Combinational Circuit

Combinational circuits are specially designed using multiple interconnected logic gates such that the output will be generated by computing the logical combinations of the present input only.

Features of Combinational circuit

- In this output depends only upon present input.
- It's speed is fast.
- Easy design
- There is no feedback between input and output.
- It is time independent.
- Used for both arithmetic and boolean operations.
- Combinational circuits don't have the capability to store any state.

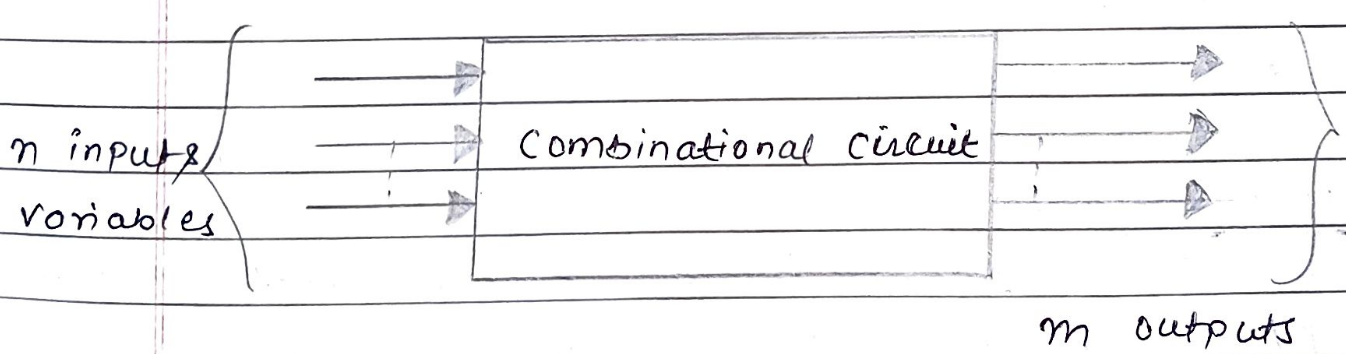


Figure :- Block diagram of Combinational circuit

Examples:-

In areas combinational circuits are used

- Adders and subtractors
- multiplexers and Demultiplexers
- Encoders and Decoders
- Comparator

ADDER

- An adder is a digital logic circuits in electronics that implements addition of numbers.
- In many computers and other type of processors, adders are used to calculate addresses, similar operations and also in other parts of the processors. An adder is a digital circuit that performs addition of numbers.

Types of Adder

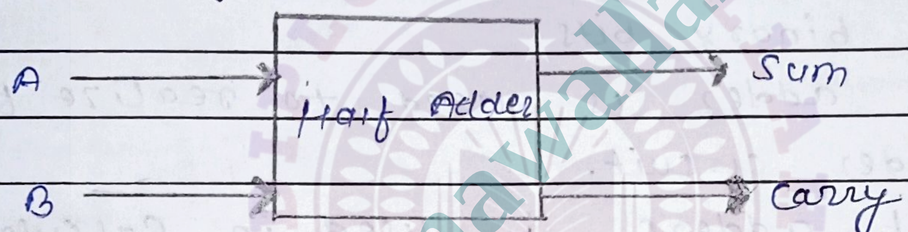
- Half Adder
- Full Adder

Half Adder

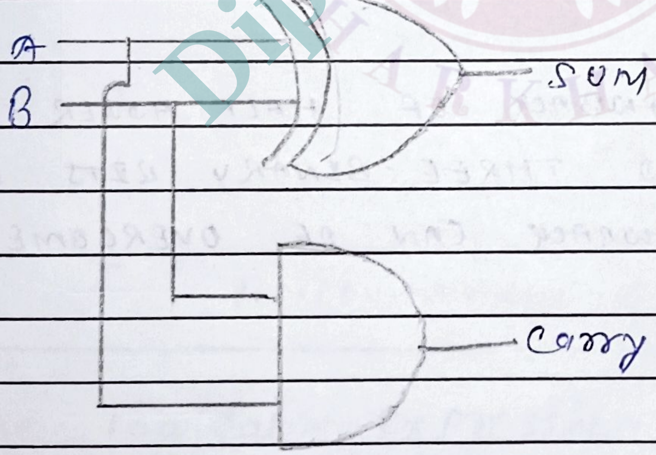
A half adder is a digital logic circuit that performs binary addition of two single-bit binary numbers. It has two inputs, A and B, and two outputs SUM and carry (CARRY)

The half adder can be implemented using basic gates such as XOR and AND gates. The SUM output is the least significant bit (LSB) of the result, which is the XOR of the two inputs A and B. The CARRY output is the most significant bit (MSB) of the result, which is the AND of the two inputs A and B.

Block diagram:-



Logical circuit:-



The logical expression

FOR SUM : $S = A \oplus B = AB' + A'B$

FOR CARRY : $C = A \cdot B$

Truth Table

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Applications of Half Adder

- Half adder is used in ALU (Arithmetic logic unit) of computer processors to add binary bits.
- Half adder is used to realize full adder circuit.
- Half adders is used in calculators.
- Half adder is used to calculate addresses and tables.

THE MAIN DRAWBACK OF HALF ADDER is that we can't ADD THREE BINARY BITS AT A TIME. THIS DRAWBACK CAN BE OVERCOME IN FULL ADDER.

Full Adder

A combinational circuit which is designed to add three binary digits and produces two output (Sum and Carry) is known as a full adder. Thus, a full adder circuit adds three binary digits, where

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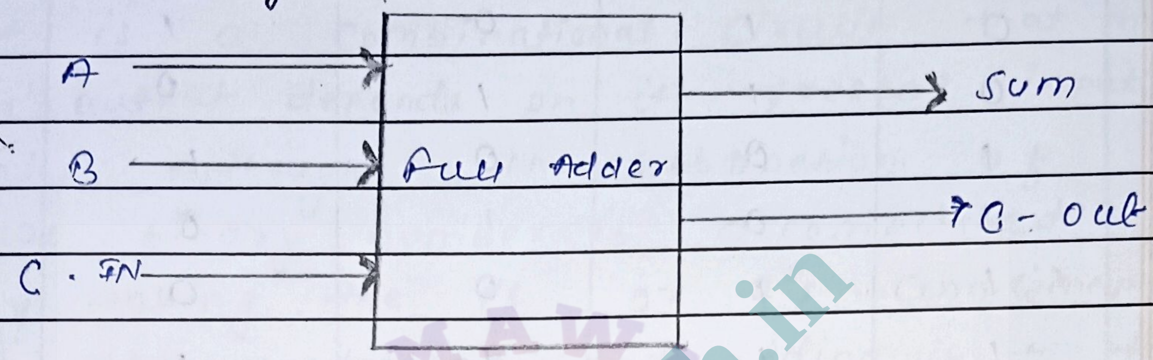
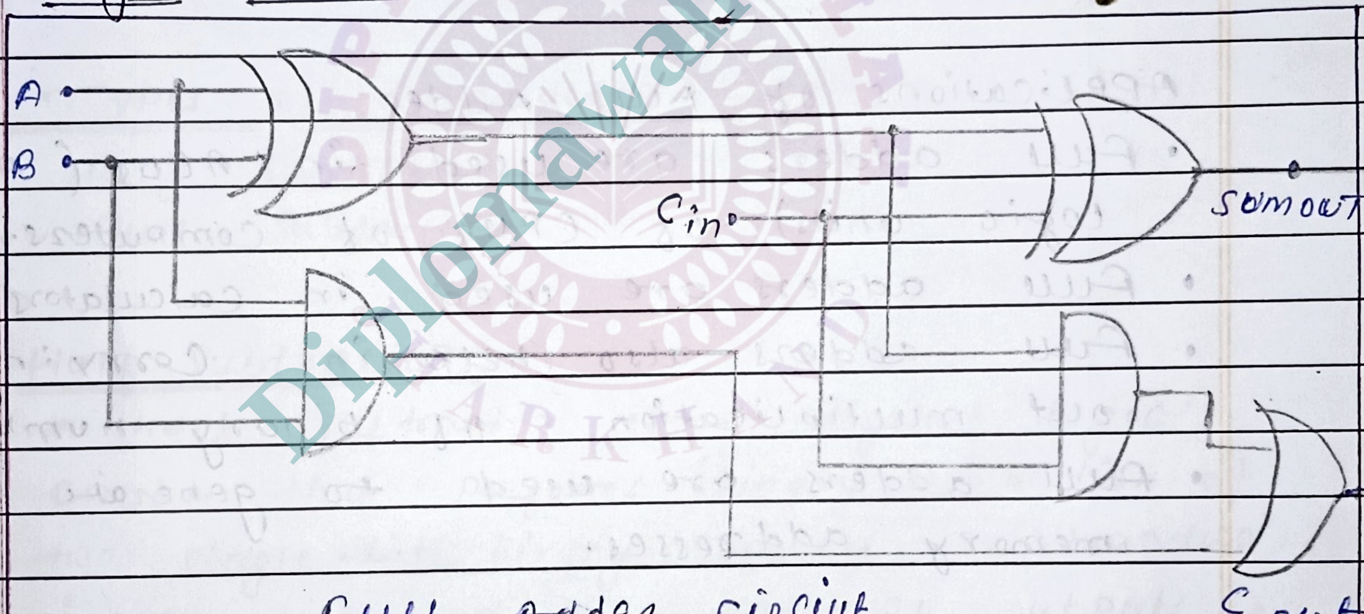
two are the inputs and one is the carry forwarded from the previous addition

Block Diagram :-



Logic circuit



Full Adder circuit

The logical expression

Sum, $S = A \oplus B \oplus Cin$

Carry out :- $AB + C(A \oplus B)$

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

Applications of Full Adder

- Full adders are used in ALUs (Arithmetic logic units) of CPUs of computers.
- Full adders are used in calculators.
- Full adders also help in carrying out multiplication of binary numbers.
- Full adders are used to generate memory addresses.

Subtractor

A Subtractor is a combinational logic circuit that can perform the subtraction of two number (binary numbers) and produce the difference between them. It is a combinational circuit that means its output depends on its present inputs only. Although, the subtraction of two binary number is accomplished by taking the 1's or 2's complement of the subtrahend and adding it to the minuend.

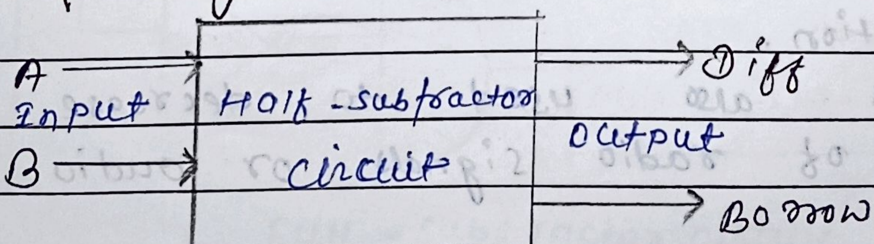
Types of Substractor

- Half Subtractor
- Full Subtractor

Half Subtractor:

A half subtractor is a digital logic circuit that performs binary subtraction of two single-bit binary numbers. It has two inputs, A and B, and two outputs, DIFFERENCE and BORROW.

Block Diagram



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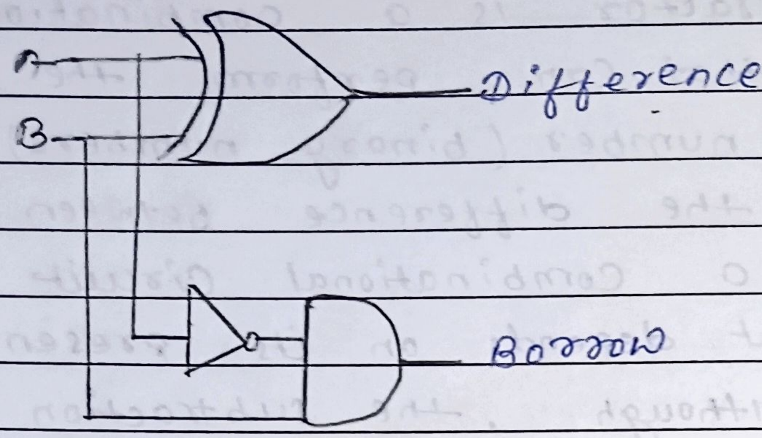
Logic circuit



Equation :-

Difference , Diff = $A \oplus B = A'B + AB'$

Borrow , $b = A'B$

Truth table :-

A	B	Diff	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

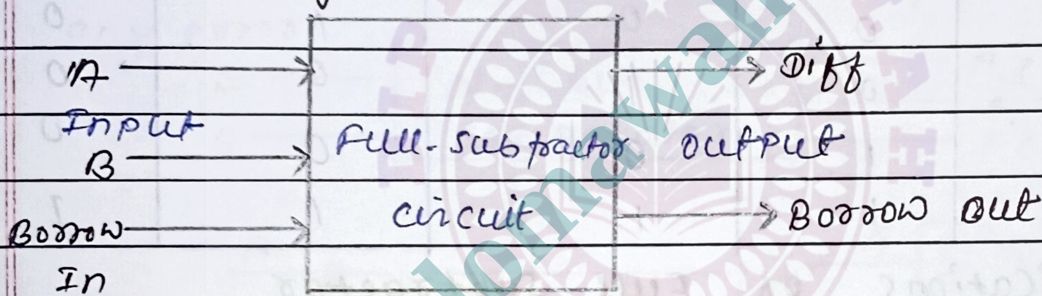
Applications of Half Subtractor

- Half subtractor is used in ALU (Arithmetic Logic Unit) of processors.
- Half subtractor can also be used in amplifers to compensate the sound distortion.
- It is also used to decrease the force of radio signals or audio signals.

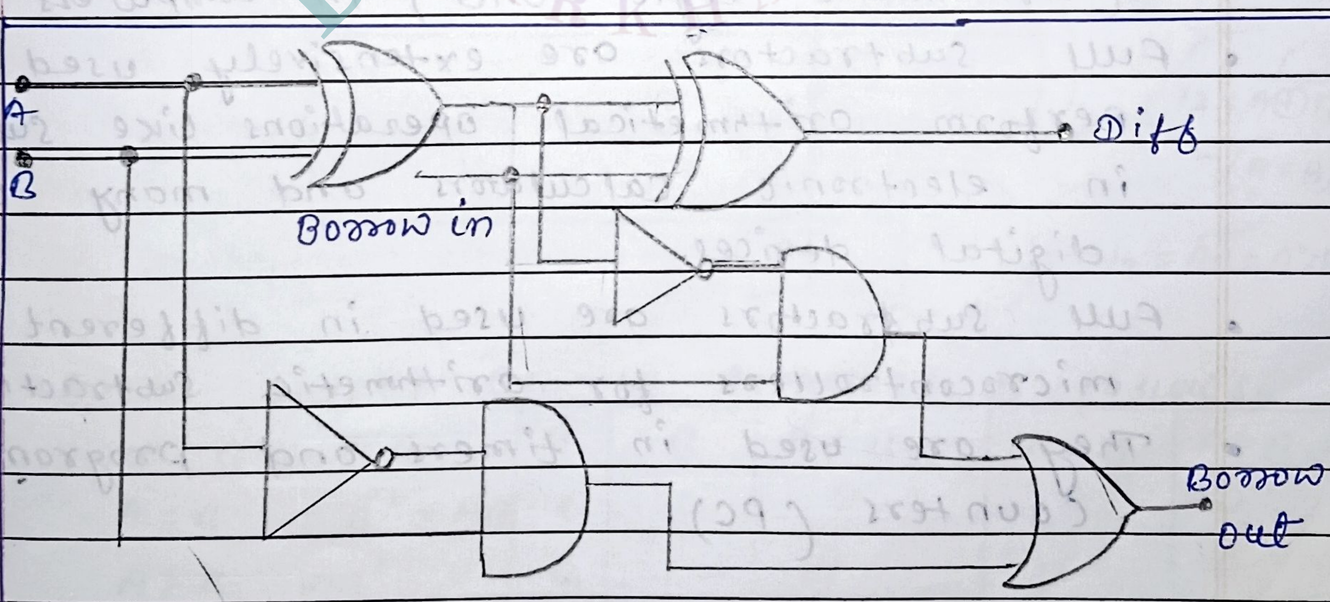
Full Substractor

The Half Subtractor is used to subtract only two numbers. To overcome this problem, a full subtractor was designed. The full subtractor is used to subtract three 1-bit numbers A, B and Borrow-In, which are minuend, subtrahend and borrow, respectively. The full substractor has three input states and two output states i.e, diff and Borrow-Out

Block diagram



logic circuit



Full - subtractor circuit

Equation:-

Difference, $d = A \oplus B$ $b_{in} = A'B'b_{in} + AB'b'_{in} + A'Bb'_{in} + ABb_{in}$

Borrow, $b = A'B + (A \oplus B)'b_{in}$.

Truth table.

Inputs			Outputs	
A	B	Borrow in	Diff	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

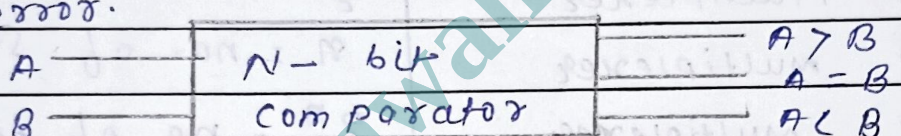
Applications of Full Subtractor

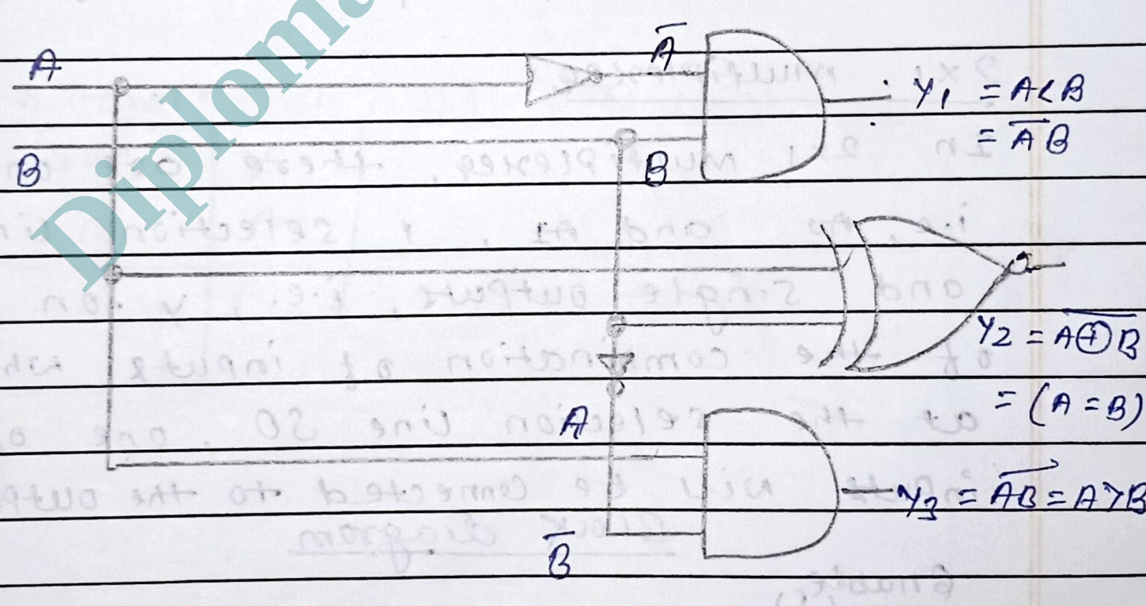
- Full subtractors are used in ALU (Arithmetic Logic Unit) in computers GPUs.
- Full subtractors are extensively used to perform arithmetical operations like subtraction in electronic calculators and many other digital devices.
- Full subtractors are used in different microcontrollers for arithmetic subtraction.
- They are used in timers and program counters (PC).

Magnitude Comparator

Magnitude comparator is a type of Combinational circuit; It Basically compares two binary numbers and determines their relative magnitude. It gives output whether one number is greater than the other, or less than or equal.

These comparators are used in digital systems, such as for sorting networks, and decision-making circuits to handle numerical comparisons perfectly without any error.





Each output can be expressed as follows.

A < B : A'B

A = B : A'B' + AB

A > B : AB'

A	B	A < B	A = B	A > B
0	0	0	1	0
0	1	1	0	0
1	0	0	0	1
1	1	0	1	0

Multiplexer

A multiplexer is a combinational circuit that has 2^n input lines and a single output line. Simply, the multiplexer is a multi input and single-output combinational circuit. The binary information is received from the input line and directed to the output line. On the basis of the value of the selection lines one of these data inputs will be connected to the output.

There are various types of the multiplexer which are as follows :-

- 2×1 Multiplexer
- 4×1 multiplexer
- 8×1 Multiplexer

2^n

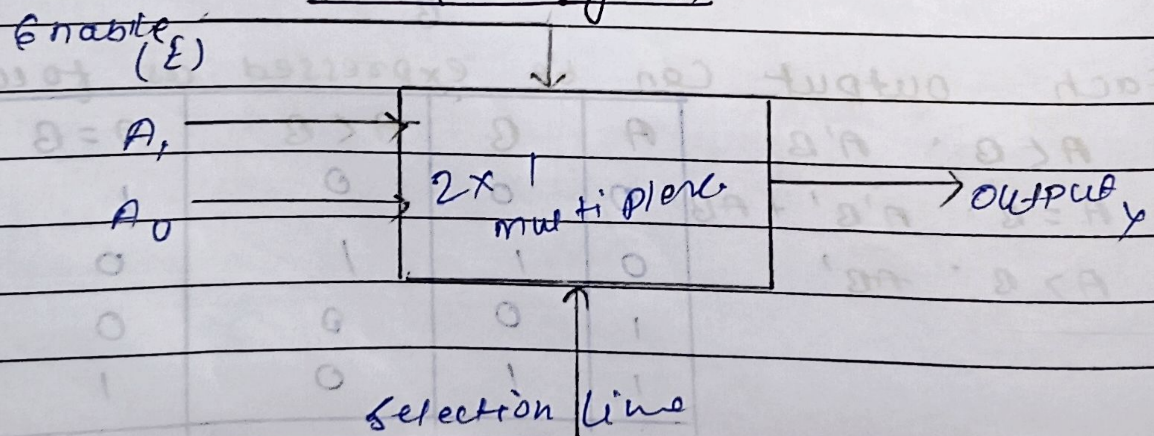
n = no. of selection line

2^n = no of output

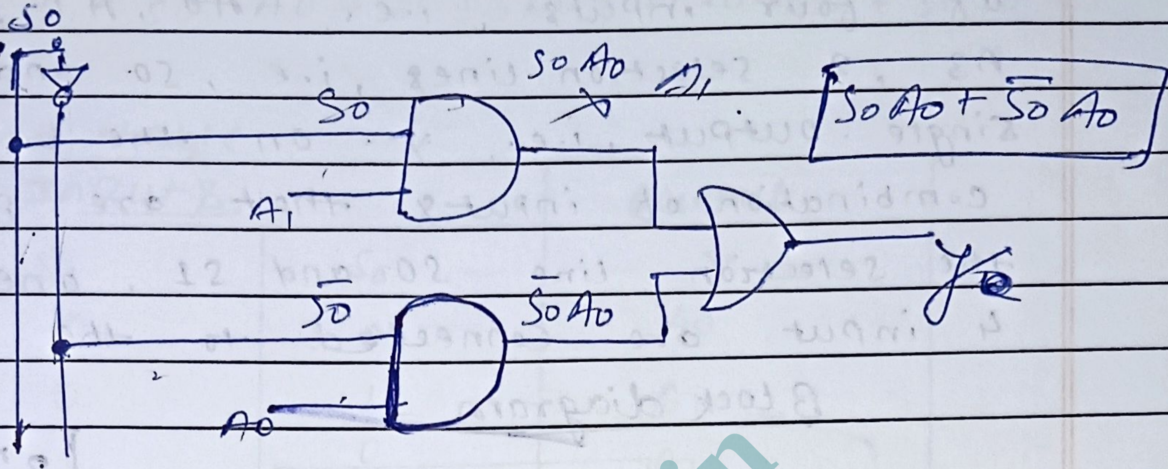
2×1 multiplexer

In 2×1 multiplexer, there are only two inputs i.e, A0 and A1, 1 selection line, i.e., S0 and single outputs, i.e., Y. On the basis of the combination of inputs which are present at the selection line S0, one of these 2 inputs will be connected to the output.

Block diagram



Logic circuit:-



logical expression.

$Y = S0' \cdot A0 + S0 \cdot A1$

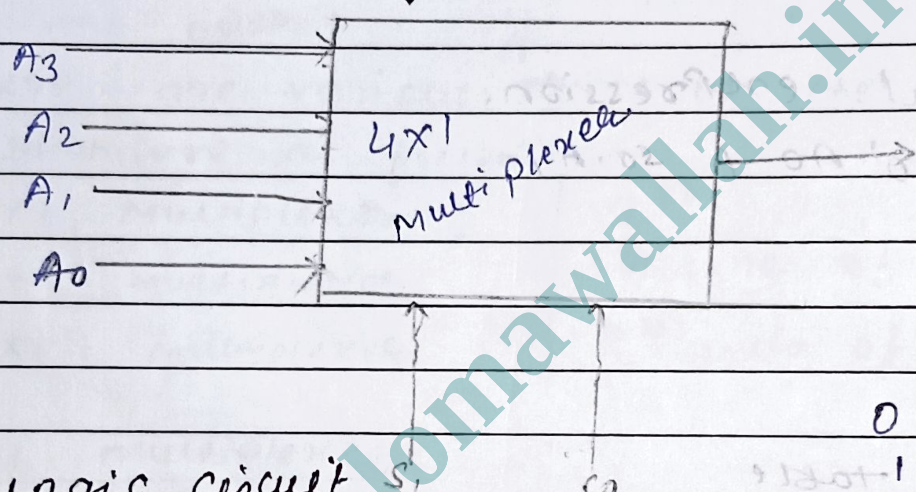
Truth table

S0	Y
0	A0
1	A1

4x1 Multiplexer :-

In the 4x1 Multiplexer, there is a total of four inputs, i.e. A0, A1, A2 and A3, 2 selection lines, i.e, S0 and S1 and single output, i.e., Y. On the basis of the combination of inputs that are present at the selection line S0 and S1, one of these 4 input are connected to the output.

Block diagram



$2^n = 4 = 2^2$

no of output = y

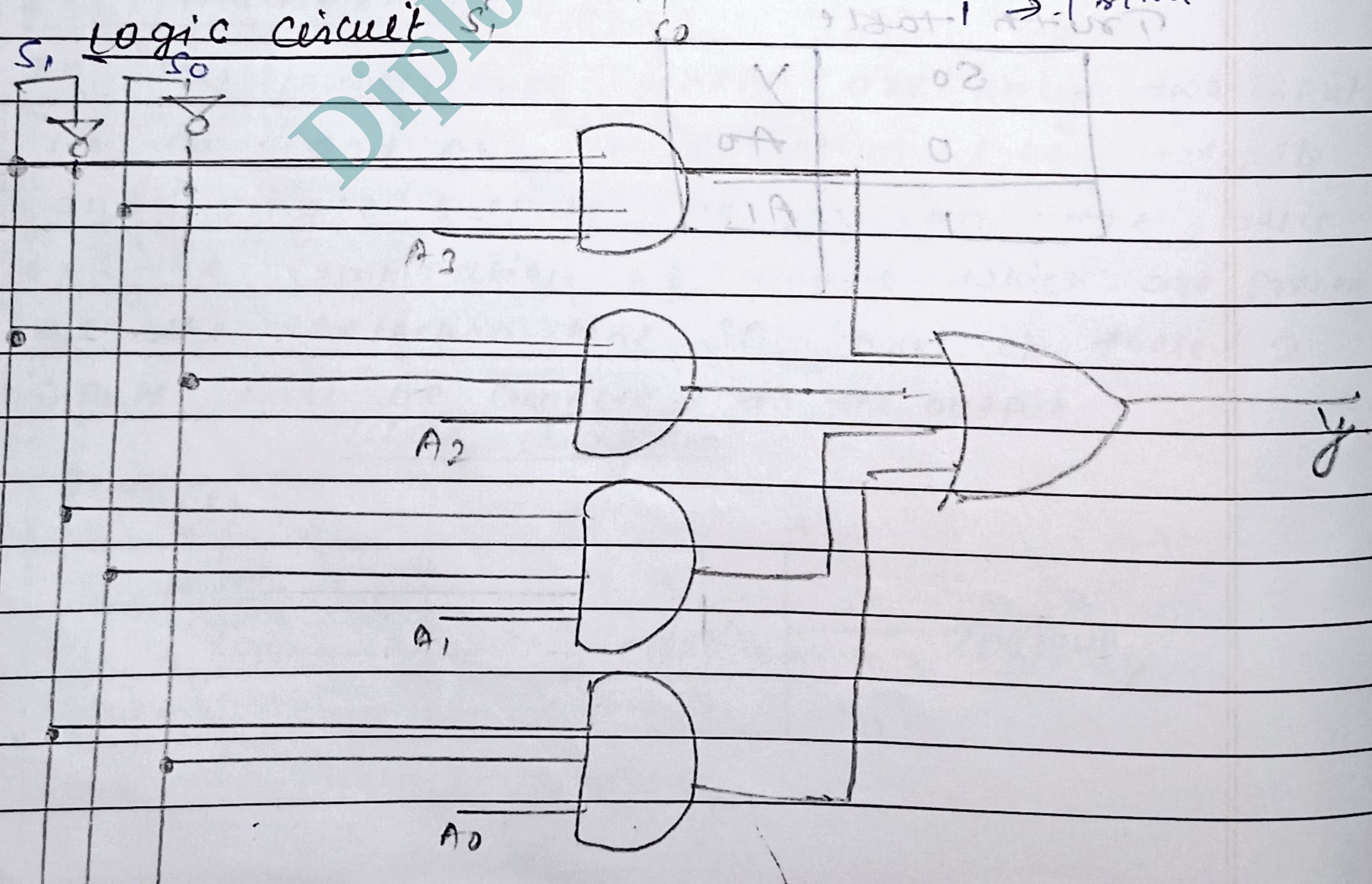
output = 1

selection line 2.

0 ⇒ D0

1 → 1 simple line

Logic circuit



The logical expression :-

$y = S_1' \cdot S0' \, A0 + S1' \, S0 \, A1 + S1 \, S0' \, A2 + S1 \, S0 \, A3$

Truth table

Inputs		Output
S_1	S_0	y
0	0	A0
0	1	A_1
1	0	A_2
1	1	A_3

8x1 multiplexer

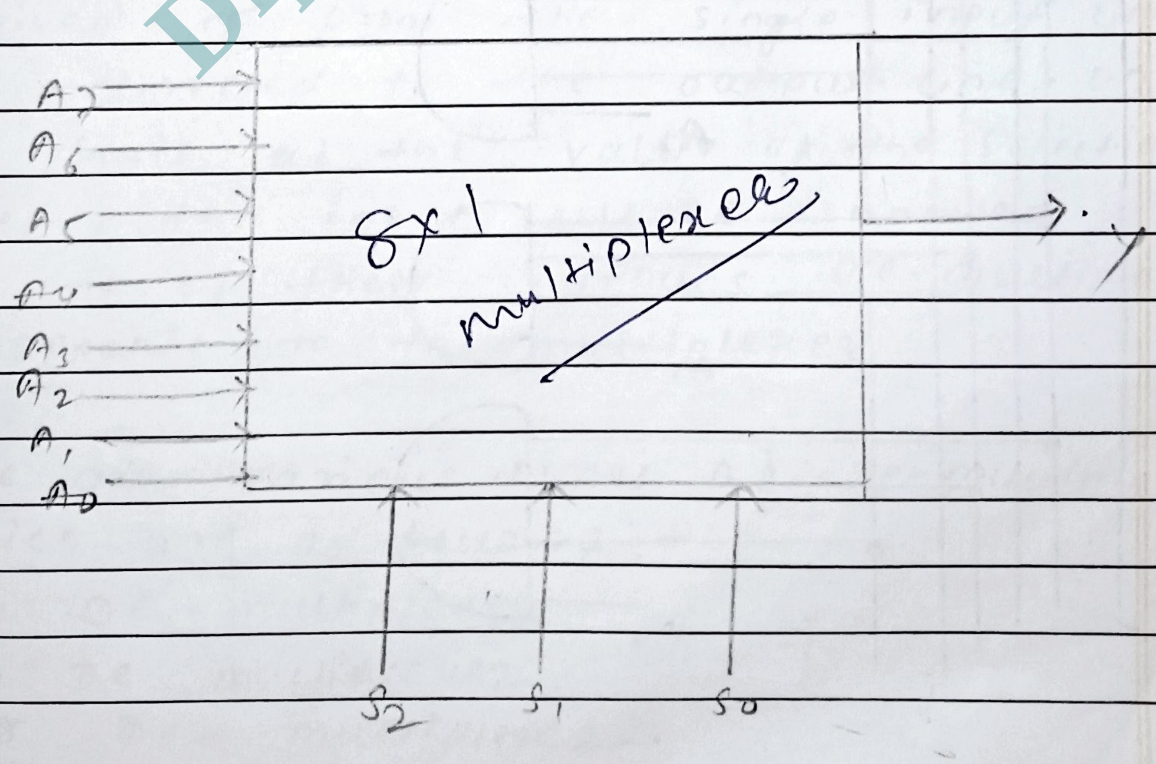
$2^n = 8 = 2^3$

no of input = 8

output = 1

selection = 3

Block diagram.



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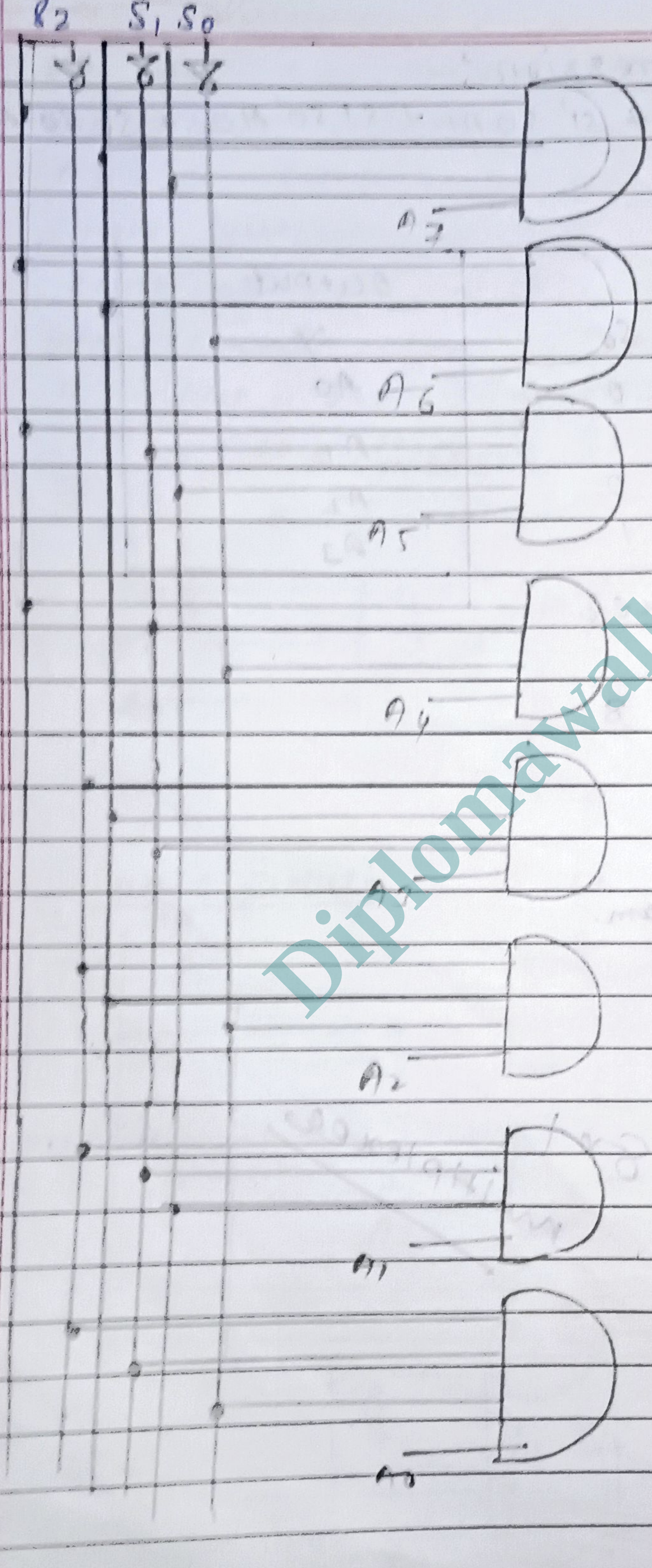

Truth table:

Inputs			Output
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

De - Multiplexer

A De-multiplexer is a combinational circuit that has only 1 input line and 2^n output lines. Simply, the Demultiplexer is a single-input and multi output combinational circuit. The information is received from the single input lines and directed to the output line. On the basis of the value of the selection lines, the input will be connected to one of these outputs. De-multiplexer is opposite to the multiplexer.

There are various types of De-multiplexer which are as follows:-

- 1x2 De-multiplexer
- 1x4 De multiplexer
- 1x8 De-multiplexer.

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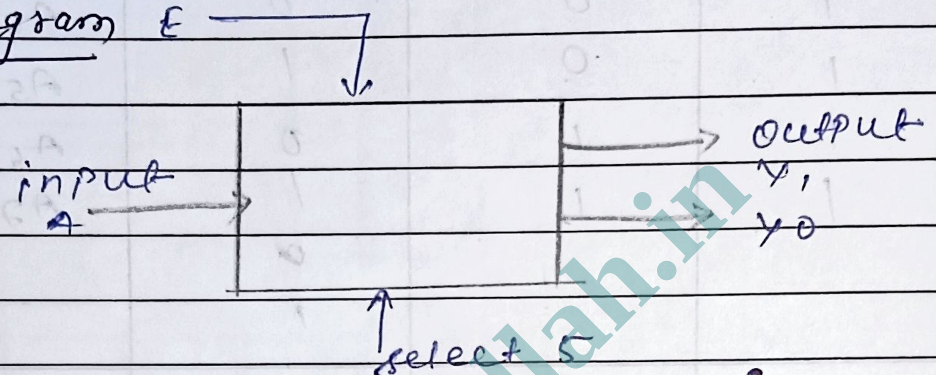
1:2

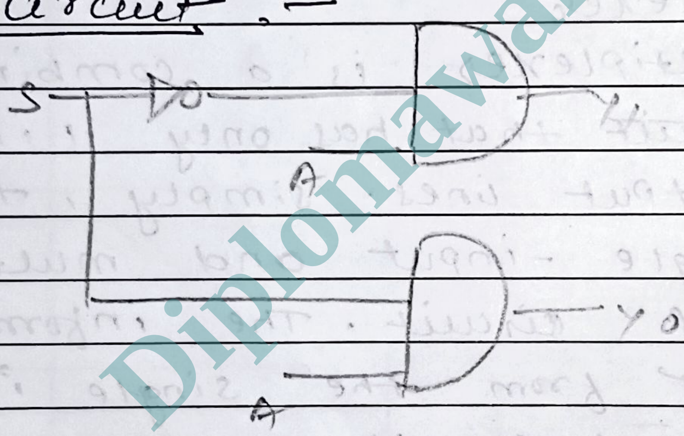
1x2 De-multiplexer

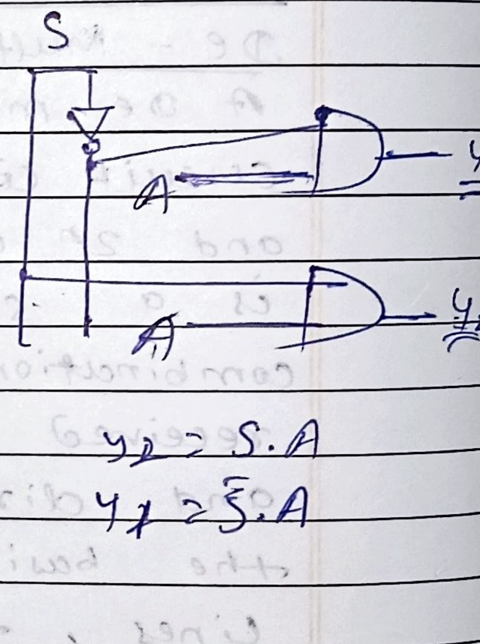
In the 1 to 2 De multiplexer, there are only two outputs, i.e; Y0 and Y1, 1 selection lines, i.e, S0 and single input, i.e .A. on the basis of the selection values, the input will be connected to one of the outputs.

Block diagram



Logic circuit :-





$y_2 = S.A$

$y_1 = \bar{S}.A$

The logical expression.

$Y0 = S0'.A$

$Y1 = S0.A$

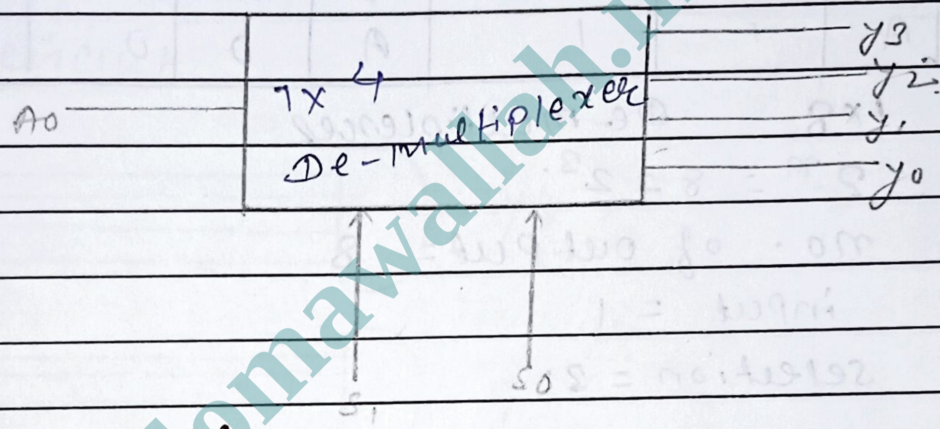
Truth table

Inputs	Output	
S0	Y1	Y0
0	0	A
1	A	0

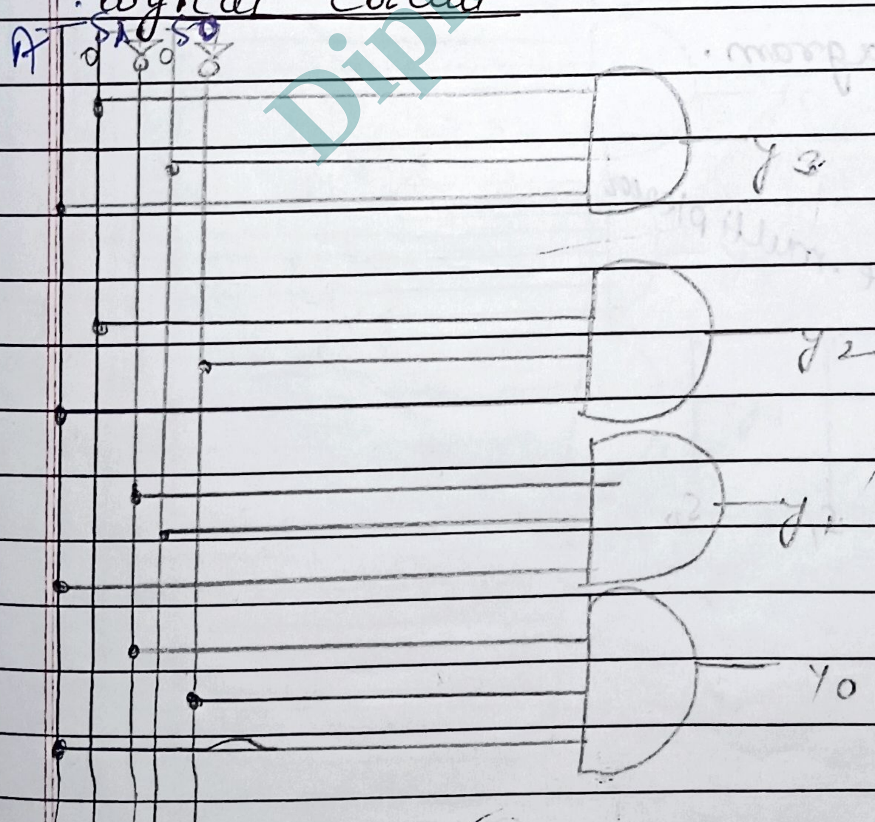
1x4 De-multiplexer

In 1 to 4 De-multiplexer, there are total of four outputs i.e Y_0, Y_1, Y_2, Y_3 and 2 selection line i.e. S_0 and S_1 and single input, i.e A. On the basis of the combination of inputs which are present at the selection lines S_0 and S_1, the input be connected to one of the outputs

Block diagram.



logical circuit



$Y_3 = A\ S_1 \cdot S_0$

$Y_2 = A\ S_1\ \overline{S_0}$

$Y_1 = A \cdot \overline{S_1} \cdot S_0$

$Y_0 = A \cdot \overline{S_1} \cdot \overline{S_0}$

$y_0 = A \cdot S_1 S_0$

$y_1 = A \; S_1 \overline{S_0}$

$y_2 = A \; \overline{S_1} \; S_0$

$y_3 = A \; \overline{S_1} \cdot \overline{S_0}$

Truth table

A	S_1	S_0	Y_3	Y_2	Y_1	Y_0
A	0	0	0	0	0	A
A	0	1	0	0	A	0
A	1	0	0	A	0	0
A	1	1	A	0	0	0

1x8. De-multiplexer

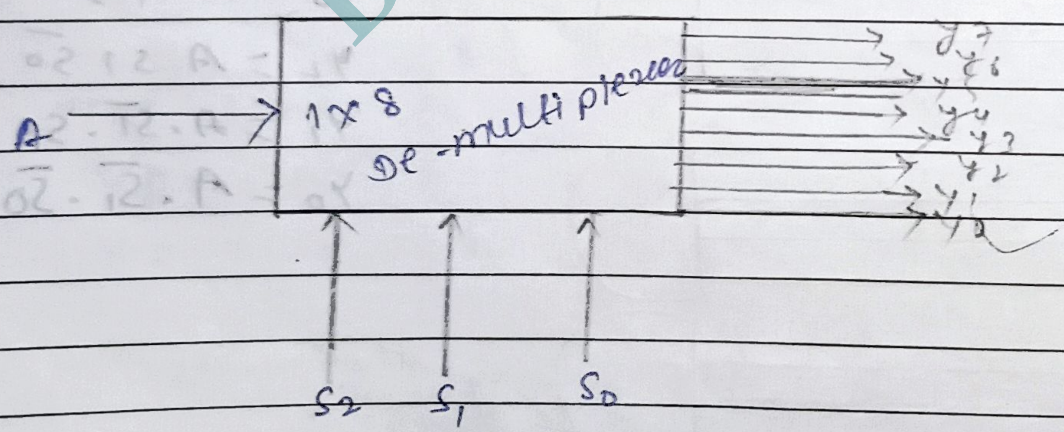
$2^n = 8 = 2^3$.

no. of output = 8

input = 1

selection = 3.

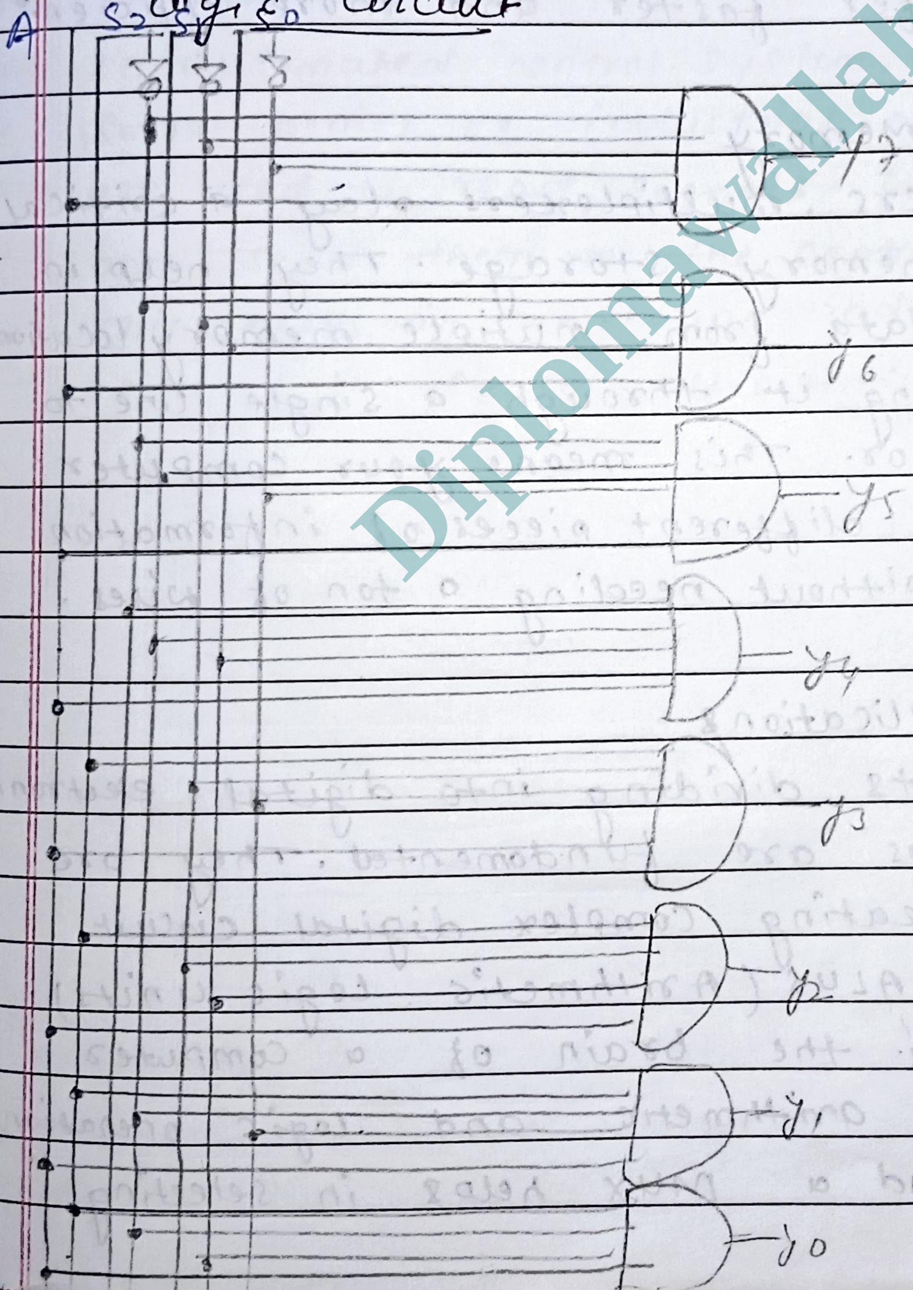
Block diagram.



Truth table

S_2	S_1	S_0	y
0	0	0	y_7
0	0	1	y_6
0	1	0	y_5
0	1	1	y_4
1	0	0	y_3
1	0	1	y_2
1	1	0	y_1
1	1	1	y_0

Logic circuit



Applications of Multiplexer.

1. Telecommunication Networks.

In the world of telecommunication, multiplexers are like magicians. They allow multiple telephone calls or data streams to travel across a single communication line, saving a lot of space and money. For instance, in a fiber-optic cable, a MUX combines several signals into one, making data transfer faster and more efficient.

2. Computer Memory

In computers, multiplexers play a critical role in memory storage. They help in reading data from mutiple memory locations and sending it through a single line to the processor. This means your computer can access different pieces of information quickly without needing a ton of wires.

3. Digital Applications

For students dividing into digital electronics, multiplexers are fundamental. They are used in creating complex digital circuit, such as ALUS (Arithmetic Logic units). An ALU is the brain of a computer where all arithmetic and logic operations happen, and a MUX helps in selecting the operation to be performed.

4. Consumer Electronics
Ever wondered how your TV can switch between hundreds of channels? well, it's the multiplexer at work! It selects the channel you want from the many signals it receives and send it to your TV screen.

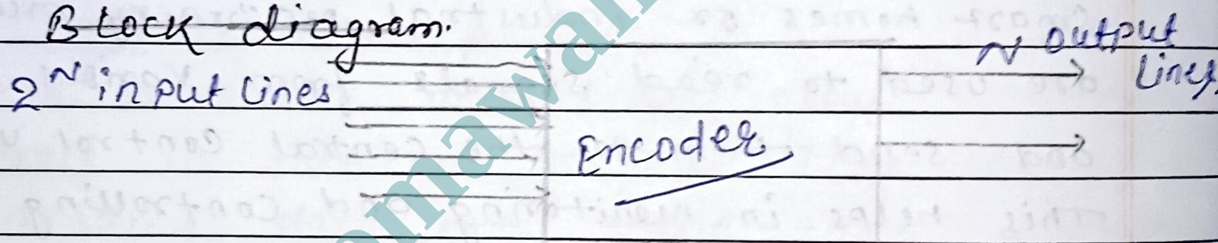
5. Control Systems
In automated control system, like those in smart homes or industrial machinery multiplexers are used to read signals from various sensors and send them to the central control unit. This helps in monitoring and controlling different parts of the system efficiently.

Encoder

An encoder is a digital circuit that converts a set of binary inputs into a unique binary code. Encoders are commonly used in digital systems to convert a parallel set of inputs into a serial code.

An encoder in digital electronics is a combinational circuit that has 2^n input and n outputs. The encoder produces a binary code equivalent to the given input. The encoder encodes information from 2^n inputs to n outputs.

~~Block diagram.~~



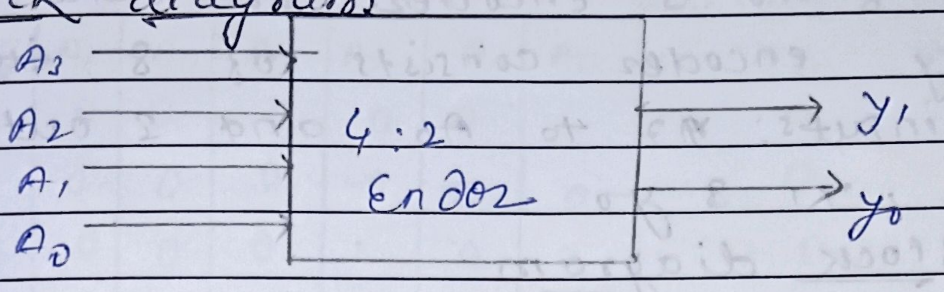
Types of Encoder.

* 4 to 2 Encoder
* Octal to Binary Encoder (8 to 3 Encoder)
* Decimal to BCD Encoder.

4 to 2 Encoder

The 4 to 2 Encoder consists of four inputs Y_3, Y_2, Y_1 & Y_0, and two outputs A_1 & A_0. At any time, only one of these 4 inputs can be '1' in order to get the respective binary code at the output.

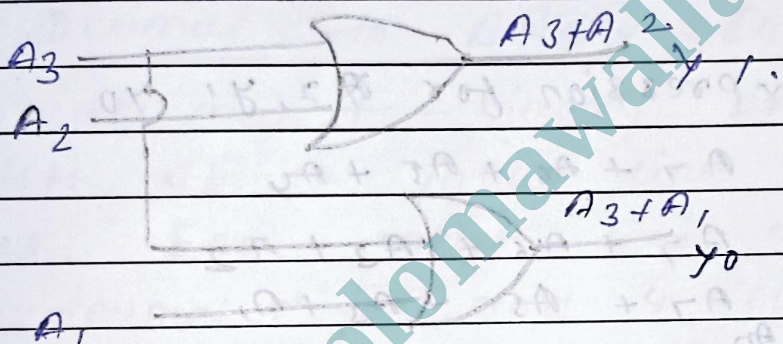
Block diagram



Logical expression for A1 and A0:-

$$Y_1 = A_3 + A_2$$
$$Y_0 = A_3 + A_1$$

logic circuits:



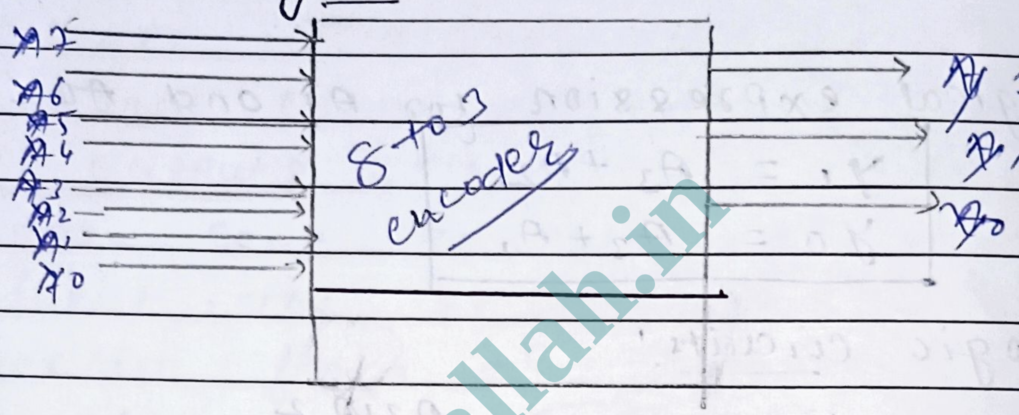
Truth table.

Input				Output	
A3	A2	A1	A0	Y1	Y0
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1

Octal to Binary Encoder (8 to 3 Encoder)

The 8 to 3 Encoder or octal to Binary encoder consists of 8 inputs: A_7 to A_0 and 3 output Y_2, Y_1 & Y_0

Block diagram



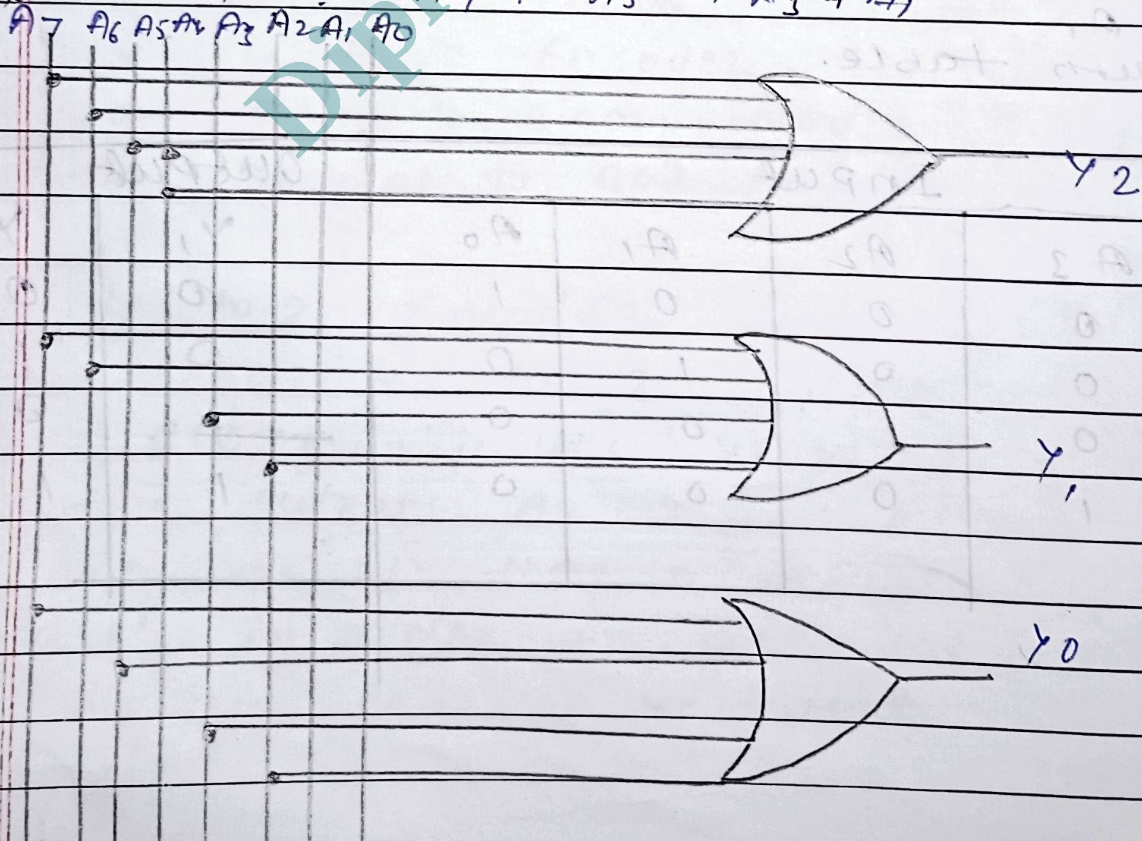
Logic expression for Y_2, Y_1, Y_0

$Y_2 = A_7 + A_6 + A_5 + A_4$

$Y_1 = A_7 + A_6 + A_3 + A_2$

$Y_0 = A_7 + A_5 + A_3 + A_1$

Logic circuit



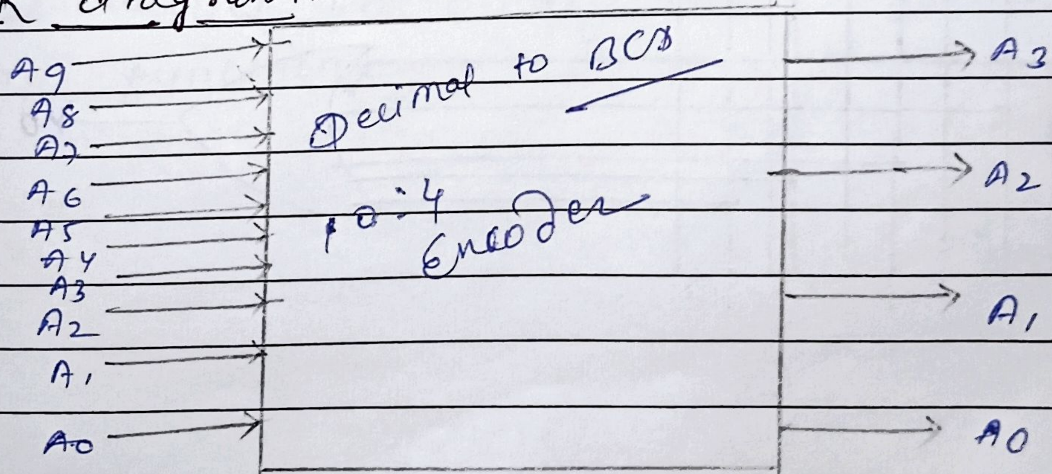
Truth Table.

Input								Output		
A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	1
0	0	0	1	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	0	0	1	1	0
1	0	0	0	0	0	0	0	1	1	1

(3) **Decimal to Binary Encoder (10 : 4)**

The decimal-to-binary encoder usually consists of 10 input lines and 4 output lines. Each input line corresponds to each decimal digit and 4 outputs correspond to the BCD code. This encoder accepts the decoded decimal data as an input and encodes it to the BCD output which is available on the output lines.

Block diagram.



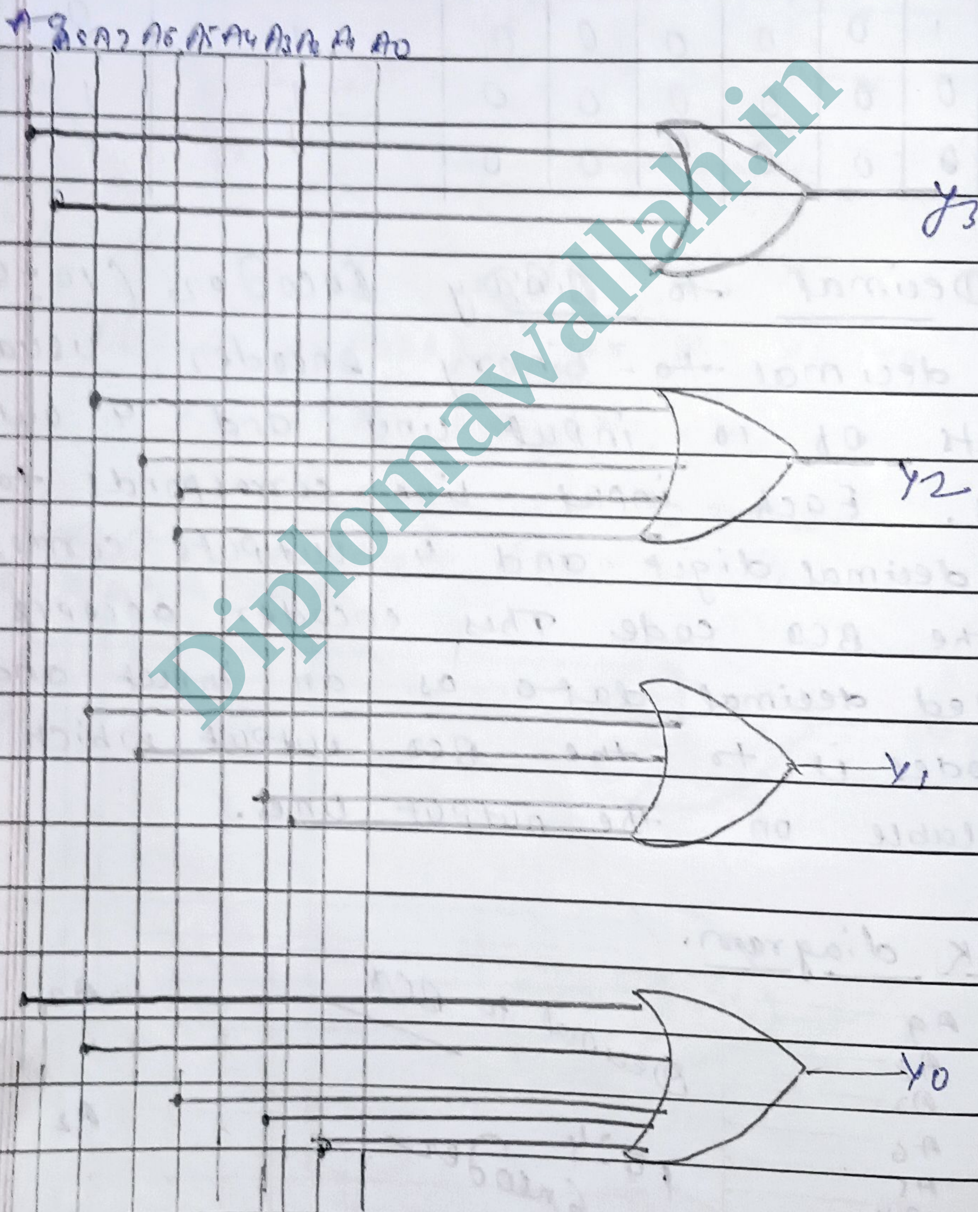
logic expression:-

$Y_3 = A_9 + A_8$

$Y_2 = A_7 + A_6 + A_5 + A_4$

$Y_1 = A_7 + A_6 + A_3 + A_2$

$Y_0 = A_9 + A_7 + A_5 + A_3 + A_1$



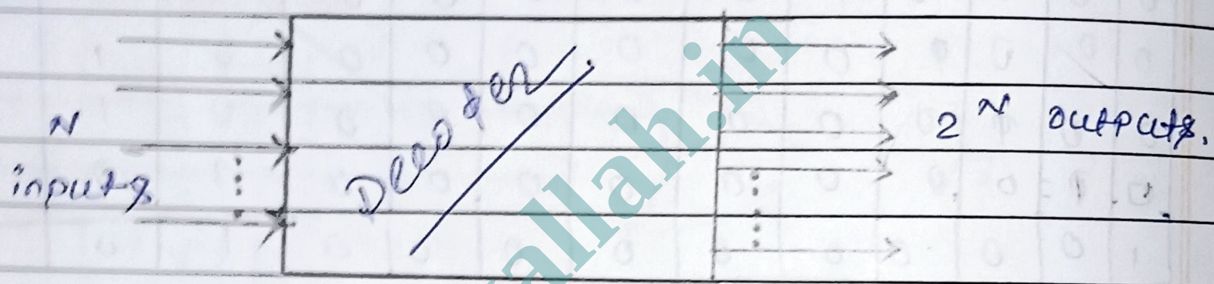
Input										Output			
A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	0	1	0	1
0	0	0	1	0	0	0	0	0	0	0	1	1	0
0	0	1	0	0	0	0	0	0	0	0	1	1	1
0	1	0	0	0	0	0	0	0	0	1	0	0	0
1	0	0	0	0	0	0	0	0	0	1	0	0	1

Applications of Encoders.

- Encoders are used to translate the decimal value to the binary in order to perform binary functions such as addition, subtraction, multiplication etc.
- Digital signals can be generated by using an encoder.
- They are used in printed circuit boards.
- Encoders are used in calculator to encode decimal values in binary to perform certain binary functions.

Decoder :-

A decoder in digital electronics is a combination circuit that has n inputs and 2n outputs. The binary information from n input lies is converted to a maximum of 2n unique output lies in the decoder. The operation of the decoder is reverse ~~to~~ that of encoder.



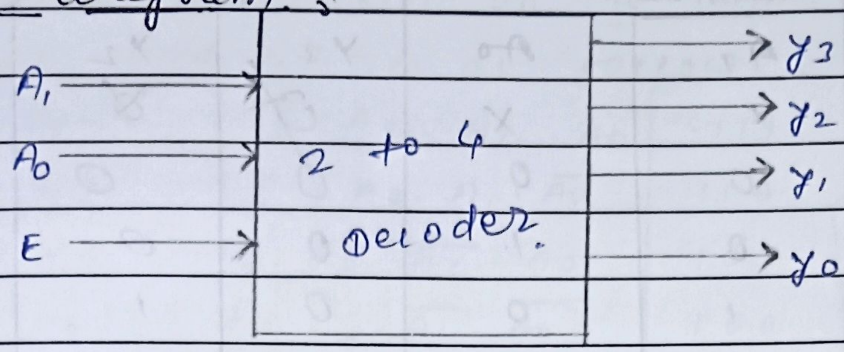
Type of Decoders.

(i) 2 to 4 decoder.
(ii) 3 to 8 decoder
(iii) 4 to 10 decoder.

2 to 4 decoder

In the 2 to 4 line decoder, there is a total of ~~three~~ ~~2~~ inputs, i.e, A0 and A1 and E and four outputs, i.e, Y0, Y1, Y2, and Y3 for each combination of inputs, when the enable 'E' is set to 1, one of these four outputs will be 1.

Block diagram :-



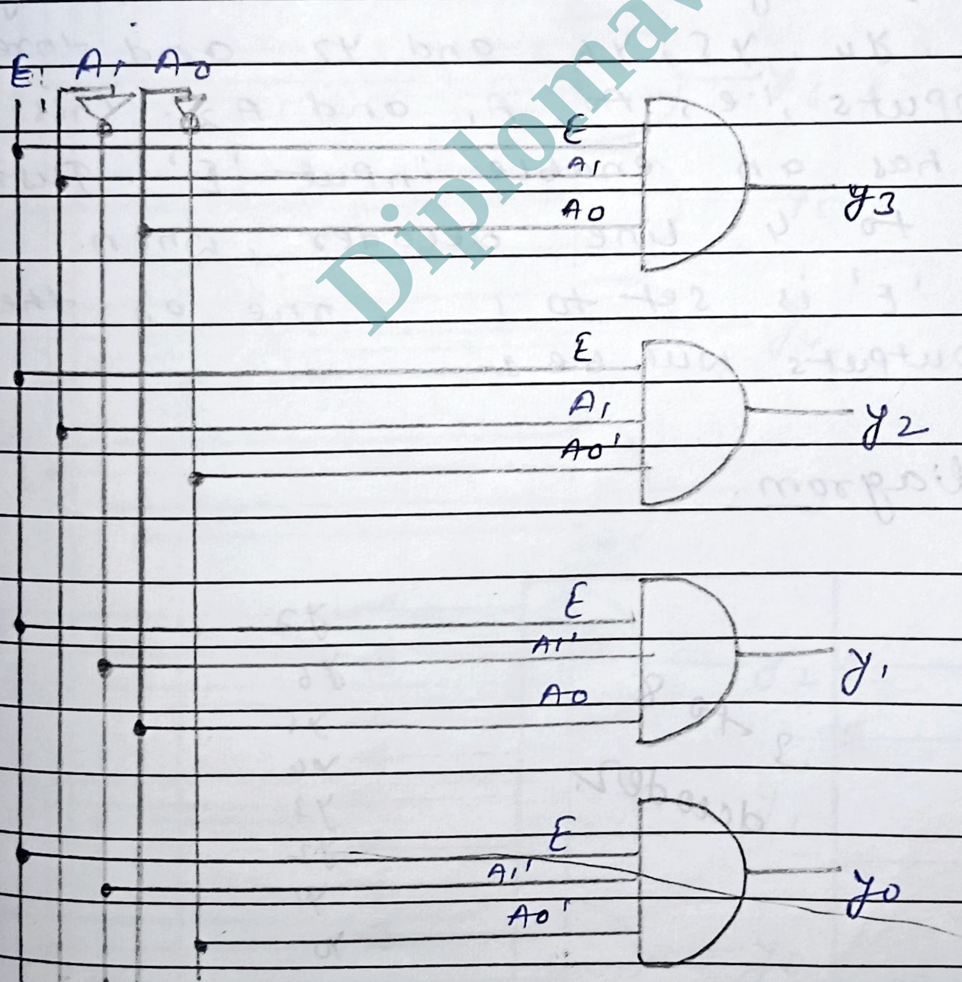
Logical ~~circuit~~ expression of the term y0, y1, y2 and y3 is as follows :-

$Y_3 = E \cdot A_1 \cdot A_0$

$Y_2 = E \cdot A_1 \cdot A_0'$

$Y_1 = E \cdot A_1' \cdot A_0$

$Y_0 = E \cdot A_1' \cdot A_0'$



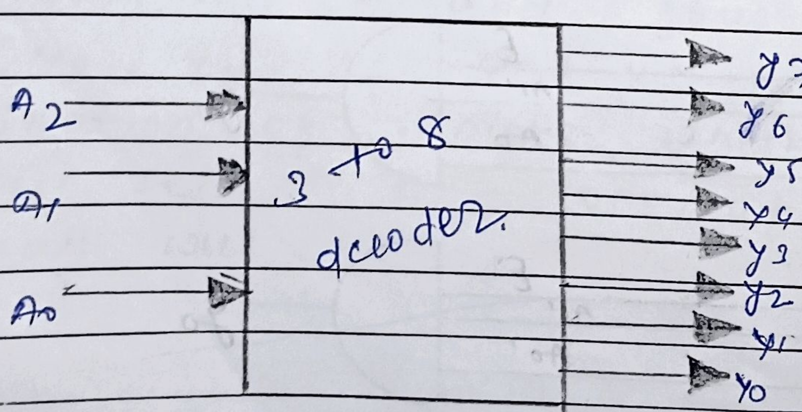
Truth table.

Enable.	Inputs		Outputs			
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

3 to 8 line decoder:-

The 3 to 8 line decoder is also known as Binary to Octal Decoder. In a 3 to 8 line decoder, there is a total of eight outputs, i.e, Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6 and Y_7 and three ~~out~~ inputs, i.e, A_0, A_1 and A_2. This circuit has an enable input 'E'. Just like 2 to 4 line decoder, when enable 'E' is set to 1, one of these four outputs will be 1.

Block diagram.



The logical expression of the term $y_0, y_1, y_2, y_3, y_4, y_5, y_6$ and y_7 is as follows :-

Y_7	$= E \cdot A_2 \cdot A_1 \cdot A_0$	111
Y_6	$= E \cdot A_2 \cdot A_1 \cdot \overline{A_0}$	110
Y_5	$= E \cdot A_2 \cdot \overline{A_1} \cdot A_0$	101
y_4	$= E \cdot A_2 \cdot \overline{A_1} \cdot \overline{A_0}$	100
y_3	$= E \cdot \overline{A_2} \cdot \overline{A_1} \cdot A_0$	011
y_2	$= E \cdot \overline{A_2} \cdot A_1 \cdot \overline{A_0}$	010
y_1	$= E \cdot \overline{A_2} \cdot \overline{A_1} \cdot A_0$	001
y_0	$= E \cdot \overline{A_2} \cdot \overline{A_1} \cdot \overline{A_0}$	000

Where
$0 = \overline{A_1}$
$1 = A_1$

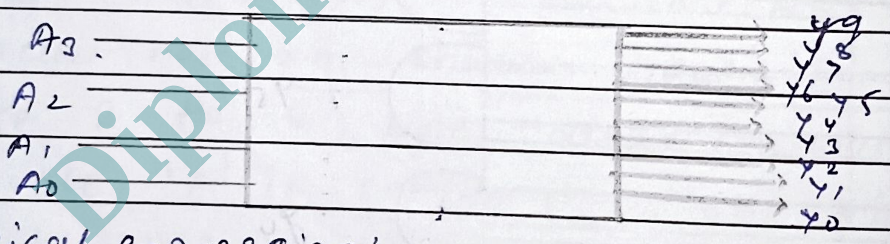
Logic circuit

0 out
1

Truth table :-

Enable	Inputs			Outputs							
E	A_2	A_1	A_0	Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0
0	X	X	X	X	X	X	X	X	X	X	X
1	0	0	0	0	0	0	0	0	0	0	1
1	0	0	1	0	0	0	0	0	0	1	0
1	0	1	0	0	0	0	0	0	1	0	0
1	0	1	1	0	0	0	0	1	0	0	0
1	1	0	0	0	0	0	1	0	0	0	0
1	1	0	1	0	0	1	0	0	0	0	0
1	1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0

(iii) 4 to 10 line decoder
OR Binary to decimal decoder



Logical expression :-

Trick $0 = \bar{A_1}, 1 = A_1$

$Y_9 = E \cdot A_3 \cdot \bar{A_2} \cdot \bar{A_1} \cdot A_0$	1001
$Y_8 = E \cdot A_3 \cdot \bar{A_2} \cdot \bar{A_1} \cdot \bar{A_0}$	1000
$Y_7 = E \cdot \bar{A_3} \cdot A_2 \cdot A_1 \cdot A_0$	0111
$Y_6 = E \cdot \bar{A_3} \cdot A_2 \cdot A_1 \cdot \bar{A_0}$	0110
$Y_5 = E \cdot \bar{A_3} \cdot A_2 \cdot \bar{A_1} \cdot A_0$	0101
$Y_4 = E \cdot \bar{A_3} \cdot A_2 \cdot \bar{A_1} \cdot \bar{A_0}$	0100
$Y_3 = E \cdot \bar{A_3} \cdot \bar{A_2} \cdot A_1 \cdot A_0$	0011
$Y_2 = E \cdot \bar{A_3} \cdot \bar{A_2} \cdot A_1 \cdot \bar{A_0}$	0010
$Y_1 = E \cdot \bar{A_3} \cdot \bar{A_2} \cdot \bar{A_1} \cdot A_0$	0001
$Y_0 = E \cdot \bar{A_3} \cdot \bar{A_2} \cdot \bar{A_1} \cdot \bar{A_0}$	0000

Date ________
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Logic Circuit