Combinational building Blocks.

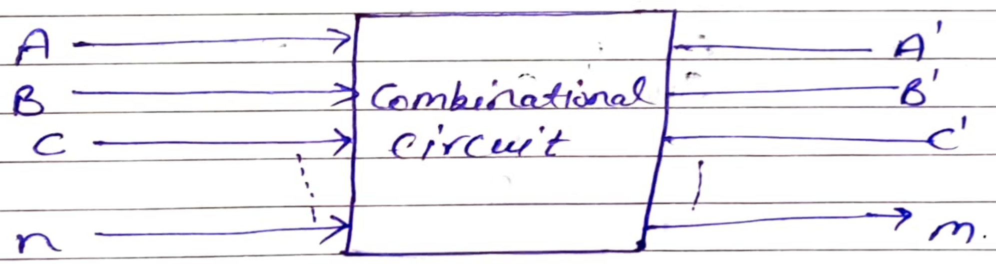
Unit - IInd.

Combinational circuit is a circuit in which we combine the different gates in circuit.
eg:- Encoder, Decoder, multiplexer & demultiplexer.

Characterstics of combinational circuit :-

(1) The output of combinational circuit at any instant of time, depends only on the levels present at input terminals.
(2) The combinational circuit do not use any memory. The previous state of input does not have any affect on the present state of ~~xx~~ the circuit.
(3) A combinational circuit can have an 'n' number of inputs & m number of outputs.

Block diagram:-

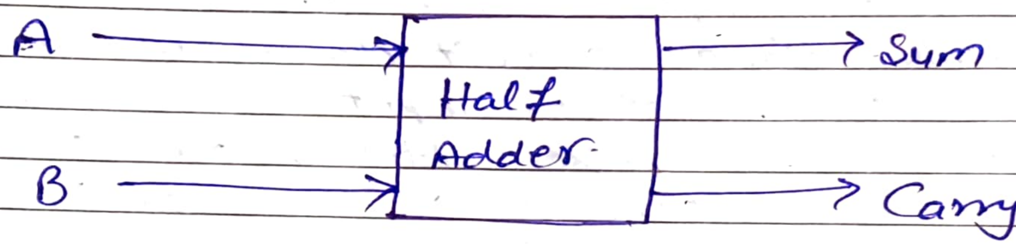


Designing of combinational circuit

(1) find the number of inputs & outputs
(2) write the truth table.
(3) write the logical Expression.
(4) Minimize the logical Expression.
(5) Hardware implementation.

(i) **Half Adder** :- The half adder is a basic building block having two inputs & two outputs. The adder is used to perform OR operation of two single bit binary numbers. The Carry & Sum are two output states of the half adder.

Block diagram :-



Truth Table

LSB
MSB

Inputs		Outputs	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

In the above table,

(1) 'A' and 'B' are the input states, and 'sum' & 'Carry' are the output states.

(2) The 'Carry' output is 0 in case where both the inputs are not 1.

(3) The least significant bit of the sum is defined by the 'Sum' bit.

The SOP form of the sum & carry are as follows:-

$Sum = x'y + xy'$ ← minterm (SOP) $\bar{x}=0, \bar{x}=1$

$Carry = xy$

Construction of half Adder circuit:-

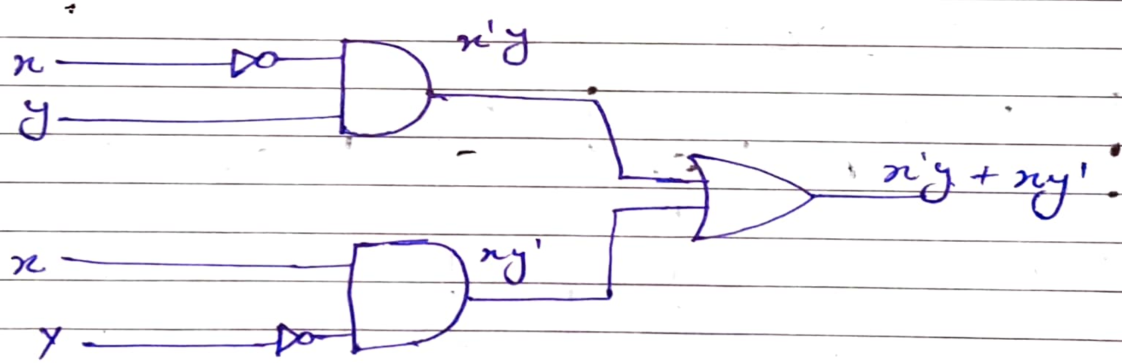
The half adder is designed with the help of the following two logic gates:-

(1) 2-input AND gate.

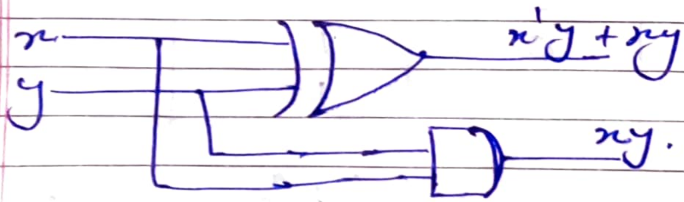
(2) 2-input Exclusive-OR Gate or Ex-OR gate.

$Sum = x'y + xy'$ OR $Sum = x \oplus R$

$Carry = xy$



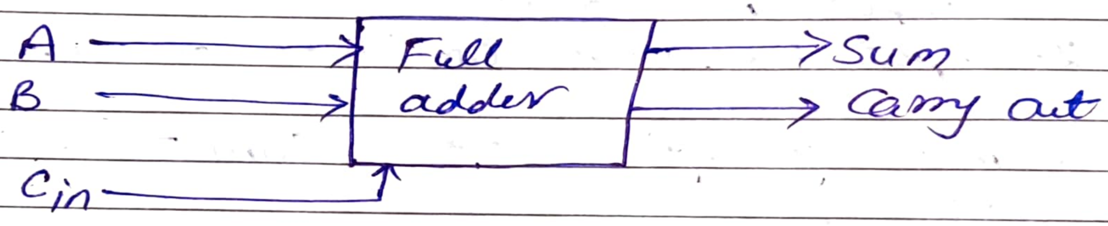
OR



Half-Adder circuit

Full Adder :- The half adder is used to add only two numbers. To overcome this problem, the full adder was developed. The full adder is used to add three 1 bit binary numbers A, B & carry C. The full adder has three input states & two output states i.e. Sum & Carry.

Block diagram :-



Truth Table

Inputs			Outputs	
A	B	Cin	Sum	Carry
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

(1) 'A' & 'B' are the input variables. These variables represent the two significant bits which are going to be added.

(2) 'Cin' is the third input which represents the carry. from the previous lower significant position, the carry bit is fatched.

(3) The Sum & Carry are the output variables that defined the output values.

(4) The eight rows under the input variable designate all possible combinations of 0 & 1 that can occur in these variables.

The SOP form can be obtained with the help of K-map as:-

x \ yz	00	01	11	10
0		1		1
1	1		1	

$$Sum = x'y'z + x'yz + xy'z' + xyz$$

x \ yz	00	01	11	10
0			1	
1		1	1	1

$$Carry = xy + xz + yz$$

Construction of full adder using half adder:-

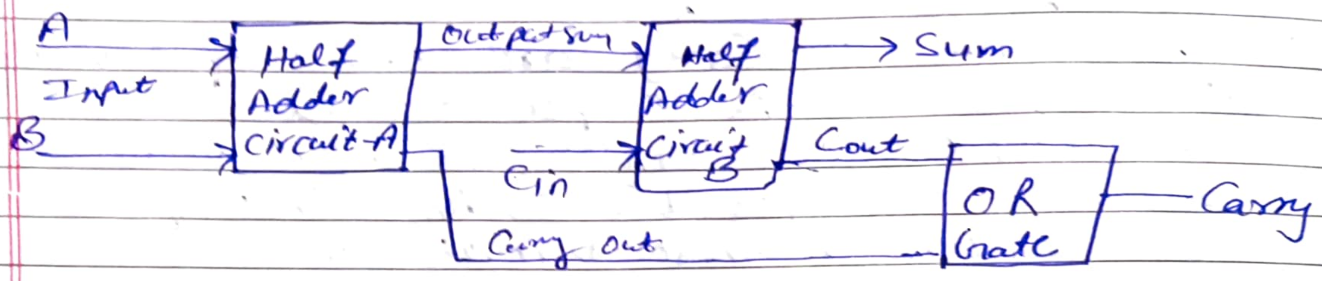
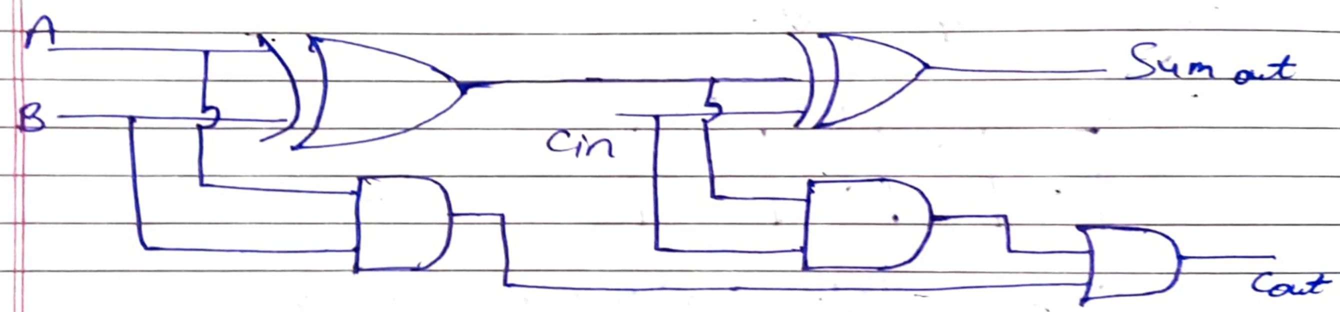


fig:- Block diagram of full adder



full adder circuit

Sum :- Perform the XOR operation of input A & B.

- Perform the XOR operation of the outcome with Carry. So, the sum is (A XOR B) XOR Cin which is also represented as $(A \oplus B) \oplus Cin$.

Carry :- Perform the 'AND' operation of input A & B.

- Perform the 'XOR' operation of input A & B.
- Perform the 'OR' operations of both the o/p that come from the previous two steps. So the 'Carry' can be represented as:- $A \cdot B + (A \oplus B)$

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Subtractor :- A subtractor is a combinational logic circuit that can perform the subtraction of two number (binary) & produce the difference between them. It is a combinational circuit that means its output depends on its present inputs only. There are two types of subtractors.

(1) Half Subtractor
(2) Full Subtractor

(1) Half Subtractor :- It is a combinational circuit which is used to perform subtraction of two bits. It has two inputs & two outputs. output is known as Difference & Borrow. The logic symbol & truth table are show below:-

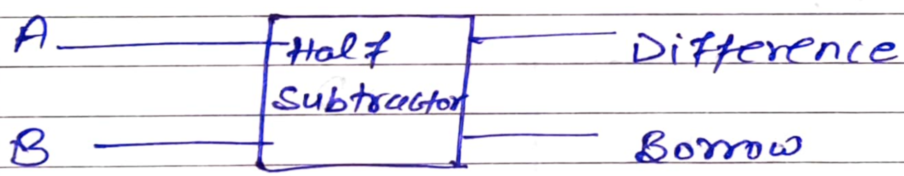


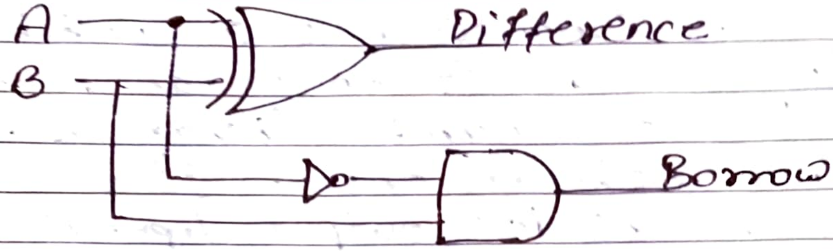
fig:- Logic symbol of Half subtractor

Truth Table :-

Inputs		Outputs	
A	B	Difference	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Boolean Expression

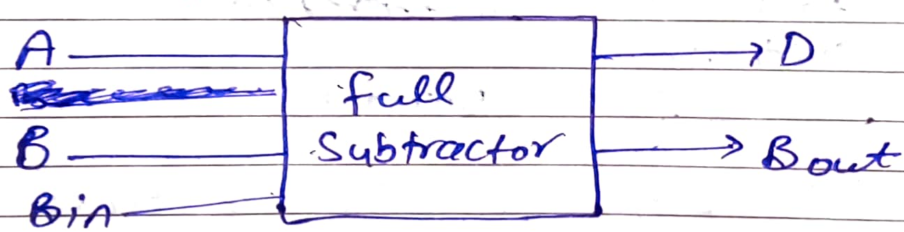
Diff = $A \oplus B$
Borrow = $A'B$



* Circuit diagram *

(*2) full Subtractor :- It is a combinational circuit that performs subtraction involving three bits, namely A, B & Bin (Borrow-in). It accepts three inputs A, B & Bin & it produces two outputs: D (difference) & Bout (Borrow out).

Logic Symbol :-



A	B	Bin	D	Bout
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

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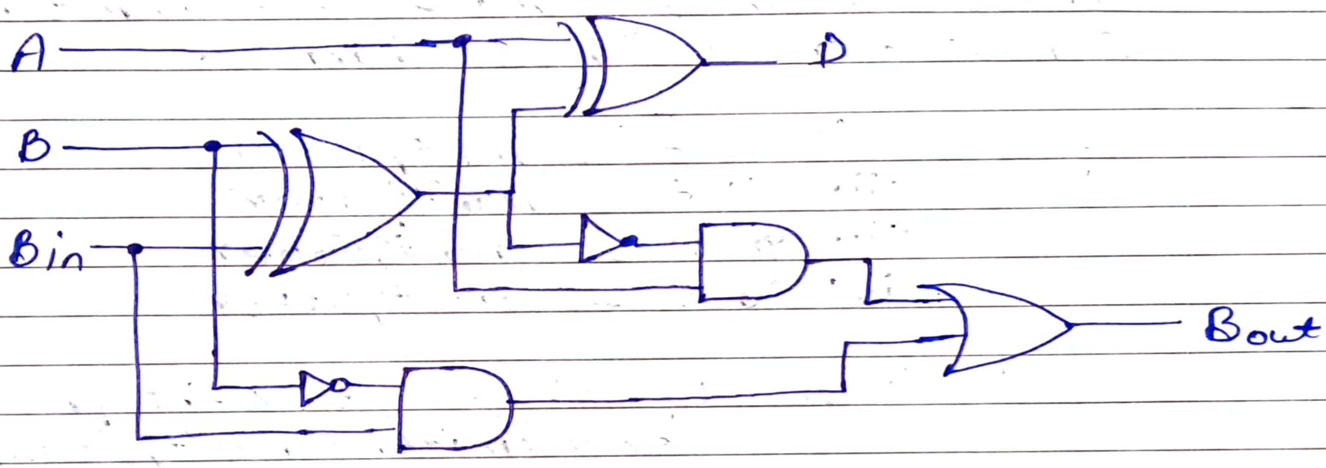
Boolean Expression :-

$$D = A \oplus B \oplus B_{in}$$

$$B_{out} = A' B_{in} + A'B + B\, B_{in}$$



circuit diagram of full subtractor

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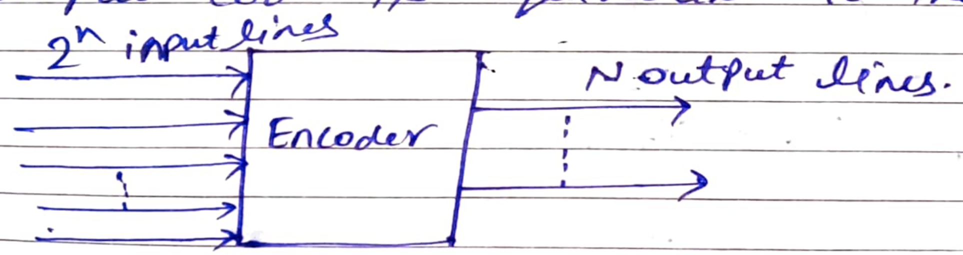
Encoder in Digital Logic :- An encoder is a digital circuit that converts a set of binary inputs in to a unique binary code. The binary code represents the position of the input & is used to identify the specific input that is active. Encoders are commonly used in digital system to convert a parallel set of inputs in to a serial code.

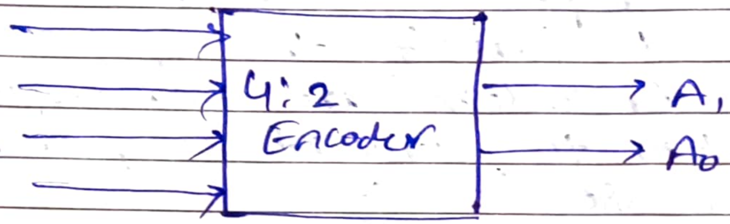
The combinational circuits that change the binary information into N output lines are known as Encoders. The binary information is passed in the form of 2^N input lines. The output lines define the N-bit code for the binary information.
Encoder performs the reverse operation of the decoder. At a time, only one input line is activated for simplicity. The produced N-bit output code is equivalant to the binary information.



There are various types of encoders which are as follows:-

(1) 4 to 2 line Encoder :- In 4 to 2 line encoder, there are total of four inputs i.e., Y_0, Y_1, Y_2, Y_3 & two outputs i.e., A_0, A_1.

In 4-input lines, one input line is set to true at a time to get the respective binary code.

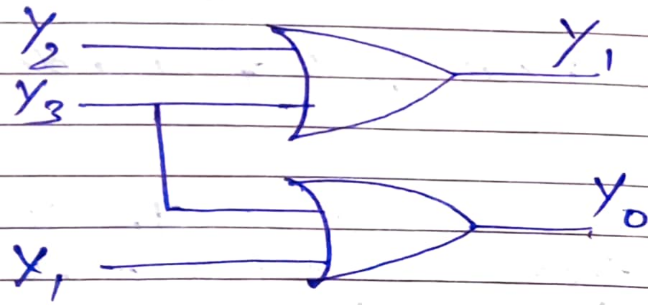


INPUTS				Outputs	
Y_0	Y_1	Y_2	Y_3	A_1	A_0
1	0	0	0	0	0
0	1	0	0	0	1
0	0	1	0	1	0
0	0	0	1	1	1

Boolean Expression :-

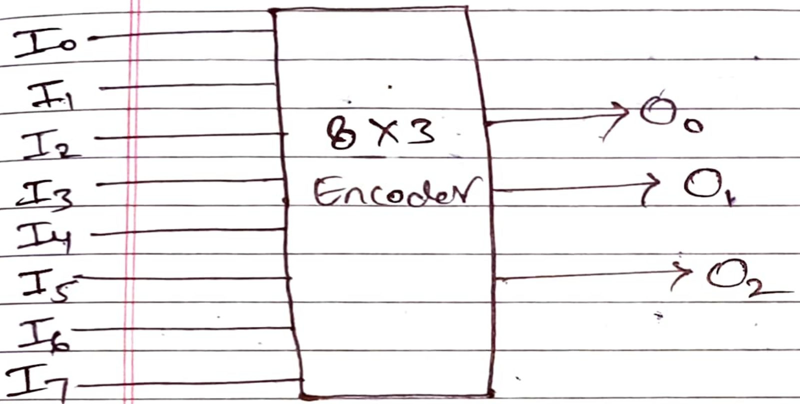
* $A_1 = Y_2 + Y_3$
  $A_0 = Y_1 + Y_3$

Logic Diagram



(*) 8 : 3 Encoder (Octal to binary Encoder) :-

8 → Input line
3 → output line.



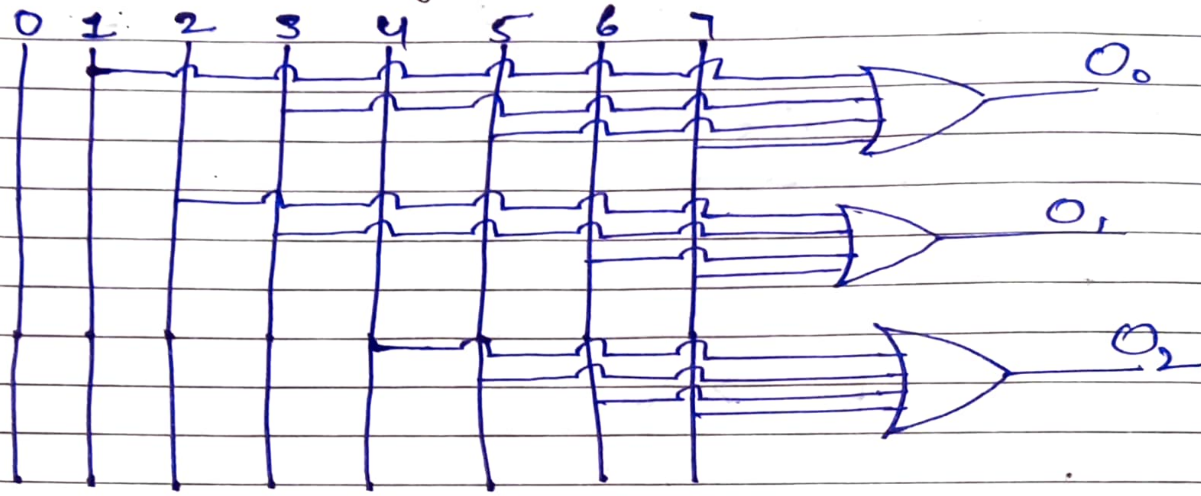
	Input								Output		
	I_0	I_1	I_2	I_3	I_4	I_5	I_6	I_7	O_2	O_1	O_0
0	1	0	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0	1
2	0	0	1	0	0	0	0	0	0	1	0
3	0	0	0	1	0	0	0	0	0	1	1
4	0	0	0	0	1	0	0	0	1	0	0
5	0	0	0	0	0	1	0	0	1	0	1
6	0	0	0	0	0	0	1	0	1	1	0
7	0	0	0	0	0	0	0	1	1	1	1

$O_2 \rightarrow I_4 + I_5 + I_6 + I_7$

$O_1 \rightarrow I_2 + I_3 + I_6 + I_7$

$O_0 \rightarrow I_1 + I_3 + I_5 + I_7$

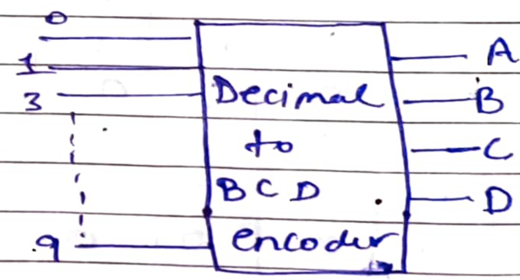
Logic diagram.



(2) Decimal to BCD Encoder :- 10 : 4 line Encoder

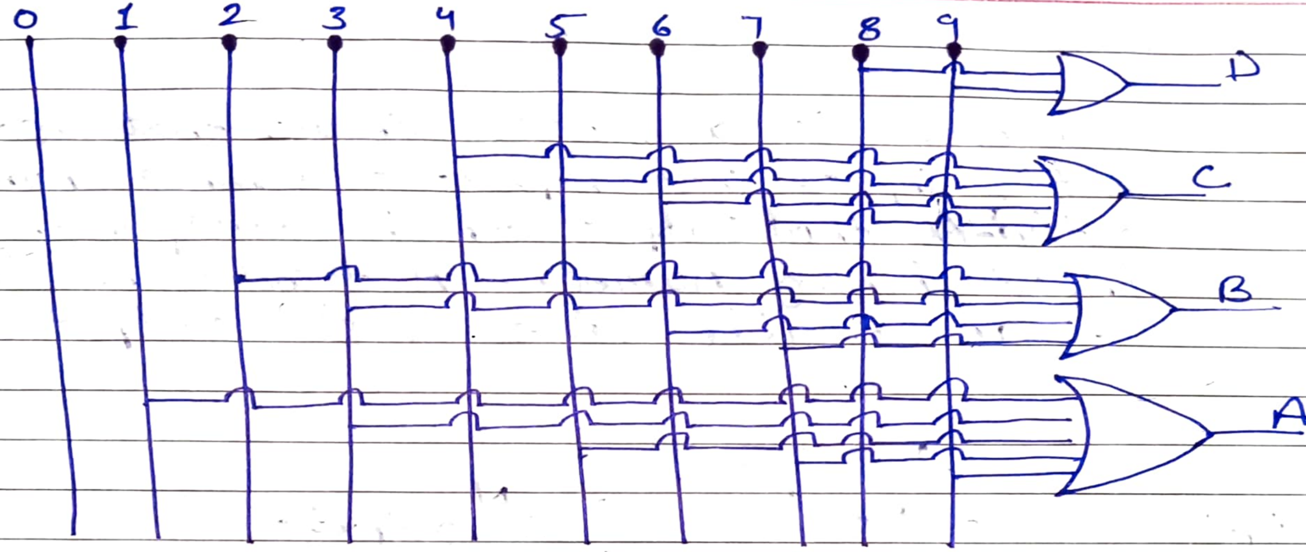
10 – Input line
4 – output line

Input	Output			
I_0	D	C	B	A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1



$D \rightarrow 8 + 9$
$C \rightarrow 4 + 5 + 6 + 7$
$B \rightarrow 2 + 3 + 6 + 7$
$A \rightarrow 1 + 3 + 5 + 7 + 9$

Decimal



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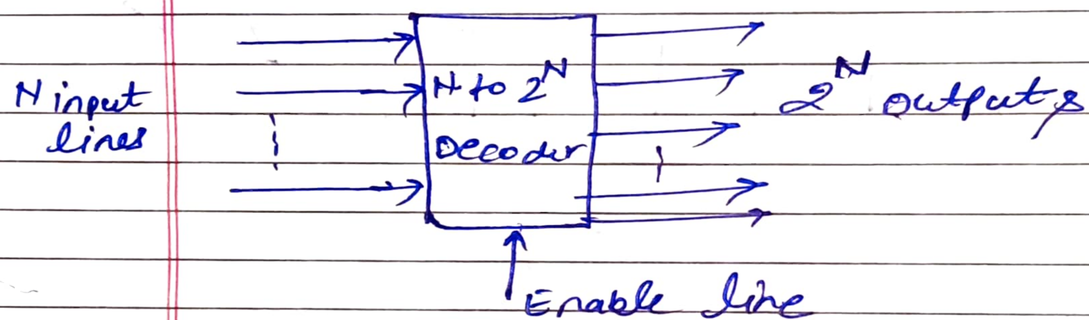
Decoders in digital Electronics:-

A decoder is a logic circuit that accepts a set of inputs that represent a binary number & activates that output which corresponding to the input binary number. A decoder has 'n' inputs & an enable line & '2^n' output lines.

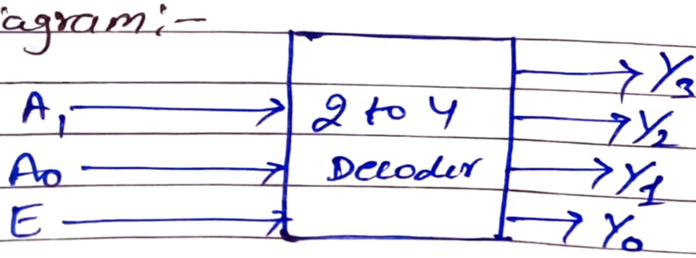


④ 2 to 4 Decoder in Digital Electronics

It is a combinational circuit that converts the 2 bit binary information in to 4 bit binary info. on basis of Enable signal.

Inputs :- A_0, A_1, E (enable line)
Outputs :- Y_0, Y_1, Y_2, Y_3

Block Diagram:-



Truth Table :- when the Enable Signal (E) is 1, One of the outputs is 1 & the rest corresponds to 0. ~~Here is~~

Enable	Input		Output			
E	A_1	A_0	Y_3	Y_2	Y_1	Y_0
0	X	X	0	0	0	0
1	0	0	0	0	0	1
1	0	1	0	0	1	0
1	1	0	0	1	0	0
1	1	1	1	0	0	0

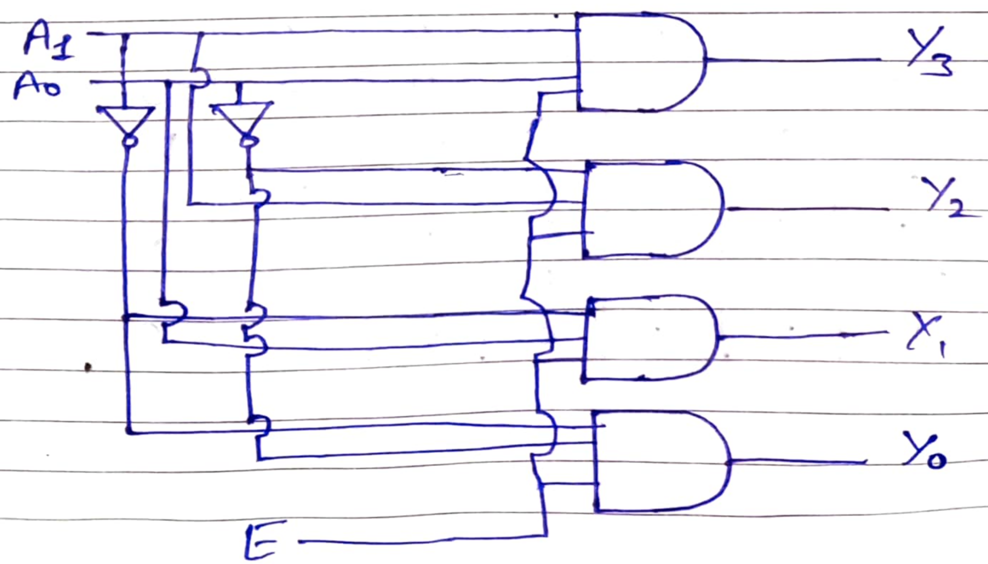
$Y_3 = E, A_1 \cdot A_0$

$Y_2 = E A_1 A_0'$

$Y_1 = E A_1' A_0$

$Y_0 = E A_1' A_0'$

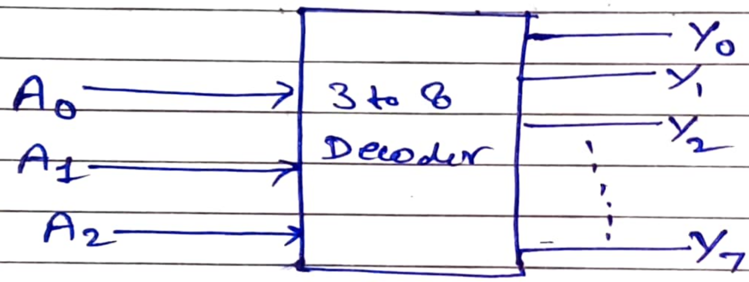
Logic circuit :-



3 to 8 Decoder :- The 3 to 8 Decoder is responsible for Converting 3-bit data to 8-bit data. It can be better understood by Keeping in mind, that from 3 bits of data, maximum 8 numbers of Combinations are possible.

Input :- A_0, A_1, A_2
Output :- $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7$.

Block Diagram :-



Truth Table

INPUT			Outputs							
A_2	A_1	A_0	Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	1	0	0
0	1	1	0	0	0	0	1	0	0	0
1	0	0	0	0	0	1	0	0	0	0
1	0	1	0	0	1	0	0	0	0	0
1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0

$Y_0 = A_0' \, A_1' \, A_2'$

$Y_1 = A_0 \, A_1' \, A_2'$

$Y_2 = A_0' \, A_1 \, A_2'$

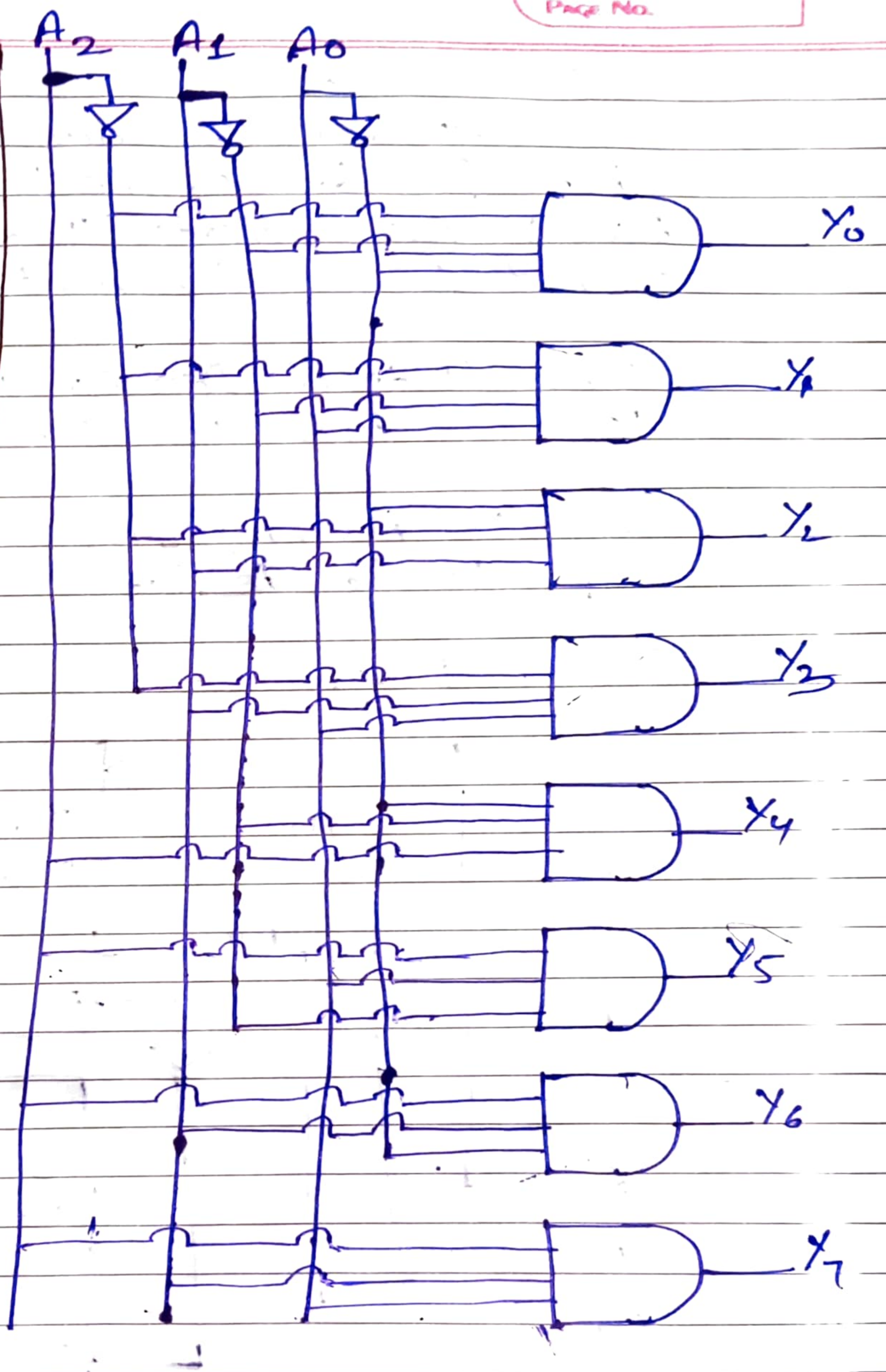
$Y_3 = A_0 \, A_1 \, A_2'$

$Y_4 = A_0' \, A_1' \, A_2$

$Y_5 = A_0 \, A_1' \, A_2$

$Y_6 = A_0' \, A_1 \, A_2$

$Y_7 = A_0 \, A_1 \, A_2$



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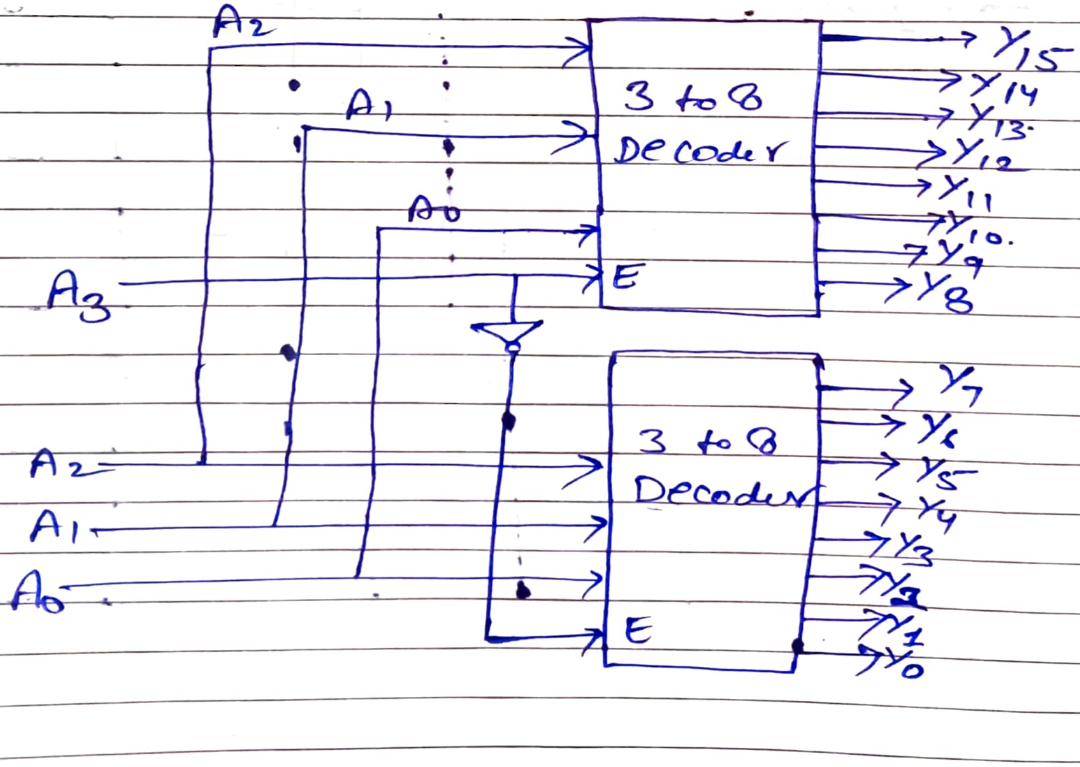
(2) 4 to 16 Decoder :- • Now since the maximum number of combinations possible from 4 bits is 16. So, the 4 to 16 Decoder in digital Electronics converts 4-bit input data into 16-bit output binary information.

This 4 to 16 Decoder is constructed using two 3 to 8 Decoders.

Inputs :- A_0, A_1, A_2
outputs :- Y_0 to Y_{15}

Block Diagram :-



Inputs				Outputs															
A_3	A_2	A_1	A_0	Y_{15}	Y_{14}	Y_{13}	Y_{12}	Y_{11}	Y_{10}	Y_9	Y_8	Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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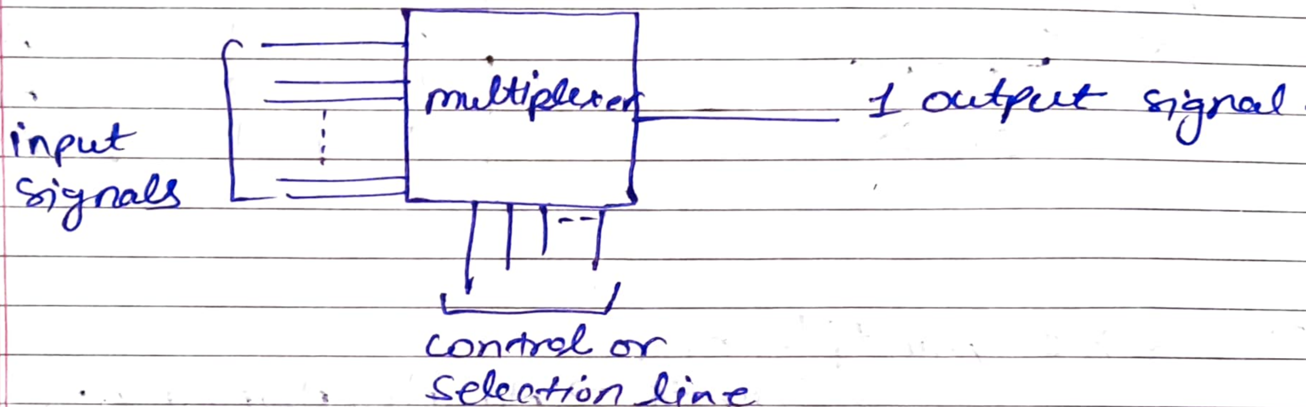
Multiplexer :- Multiplexer, also known as MUX, are essential components in digital electronics. Multiplexer in digital electronics is widely used for data selection, signal routing, & address decoding in microprocessors & microcontrollers. They are also used in communication systems to to transmit multiple signals over a single channel.

Types :- (i) 2 to 1 multiplexer
(ii) 4 to 1 multiplexer
(iii) 8 to 1 multiplexer
(iv) 16 to 1 multiplexer

What is multiplexing :- It is the process of transmitting multiple signals or data streams over a single communication channel or transmission medium. This is achived by combining multiple input signals into a single output signal and then transmitting it over a shared communication channel.

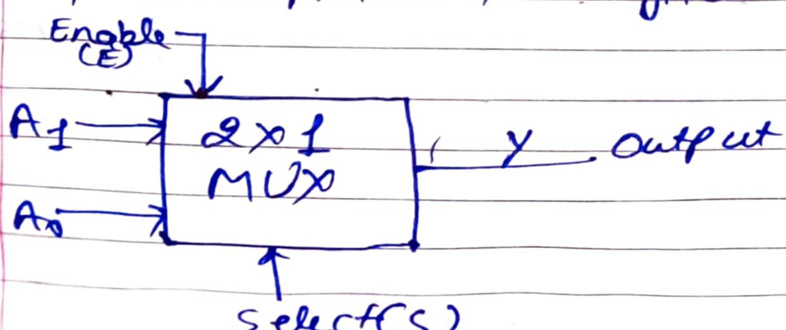
Multiplexer in Digital Electronics :- A multiplexer in digital electronics is known as a data selector. It is a combinational logic circuit having multiple input lines, one output line, & many select line or control lines. It receives binary information from several input lines & routes it to a single output line based on a set of select/control lines. Multiplexer in digital electronics is also known as many to one combinational circuits.

The block diagram below depicts a multiplexer with n input line, m selection lines, and one output line. if there are m selection/control lines, the number of possible input lines are 2^m. ~~2m~~.



Types:-

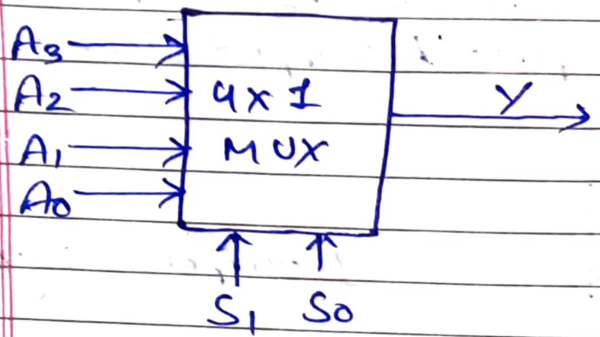
(1) 2x1 multiplexer:- It ~~has~~ is a combinational logic circuit that has only two inputs i.e: A_0 & A_1, 1 selection line, i.e: S_0 & ~~sign~~ single output Y. ON the basis of the combination of inputs that are present at the selection line S0, one of these 2 inputs forwards to the output line. It is the simplest type of multiplexer in digital electronics.



Truth Table:-

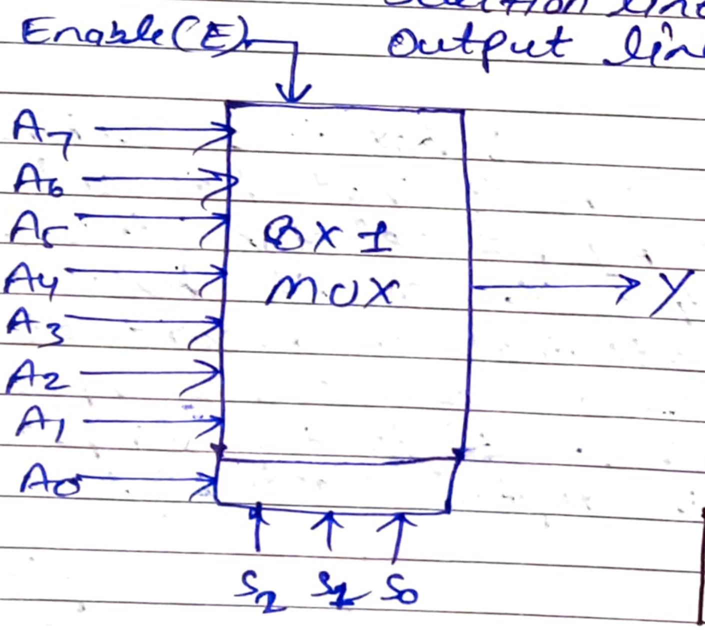
Inputs S_0	Outputs Y
0	A_0
1	A_1

(2) 4 x 1 multiplexer :- input → A_0, A_1, A_2, A_3
output → Y
selection line → S_0, S_1



Inputs		Outputs
S_1	S_0	Y
0	0	A_0
0	1	A_1
1	0	A_2
1	1	A_3

(3) 8 x 1 multiplexer :-
Inputs → $A_0, A_1, A_2, A_3, A_4, A_5, A_6, A_7$
Selection line → S_0, S_1, S_2
Output line → Y



Inputs			Outputs
S_2	S_1	S_0	Y
0	0	0	A_0
0	0	1	A_1
0	1	0	A_2
0	1	1	A_3
1	0	0	A_4
1	0	1	A_5
1	1	0	A_6
1	1	1	A_7