(Digital Circuits)

Combinational circuits

Code Convertors :-

- BCD to E-3
- E-3 to BCD
- 4-bit Binary to Gray code
- 4-bit Gray to Binary
- 5-4-2-1 BCD to Natural BCD
- Natural BCD to 54-2-1 BCD

Excess - 3 (self - complimentary) code :-

	BCD		E-3	
9's	5 = 0101	$\xrightarrow{+3}$	1000	1's
	4 = 0100	$\longleftarrow$	0111	

- The once compliment of given BCD excess-3 code is 9's compliment of the given BCD in E-3 form.
- E-3 codes are used in BCD subtractor ckt design.

NOTE :- E-3 code is unweighted code.

Q. when 8-bit register is used to represent a BCD number, how many combinations are unused combination <u>156</u>.

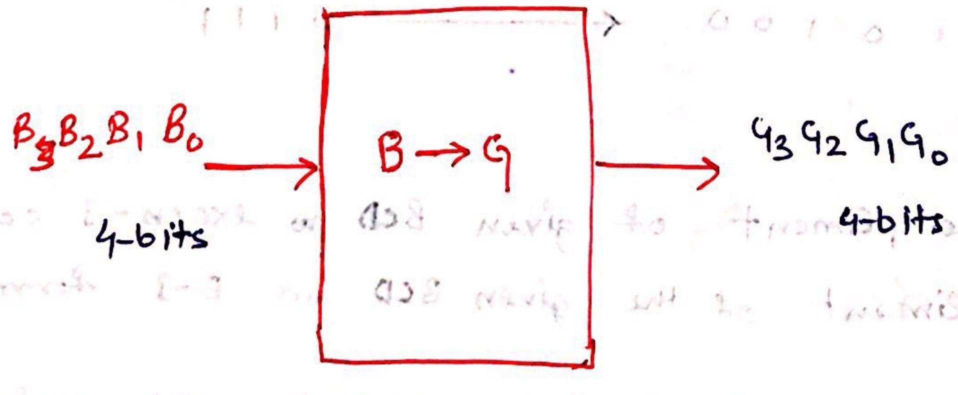
$$\overbrace{b_7 \quad b_4}^{\text{4 bits}}\ \overbrace{b_3 \quad b_0}^{\text{4 bits}}$$

$$(0-9) \qquad (0-9)$$

So Total possible BCD = 100 i.e 0 – 99

so, unused combination $= 2^8 - 100 = \boxed{156}$

4-Bit Binary to Grey code convertor:-

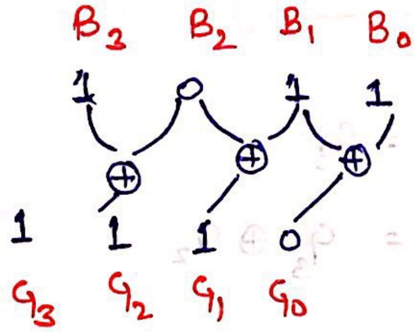


$G_3 = B_3$

$G_2 = B_3 \oplus B_2$

$G_1 = B_2 \oplus B_1$

$G_0 = B_1 \oplus B_0$

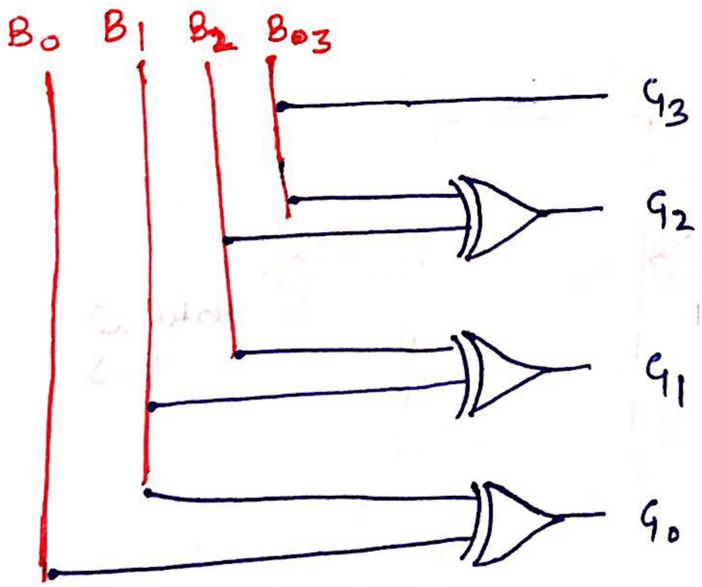


	Binary	Grey
10	1 0 1 0	1 1 1 $\boxed{1}$
11	1 0 1 1	1 1 1 $\boxed{0}$
11	1 0 1 1	1 $\boxed{1}$ 1 0
12	1 1 0 0	1 $\boxed{0}$ 1 0

Any two succeeding binary equivalent Grey code are differ in only 1-bit, that's why they are known as unit distance code or cyclic code or reflecting code.

NOTE:- Grey code is unweighted code.

- Grey codes are used in computer networking for error detection & correction purpose.



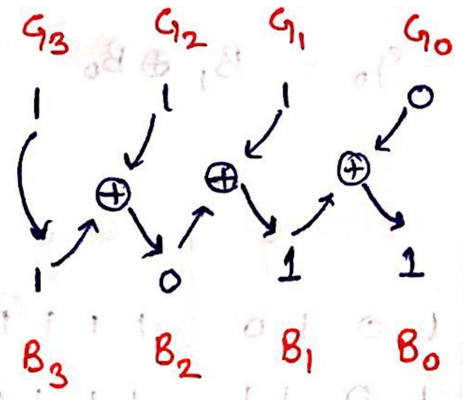
4-Bit Grey to Binary code convertor:-

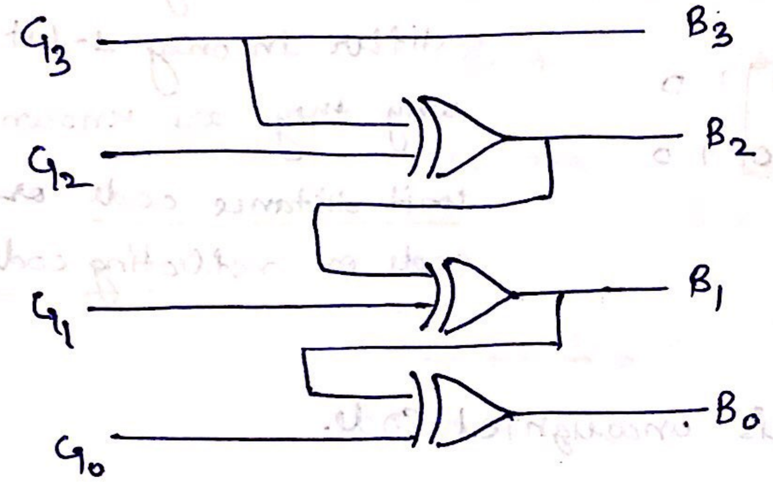
$B_3 = G_3$

$B_2 = G_3 \oplus G_2$

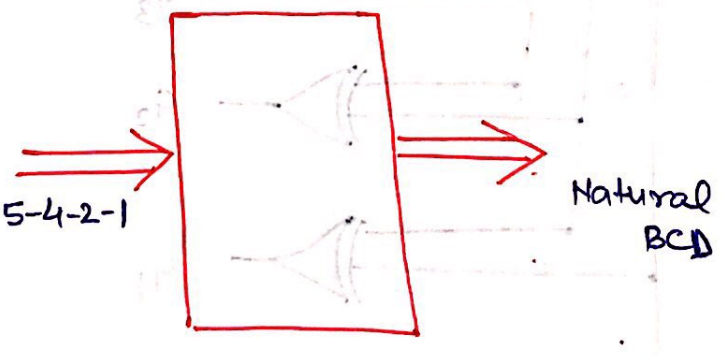
$B_1 = G_3 \oplus G_2 \oplus G_1$

$B_0 = G_3 \oplus G_2 \oplus G_1 \oplus G_0$





5-4-2-1 BCD to Natural BCD :-



$$\begin{array}{cccc} 5 & 4 & 2 & 1 \\ X_3 & X_2 & X_1 & X_0 \end{array} \longrightarrow \begin{array}{cccc} 8 & 4 & 2 & 1 \\ D & C & B & A \end{array}$$

$$5X_3 + 4X_2 + 2X_1 + X_0 = 8D + 4C + 2B + A$$

Truth Table:-

		X_3	X_2	X_1	X_0	D	C	B	A
0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	1	0	0	0	1
2	2	0	0	1	0	0	0	1	0
3	3	0	0	1	1	0	0	1	1
4	4	0	1	0	0	0	1	0	0
8	5	1	0	0	0	0	1	0	1
9	6	1	0	0	1	0	1	1	0
10	7	1	0	1	0	0	1	1	1
11	8	1	0	1	1	1	0	0	0
12	9	1	1	0	0	1	0	0	1

X_3X_2 \ X_1X_0	00	01	11	10
00	(0)	(1)	(3)	(2)
01	(4)	(5) X	(7) X	(6) X
11	(12) 1	(13) X	(15) X	(14) X
10	(8)	(9)	(11) 1	(10)

$$D(X_3, X_2, X_1, X_0) = \Sigma m(11, 12) + d(5, 6, 7, 13, 14, 15)$$

$$D = X_3X_2 + X_3X_1X_0$$

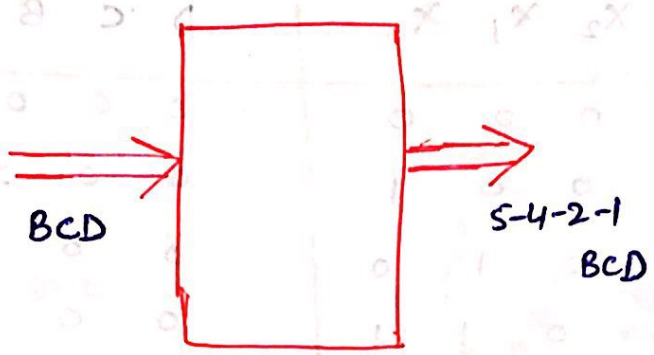
X_3X_2 \ X_1X_0			X_1	
X_2	1	X	X	X
X_3		X	X	X
	1	1		1
		X_0		

$$C = \overline{X_3}X_2 + X_3\overline{X_2}\,\overline{X_1} + X_3\overline{X_2}\,\overline{X_0}$$

$$B = \overline{X_3}X_2 + X_1\overline{X_0}$$

$$A = X_3\overline{X_0} + \overline{X_3}X_0 = X_3 \oplus X_0$$

Natural BCD to 5-4-2-1 code covertor :-



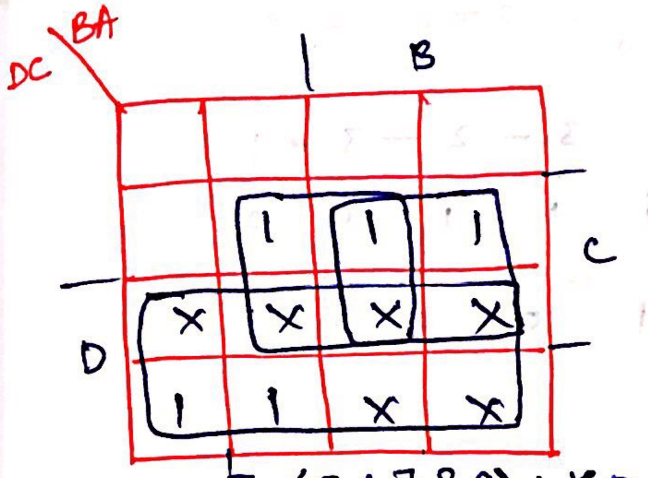
8	4	2	1		5	4	2	1
D	C	B	A	$\longrightarrow$	X_3	X_2	X_1	X_0

$$8D + 4C + 2B + A = 5X_3 + 4X_2 + 2X_1 + X_0$$

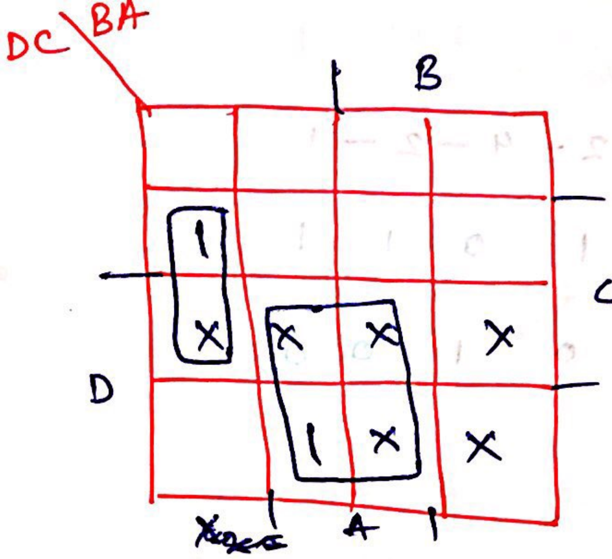
Truth Table :-

	D	C	B	A	X_3	X_2	X_1	X_0
0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1
2	0	0	1	0	0	0	1	0
3	0	0	1	1	0	0	1	1
4	0	1	0	0	0	1	0	0
5	0	1	0	1	1	0	0	0
6	0	1	1	0	1	0	0	1
7	0	1	1	1	1	0	1	0
8	1	0	0	0	1	0	1	1
9	1	0	0	1	1	1	0	0

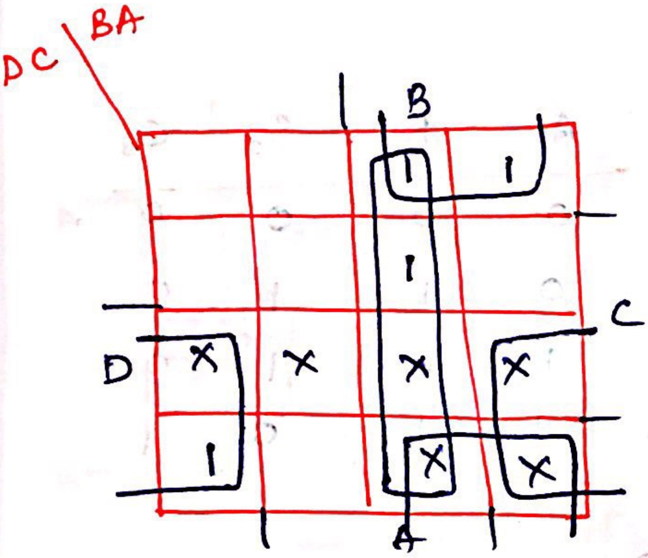
$$Q = d(10, 11, 12, 13, 14, 15)$$



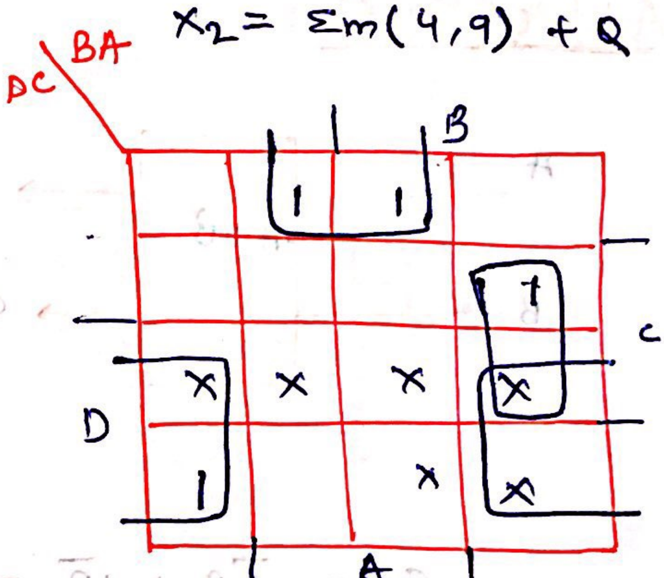
$X_3 = \Sigma m(5,6,7,8,9) + Q$



$X_2 = \Sigma m(4,9) + Q$



$X_1 = \Sigma m(2,3,7,8) + Q$



$X_0 = \Sigma m(1,3,6,8) + Q$

$$X_3 = D + AC + BC$$

$$X_2 = AD + C\bar{B}\bar{A}$$

$$X_1 = CBA + D\bar{A} + B\bar{C}$$

$$X_0 = D\bar{A} + \bar{D}\bar{C}A + CB\bar{A}$$

NOTE:- when the sum of the weight of a BCD code equals to 9. Such BCD code is name as self complimentary codes

$2+4+2+1 = 9$

$2 - 4 - 2 - 1$

5	1	0	1	1
4	0	1	0	0

9's

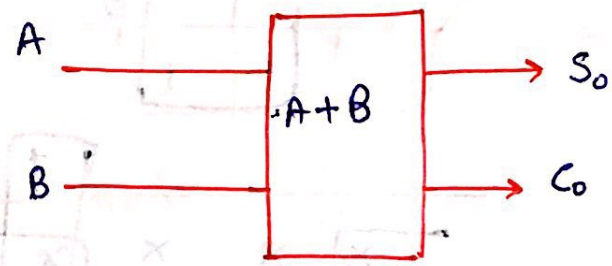
$3+2+3+1 = 9$

$3 - 2 - 3 - 1$

5	1	1	0	0
4	0	0	1	1

9's

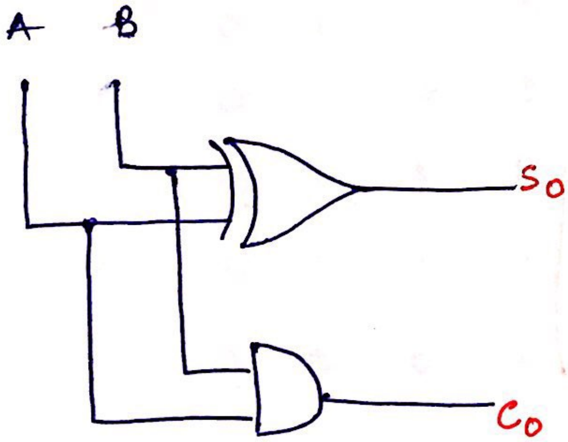
Adder (Half) :-

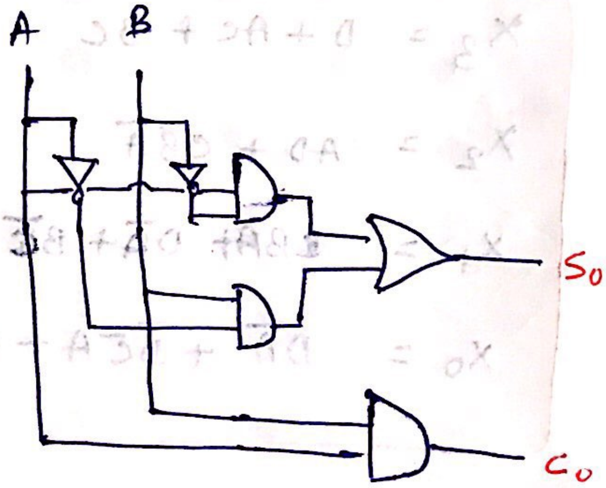


A	B	S_o	C_o
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

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

$$C_o = AB$$



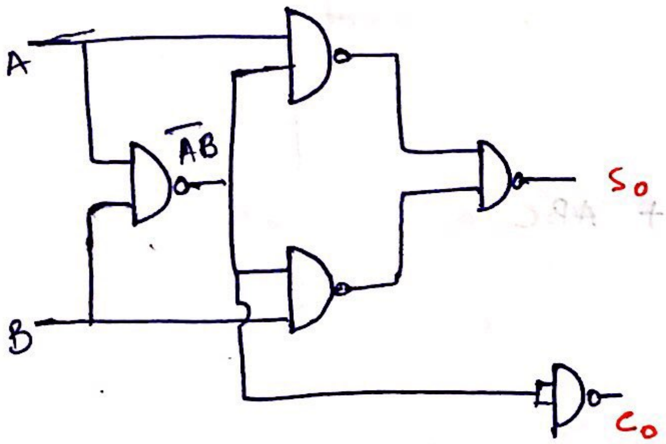


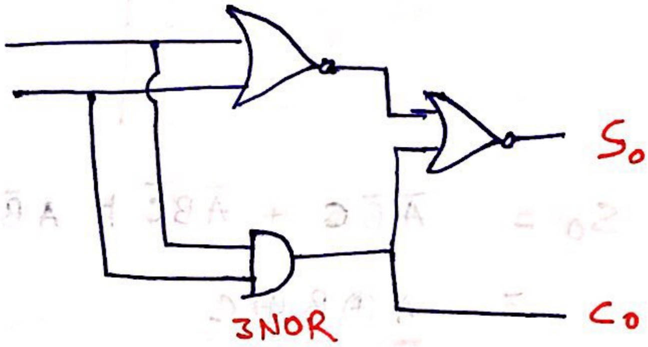
Q. Minimum no. of NAND & NOR gates required to realize half-adder?

(a) 3, 4 (b) 4, 3 (c) 4, 4, (d) 5, 5 ✓

NAND

NOR





$$S_o = A \oplus B$$

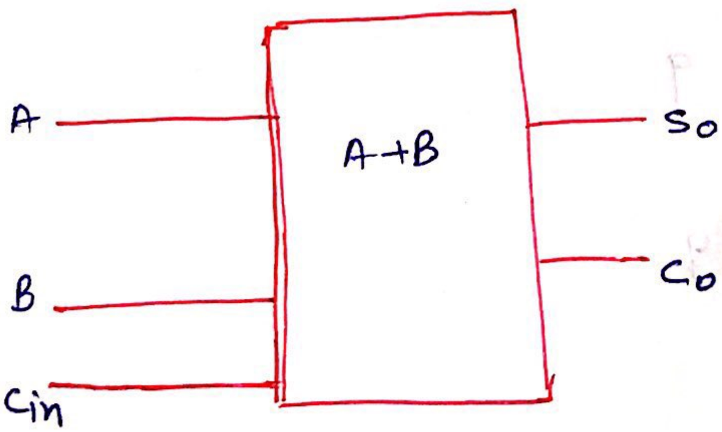
$$= \overline{A \odot B}$$

$$= \overline{AB + \bar{A}\bar{B}}$$

$$\quad X \qquad Y$$

$$= \overline{X + Y}$$

Full Adder :-



A	B	C	S_o	C_o
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

$$S_o = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$

$$= \underline{A \oplus B \oplus C}$$

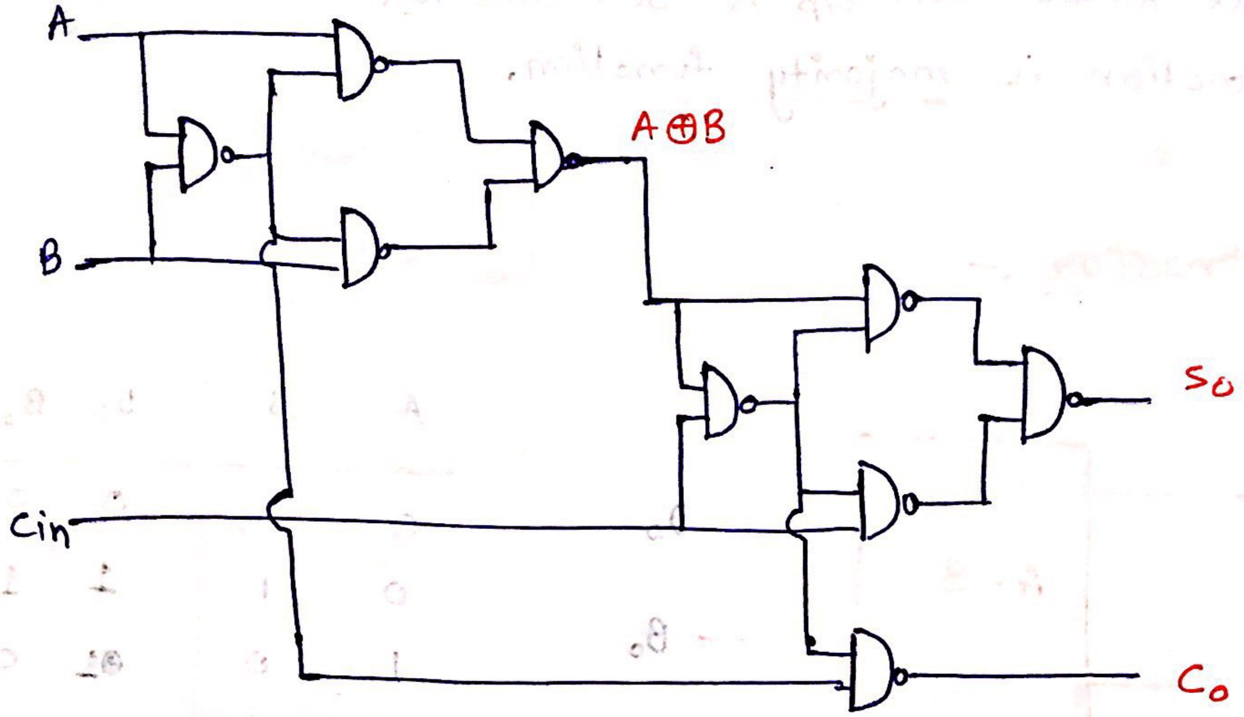
$$C_o = \bar{A}BC + A\bar{B}C + AB\bar{C} + ABC$$

$$= \underline{AB + BC + AC}$$

$$= \underline{C(A \oplus B) + AB}$$

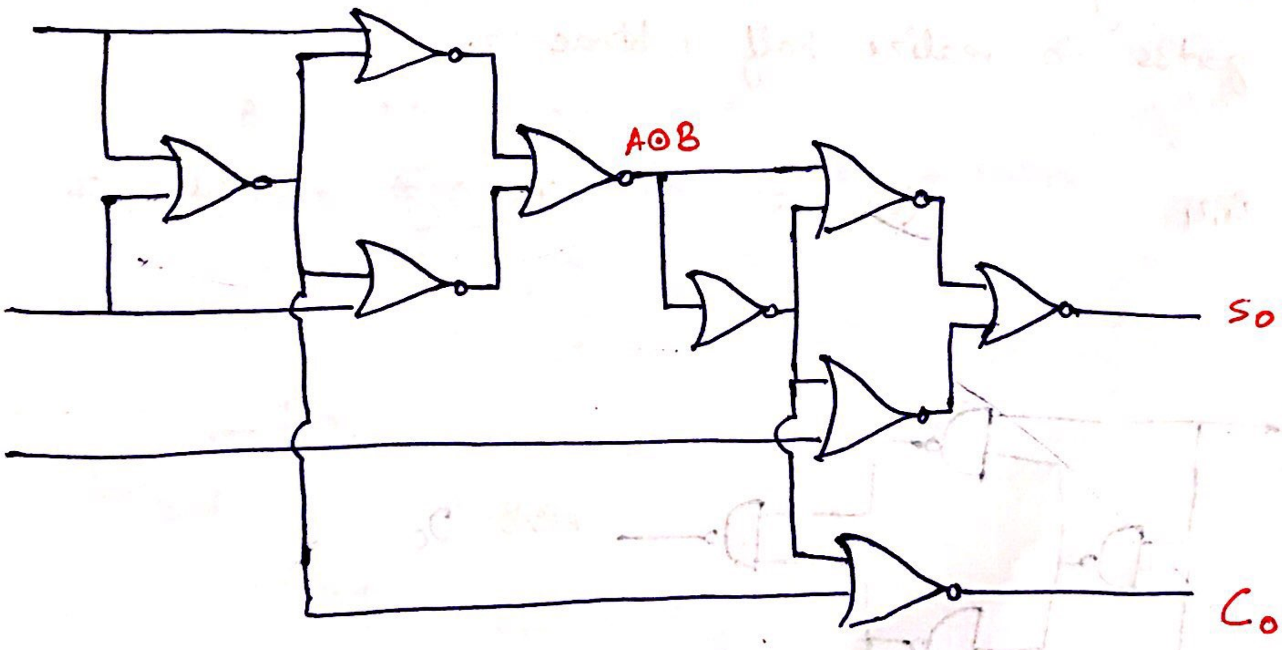
The minimum number of 2-I/p NAND & NOR gates required to realize full adder -

$$\boxed{\begin{aligned} \text{NAND} &= 9 \\ \text{NOR} &= 9 \end{aligned}}$$



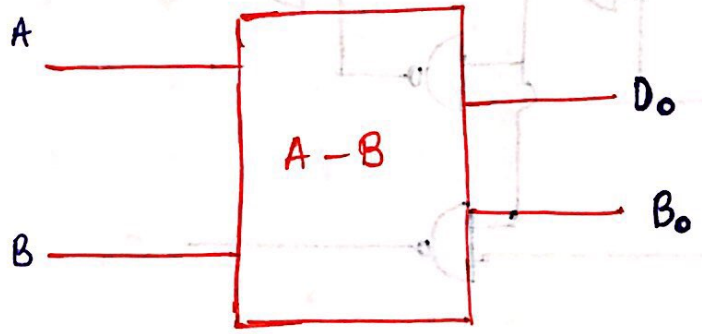
$$C_o = C_{in}(A \oplus B) + AB$$

$$= \overline{\overline{AB} \cdot \overline{C_{in}(A \oplus B)}}$$



- Full Adder SUM o/p is odd function and carry function is majority function.

Half Subtractor :-

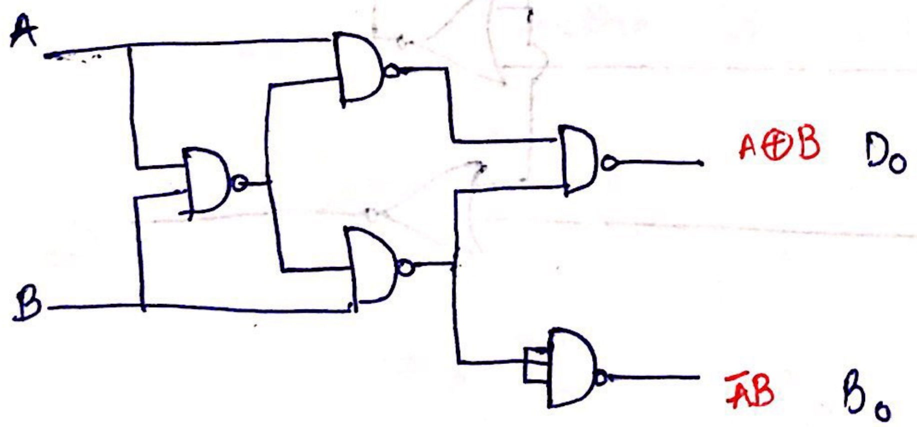


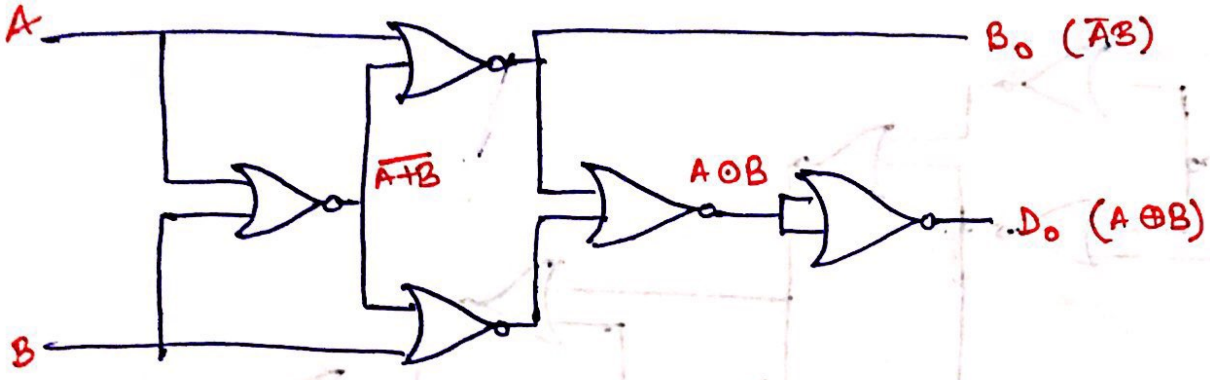
A	B	D_o	B_o
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

$$\boxed{\begin{aligned} D_o &= A \oplus B \\ B_o &= \bar{A}B \end{aligned}}$$

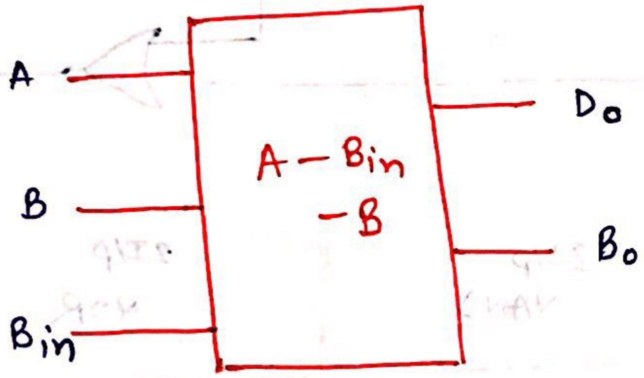
Q. Identify the minimum no. of two input NAND or NOR gates to realize half subtractor.

(a) 4,4 (b) 5,5 (c) 6,7 (d) 7,7





Full Subtractor :-



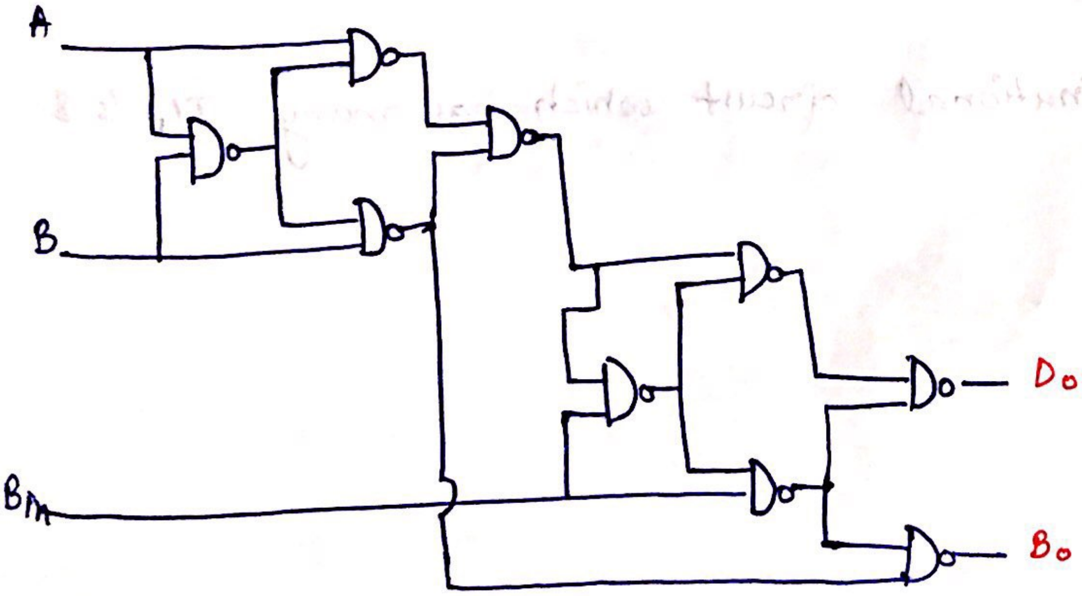
A	B	B_{in}	D_o	B_o
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

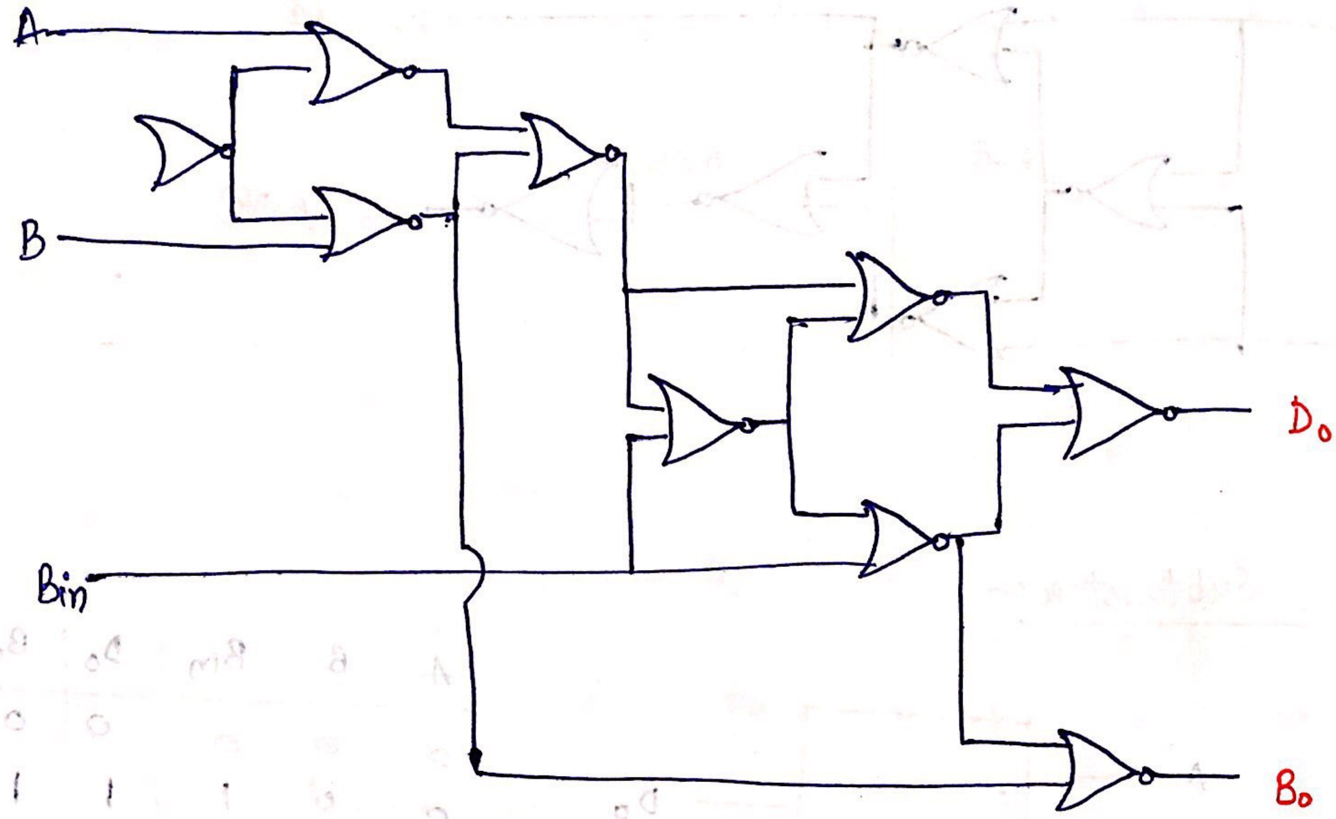
$$D_o = A \oplus B \oplus B_{in}$$

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

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

$$B_o = (\overline{A \oplus B})B_{in} + \bar{A}B$$

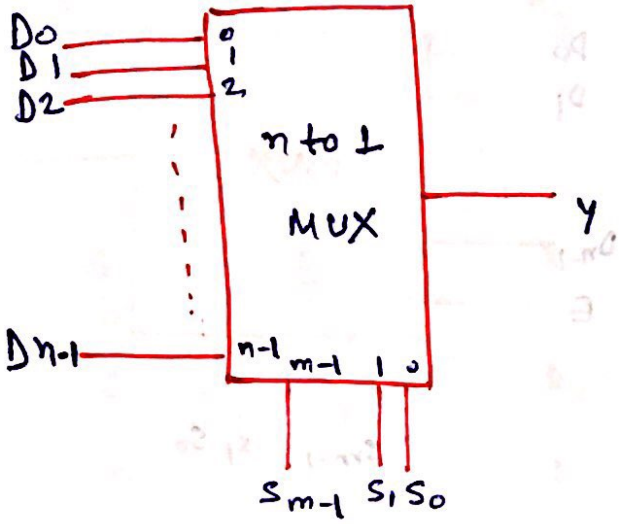




	2I/p NAND	2I/p NOR
Half Adder/Substractor	5	5
Full Adder/substractor	9	9

Multiplexer :-

It is a combinational circuit which has many I/p's & single output.



$(2^m \geq n)$

$\left.\begin{array}{l} 2\times1 \\ 2:1 \end{array}\right\} S_0$

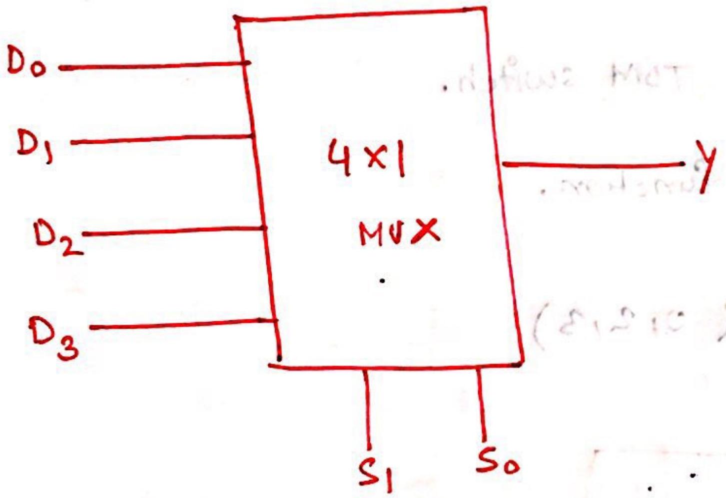
4×1 — S_0, S_1

8 to 1 — S_0, S_1, S_2

10×1 — S_0, S_1, S_2, S_3

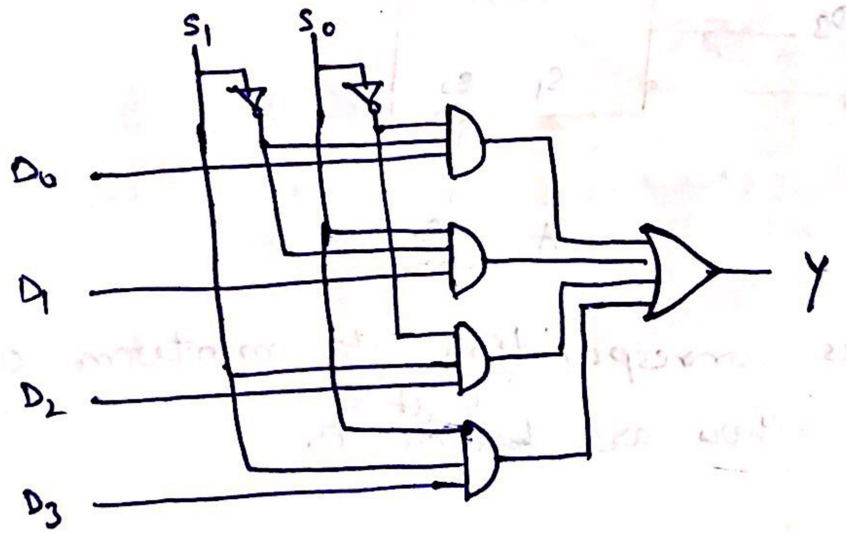
16 to 1 — S_0, S_1, S_2, S_3

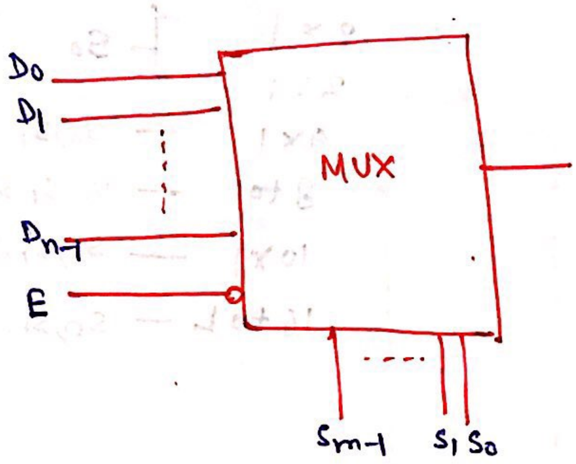
4 × 1 MUX:-



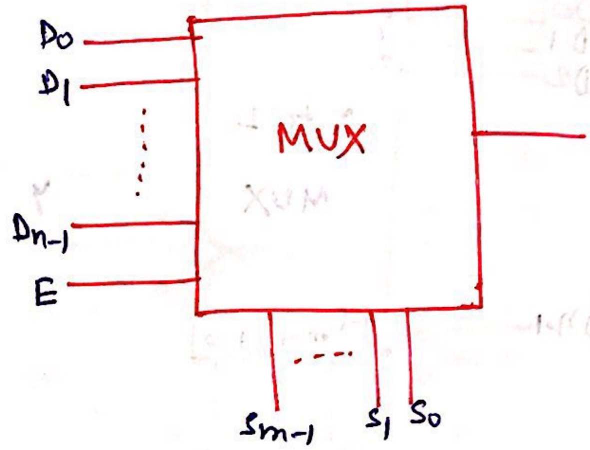
S_1	S_0	Y
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3

$$Y = \bar{S_1}\bar{S_0}D_0 + \bar{S_1}S_0D_1 + S_1\bar{S_0}D_2 + S_1S_0D_3$$





(Active-Low)

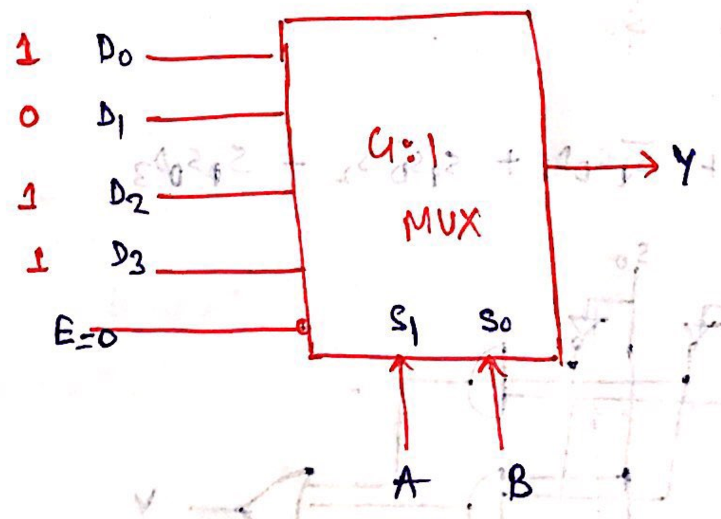


(Active-High)

Application :-

- It is possible to convert parallel data to serial form.
- It is possible to use as TDM switch.
- Use for realizing boolean function.

$$f(A,B) = \Sigma m(0,2,3)$$



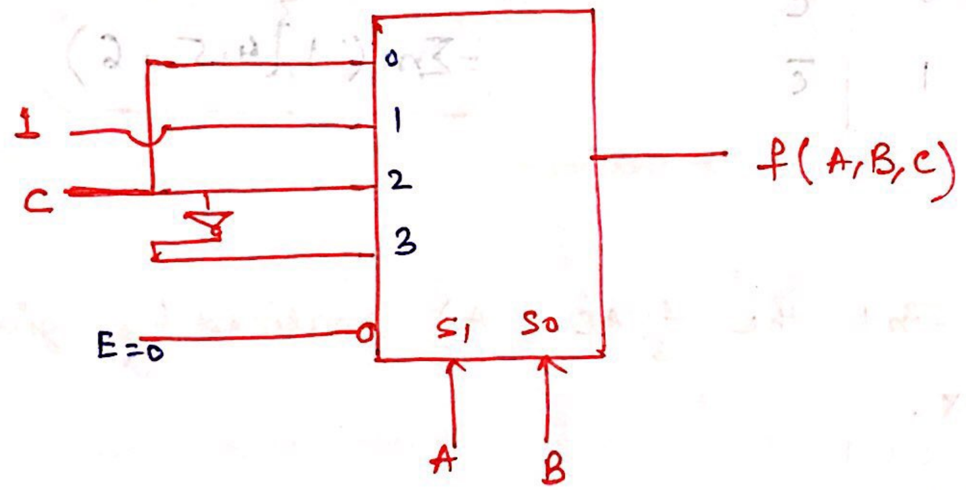
Input lines corresponding to minterm are 1 and others are ~~become~~ set to 0.

So, $D_0 = D_2 = D_3 = 1$

$D_1 = 0$

A S_1	B S_0	Y
0	0	D_0 (1)
0	1	D_1 (0)
1	0	D_2 (1)
1	1	D_3 (1)

Q. Find the funcn $f_1(A,B,C)$ which is realized by ~~with~~ the given 4x1 MUX.

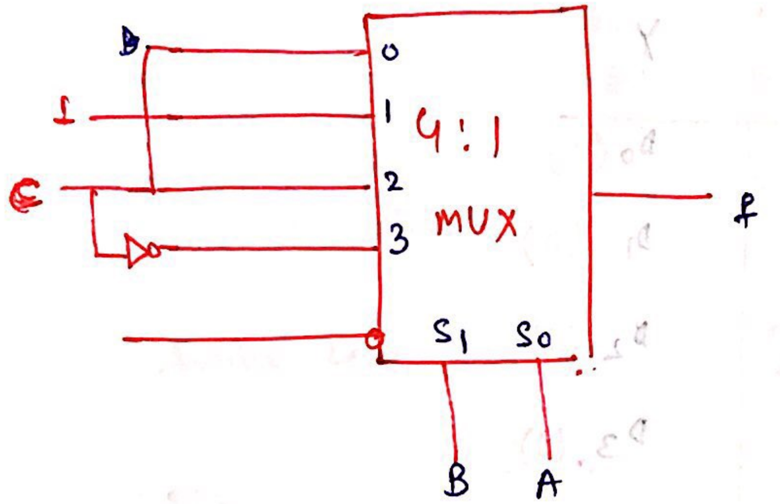


A	B	Y ~~f(A~~.
0	0	D_0 (C)
0	1	D_1 (1)
1	0	D_2 (C)
1	1	D_3 ($\bar{C}$)

$Y = \bar{A}\bar{B}C + \bar{A}B + A\bar{B}C + AB\bar{C}$

$$\boxed{f(A,B,C) = \Sigma m(1,2,3,5,6)}$$

Q. Find the function $f_2(A,B,C)$ realized by the given 4:1 MUX.

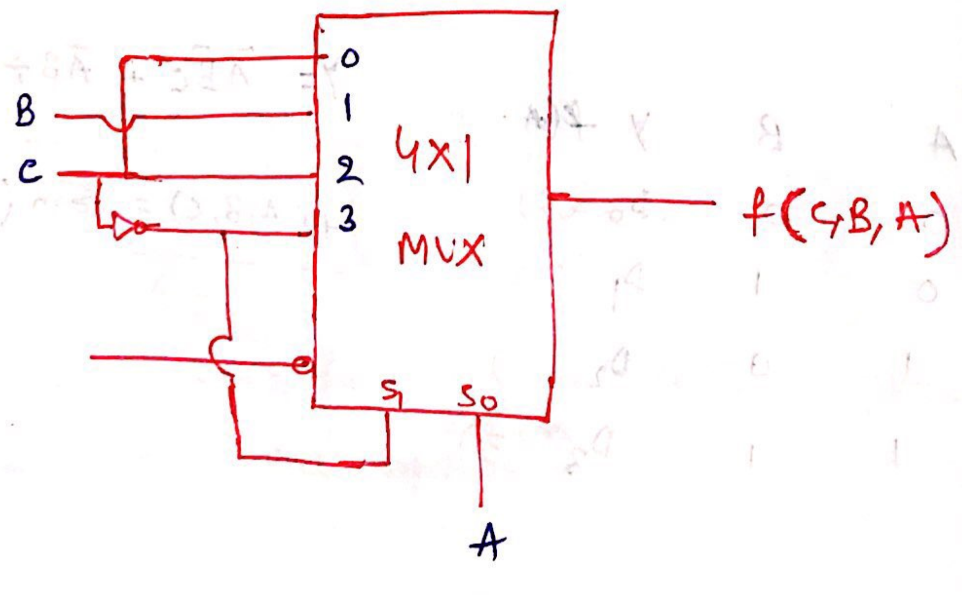


B (S_1)	A (S_0)	Y
0	0	C
0	1	1
1	0	C
1	1	$\bar{C}$

$$f(A,B,C) = \bar{A}\bar{B}C + A\bar{B} + \bar{A}BC + AB\bar{C}$$

$$= \Sigma m(1, 3, 4, 5, 6)$$

Q. Find the $f_3(AC, B, A)$ realized by given MUX.



S_1	S_0	Y	
$\overline{C}$	A		
0	0	D_0	C
0	1	D_1	B
1	0	D_2	C
1	1	D_3	$\overline{C}$

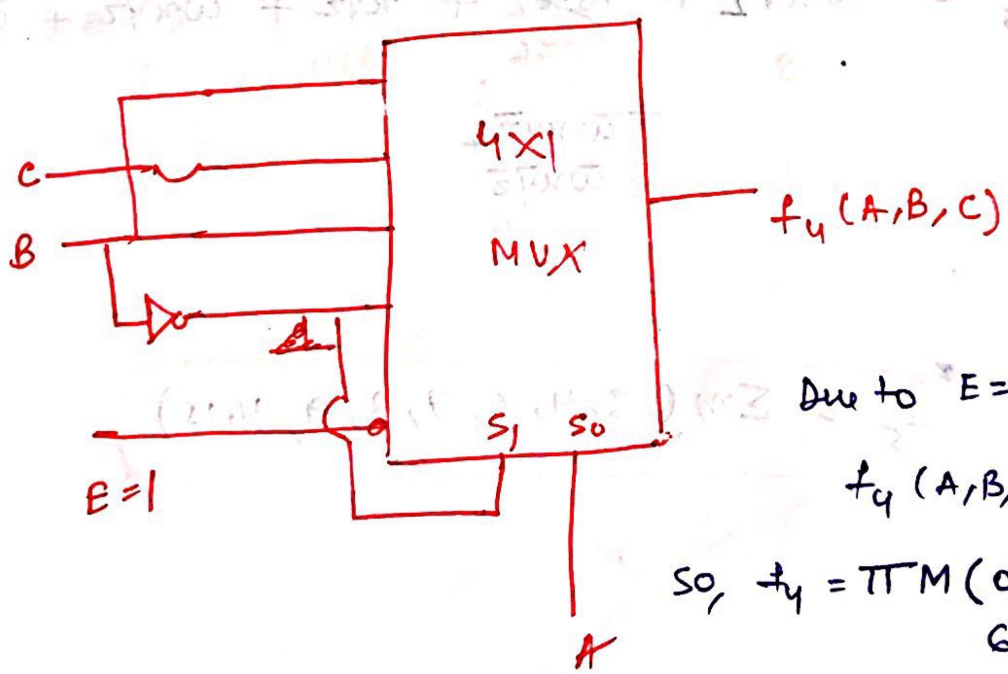
$$f' = C\overline{A}C + CAB + \overline{C}\overline{A}C + \overline{C}A\overline{C}$$

$$= \underset{4,6}{C\overline{A}} + \underset{7}{\overset{CBA}{\cancel{CAB}}} + 0 + \underset{0}{\overline{C}A}$$

$$= \underset{6}{CB\overline{A}} + \underset{4}{C\overline{B}\overline{A}} + \underset{7}{CBA} + \underset{3}{\overline{C}BA} + \underset{1}{\overline{C}\overline{B}A}$$

$$\boxed{f(C,B,A) = \Sigma m(1,3,4,6,7)}$$

Q. Find the $f_4(A,B,C)$ realized by given MUX.

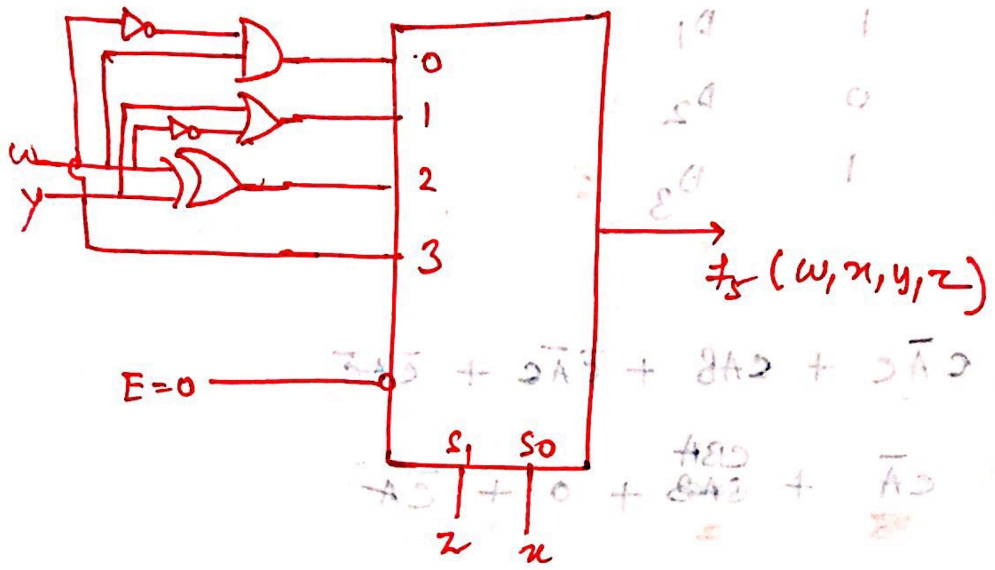


Due to E=1

$f_4(A,B,C) = 0$

So, $f_4 = \Pi M(0,1,2,3,4,5,6,7)$.

Q: Find the func^n $f_5(w,x,y,z)$



$D_0 = w\bar{y}$

$D_1 = \bar{w} + y$

$D_2 = w \oplus y$

$D_3 = y$

$f_5 = \bar{s}_1\bar{s}_0 D_0 + \bar{s}_1 s_0 D_1 + s_1\bar{s}_0 D_2 + s_1 s_0 D_3$

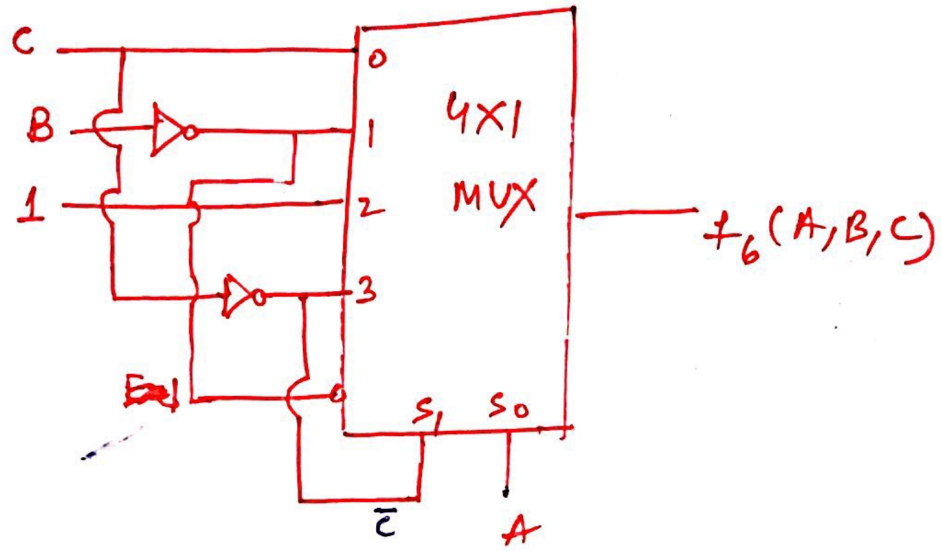
$= \bar{z}\bar{x}w\bar{y} + \bar{z}x(\bar{w}+y) + z\bar{x}(w\bar{y}+\bar{w}y) + zxy$

$$\begin{array}{ccccccccccc} & & & \cancel{0101} & & 0110 & & & & & \\ & & & \cancel{0100} & & 1110 & & & & & \\ f_5 & = & w\bar{x}\bar{y}\bar{z} + & \cancel{\bar{w}x\bar{z}} + & & xy\bar{z} + & & w\bar{x}\bar{y}z + & & \bar{w}\bar{x}yz & \\ & & 8 & \cancel{546} & & 614 & & 9 & & 3 & \end{array}$$

$+ \bar{w}xy\bar{z}$ (6) $+ \bar{w}x\bar{y}\bar{z}$ (4) $+ wxyz$ (15) $+ \bar{w}xyz$ (7)

$$\boxed{f_5 = \Sigma m(3,4,6,7,8,9,14,15)}$$

Q. Find funcⁿ $f_6(A, B, C)$



$$f_6 = \left[\bar{S}_1\bar{S}_0 D_0 + \bar{S}_1 S_0 D_1 + S_1\bar{S}_0 D_2 + S_1 S_0 D_3\right]\bar{B}$$

$$= \left[\bar{C}\bar{A}C + CA\bar{B} + \bar{C}\bar{A}(1) + \bar{C}A\bar{C}\right]\bar{B}$$

$$= \left[\cancel{\bar{A}BC} + \bar{A}\bar{B}C + \cancel{A\bar{B}C} + \cancel{\bar{A}B\bar{C}} + \bar{A}\bar{B}\bar{C} + \cancel{AB\bar{C}} + \cancel{A\bar{B}\bar{C}}\right]\bar{B}$$

$$= \bar{A}\bar{B}C + A\bar{B}C + \bar{A}\bar{B}\bar{C} + A\bar{B}\bar{C}$$

$$= \Sigma m(0, 1, 4, 5)$$

$$= \overset{3}{\bar{A}BC} + \overset{2}{\bar{A}B\bar{C}} + \overset{6}{AB\bar{C}}$$

$$= \underline{\Sigma m(2, 3, 6)}$$