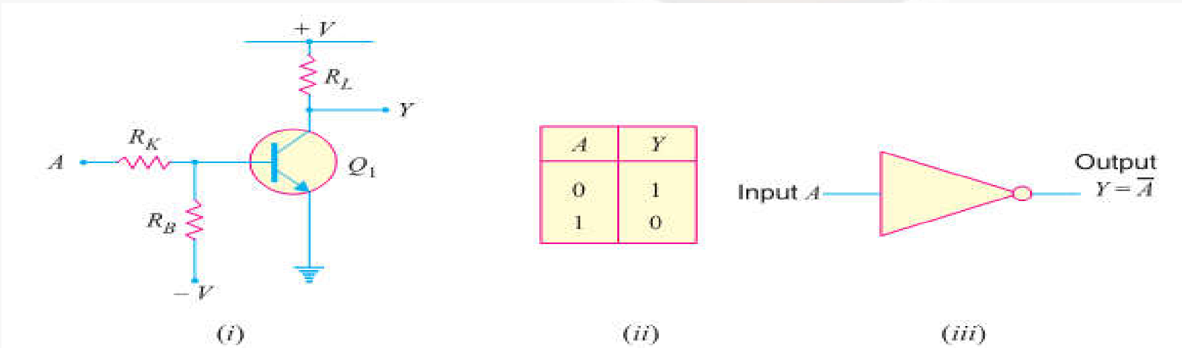


Figure (i) shows a typical inverter circuit. When A is connected to ground, the base of transistor Q1 will become negative. This negative potential causes the transistor to cut off and collector current is zero and output is + V volts. In binary terms, when A = 0, Y = 1. If sufficiently large positive voltage is applied at A, the base of the transistor will become positive, causing the transistor to conduct heavily. Therefore, the output voltage is zero. In binary terms, when A = 1, Y = 0. Fig. (ii) shows truth table for an inverter. It is clear from the truth table that whatever the input to the

inverter, the output assumes opposite polarity. If the input is 0, the output will be 1 ; if the input is 1, the output will be 0.

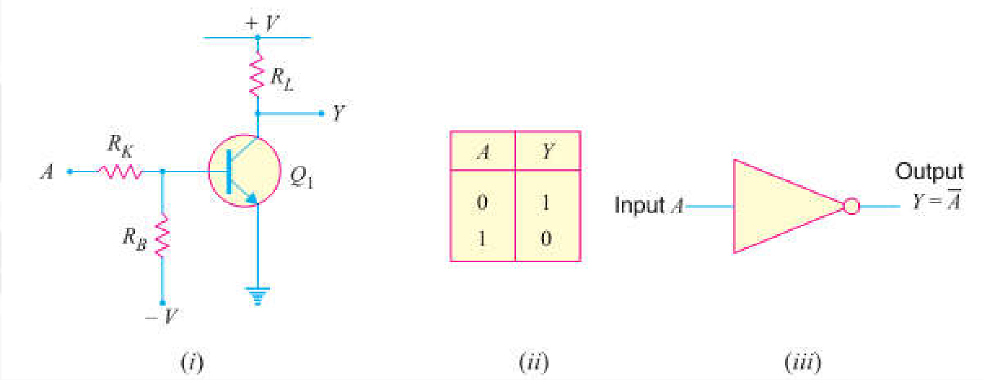
Figure (iii) shows the logic symbol for NOT gate or inverter. Note that small bubble on the inverter symbol represents inversion. The Boolean expression for NOT function is

$$Y = \overline{A}$$

Note that bar above the input A represents inversion.

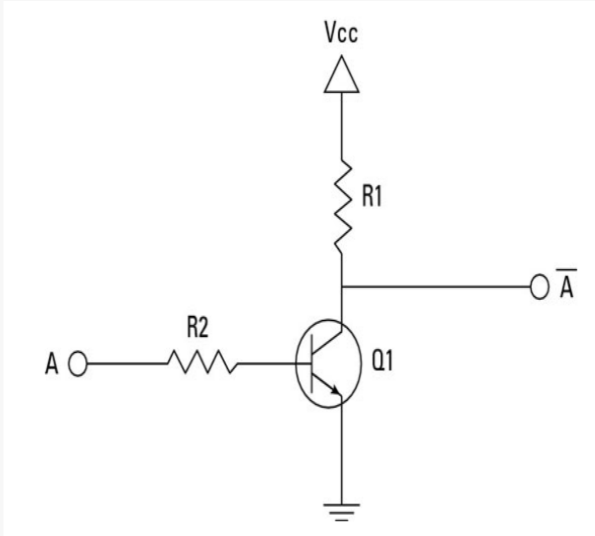
If $A = 0$, then $Y = \overline{0}$ or $Y = 1$.

If $A = 1$, then $Y = \overline{1}$ or $Y = 0$.



NOT Gate using transistor

A NOT gate simply inverts its input. If the input is HIGH, the output is LOW, and if the input is LOW, the output is HIGH. Such a circuit is easy to build, using a single transistor and a pair of resistors.

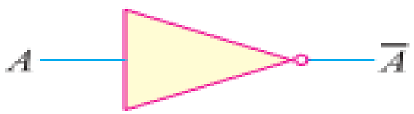
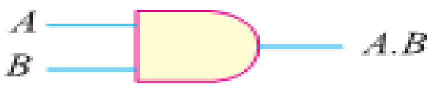
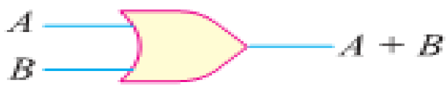


The operation of this circuit is simple. The input is connected through resistor R2 to the transistor's base. When no voltage is present on the input, the transistor turns off. When the transistor is off, no current flows through the collector-emitter path. Thus, current from the supply voltage (V_{cc} in the schematic) flows through resistor R1 to the output. In this way, the circuit's output is HIGH when its input is LOW.

When voltage is present at the input, the transistor turns on, allowing current to flow through the collector-emitter circuit directly to ground. This ground path creates a shortcut that bypasses the output, which causes the output to go LOW.

In this way, the output is HIGH when the input is LOW and LOW when the input is HIGH.

Summary

Logic Function	Symbol
Inverter	
AND	
OR	

A	Y
0	1
1	0

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

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

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