APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

LOGIC CIRCUIT DESIGN (ECT-203)

MODULE 3
NOTES

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Module 3: Combinatorial and Arithmetic Circuits

Combinatorial Logic Systems - Comparators, Multiplexers, Demultiplexers, Encoder, Decoder. Half and Full Adders, Subtractors, Serial and Parallel Adders, BCD Adder. Modeling and simulation of combinatorial circuits with verilog codes at the gate level.

3	**Combinatorial and Arithmetic Circuits**	
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MODULE 3
(TOPIC-1)

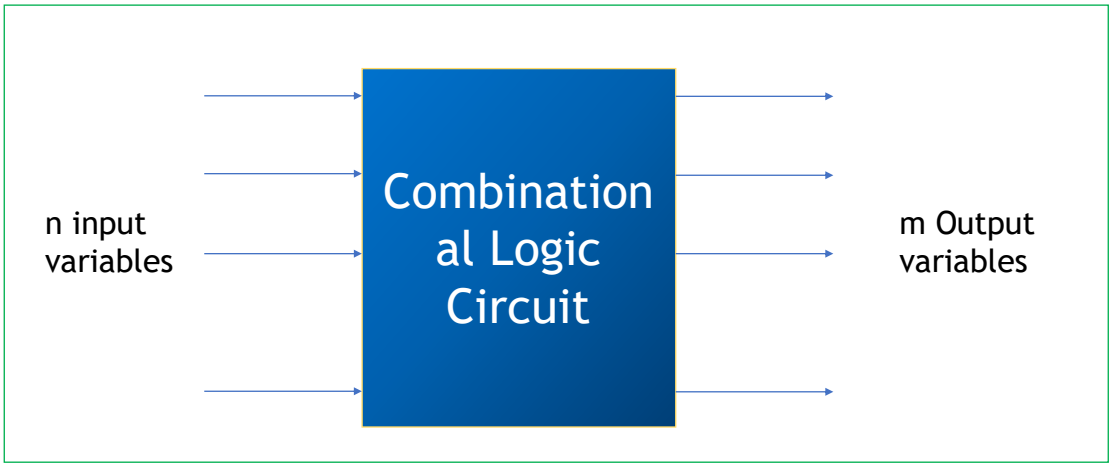
INTRODUCTION TO COMBINATIONAL CIRCUITS

https://youtu.be/gvTM4oGD_Y

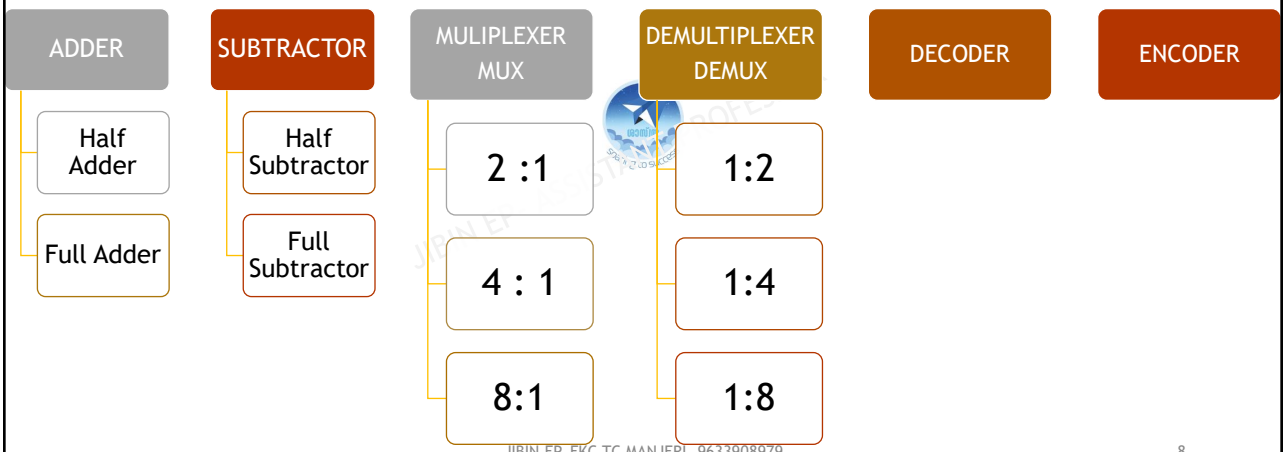
Combinational Logic Circuits

- When Logic Gates are connected together to produce a specified output for certain specified combination of input variables, with no storage involved , the resulting circuit is called combinational logic circuit
- In Combinational Logic Circuits, the output variables are all time depends on combination of input variables
- A Combinational Circuit consist of Input variables, Logic Gates & Output Variables.
- The Logic Gates accepts signal from the input variable and generate output signals

Block Diagram of Combinational Logic Circuit



TYPES OF COMBINATIONAL CIRCUITS



Design Procedure

1. Problem Definition
2. Determination of input and output variables
3. Assigning letter symbols to input and output variables
4. Derivation of Truth Table
5. Obtain Simplified Boolean Expression
6. Obtain the Logic Diagram

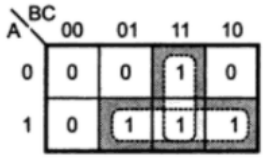
Example 1 :

Design a combinational Logic Circuit with three input variables that will produce a logic 1 output when more than one input variable are logic 1

TRUTH TABLE

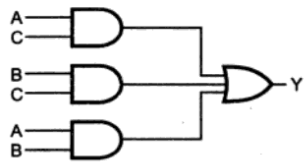
A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

BOOLEAN EXPRESSION



$Y = AC + BC + AB$

LOGIC DIAGRAM



Example 2 :

A Majority gate is digital circuit whose output is equal to 0 if majority of inputs are 1's . The output is 1 otherwise. Using TT Find Boolean Function and Logic Diagram

TRUTH TABLE

BOOLEAN EXPRESSION

LOGIC DIAGRAM

MODULE 3
(TOPIC-2)

DESIGN OF ADDERS (HALF ADDER AND FULL ADDER)

https://youtu.be/gvTM4oGD_XU

Design of Adders

0+0 =0
0+1 =1
1+0=1
1+1= 10

(1+1= Sum 0, Carry 1)

- The Simple addition consist of four possible elementary operations
- The First 3 Operations Produces Sum whose length is one digit
- Last Operation Performed sum in two digits. Higher Significant result is Called Carry & Lower Significant bit is Called Sum

HALF ADDER

- Half adder is a combinational logic circuit with two inputs and two outputs.
- The half adder circuit is designed to add two single bit binary number A and B.
- It is the basic building block for addition of two **single** bit numbers. This circuit has two outputs **carry** and **sum**.

HALF ADDER

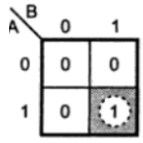
0+0 =0,0+1 =1
1+0=1,1+1= 0

TRUTH TABLE

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

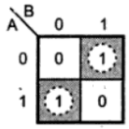
BOOLEAN EXPRESSION

For Carry



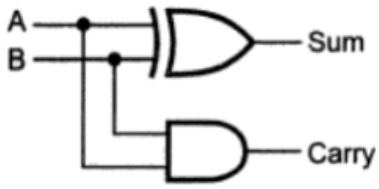
Carry = AB

For Sum



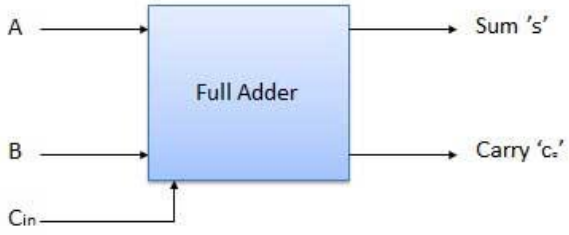
Sum = $A\bar{B} + \bar{A}B$
= $A \oplus B$

LOGIC DIAGRAM



FULL ADDER

- Full adder is developed to overcome the drawback of Half Adder circuit.
- It can add two one-bit numbers A and B, and C.
- The full adder is a three input and two output combinational circuit.



FULL ADDER

0+0 =0,0+1 =1
1+0=1,1+1= 0

TRUTH TABLE

BOOLEAN EXPRESSION

Inputs			Outputs	
A	B	C_{in}	Carry	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

For Carry (C_{out})

A \ BC_{in}	00	01	11	10
0	0	0	1	0
1	0	1	1	1

$C_{out} = AB + A C_{in} + B C_{in}$

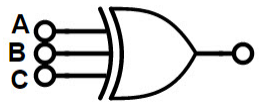
For Sum

A \ BC_{in}	00	01	11	10
0	0	1	0	1
1	1	0	1	0

$Sum = \bar{A}\,\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\,\bar{C}_{in} + ABC_{in}$

Reference : 3 Input XOR Gate

Inputs			outputs
W	X	Y	Q = A⊕B⊕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

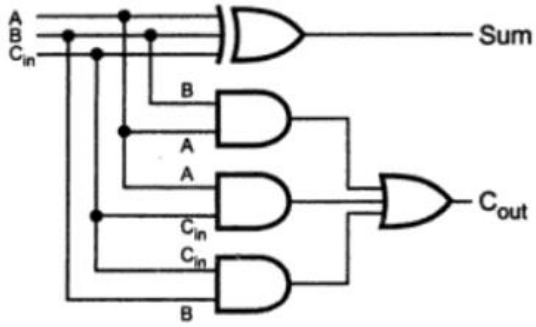


Sum= $A \oplus B \oplus C\_in$

FULL ADDER

0+0 =0,0+1 =1
1+0=1,1+1= 0

LOGIC DIAGRAM



Sum= $A \oplus B \oplus C\_in$

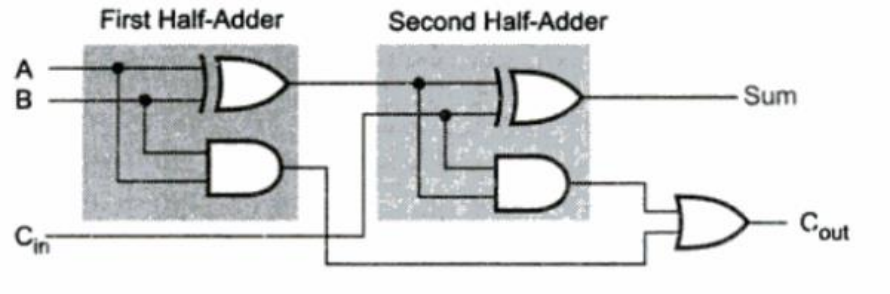
Carry= $AB + AC_{in} + BC_{in}$

FULL ADDER

0+0 =0,0+1 =1
1+0=1,1+1= 0

LOGIC DIAGRAM

Implementation of Full Adder Circuit using two Half Adders



MODULE 3
(TOPIC-3)

DESIGN OF SUBTRACTORS (HALF SUBTRACTOR AND FULL SUBTRACTOR)

https://youtu.be/FOGczanvVEk

Design of Subtractors

0-0 =0

0-1 =1 With Borrow 1

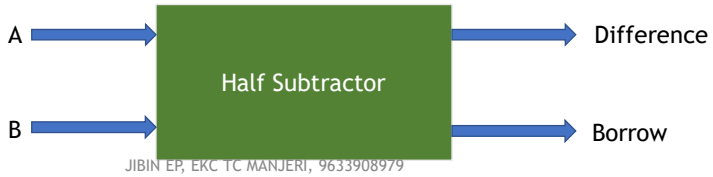
1-0=1

1-1= 0

- The Simple Subtraction consist of four possible elementary operations
- The First , 3rd and 4th Operations Produces Difference whose length is one digit. In these Operations, Each Subtrahend bit is subtracted from Minuend bit
- 2nd Operation the minuend bit is smaller than the subtrahend bit, Hence 1 is borrowed

Half Subtractor

- Half subtractor is a combination circuit with two inputs and two outputs (difference and borrow).
- It produces the difference between the two binary bits at the input and also produces an output (Borrow) to indicate if a 1 has been borrowed.
- In the subtraction (A-B), A is called as Minuend bit and B is called as Subtrahend bit



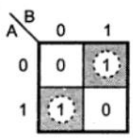
HALF SUBTRACTO

0-0 =0,0-1 =1 WITH BORROW 1
1-0=1,1-1= 0

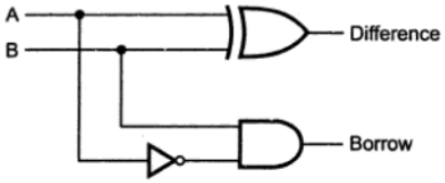
TRUTH TABLE | BOOLEAN EXPRESSION | LOGIC DIAGRAM

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

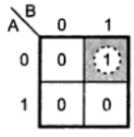
For Difference



Difference = $A\bar{B} + \bar{A}B$
= $A \oplus B$



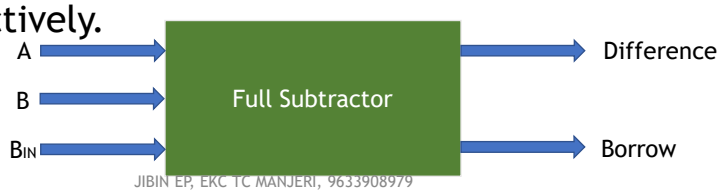
For Borrow



Borrow = $\bar{A}B$

Full Subtractor

- The disadvantage of a half subtractor is overcome by full subtractor.
- The full subtractor is a combinational circuit with three inputs A,B,B_{in} and two output D and B_{OUT}.
- The three inputs A, B and Bin, denote the Minuend, Subtrahend, and Previous Borrow, respectively. The two outputs, D and Bout represent the difference and output borrow, respectively.



FULL SUBTRACTO

0-0 =0,0-1 =1 WITH BORROW 1
1-0=1,1-1= 0

TRUTH TABLE

Inputs			Outputs	
A	B	B_{in}	D	B_{out}
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

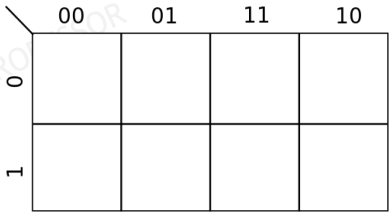
FULL SUBTRACTO

0-0 =0,0-1 =1 WITH BORROW 1
1-0=1,1-1= 0

TRUTH TABLE

BOOLEAN EXPRESSION

Inputs			Outputs	
A	B	B_{in}	D	B_{out}
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



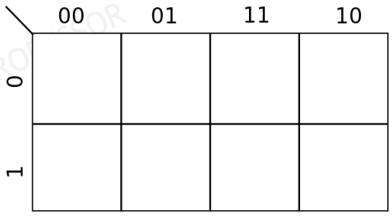
FULL SUBTRACTO

0-0 =0,0-1 =1 WITH BORROW 1
1-0=1,1-1= 0

TRUTH TABLE

BOOLEAN EXPRESSION

Inputs			Outputs	
A	B	B_{in}	D	B_{out}
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



FULL SUBTRACTO

0-0 =0,0-1 =1 WITH BORROW 1
1-0=1,1-1= 0

TRUTH TABLE

Inputs			Outputs	
A	B	B_{in}	D	B_{out}
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

BOOLEAN EXPRESSION

For D

A \ BB_{in}	00	01	11	10
0	0	1	0	1
1	1	0	1	0

$D = \bar{A}\bar{B}B_{in}+\bar{A}B\bar{B}_{in}+A\bar{B}\bar{B}_{in}+ABB_{in}$

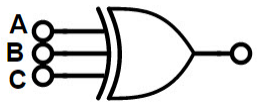
For B_{out}

A \ BB_{in}	00	01	11	10
0	0	1	1	1
1	0	0	1	0

$B_{out} = \bar{A}B_{in}+\bar{A}B+BB_{in}$

Reference : 3 Input XOR Gate

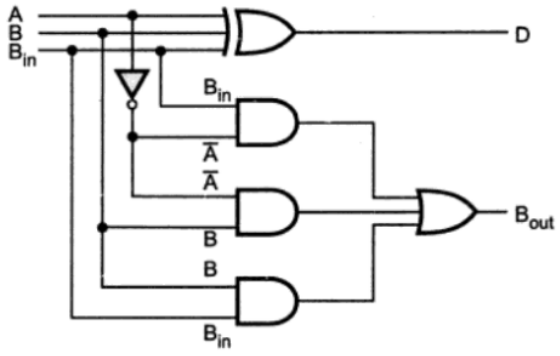
Inputs			outputs
W	X	Y	Q = A⊕B⊕C
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1



Sum= $A \oplus B \oplus C\_in$

FULL SUBTRACTOR

LOGIC DIAGRAM



Difference

$$B_{in} \oplus (A \oplus B)$$

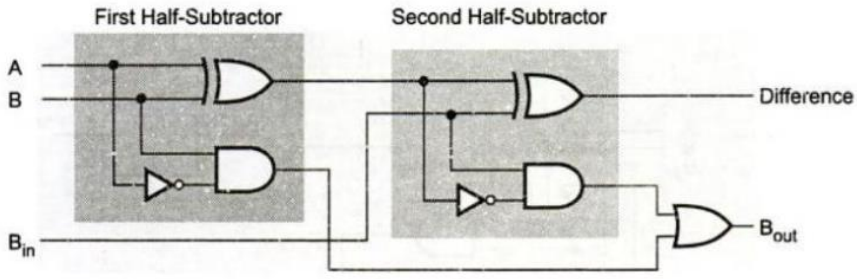
Borrow

$$B_{out} = \bar{A}B_{in} + \bar{A}B + BB_{in}$$

FULL SUBTRACTOR

LOGIC DIAGRAM

Implementation of Full Subtractor Circuit using two Half Subtr



MODULE 3
(TOPIC-4)

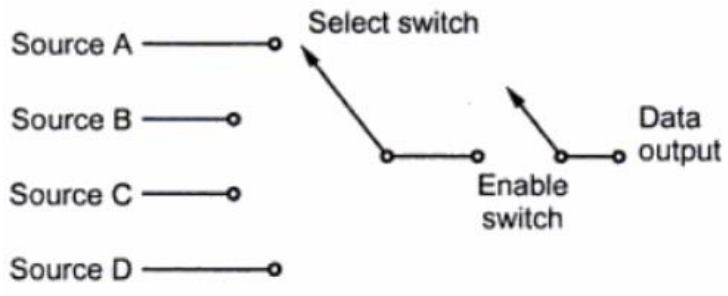
MULTIPLEXER AND DEMULTIPLEXER

https://youtu.be/J8-fKhmLWu0
https://youtu.be/Tt_cZOn2YBA

MULTIPLEXER (MUX)

- Multiplexer is a digital circuit that has multiple inputs and a single output.
- It is also known as Data Selector
- The Section of particular input line is controlled by set of Selection lines
- Normlly there are 2^n Input lines and n Selection Lines Whose bit combination determines which input is selected
- Therefore Multiplexer is 'Many to One' and it provide digital equivalent of an analog selector switch

MULTIPLEXER (MUX)



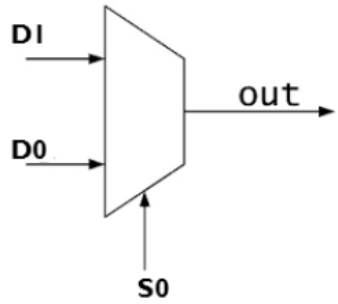
TYPES OF MULIPLEXE

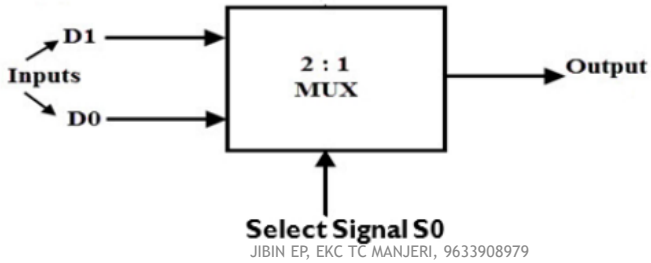
n Selection Lines
2^n Input Lines
1 Output Line

- 2 :1 Mux
- 4 :1 Mux
- 8 : 1 Mux

2:1 MULTIPLEXER

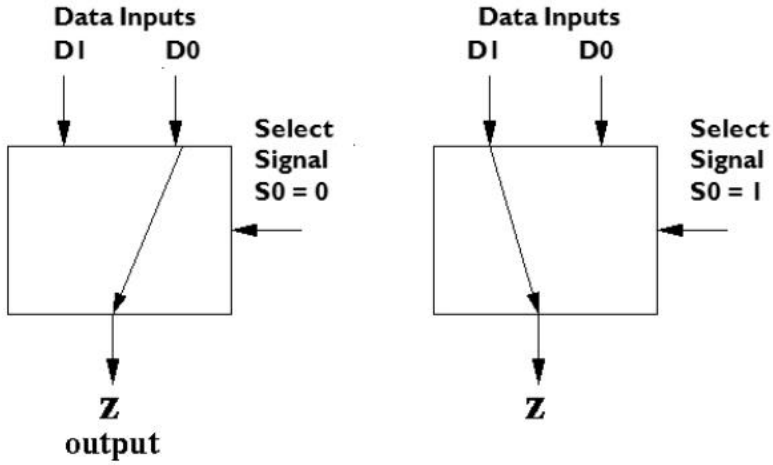
- 2:1 Multiplexer has
  - two data inputs, D0 and D1
  - one select line S0.
  - One output Z.





OPERATION OF 2:1 MUX

- If Select Line S0=0, then output = D0 and if Select Line S0=1, then output = D1

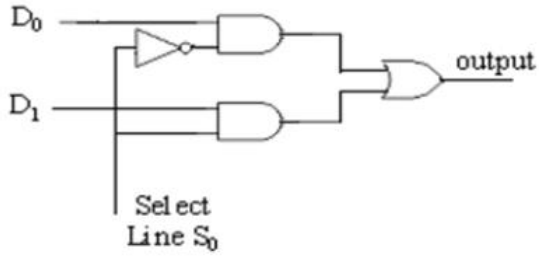


2:1 MUX

S0	Output Z
0	D0
1	D1

$$Z = D0.\overline{S0} + D1.S0$$

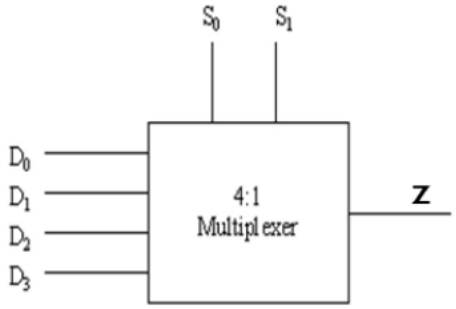
Circuit

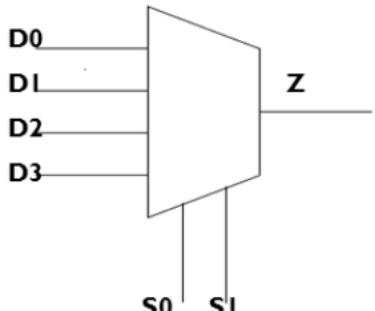


- 2:1 MUX requires
  - 2 AND Gates
  - 1 NOT Gate
  - 1 OR Gate

4:1 MULTIPLEXER

- 4:1 Multiplexer has
  - four data inputs, D0, D1, D2 and D3
  - Two select lines S0 and S1.
  - One output Z.





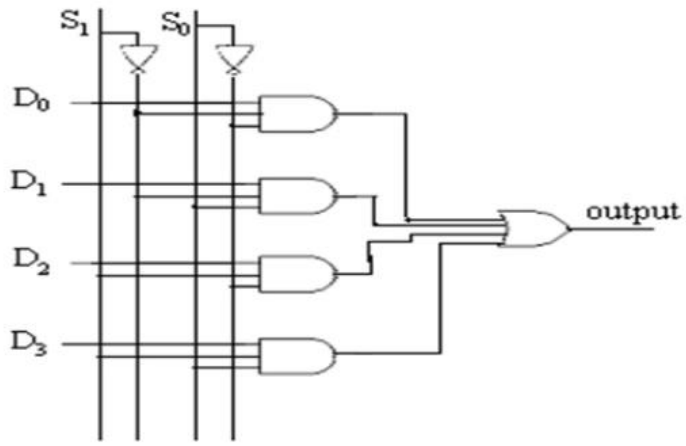
TRUTH TABLE OF 4:1 MUX

S1	S0	Output Z
0	0	D0
0	1	D1
1	0	D2
1	1	D3

$$Z = D0.\overline{S1}.\overline{S0} + D1.\overline{S1}.S0 + D2.S1.\overline{S0} + D3.S1.S0$$

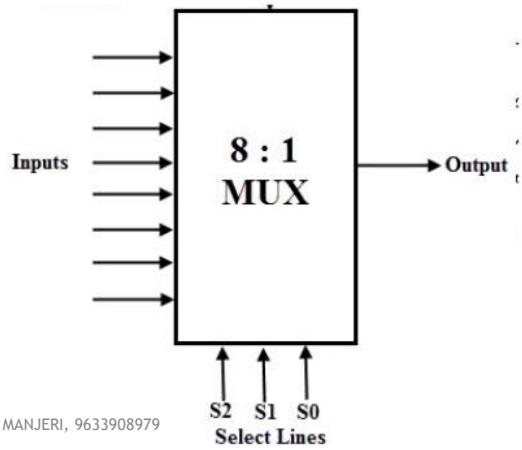
CIRCUIT OF 4:1 MUX

$$Z = D0.\overline{S1}.\overline{S0} + D1.\overline{S1}.S0 + D2.S1.\overline{S0} + D3.S1.S0$$



8:1 MULTIPLEXER

- 4:1 Multiplexer has
  - Eight data inputs, D0, D1, D2, D3, D4, D5, D6 and D7
  - Three select lines S0, S1 and S2.
  - One output Z.

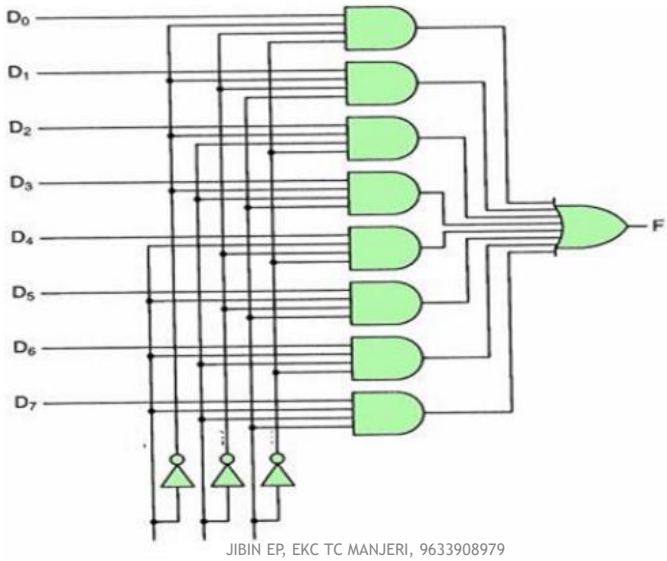


TRUTH TABLE OF 8:1 MUX

S2	S1	S0	Output Z
0	0	0	D0
0	0	1	D1
0	1	0	D2
0	1	1	D3
1	0	0	D4
1	0	1	D5
1	1	0	D6
1	1	1	D7

Z = S2'.S1'.S0'.D0 + S2'.S1'.S0.D1 + S2'.S1.S0'.D2 + S2'.S1.S0.D3 + S2.S1'.S0'.D4 + S2.S1'.S0.D5 + S2.S1.S0'.D6 + S2.S1.S0.D7

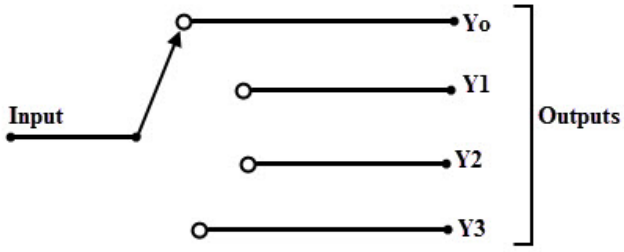
CIRCUIT OF 8:1 MUX



DEMULTIPLEXER (DEMUX)

- Demultiplexer is a digital circuit that has multiple Outputs and a single Input.
- It is also known as Data Distributer
- The Section of particular Output line is controlled by set of Selection lines
- Normlly there are 2^n Output lines and n Selection Lines Whose bit combination determines which input is selected
- Therefore demultiplexer is 'One to Many'

DEMULTIPLEXER (DEMUX)



TYPES OF DEMULIPLE

n Selection Lines
2^n Output Lines
1 Input Line

- 1 :2 Mux
- 1 :4 Mux
- 1 : 8 Mux

1x2 DEMUX

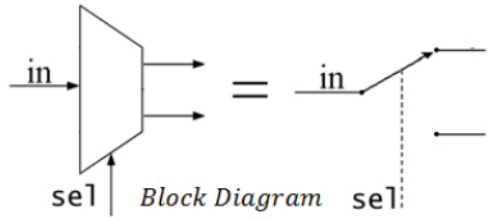
It has **one select line** and **two outputs,** Y_0 and Y_1. The input connected is F.

TRUTH TABLE:

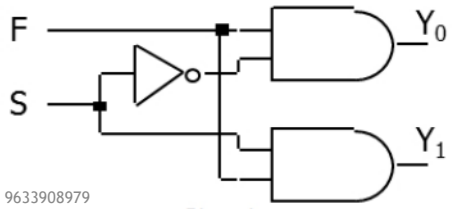
S_0	Y_0	Y_1
0	F	0
1	0	F

$$Y_o = \overline{S_o}.F + S_o.0 = \overline{S_o}.F$$

$$Y_1 = \overline{S_o}.0 + S_o.F = S_o.F$$



Block Diagram



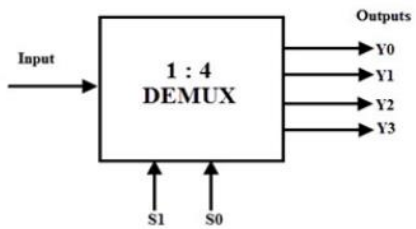
Circuit

1x4 DEMUX

It has **two select lines** and **four outputs,** Y_0 , Y_1, Y_2 and Y_3. The input connected is F.

TRUTH TABLE:

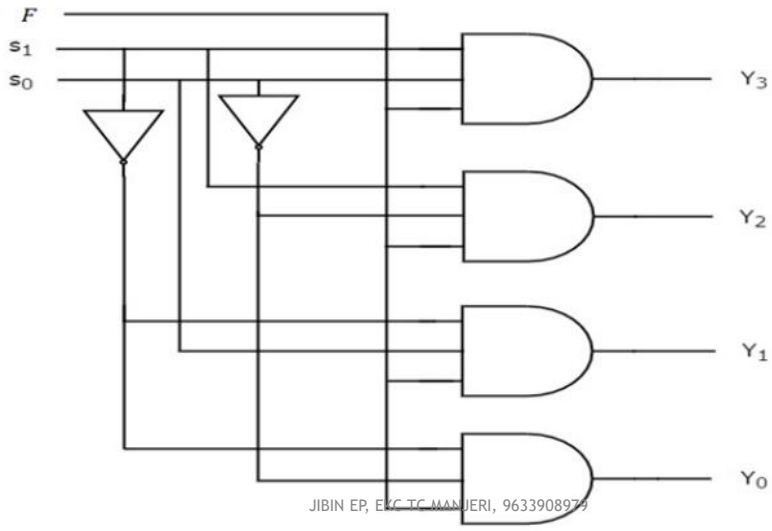
S_1	S_0	Y_0	Y_1	Y_2	Y_3
0	0	F	0	0	0
0	1	0	F	0	0
1	0	0	0	F	0
1	1	0	0	0	F

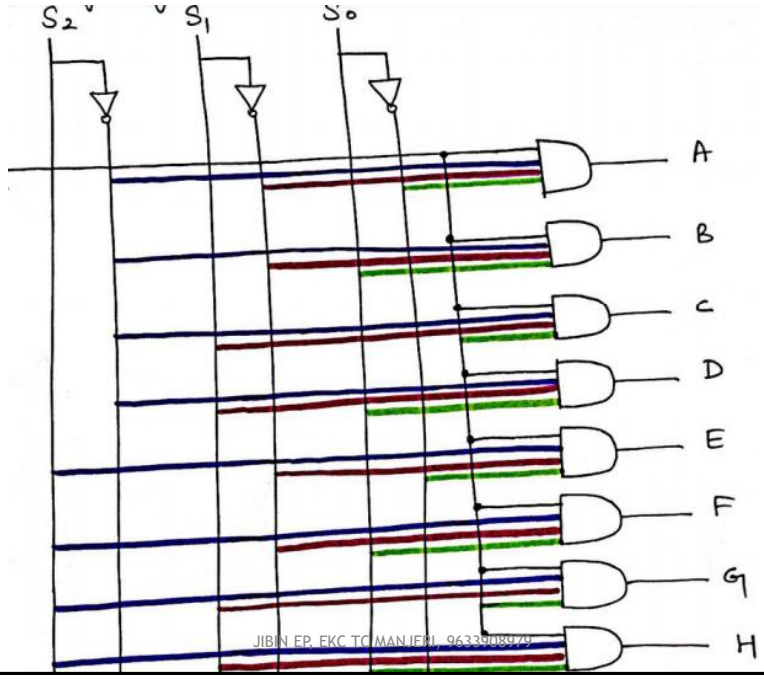


$$Y_o = \overline{S_1}.\overline{S_0}.F \qquad Y_1 = \overline{S_1}.S_0.F$$

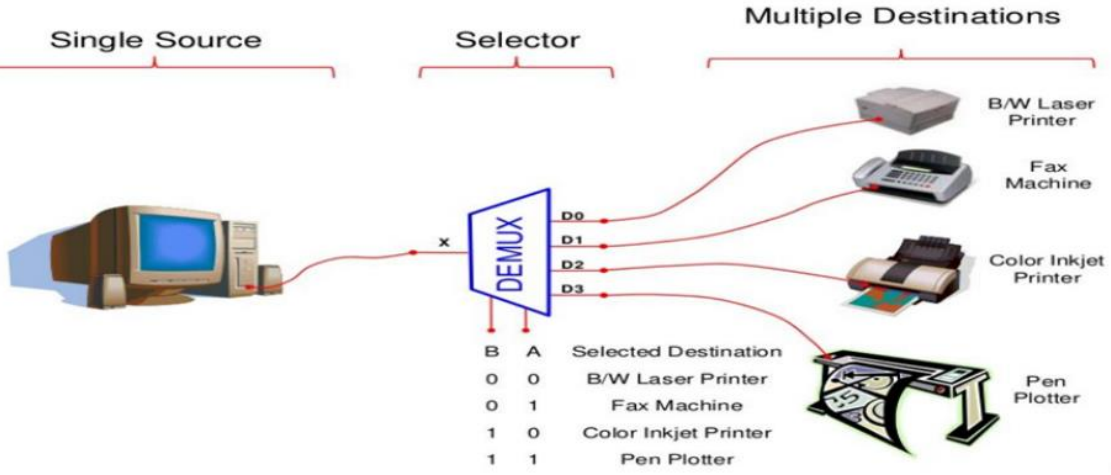
$$Y_2 = S_1.\overline{S_0}.F \qquad Y_3 = S_1.S_0.F$$

1x4 DEMUX CIRCUIT





APPLICATION OF DEMUX



MODULE 3
(TOPIC-5)

MULTIPLEXER AND DEMULTIPLEXER (NUMERICAL PROBLEMS)

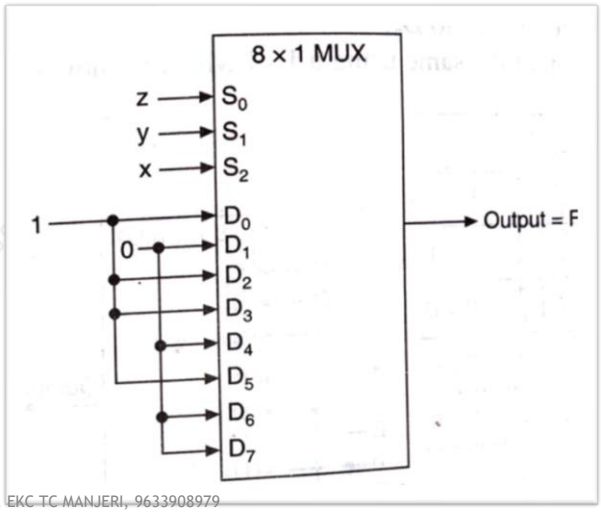
https://youtu.be/2p9Ex6YPBc4 YouTube

Problem 1:

Implement the following function using 8-to-1 Mux

$f(x,y,z) = \sum m(0,2,3,5)$

S2	S1	S0	F
X	Y	Z	
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	0



Problem 2:

Use a 4:1 Mux to implement the logic function

$f(A,B,C) = \sum m(1,2,4,7)$

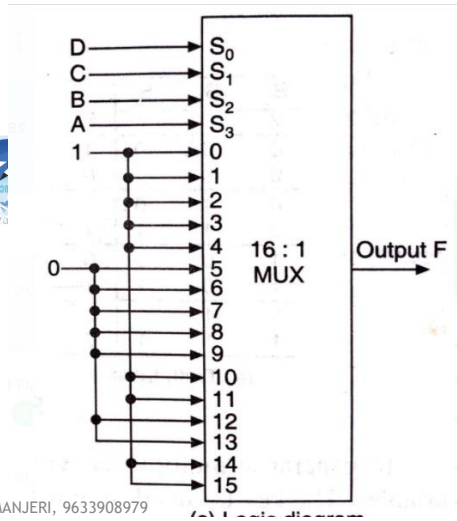
Minterm	S2	S1	C	F	
	A	B			
0	0	0	0	0	
1	0	0	1	1	F=C
2	0	1	0	1	
3	0	1	1	0	F=C'
4	1	0	0	1	
5	1	0	1	0	F=C'
6	1	1	0	0	
7	1	1	1	1	F=C

Problem 3a:

Use a multiplexer having Four data select the input to implement the logic for the function given below. Also realize the same using 16:1 Mux and 8:1 Mux

$f = \sum m(0,1,2,3,4,10,11,14,15)$

Minter	S3 A	S2 B	S1 C	S0 D	F
0	0	0	0	0	1
1	0	0	0	1	1
2	0	0	1	0	1
3	0	0	1	1	1
4	0	1	0	0	1
5	0	1	0	1	0
6	0	1	1	0	0
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	0
10	1	0	1	0	1
11	1	0	1	1	1
12	1	1	0	0	0
13	1	1	0	1	0
14	1	1	1	0	1
15	1	1	1	1	1

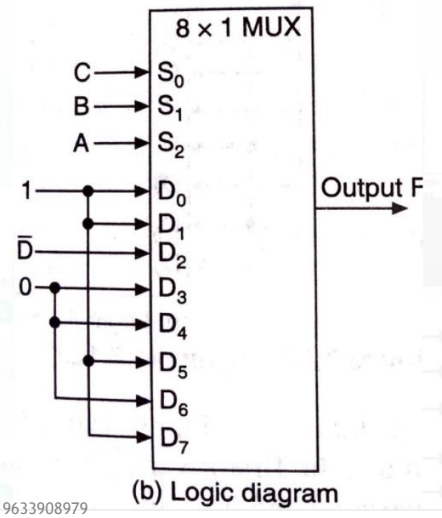


Problem 3b:

Use a multiplexer having three data select the input to implement the logic for the function given below. Also realize the same using 8:1 Mux

$f = \sum m(0,1,2,3,4,10,11,14,15)$

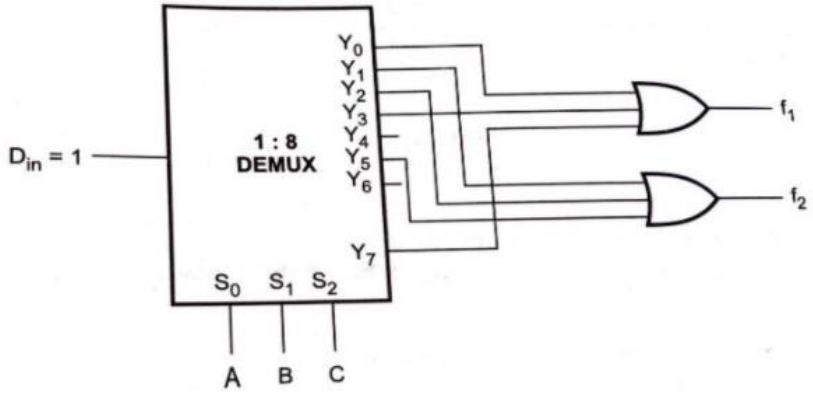
Minterm	S3 x	S2 x	S1 y	D	F	
0	0	0	0	0	1	
1	0	0	0	1	1	F=1
2	0	0	1	0	1	
3	0	0	1	1	1	F=1
4	0	1	0	0	1	
5	0	1	0	1	0	F=D'
6	0	1	1	0	0	
7	0	1	1	1	0	F=0
8	1	0	0	0	0	
9	1	0	0	1	0	F=0
10	1	0	1	0	1	
11	1	0	1	1	1	F=1
12	1	1	0	0	0	
13	1	1	0	1	0	F=0
14	1	1	1	0	1	
15	1	1	1	1	1	F=1



(b) Logic diagram

Problem 4

Use a demultiplexer Implement the functions f1= $\sum m(0,3,7)$ f2= $\sum m(1,2,5)$



Problem 5 (Home Work)

Use Multiplexer implement the logic functions

F=$A \oplus B \oplus C$

Inputs			outputs
W	X	Y	Q = A⊕B⊕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

Problem 6 (Home Work)

Use a demultiplexer Implement the functions f1= $\sum m(1,5,7)$ f2= $\sum m(3,6,7)$

Problem 7 (Home Work)

Implement the functions f(w,x,y,z)= $\sum m(1,4,6,7,8,9,10,11,15)$ Using 8 to 1 Mux

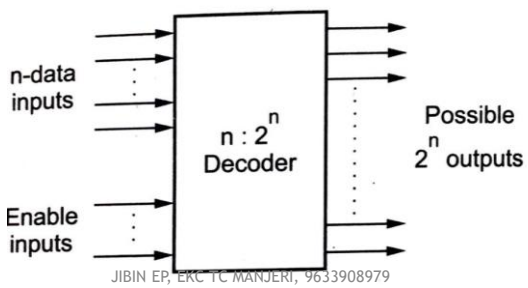
MODULE 3
(TOPIC-6)

DECODER AND ENCODER

https://youtu.be/Zxd-imLGFFc

DECODER

- Decoder is a Multiple Input , Multiple Output logic circuit which converts coded inputs to coded outputs, where the input and output are different
- Decoder consist of n input and 2^n Maximum Possible Outputs



Examples

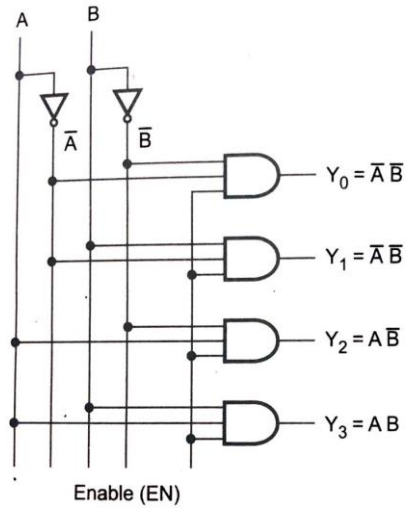
2 to 4

3 to 8

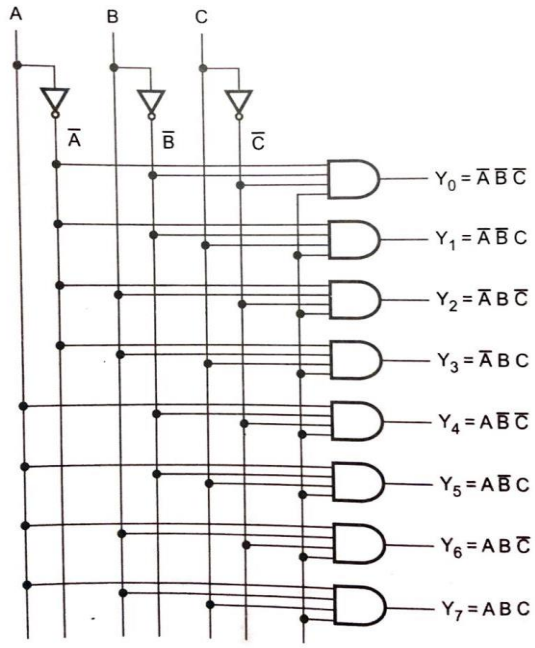
4 to 16

Binary Decoder (2 to 4 Decoder)

Inputs			Outputs			
ENABLE	A	B	Y3	Y2	Y1	Y0
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



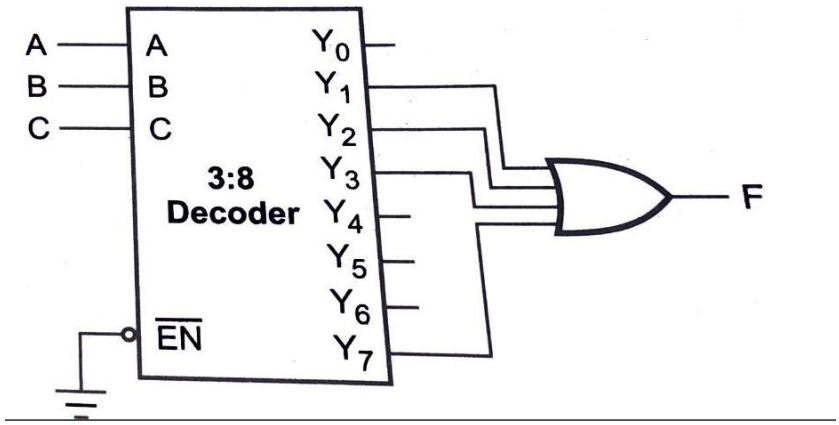
3 to 8 Decoder



3 to 8 Decoder

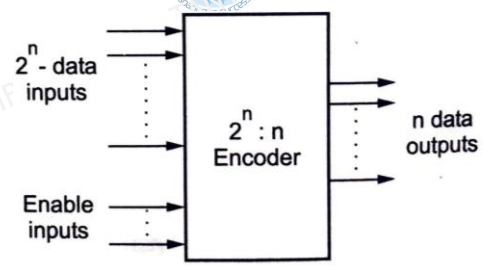
Inputs								Outputs			
ENABLE	A	B	C	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0
1	0	0	0	0	0	0	0	0	0	0	1
1	0	0	1	0	0	0	0	0	0	1	0
1	0	1	0	0	0	0	0	0	1	0	0
1	0	1	1	0	0	0	0	1	0	0	0
1	1	0	0	0	0	0	1	0	0	0	0
1	1	0	1	0	0	1	0	0	0	0	0
1	1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0

Implement the Boolean function f= $\sum m(1,2,3,7)$



ENCODER

- Encoder is a digital circuit which perform inverse operation of Decoder
- Decoder is a Multiple Input , Multiple Output logic circuit which converts coded inputs to coded outputs, where the input and output are different
- Decoder consist of n Outputs and 2^n Maximum Possible Inputs

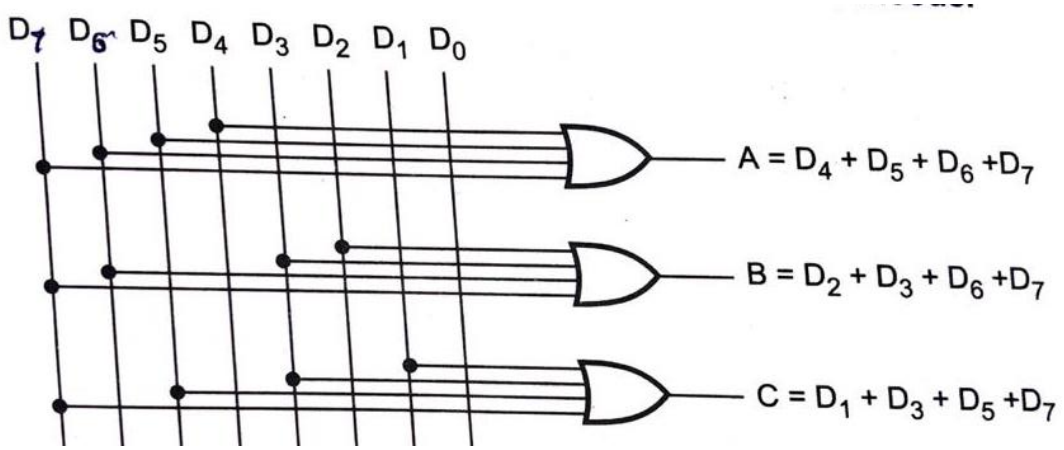


Examples

8 TO 3 ENCODER (OCTAL TO BINARY)

Inputs								Outputs		
D0	D1	D2	D3	D4	D5	D6	D7	A	B	C
1	0	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	1	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	1	0	0
0	0	0	0	0	1	0	0	1	0	1
0	0	0	0	0	0	1	0	1	1	0
0	0	0	0	0	0	0	1	1	1	1

8 TO 3 ENCODER (OCTAL TO BINARY)



PRIORITY ENCODER

- A Priority encoder is one of the types of encoders in which an ordering is imposed to the inputs that means compared with the standard encoder, it includes the priority function.
- However, this priority is based on the relative magnitudes of the inputs. Hence, the input with larger magnitude is the one that is encoded first.
- Priority encoders can select the inputs with highest priority in many practical applications. This process of selection is called arbitration.
- One of the most common examples of arbitration is that , there are numerous input devices in computer system and several of which devices attempt to supply the data to the computer simultaneously. In those cases, a priority encoder enables the input device having the highest priority among those devices trying to access the computer at the same time.

PRIORITY ENCODER

This Priority encoder consists of 4 inputs and three outputs.
Although an encoder has 2^n inputs and n outputs, it has a third output 'V' which is a valid bit indicator and is set to one when one or more inputs are active or equal to 1.

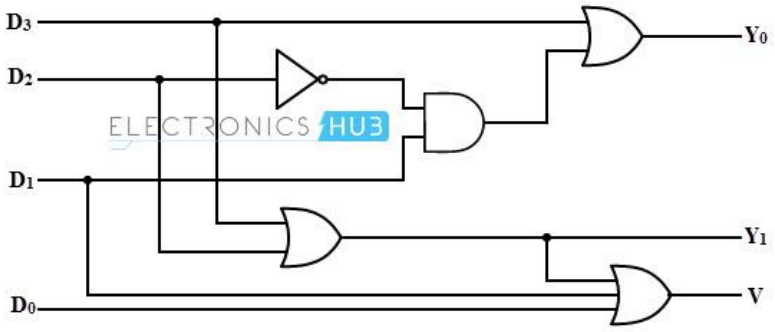
Inputs				Outputs		
D_0	D_1	D_2	D_3	Y_1	Y_0	V
0	0	0	0	×	×	0
1	0	0	0	0	0	1
×	1	0	0	0	1	1
×	×	1	0	1	0	1
×	×	×	1	1	1	1

$$Y1 = D3 + \overline{D3}\,D2 = D3 + D2$$

$$Y0 = D3 + \overline{D3}\,\overline{D2}\,D1 = D3 + \overline{D2}\,D1$$

$$V = D3 + D2 + D1 + D0$$

PRIORITY ENCODER



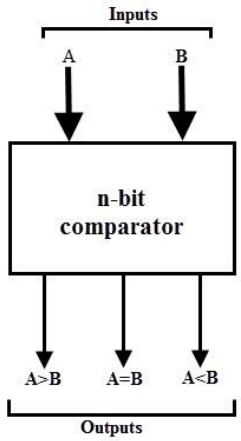
MODULE 3
(TOPIC-7)

MAGNITUDE COMPARATORS

https://youtu.be/7xHM5HeGCHo

MAGNITUDE COMPARATOR

- A magnitude digital comparator is a combinational circuit that compares two digital or binary numbers (consider A and B) and determines their relative magnitudes in order to find out whether one number is equal, less than or greater than the other digital number.
- Three binary variables are used to indicate the outcome of the comparison as A>B, A<B, or A=B. The below figure shows the block diagram of a n-bit comparator which compares the two numbers of n-bit length and generates their relation between themselves.

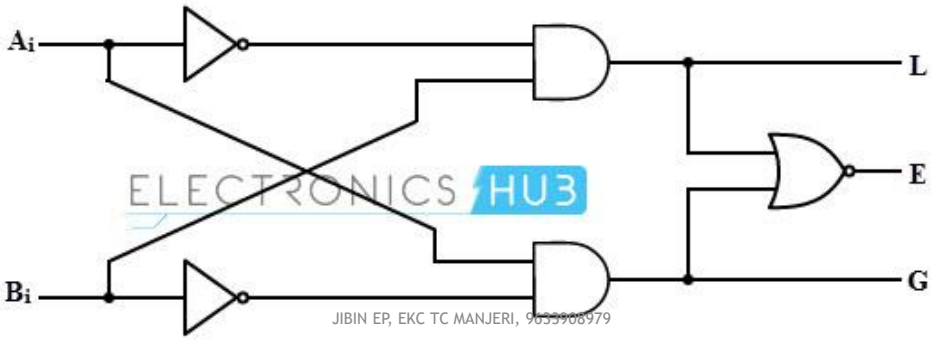


Single Bit Magnitude Comparator

- comparator used to compare two bits, i.e., two numbers each of single bit is called a single bit comparator. It consists of two inputs for allowing two single bit numbers and three outputs to generate less than, equal and greater than comparison outputs.
- The figure below shows the block diagram of a single bit magnitude comparator. This comparator compares the two bits and produces one of the 3 outputs as L (A<B), E (A=B) and G (A>B).

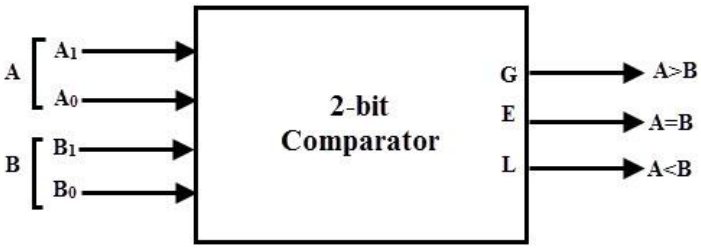
Truth Table

A_0	B_0	L	E	G
0	0	0	1	0
0	1	1	0	0
1	0	0	0	1
1	1	0	1	0



Two Bit Magnitude Comparator

- A 2-bit comparator compares two binary numbers, each of two bits and produces their relation such as one number is equal or greater than or less than the other. The figure below shows the block diagram of a two-bit comparator which has four inputs and three outputs.
- The first number A is designated as A = A1A0 and the second number is designated as B = B1B0. This comparator produces three outputs as = 1 if A<B).



Inputs				Outputs		
A_1	A_0	B_1	B_0	A>B	A=B	A<B
0	0	0	0	0	1	0
0	0	0	1	0	0	1
0	0	1	0	0	0	1
0	0	1	1	0	0	1
0	1	0	0	1	0	0
0	1	0	1	0	1	0
0	1	1	0	0	0	1
0	1	1	1	0	0	1
1	0	0	0	1	0	0
1	0	0	1	1	0	0
1	0	1	0	0	1	0
1	0	1	1	0	0	1
1	1	0	0	1	0	0
1	1	0	1	1	0	0
1	1	1	0	1	0	0
1	1	1	1	0	1	0

A>B

A_1A_0 \ B_1B_0	00	01	11	10
00	0	0	0	0
01	1	0	0	0
11	1	1	0	1
10	1	1	0	0

A=B

A_1A_0 \ B_1B_0	00	01	11	10
00	1	0	0	0
01	0	1	0	0
11	0	0	1	0
10	0	0	0	1

$$A>B:\ G = A0\,\overline{B1}\ \ \overline{B0} + A1\,\overline{B1} + A1\ A0\,\overline{B0}$$

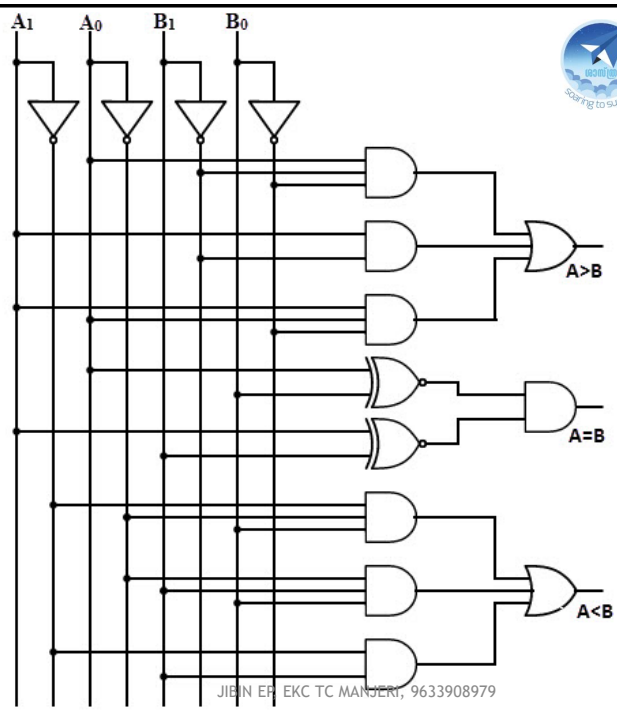
$$A = B:\ E = \overline{A1}\ \ \overline{A0}\ \overline{B1}\ \ \overline{B0} + \overline{A1}\ A0\ \ \overline{B1}\ B0 + A1\ \ A0\ B1\ B0 + A1\,\overline{A0}\ B1\ \overline{B0}$$

$$= \overline{A1}\ \ \overline{B1}\ (\overline{A0}\ \ \overline{B0} + A0\,B0) + A1\,B1\ (A0\,B0 + \overline{A0}\ \ \overline{B0}\ )$$

$$= (A0\,B0 + \overline{A0}\ \ \overline{B0})\ (A1\,B1 + \ \overline{A1}\ \ \overline{B1})$$

$$= (A0 \text{ Ex-NOR } B0)\ (A1 \text{ Ex-NOR } B1)$$

$$A < B:\ L = \overline{A1}\ \ B1 + \overline{A0}\ B1\ B0 + \overline{A1}\ \ \overline{A0}\ B0$$



Application of Comparators

- These are used in the address decoding circuitry in computers and microprocessor based devices to select a specific input/output device for the storage of data.
- These are used in control applications in which the binary numbers representing physical variables such as temperature, position, etc. are compared with a reference value. Then the outputs from the comparator are used to drive the actuators so as to make the physical variables closest to the set or reference value.
- Process controllers
- Servo-motor control

MODULE 3
(TOPIC-9)

BINARY PARALLEL ADDER
CARRY LOOK AHEAD ADDER
BCD ADDER

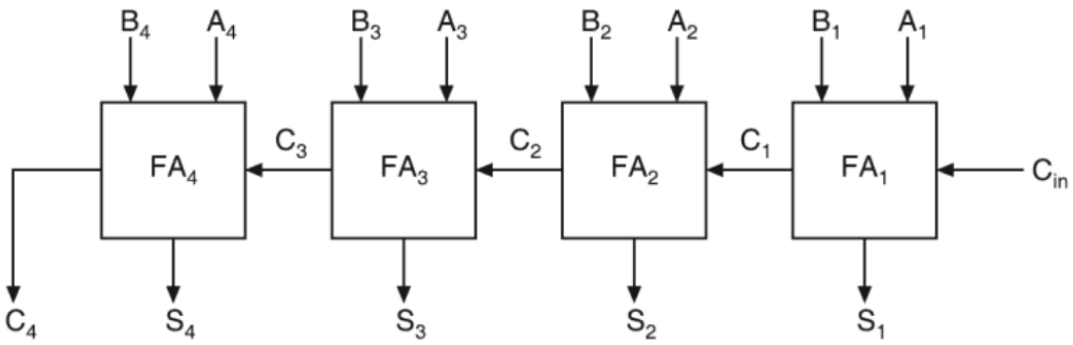
https://youtu.be/8G29l4BFg_o
https://youtu.be/hfbvmGZ79SA

YouTube

PARALLEL ADDER

- A single full adder performs the addition of two one bit numbers and an input carry.
- But a **Parallel Adder** is a digital circuit capable of finding the arithmetic **sum** of two binary numbers that is **greater than one bit** in length by operating on corresponding pairs of bits in parallel.
- It consists of **full adders connected in a chain** where the output carry from each full adder is connected to the carry input of the next higher order full adder in the chain.
- **A n bit parallel adder requires n full adders to perform the operation.** So for the two-bit number, two adders are needed while for four bit number, four adders are needed and so on. Parallel adders normally incorporate carry lookahead logic to ensure that carry propagation between subsequent stages of addition does not limit addition speed.

PARALLEL ADDER



CARRY LOOK AHEAD ADDER

- A carry-Lookahead adder is a fast parallel adder as it reduces the propagation delay by more complex hardware, hence it is costlier. In this design, the carry logic over fixed groups of bits of the adder is reduced to two-level logic, which is nothing but a transformation of the ripple carry design.
- This method makes use of logic gates so as to look at the lower order bits of the augend and addend to see whether a higher order carry is to be generated or not.
- **Carry-Lookahead Adder Ics** A typical carry-Lookahead generator IC is 74182 which accept four pairs of active low carry propagate (as P0, P1, P2 and P3) and carry generate (Go, G1, G2 and G3) signals and an active high input (Cn).

CARRY LOOK AHEAD ADDER

Consider the full adder circuit shown above with corresponding truth table. If we define two variables as carry generate Gi and carry propagate Pi then,

$P_i = A_i \oplus B_i$

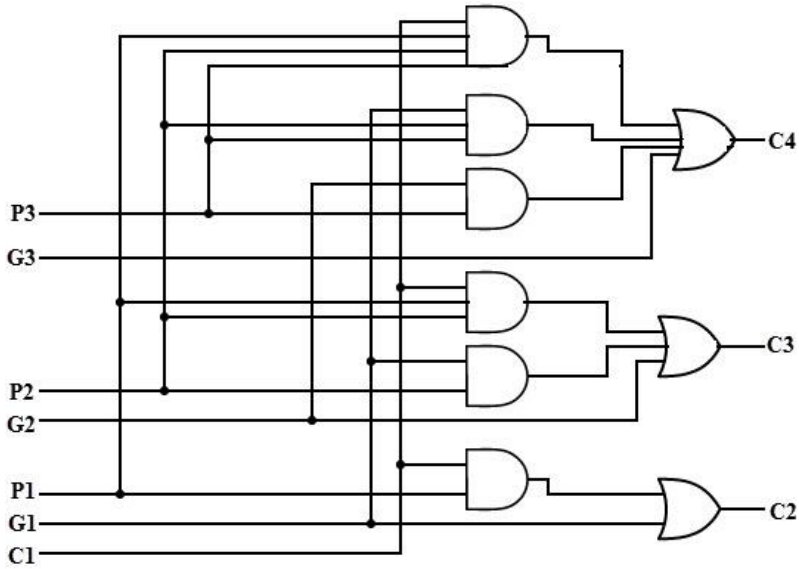
Gi = Ai Bi

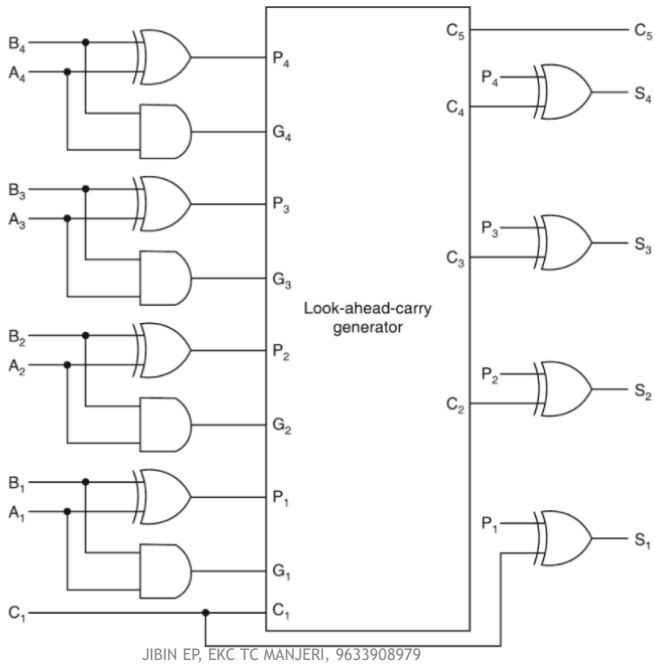
The sum output and carry output can be expressed as

Si = Pi ⊕ Ci

C i +1 = Gi + Pi Ci

A	B	Ci	C i +1	Condition
0	0	0	0	No carry generate
0	0	1	0	
0	1	0	0	
0	1	1	1	No carry propagate
1	0	0	0	
1	0	1	1	
1	1	0	1	Carry generate
1	1	1	1	


P3
G3
P2
G2
P1
G1
C1
C4
C3
C2


B4
A4
P4
G4
B3
A3
P3
G3
B2
A2
P2
G2
B1
A1
P1
G1
C1
C1
Look-ahead-carry generator
C5
C5
P4
C4
S4
P3
C3
S3
P2
C2
S2
P1
S1

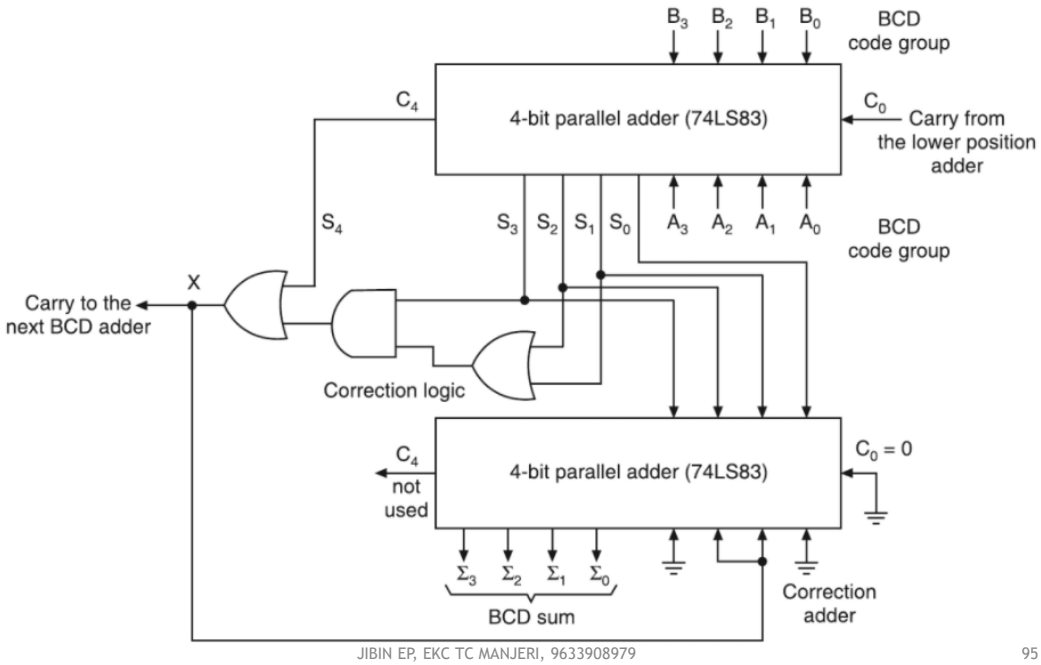
BCD ADDER

- BCD adder must be able to operate in accordance with above steps
- **1) Add two bit BCD Code Groups , using straight binary addition**
- **2) Determine if the sum of addition is greater than 1001 (Decimal 9); If it is , add 0110 (Decimal 6) to this sum and generate a carry to the next decimal position**
- The first requirement is easily met by using a 4 bit binary parallel adder
- The sum output S4 S3 S2 S1 S0 can range anywhere from 00000 to 10010

The Circuitry for a BCD adder must include the logic needed to detect whenever the sum is greater than 01001, so that correction can be added in

The circuit consists of three basic parts. The two BCD code groups $A_3A_2A_1A_0$ and $B_3B_2B_1B_0$ are added together in the upper 4-bit adder, to produce the sum $S_4S_3S_2S_1S_0$. The logic gates shown implement the expression for X. The lower 4-bit adder will add the correction 0110 to the sum bits, only when X = 1, producing the final BCD sum output represented by $\Sigma_3\Sigma_2\Sigma_1\Sigma_0$. The X is also the carry-out that is produced when the sum is greater than 01001. Of course, when X = 0, there is no carry and no addition of 0110. In such cases, $\Sigma_3\Sigma_2\Sigma_1\Sigma_0 = S_3S_2S_1S_0$.

Two or more BCD adders can be connected in cascade when two or more digit decimal numbers are to be added. The carry-out of the first BCD adder is connected as the carry-in of the second BCD adder, the carry-out of the second BCD adder is connected as the carry-in of the third BCD adder and so on.

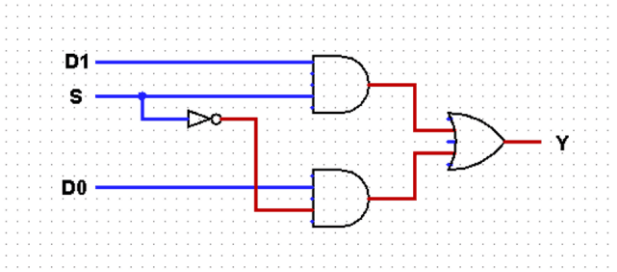


MODULE 3
(TOPIC-9)

VERILOG PROGRAMMING PART 2

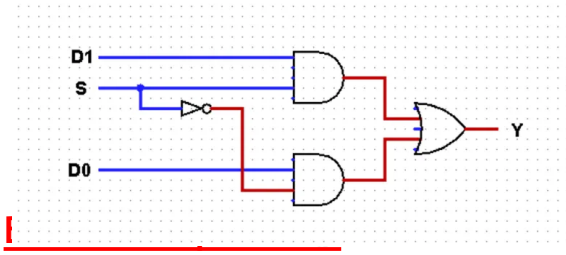
https://youtu.be/ZgGDLuHmpOE YouTube

2:1 MUX



2:1 Mux Theory

Circuit Diagram



$$Y = D0.S' + D1.S$$

Truth Table

S	Y
0	D0
1	D1

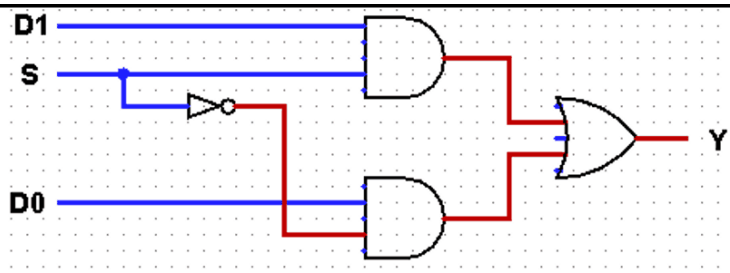
2:1 MODELING DATA FLOW MODELING

Boolean Expression

$Y = D0.S' + D1.S$

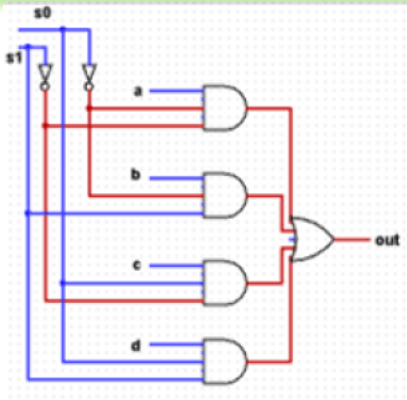
```
module 2TO1MUX(D0, D1, S, Y);
output Y;
Input D0, D1, S;
assign Y = (D0~S)|(D1S);
end module
```

2:1 MODELING GATE LEVEL MODELING



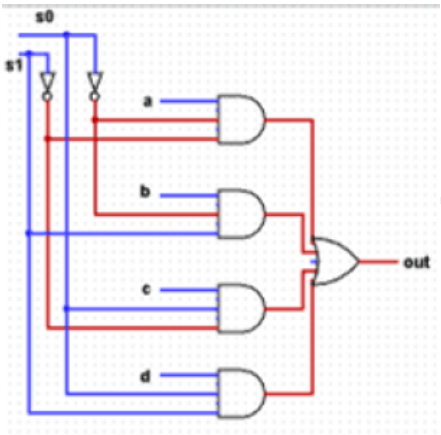

```
module 2TO1MUX(Y, D0, D1, S);
output Y;
input D0, D1, S;
wire T1, T2, Sbar;
and (T1, D1, S), (T2, D0, Sbar);
not (Sbar, S);
or (Y, T1, T2);
endmodule
```

4:1 MUX



4:1 Mux Theory

Circuit Diagram



Truth Table

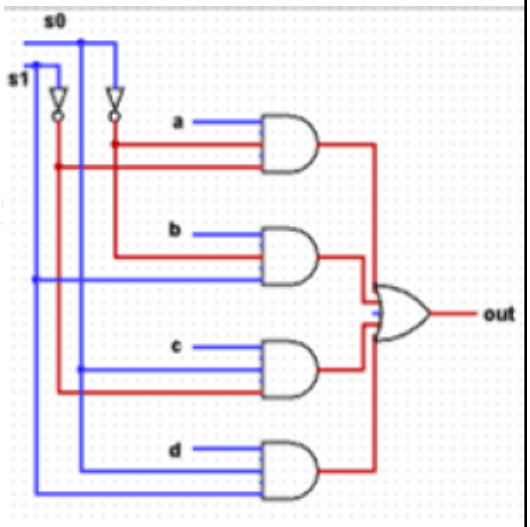
S0	S1	Y
0	0	D0
0	1	D1
1	0	D2
1	1	D3

Boolean

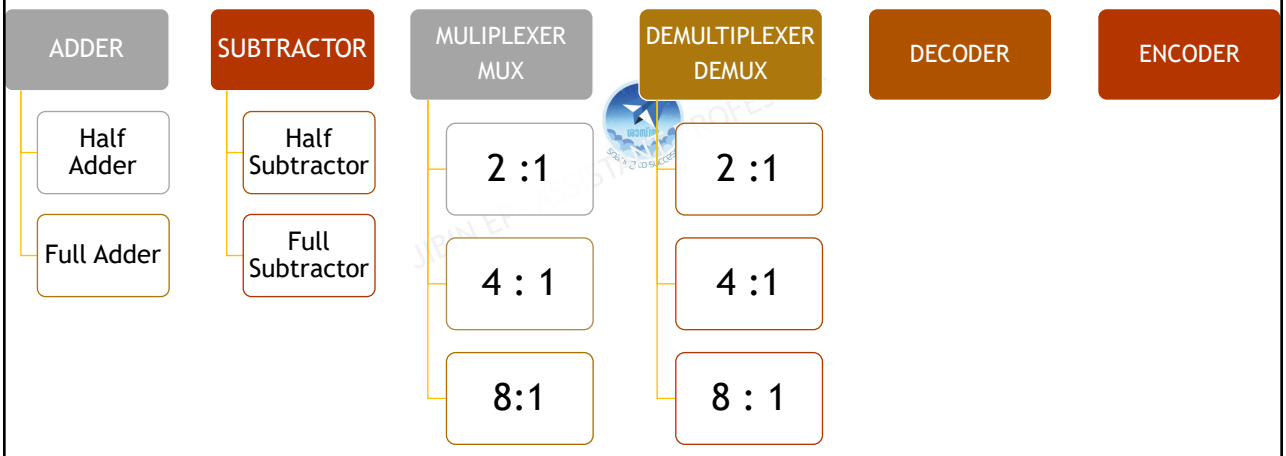
$$Y = D0S0'S1' + D1.S0'S1 + D2S0S1' + D3S0S1$$

4:1 MODELING GATE LEVEL MODELING

```
module 4TO1 MUX(out, a, b, c, d, s0,
s1); output out;
input a, b, c, d, s0, s1;
wire sobar, s1bar, T1, T2, T3, T4;
not (s0bar, s0), (s1bar, s1);
and (T1, a, s0bar, s1bar), (T2, b, s0bar,
s1), (T3, c, s0, s1bar), (T4, d, s0, s1);
or(out, T1, T2, T3, T4);
endmodule
```



TYPES OF COMBINATIONAL CIRCUITS



HALF ADDER

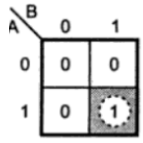
0+0 =0,0+1 =1
1+0=1,1+1= 0

TRUTH TABLE

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

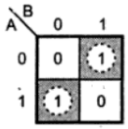
BOOLEAN EXPRESSION

For Carry



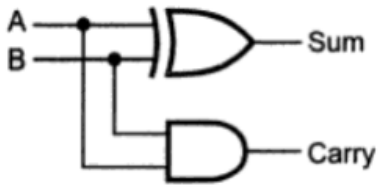
Carry = AB

For Sum



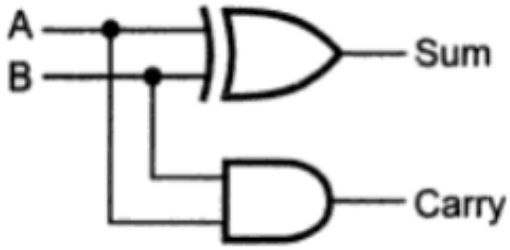
Sum = $A\bar{B} + \bar{A}B$
= $A \oplus B$

LOGIC DIAGRAM



HALF ADDER GATE LEVEL MODELING

Refer the Video



FULL ADDER

0+0 =0,0+1 =1
1+0=1,1+1= 0

TRUTH TABLE

BOOLEAN EXPRESSION

Inputs			Outputs	
A	B	C_{in}	Carry	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

For Carry (C_{out})

A \ BC_{in}	00	01	11	10
0	0	0	1	0
1	0	1	1	1

$C_{out} = AB + A C_{in} + B C_{in}$

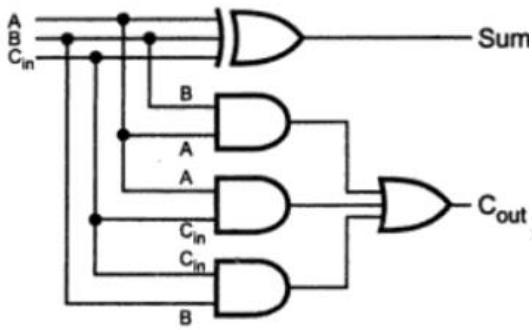
For Sum

A \ BC_{in}	00	01	11	10
0	0	1	0	1
1	1	0	1	0

$Sum = \bar{A}\,\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\,\bar{C}_{in} + ABC_{in}$

FULL ADDER

LOGIC DIAGRAM



Refer the Video

Sum= $A \oplus B \oplus C\_in$

Carry= $AB + AC_{in} + BC_{in}$

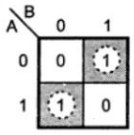
HALF SUBTRACTOR

TRUTH TABLE

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

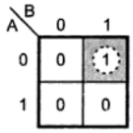
BOOLEAN EXPRESSION

For Difference



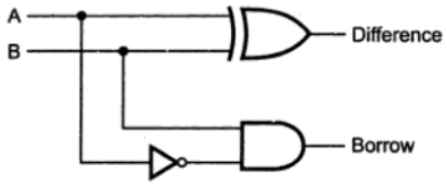
Difference = $A\overline{B} + \overline{A}B$
= $A \oplus B$

For Borrow



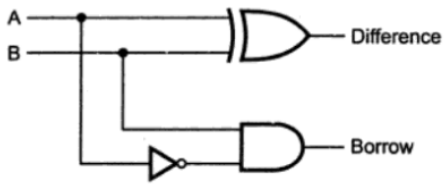
Borrow = $\overline{A}B$

LOGIC DIAGRAM



HALF SUBTRACTOR

LOGIC DIAGRAM



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FULL SUBTRACTO

0-0 =0,0-1 =1 WITH BORROW 1
1-0=1,1-1= 0

TRUTH TABLE

Inputs			Outputs	
A	B	B_{in}	D	B_{out}
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

BOOLEAN EXPRESSION

For D

A \ BB_{in}	00	01	11	10
0	0	1	0	1
1	1	0	1	0

$D = \bar{A}\bar{B}B_{in}+\bar{A}B\bar{B}_{in}+A\bar{B}\bar{B}_{in}+ABB_{in}$

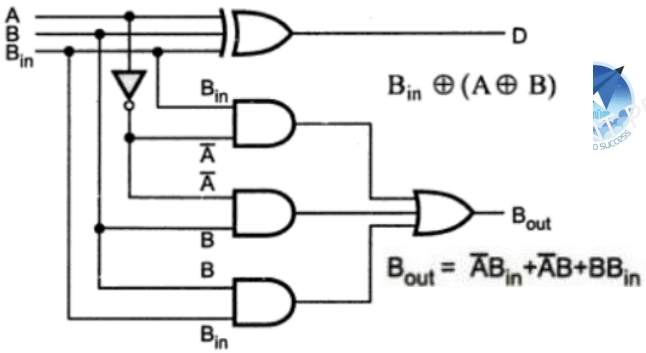
For B_{out}

A \ BB_{in}	00	01	11	10
0	0	1	1	1
1	0	0	1	0

$B_{out} = \bar{A}B_{in}+\bar{A}B+BB_{in}$

FULL SUBTRACTOR

LOGIC DIAGRAM



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