LOGIC GATES

Introduction

This chapter introduces the Logic Gates, logic gates are the fundamental building blocks of digital system. A circuit with one or more input signal but only one output signal. Gates are digital or electronic circuits because they are made up of a number of electronic devices and components with the input and output signal are either low (0) or high (1) voltages. Gates are often called logic circuits because they can be analyzed with Boolean algebra.

Types of logic gates

There are three types of logic gates.

1. Basic or Fundamental gates. (AND, OR, NOT)
   - AND Gate.
   - OR Gate.
   - NOT Gate
2. Universal gates. (NAND, NOR)
   - NAND Gate.
   - NOR Gate.
3. Exclusive gates. (EX-OR, EX-NOR)
   - EX-OR Gate.
   - EX-NOR Gate.

1. Basic or Fundamental gates.

AND Gate:

An AND gate has two or more input signal but only one output signal. In this types of gate all inputs are high the output must be high.

The logic symbol of two, three and four input AND gates are shown in Figs.1. A dot (.) is used to show the AND operation.

Symbol:

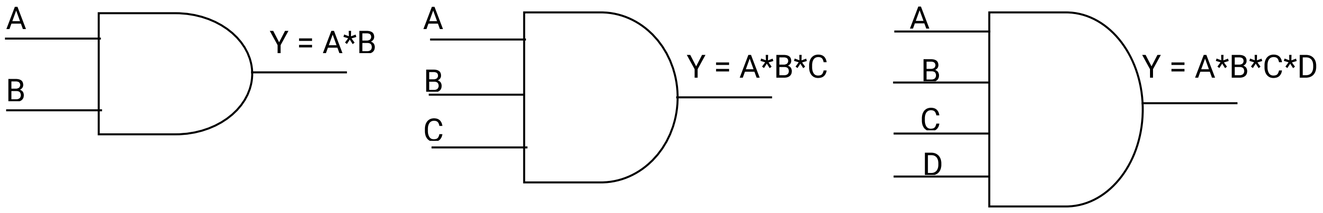


Fig.1. AND Gate symbol for two, three and four input

Truth table:

"A table which list all the possible combination of input variables and the corresponding output is called a truth table"

Table 1, two inputs AND gate.

INPUT		OUTPUT
A	B	Y=A*B
0	0	0
0	1	0
1	0	0
1	1	1

Table 2, three inputs AND gate

INPUT			OUTPUT
A	B	C	Y=A*B*C
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

NOTE: all input must be high (1) to get a high output

OR Gate:

An OR gate has two or more input signal but only one output signal. In this types of gate if any input signal is high then output will be a high. Output goes to low only when all the input is low.

The logic symbol of two, three and four input OR gates are shown in Figs.2. A plus (+) is used to show the OR operation.

Symbol:

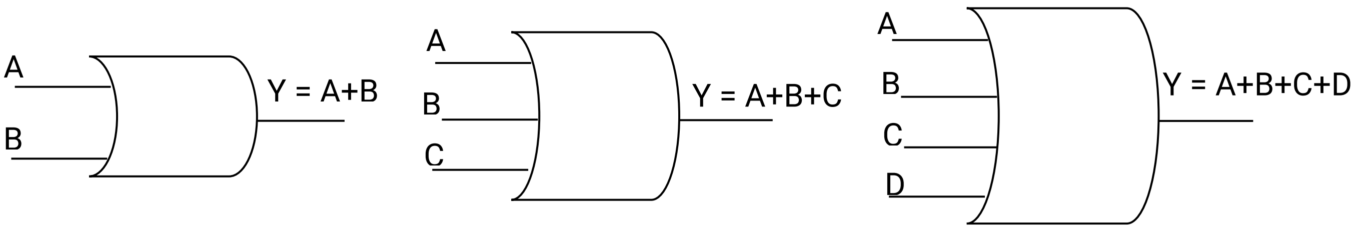


Fig.2. OR Gate symbol for two, three and four input

Truth table:

Table 3, two inputs OR gate.

INPUT		OUTPUT
A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

Table 4, three inputs OR gate

	INPUT		OUTPUT
A	B	C	Y=A+B+C
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

NOTE: if any input signal is high then output will be a high

NOT Gate (Inverter):

NOT gate is also known, as an inverter or inverse gate. A NOT gate with only one input signal and only one output signal. The output signal is always the opposite of the input signal.

Symbol:

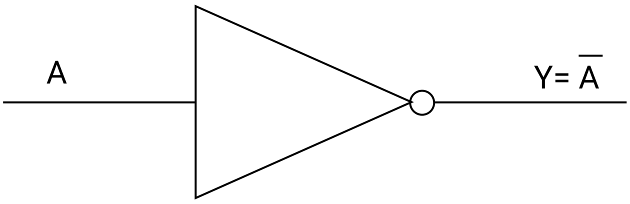


Fig.3. NOT Gate symbol

Truth table:

INPUT	OUTPUT
A	A
0	$\overline{1}$
1	0

2. Universal gates.

Though logic circuit of any complexity can be realized by using only the three basic gates (AND, OR and NOT), there are two universal gates (NAND and NOR), each of which can also realize logic circuit single. The NAND and NOR gates are also, therefore, called universal building blocks. Both NAND and NOR gates can perform all the three basic logic gates (AND, OR and NOT).

There are two types of universal gates.

(1). NAND.
(2). NOR.

NAND Gate

The NAND gate has two or more input signal but only one output signal. NAND gate is a combination of an AND gate and NOT gate. The output of NAND gate is opposite to AND gate. In the NAND gate all input signal must be high then output must be low

The logic symbol of two, three and four input NAND gates are shown in Fig.4. A dot (.) is used to show the NAND operation.

Symbol:

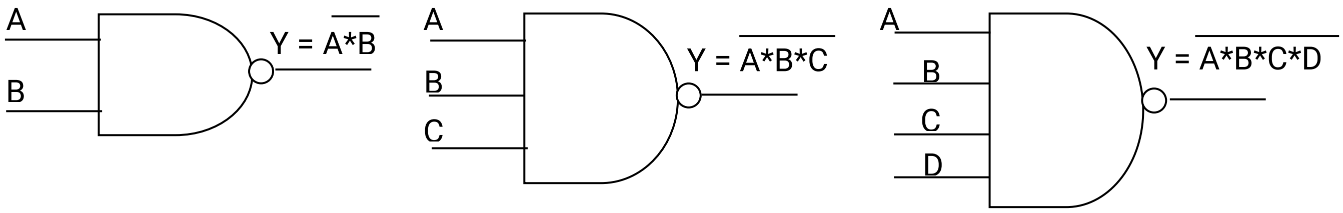


Fig.4. AND Gate symbol for two, three and four input

Truth table:

Table 6, two inputs NAND gate

INPUT		OUTPUT
A	B	$Y=\overline{A*B}$
0	0	1
0	1	1
1	0	1
1	1	0

Table 7, three inputs NAND gate

INPUT			OUTPUT
A	B	C	$Y=\overline{A*B*C}$
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

NOTE: all input must be high (1) to get a low output in NAND gate

NAND gate is also called Bubbled OR gate, the corresponding output expression is $Y = \overline{A} + \overline{B}$. So, a NAND function can also be realized by first inverting the input and then ORing the inverted inputs. Thus, a NAND gate is a combination of two NOT gate and an OR gate. The OR gate with inverted is called bubbled OR gate.

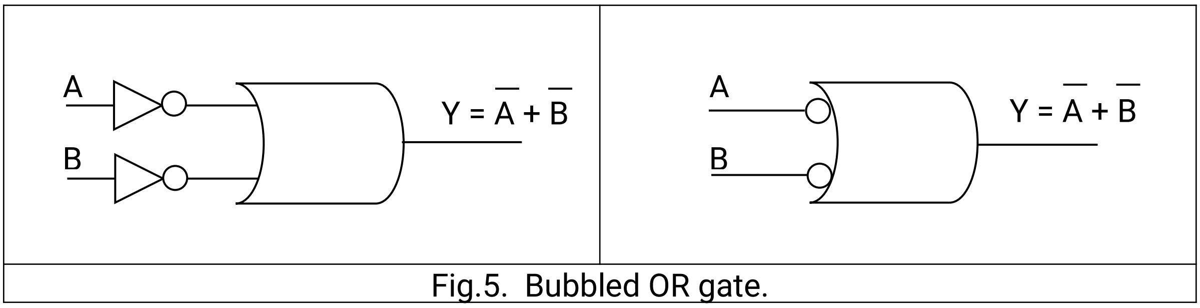

A
B
$Y = \overline{A} + \overline{B}$
A
B
$Y = \overline{A} + \overline{B}$

Fig.5. Bubbled OR gate.

NOR Gate

The NOR gate has two or more input signal but only one output signal. NOR gate is a combination of an OR gate and NOT gate. The output of NOR gate is opposite to OR gate. In the NOR gate all input signal must be low then output must be high

The logic symbol of two, three and four input NOR gates are shown in Fig.5. A plus (+) is used to show the NOR operation.

Symbol:

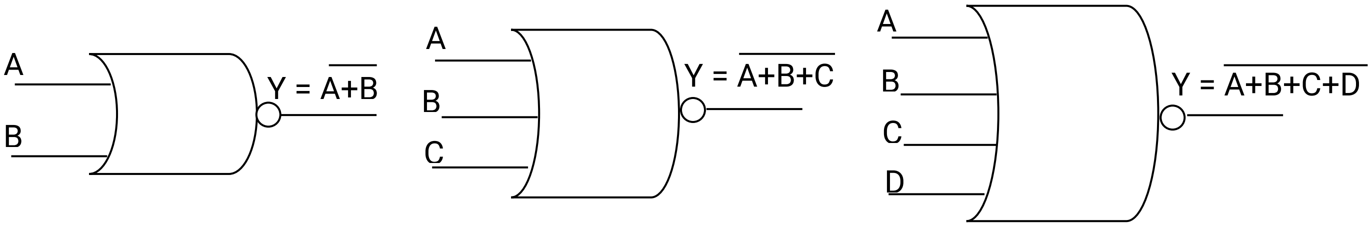


Fig.5. NOR Gate symbol for two, three and four input

Truth table:

Table 8, two inputs NOR gate.

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

Table 9, three inputs NOR gate

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

NOTE: if any input signal is high then output will be a low

NOR gate is also called Bubbled AND gate, the corresponding output expression is Y = $\overline{A} * \overline{B}$. So, a NOR function can also be realized by first inverting the input and then ANDing the inverted inputs. Thus, a NOR gate is a combination of two NOT gate and an AND gate. The AND gate with inverted is called bubbled AND gate.

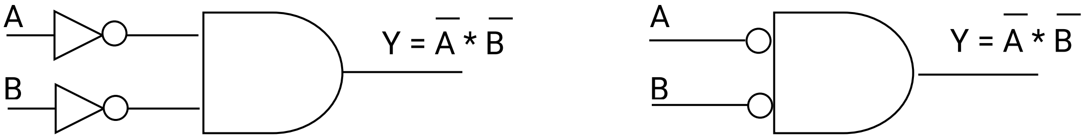

A
B
Y = $\overline{A} * \overline{B}$
A
B
Y = $\overline{A} * \overline{B}$

Fig.6. Bubbled AND gate.

3. Exclusive gates. (EX-OR, EX-NOR)

Exclusive gates are combination of the all basic gates (AND, OR, NOT)

There are two types of universal gates.

(1). Exclusive – OR gate (EX – OR).
(2). Exclusive – NOR gate (EX – NOR).

Exclusive – OR gate (EX – OR)

An EX-OR gate is a two input and one output logic circuit, in EX-OR gate both input are low and both input are high the output is low, mince both input are same the output is low, and both input are different (0,1) then output is high.

The logic symbol and truth table of two input EX-OR gate are shown in figs 7. If the input variables are represented by A and B and the output variable by Y, the expression for the output○of this gate is Y = A + B, Y = AB + AB, Y = A'B + AB'

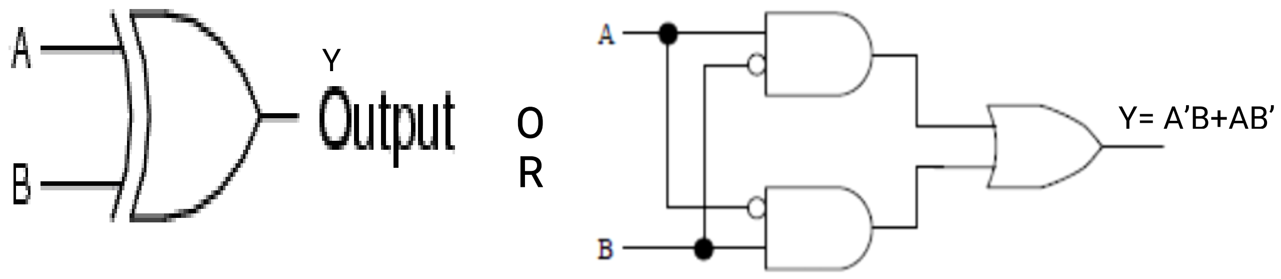


Fig.7. EX-OR Gate symbol for two input

Truth table:

Table 10, two inputs EX-OR gate.

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

Table 11, three inputs EX-OR gate

INPUT			OUTPUT
A	B	C	$Y=A\oplus B\oplus C$
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

NOTE: this gate produces high output for odd number of high input signal.

Exclusive – NOR gate (EX –NOR)

An EX-NOR gate is a two input and one output logic circuit, this gate produces a high output for even number of high input signal. In the EX-NOR gate the output are exactly opposite to EX – OR gate

The logic symbol and truth table of two input EX-NOR gate are shown in figs. If the input variables are represented by A and B and the output variable by Y, the expression for the output of this gate is Y = A + B,   A'B + AB'

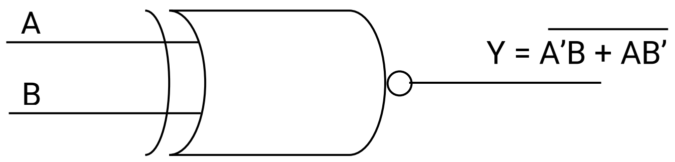


Fig.8. EX-NOR Gate symbol for two input

Truth table:

Table 12, two inputs EX-NOR gate.   Table 13, three inputs EX-NOR gate

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

INPUT			OUTPUT
A	B	C	$Y=\overline{A \oplus B \oplus C}$
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	0

NOTE: this gate produces a high output for even number of high input signal.

Exercises:-

1. What do you mince by a Logic Gate? Name the basic gates.
2. What is a Truth Table?
3. An AND gate output always differs from an OR gate output. (True or False).
4. What do you mince by a Bubbled AND and Bubbled OR gate?

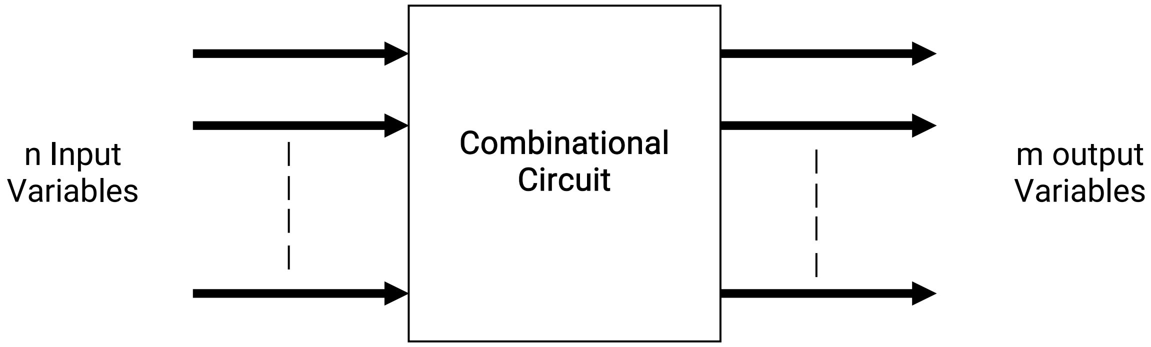
5. Explain the Basic Gates.
6. Explain the Universal Gates.
7. Explain the Exclusive gates.

COMBINATIONAL CIRCUIT

A combinational circuit is a connected arrangement of logic gates with a set of input and output. In a combination circuit at any moment the output entirely depends on the input present at the moment in the design of combination circuits AND, OR and NOT operation are required.

Combinational logic refers to circuits whose output is strictly depended on the present value of the inputs. As soon as inputs are changed, the information about the previous inputs is lost, that is, combinational logics circuits have no memory. In many applications, information regarding input values at a certain instant of time is required at some future time. Although every digital system is likely to have combinational circuits, most systems encountered in practice also include memory elements, which require that the system be described in terms of sequential logic.

Examples of combination circuit are: **Adder/Subtractor, arithmetic/logic unit, digital comparator, digital multiplexer, Demultiplexer, Encoder, Decoder,**



(Fig. Combinational Circuit)

In the fig. the n binary input variables come from an external source, the m binary output variables go to an external destination, and in between there is an interconnection of logic gates. A combinational circuit transforms binary information from the given input data to the required output data.

ARITHMETIC ADDERS

There are two types of adder

- Half Adder
- Full Adder

HALF ADDER

A combinational circuit that performs the arithmetic operation for two bit addition is called a Half Adder. A half adder has two inputs, generally labeled A and B, and two out put, the sum S and carry C, a half adder can realized by using one X-OR gate and one AND gate. Half adders is a logic circuit that add 2 Boolean equation

1. The sum (S) is the X-OR operation of A and B therefore,

S (SUM) = $\bar{A}B + A\bar{B}$ or $A \oplus B$

2. The carry (C) is the AND operation of A and B therefore,

C (CARRY) = A*B or AB

Symbol / Circuit:

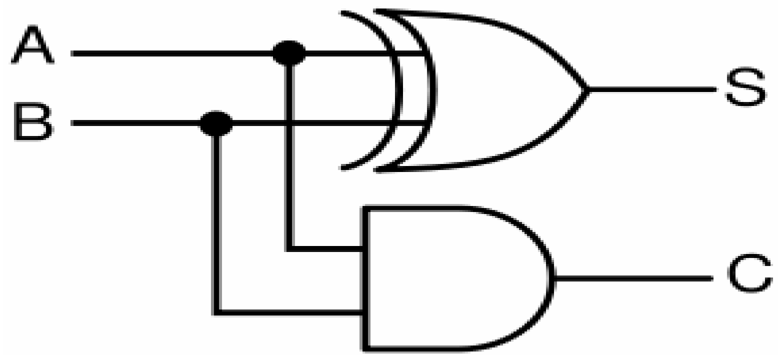


Fig.logic Diagram of a Half Adder

Table 1, Truth table for Half Adder

INPUT		OUTPUT	
A	B	S (SUM) S= $\bar{A}B + A\bar{B}$	C (CARRY) C= A*B
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

NOTE:

- In half adder when the both input is same (0 or 1) that time output (SUM) is low.
- In half adder when the both input is 1 (High) A=1 and B=1 that time CARRY is 1.

FULL ADDER

A combinational circuit that performs the arithmetic operation for three bit addition is called a Full Adder. A Hull adder has three inputs, generally labeled A, B, and C_{in} and two out put, the sum S and carry C, a Full adder can realized by using X-OR gate and AND gate. Full adders is a logic circuit that add 2 Boolean equation

1. The sum (S) is the X-OR operation of A, B and C therefore,

$$S\ (SUM) = \overline{A}\,\overline{B}C + \overline{A}B\overline{C} + AB\overline{C}\ \text{ or }\ A + B\bigcirc + C\bigcirc$$

2. The carry (C) is the AND operation of A and B therefore,

C (CARRY) = A*B +A*C + B*C
<u>or</u> AB + AC + BC
<u>or</u> AB + (A ⊕B) C

Symbol / Circuit:

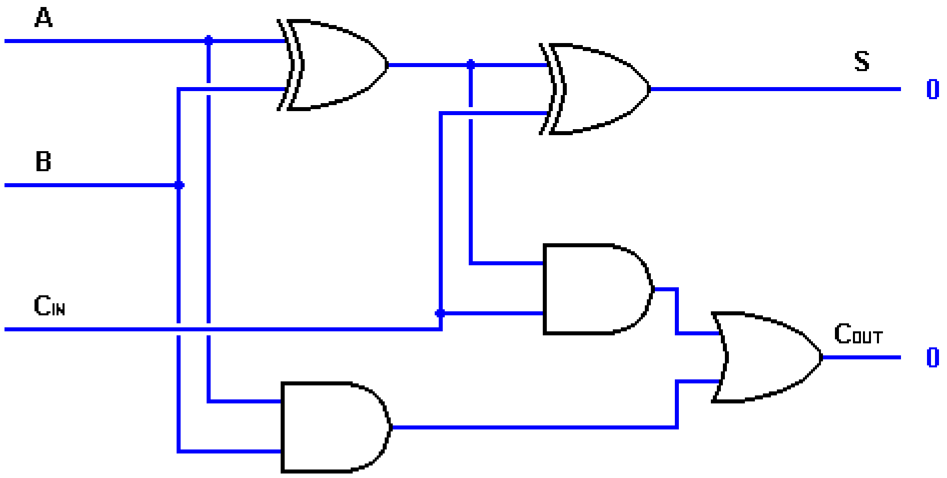


Fig.logic Diagram of a Full Adder

Table 2, Truth table for Full Adder

INPUT			OUTPUT	
A	B	C	S (SUM) S=A + B + C	C (CARRY) C=AB + AC + BC
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

NOTE:

- In the input A B C, two or more input are high (1) then output (CARRY) is 1
- In input A B C Even time input is high (1) then output (SUM) is 0. and Odd time input is high (1) then output (SUM) is 1

ARITHMETIC SUBTRACTOR

There are two types of Subtractor

- Half Subtractor
- Full Subtractor

HALF SUBTRACTOR

The Half-Subtractor is a combinational circuit which is used to perform subtraction of two bits. A Half Subtractor is an Arithmetic circuit that subtracts one bit from the other It has two inputs, A (minuend) and B (subtrahend) and two outputs D (Difference) and B (Borrow).

Half Subtractor is a logic circuit that 2 Boolean equation

1. The Difference (D) of A and B therefore,

D (Difference) = $\overline{A}B + A\overline{B}$ or A * B

2. The Borrow (C) of A and B therefore,

B (Borrow) = $\overline{A} * B$

Symbol / Circuit:

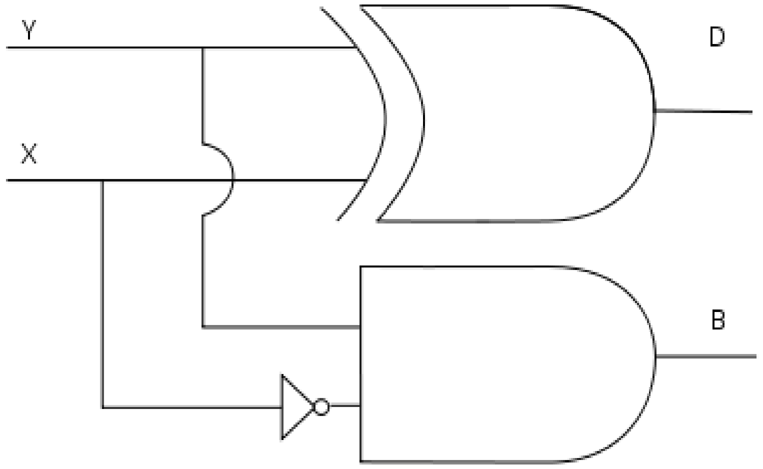


Fig.logic Diagram of a Half Subtractor

The logic diagram of a half Subtractor is made by using X-OR gate, NOT gate and AND gate

Table 3, Truth table for Half Subtractor

INPUT		OUTPUT	
A	B	D (Difference) D= A⊕B	B (Borrow) C= $\overline{A}$*B
0	0	0	0

0	1	1	1
1	0	1	0
1	1	0	0

FULL SUBTRACTOR.

The Full-Subtractor is a combinational circuit which is used to perform subtraction of three bits. A Full Subtractor is an Arithmetic circuit that subtracts one bit from the other It has three inputs, X, Y and Bi and two outputs D (Difference) and B (Borrow).

A full Subtractor is made by combining two half-subtractors and an additional OR-gate. A full Subtractor has the borrow in capability (denoted as BOR_{IN} in the diagram below) and so allows cascading which results in the possibility of multi-bit subtraction. The circuit diagram for a full Subtractor is given below.

From the truth table the every possible combination of X, Y and B_i is described by the following equation.

Full Subtractor is a logic circuit that 2 Boolean equation

1. The Difference (D),

$$D \text{ (Difference)} = \bar{X}\bar{Y}B_i + \bar{X}Y\overline{B_i} + XY\overline{B_i} + XYB_i$$

$$\text{Or } A \oplus B \oplus B_i$$

2. The Borrow (C),

$$B \text{ (Borrow)} = \bar{X}Y + (\overline{X \oplus Y})\, B_i$$

Symbol / Circuit:

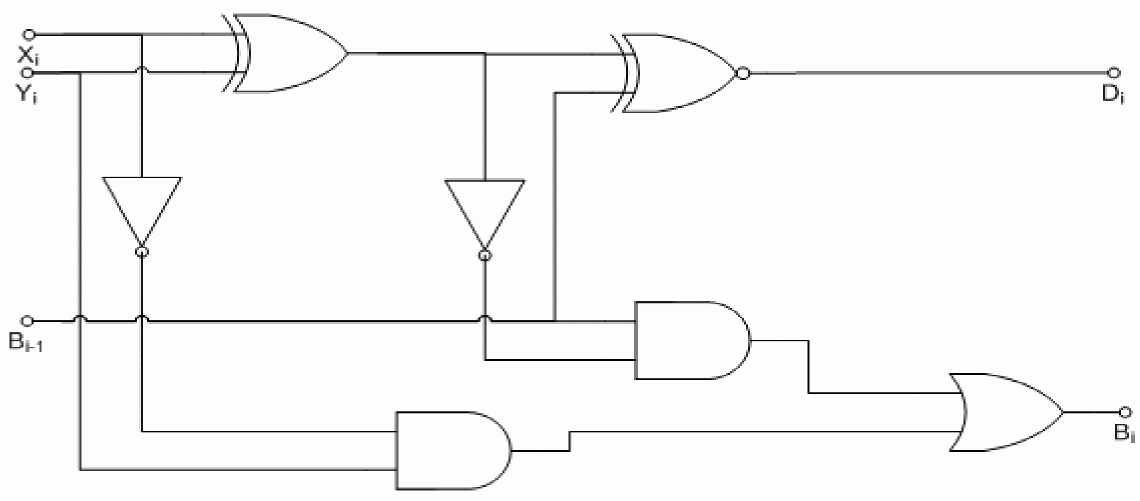


Fig.logic Diagram of a Full Subtractor

Table 4, Truth table for Full Subtractor

INPUT			OUTPUT	
X	Y	B_i	D (Difference)	B (Borrow)
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

DATA PROCESSING CIRCUIT

- Decoder
- Encoder

DECODER

A Decoder is a combinational and data processing circuit. A decoder, this circuit takes an *n*-bit binary number and produces an output on one of 2^n output lines. It is therefore commonly defined by the number of addressing input lines and the number of data output lines. A decoder is similar to Demultiplexer.

Decoders are useful circuit that widely used in memory system of computer, address decoding, Demultiplexer and display any decimal number.

Decoders are available in 2 to 4 line, 3 to 8 line, 4 to 16 line and BCD to seven segments.

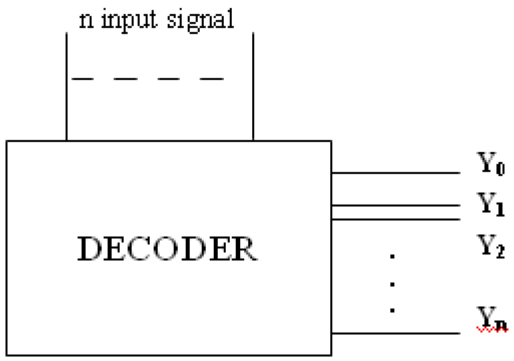


Fig. Block diagram of a Decoder

3 to 8 line Decoder.

In 3 to 8 line decoder 3 input signal and 8 output signal. It is also called Binary to Octal Decoder because it takes a 3 bit Binary input data and activates one of eight (octal) outputs signal related to the code. It uses all AND gates, and therefore, the outputs are HIGH. All NAND gates are representing LOW output.

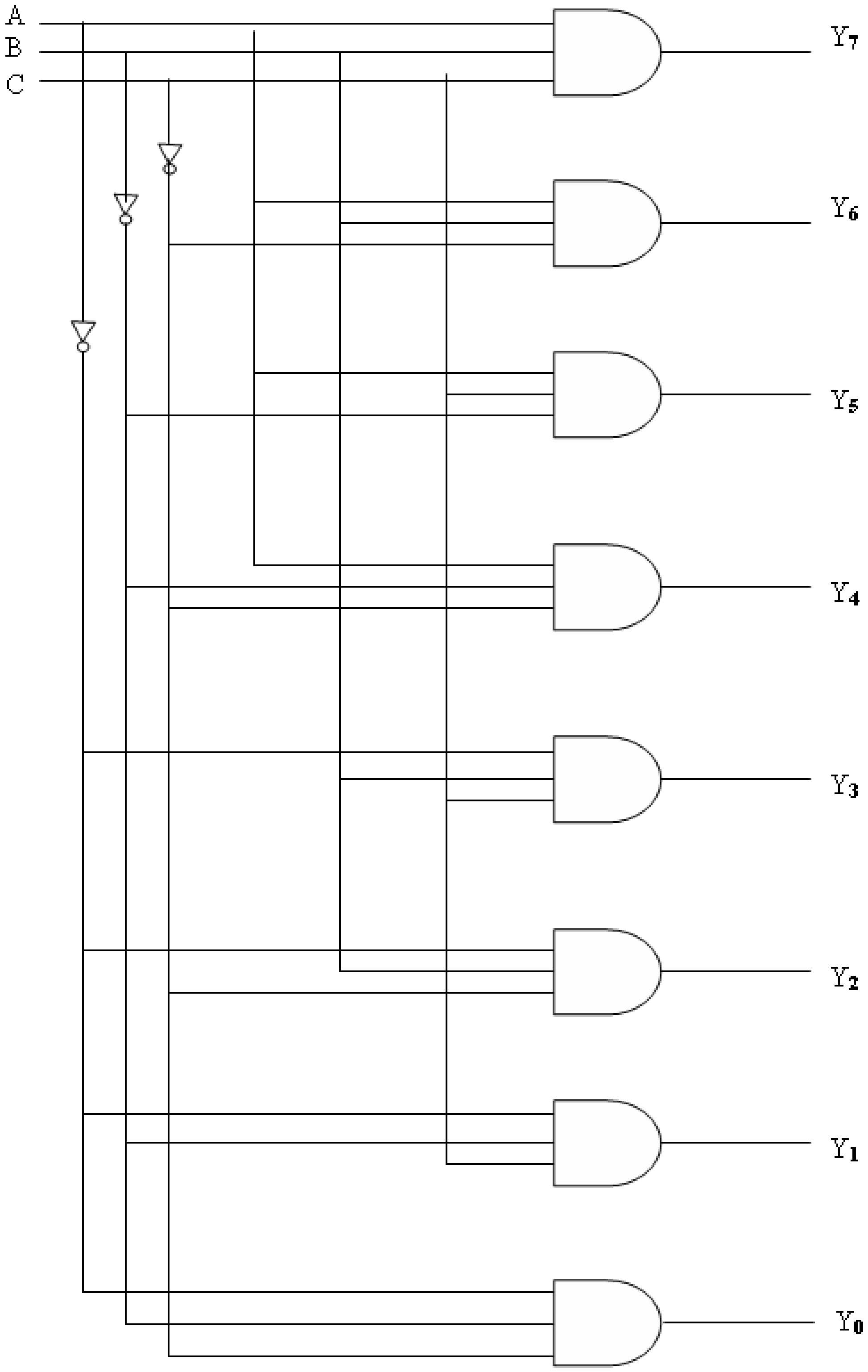


Fig. Logic Diagram of a 3 to 8 – line Decoder

In the 3 to 8 line Decoder diagram the three data input A, B and C are decoded into

8 outputs. Each output representing one of the combinations of the 3 binary input signals. The three NOT gates provide the compliment of the input and each of the Eight AND gates generates one of the binary combination.

Truth table of the 3 to 8 decoder

Table 9: Truth table of 3 to 8 line Decoder

INPUT			OUTPUT							
A	B	C	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0
1	0	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1

ENCODER

An encoder is a combinational and data processing circuit, it is a process of converting familiar number into a coded format. An encoder is a device whose inputs are decimal digit and/or alphabetic characters and whose output are the coded representation of those inputs. An encoder is performs reverse operation of decoder. The opposite of the decoding process is called encoding. An encoder has a number of input lines, only one of which is activated. Encoders are available in Octal to Binary and Decimal to Binary.

Decimal to Binary Encoder

This type of encoder has 10 input signal for each decimal digit, and 4 outputs signal corresponding to the BCD code, this is also called 10 lines to 4 line encoder

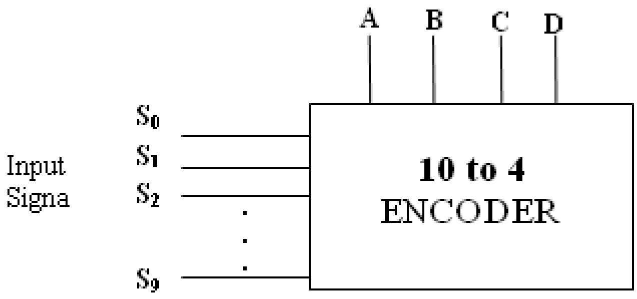


Fig.17 Block diagram of a 10 to 4 line Encoder

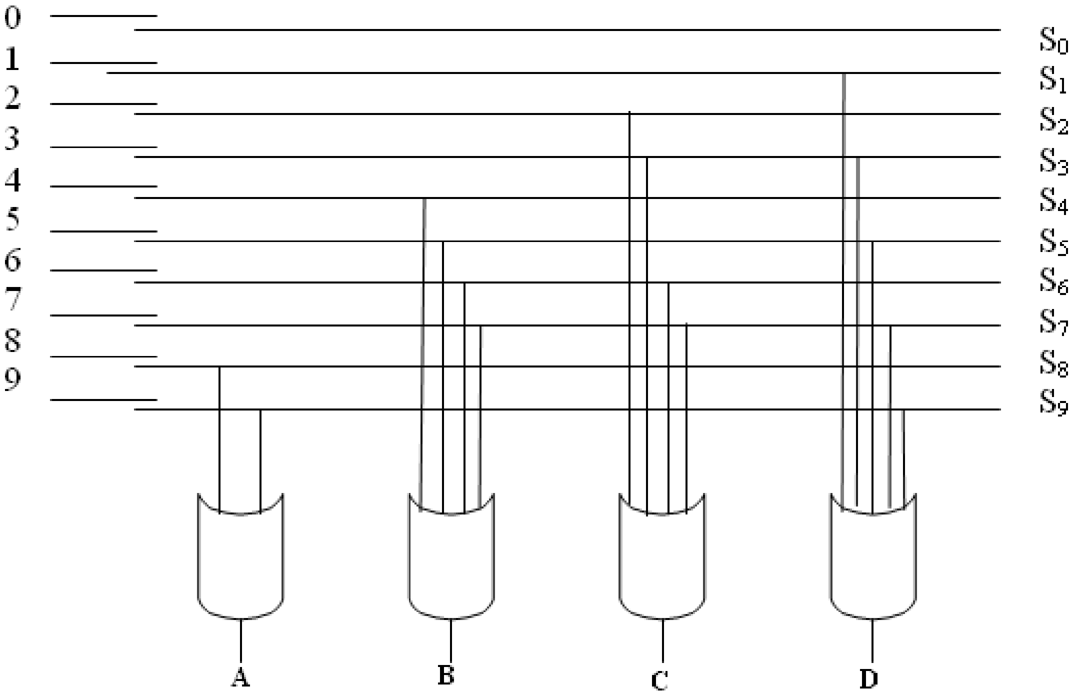


Fig. 18 Logic Circuit of a 10 to 4 line Encoder

- ✓ In Encoder 0 to 9 switches are used for connect to input signal
- ✓ And S_0 to S_9 is input line for different signal (ABCD)
- ✓ And signal ABCD work as an output signal.
- ✓ In Encoder when the switch no-3 is connected that time the signal C and D is on. When the switch no – 7 is connected that time signal B, C and D is on.
- ✓ Encoder converts an active input signal into a coded output signal

$A = S_8 + S_9$ $C = S_2 + S_3 + S_6 + S_7$

$B = S_4 + S_5 + S_6 + S_7$ $D = S_1 + S_3 + S_5 + S_7 + S_9$

Table 10: Truth table of Decimal to Binary Encoder

DECIMAL INPUT		BINARY OUTPUT			
		A	B	C	D
S_0	0	0	0	0	0
S_1	1	0	0	0	1
S_2	2	0	0	1	0
S_3	3	0	0	1	1
S_4	4	0	1	0	0
S_5	5	0	1	0	1
S_6	6	0	1	1	0
S_7	7	0	1	1	1
S_8	8	1	0	0	0
S_9	9	1	0	0	1