Representation of signed number

Binary number can be positive or negative.

Symbol '+' is used to represent positive number.

Symbol '−' is used to represent the negative number.

For representing signed number there are two methods.
1. Sign magnitude form
2. Complement form

Sign Magnitude form

To represent sign magnitude form there is two parts.
1. Sign part
2. Magnitude part

$$\underset{\text{Sign bit}}{0}\;\;\underbrace{\overset{\text{MSB}}{1}\;0\;1\;0\;1\;\overset{\text{LSB}}{1}}_{\text{Magnitude}}$$

1 → Negative Number
0 → positive Number

Q. Represent (−42) using sign magnitude representation.

2	42	
2	21	0
2	10	1
2	5	0
2	2	1
2	1	0
	0	1

$(42)_{10} \rightarrow (101010)_2$

sign bit

$+42 \longrightarrow 0\ 101010$

$-42 \longrightarrow 1\ 101010$

sign bit

Q. Represent $(-124)_{10}$ to its equivalent sign magnitude form

2	124	
2	62	0
2	31	0
2	15	1
2	7	1
2	3	1
2	1	1
	0	1

$(124)_{10} \rightarrow (1111100)_2$

$+124 \rightarrow (01111100)_2$

$-124 \rightarrow 11111100$

Representation of signed number using 1's complement or 2's complement

The main advantage of using complement method is the reduction in hardware.

Secondly, they allow the representation of negative numbers.
for performing binary subtraction, use 1's complement & 2's complement.

1's complement of binary Number.

1's complement of binary number is obtained by complementing every bit of the number.

0 changed to 1
1 changed to 0

1 0 1 0 0 1 0 1
1's complement of this number is

0 1 0 1 1 0 1 0

① 10100110
② 110010
③ $(54)_{10}$
④ $(136)_{10}$

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2's complement method.

2's complement = 1's complement + 1

Number is
0 0 1 0 1 1 0 1
Calculate 2's complement of this no.

2's complement = 1's complement + 1

1's complement = 1 1 0 1 0 0 1 0
+ 1
1 1 0 1 0 0 1 1

① $(74)_{10}$
② $(236)_{10}$

Binary Subtraction using 1's complement

① Take 1's complement of 2nd number.

② Add two numbers.

③ If carry over is generated, Add this carry with result.

④ If MSB = 0 result is positive & in its true binary form.

⑤ If MSB = 1 result is negative & in its 1's complement form.

1 0 1 1 – (11)
+ 0 1 1 0 – (6)
$\boxed{1}$ 0 0 0 1

① 110101 − 100101

1's complement = 011010

$$\begin{array}{r} \ 1\,1\,0\,1\,0\,1 \\ +\ 0\,1\,1\,0\,1\,0 \\ \hline \boxed{1}\ 0\,0\,1\,1\,1\,1 \end{array}$$

↑ MSB

$$\begin{array}{r} 0\,0\,1\,1\,1\,1 \\ +\ 1 \\ \hline 0\,1\,0\,0\,0\,0 \end{array}$$

The difference is (10000)

② 101011 − 111001

1's complement of 111001 → 000110

$$\begin{array}{r} \ 1\,0\,1\,0\,1\,1 \\ +\ 0\,0\,0\,1\,1\,0 \\ \hline \boxed{0}\ 1\,1\,0\,0\,0\,1 \end{array}$$

↑ MSB

The difference is → (−110001)

1's complement → (−001110)

③ 1011.001 − 110.10

0110.100

1's complement of number is 1001.011

$$
\begin{array}{r}
1011.001 \\
+\ 1001.011 \\
\hline
\boxed{1}\ 0100.100
\end{array}
$$

$$
\begin{array}{r}
0100.100 \\
+\ \quad\quad 1 \\
\hline
0100.101
\end{array}
$$

The difference is 100.101

④ 10110.01 − 11010.10

1's complement of No. 11010.10

00101.01

$$
\begin{array}{r}
10110.01 \\
+\ 00101.01 \\
\hline
11011.10
\end{array}
$$

The difference is −(11011.10)

1's complement = −(00100.00)

① $12 - 8$

$12 \rightarrow 1100$

$8 \rightarrow 1000$

1's complement of 8 → 0111

	1				Carry
	1	1	0	0	A
+	0	1	1	1	B
$\boxed{1}$	0	0	1	1	Sum

$$
\begin{array}{rcccc}
 & & & 1 & 1 \\
 & 0 & 0 & 1 & 1 \\
+ & & & & 1 \\
\hline
 & 0 & 1 & 0 & 0
\end{array}
$$

The difference is +4

② $8 - 12$

$8 \rightarrow 1000$

$12 \rightarrow 1100$

1's complement of 12 → 0011

$$
\begin{array}{rcccc}
 & 1 & 0 & 0 & 0 \\
+ & 0 & 0 & 1 & 1 \\
\hline
\boxed{0} & 1 & 0 & 1 & 1
\end{array}
$$

1's complement of result → 0100

The difference is → $(-4)_{10}$

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Binary subtraction (2's complement)

1. Take 2's complement of second number.

2. Add two numbers.

3. If carry over is generated ignore the carry.

4. If MSB = 1 Result is negative & in its 2's complement form.

5. If MSB = 0 Result is positive & in it's true Binary form.

Binary Subtraction using 2's complement

① 10110 − 11010

1st Number → 10110

2nd Number → 11010

1's complement of 2nd No → 00101

$$\begin{array}{r} 00101 \\ +\ \ \ \ 1 \\ \hline 00110 \end{array}$$

Addition

$$\begin{array}{r} 10110 \\ +\ 00110 \\ \hline \boxed{1}\,1100 \end{array}$$

MSB = 1 Result is negative & its 2's complement form

Result is → 1100

2's complement of Result → 0011

$$\begin{array}{r} 0011 \\ +\ \ \ 1 \\ \hline 0100 \end{array}$$

The difference is (−100)

(2) 110110 − 10110

1st Number → 110110
2nd Number → 010110
2's complement of 2nd No → 101001
+ 1

101010

Addition :

$$\begin{array}{r} 1\,1\,0\,1\,1\,0 \\ +\;1\,0\,1\,0\,1\,0 \\ \hline \boxed{1}\,1\,0\,0\,0\,0\,0 \end{array}$$

ignore MSB

MSB = 1 Result is Negative & its 2's complement form

Result → 011111
+ 1

100000

(3) 1010.11 − 1001.01 → 1.10

(3) 10100.01 − 11011.10

(4) $(27)_{10} - (32)_{10}$

2	27	
2	13	1
2	6	1
2	3	0
2	1	1
	0	1 ↑

2	32	
2	16	0
2	8	0
2	4	0
2	2	0
2	1	0 ↑
	0	1

$(11011)_2$ $(100000)_2$

(1) ⟶ 011011

(2) ⟶ 100000

011111

\+ 1

100000

  0 1 1 0 1 1
\+ 1 0 0 0 0 0
  1 1 1 0 1 1
  ↑

MSB = 1 Result is negative & is in it's 2's complement form

2's complement → 000100
\+ 1
000101

$(5)_{10}$

Logic Minimization

Uncomplemented -

Complemented -

Complement
complement mean negate the Number.

$0 \rightarrow 1$

$1 \rightarrow 0$

$A \rightarrow \bar{A}$

$B \rightarrow \bar{B}$

Uncomplemented - A, B, C

Complemented - $\bar{A}, \bar{B}, \bar{C}$

Standard / Canonical Form

The canonical form are basic forms of expressing function in Boolean algebra.

In the canonical form every term consist of all the input variables in either complemented form or uncomplemented form.

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

$$Y = (A+B+C)(\bar{A}+B+\bar{C})(A+\bar{B}+\bar{C})(\bar{A}+B+C)$$

Minterm:

Each individual product term is called Minterm.

e.g.

ABC

$\bar{A}BC$

$A\bar{B}C$

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

Maxterm.

Each individual sum term is called Maxterm.

e.g.

$A+B+C$

$\bar{A}+B+C$

$A+\bar{B}+C$

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

Minterm & Maxterm for two binary variables

Variable		Minterm		Maxterm	
A	B	Term	Representation	Term	Representation
0	0	$\bar{A}\bar{B}$	m_0	$\cancel{\bar{A}+\bar{B}}$ $A+B$	M_0
0	1	$\bar{A}B$	m_1	$\cancel{\bar{A}+B}$ $A+\bar{B}$	M_1
1	0	$A\bar{B}$	m_2	$\cancel{A+\bar{B}}$ $\bar{A}+B$	M_2
1	1	AB	m_3	$\cancel{A+B}$ $\bar{A}+\bar{B}$	M_3

Minterm – 0 - Complement, 1 - Uncomplement

Maxterm – 0 Uncomplement, 1 Complement

Minterm & Maxterm for three binary variable

Variable			Minterm		Maxterm	
A	B	C	Term	Representation	Term	Representation
0	0	0	$\bar{A}\bar{B}\bar{C}$	m_0	$A+B+C$ $\cancel{\bar{A}+\bar{B}+\bar{C}}$	M_0
0	0	1	$\bar{A}\bar{B}C$	m_1	$A+B+\bar{C}$ $\cancel{\bar{A}+\bar{B}+C}$	M_1
0	1	0	$\bar{A}B\bar{C}$	m_2	$A+\bar{B}+C$ $\cancel{\bar{A}+B+\bar{C}}$	M_2
0	1	1	$\bar{A}BC$	m_3	$A+\bar{B}+\bar{C}$ $\cancel{\bar{A}+B+C}$	M_3
1	0	0	$A\bar{B}\bar{C}$	m_4	$\bar{A}+B+C$ $\cancel{A+\bar{B}+\bar{C}}$	M_4
1	0	1	$A\bar{B}C$	m_5	$\bar{A}+B+\bar{C}$ $\cancel{A+\bar{B}+C}$	M_5
1	1	0	$AB\bar{C}$	m_6	$\bar{A}+\bar{B}+C$ $\cancel{A+B+\bar{C}}$	M_6
1	1	1	ABC	m_7	$\bar{A}+\bar{B}+\bar{C}$ $\cancel{A+B+C}$	M_7

Write a Minterm & Maxterm

Q $F_1 = \bar{A}\bar{B}\bar{C} + \bar{A}BC + A\bar{B}C$

$= 000 + 011 + 101$

$F_1 = m_0 + m_3 + m_5$

Q $F_1 = (A+B+\bar{C}) \cdot (A+\bar{B}+C) \cdot (\bar{A}+B+C)$

$= (0+0+0) \cdot (0+1+0)(1+0+0)$

$= \cancel{M_0 \cdot M_2 \cdot M_4}$ $M_1 \cdot M_2 \cdot M_4$

Q $F_1 = (A+B+C)(A+B+\bar{C})(A+\bar{B}+C)(\bar{A}+B+\bar{C})$

$= (1+1+1)(1+1+0)(1+0+1)(0+1+0)$

$= \cancel{M_7 \cdot M_6 \cdot M_5 \cdot M_2}$ $M_0 \cdot M_1 \cdot M_2 \cdot M_5$

Q $F_1 = \bar{A}\bar{B}C + \bar{A}BC + A\bar{B}\bar{C} + AB\bar{C}$

$= 001 + 011 + 100 + 110$

$= m_1 + m_3 + m_4 + m_6$

Boolean expression can be expressed in the two standard form

1. Sum of Products (SOP)
2. Product of Sums (POS)

Sum of Products Form (SOP)

The sum of product is a type of Boolean expression that consists of AND term (product term) that are ORed together.

Every SOP expression consist of two or more AND (product) term that are ORed together.

Each product term has variable that are in normal or complemented form.

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

Σ – symbolic representation of SOP.

$$Y = AB + B\bar{C}D + AC$$

m_0, is m_1, m_2 used for SOP.

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Product of sum (POS)

The product of sum is a Boolean expression that consists of OR terms (sum terms) that are ANDed together.

Every sum term has variable that are in normal or complemented form

$$Y = (A+B+C)\cdot(A+\bar{B})\,(\bar{B}+\bar{C})$$

$\prod$ - symbolic representation of Product of sum

Standard SOP & POS forms

Standard SOP form

If every product term contains all variables in complemented or uncomplemented form called standard SOP form

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

Standard SOP form is also called standard minterm form.

Standard POS form

If every sum term contains all the variables in complemented or uncomplemented form then it is called standard POS form

$$Y = (\bar{A}+B+C)\cdot(A+\bar{B}+\bar{C})\cdot(A+B+\bar{C})$$

Standard POS form is also called maxterm standard form.

Conversion from Non standard SOP to

Date

Convert the expression $Y = A + BC$ into standard SOP form

Find missing variable in each product term.

$$Y = A + BC$$

BC → Variable A is missing

A → B & C missing.

Step 2

AND missing variable & their complement

$$Y = A(B + \bar{B})(C + \bar{C}) + BC(A + \bar{A})$$

Step 3

$$Y = (AB + A\bar{B})(C + \bar{C}) + ABC + \bar{A}BC$$

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

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

$$111 + 110 + 101 + 100 + 011$$

$$Y = 000 + 000 + 101 + 100 + 011$$

$$= m_7 + m_6 + m_5 + m_4 + m_3$$

$m_7 + m_6 + m_5 + m_4 + m_3$

$$Y = \Sigma(3, 4, 5, 6, 7)$$

$\Sigma m(3, 4, 5, 6, 7)$

Convert the expression in standard SOP form

$Y = AB + BC + AC$

$Y = AB + BC + AC$

C is missing A missing B missing

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

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

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

$= \cancel{0}0111 + 110 + 011 + 101$

$= m_7 + m_6 + m_3 + m_5$

$= m_3 + m_5 + m_6 + m_7$

$Y = \Sigma(3,5,6,7)$

Convert expression in standard SOP

$F_1 = AB + BC$

$F_1 = AB + BC$

C missing A missing

$F_1 = AB(C+\bar{C}) + BC(A+\bar{A})$

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

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

$= 111 + 110 + 011$

$= m_7 + m_6 + m_3$

$F_1 = \Sigma m(3,6,7)$

$F(PQR) = P\bar{Q} + R$

Conversion nonstandard POS to POS

1. Determine the missing variable in each sum term.

2. OR each sum term with missing variable & its complement.

3. Use distributive law & expand the terms.
   $A+BC = (A+B)(A+C)$

4. Simpilify expression excluding the sum term. $(A \cdot A = A)$

Express in standard POS form

$$Y = (A+B)(A+C)(B+\bar{C})$$

Step 1

$$Y = (A+B)\quad (A+C)\quad (B+\bar{C})$$

C is missing B is missing A is missing

Step 2

Y OR the sum term with missing variable

$$Y = [(A+B)+C\bar{C}]\,[(A+C)+B\bar{B}]\,[(B+\bar{C})+A\bar{A}]$$

$$(A+BC) = (A+B)(A+C)$$

$$Y = (A+B+C)(A+B+\bar{C})(A+B+C)(A+\bar{B}+C)(A+B+\bar{C})(\bar{A}+B+\bar{C})$$

$$= (A+B+C)(A+B+\bar{C})(A+\bar{B}+C)(\cancel{A+B+\bar{C}})(\bar{A}+B+\bar{C})$$

$$= (0+1+0)\ (110)\ (101)\ (110)\ (010)$$

$$= M_7 \cdot M_5 \cdot M_3 \cdot M_2 \quad (0+0+0)(0+0+1)(0+1+0)(1+0+1)$$

$$Y = \Pi(7,5,3,2) \qquad M_0\ M_1\ M_2\ M_5$$

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Q Express the expression in standard POS form
$F(A,B,C) = \Sigma m(0,2,5,7)$

$F(A,B,C) = \Sigma m(0,2,5,7)$

Take complement of F

$F'(A,B,C) = \Sigma m(1,3,4,6)$

$= m_1 + m_3 + m_4 + m_6$

Take complement of F.

$F'(A,B,C) = \Pi M(1,3,4,6)$

$= M_1 \cdot M_3 \cdot M_4 \cdot M_6$

$\cdot (001) \cdot (0+1+1) \cdot (1+0+0) \cdot (1+1+0)$

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

Q Express in standard POS form
$F_1 = (A+\bar{B})(B+C)$

$F_1 = [(A+\bar{B})+C\bar{C}]\ [(B+C)+A\bar{A}]$

$A+BC = (A+B)(A+C)$

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

$= (0+1+0)(0+1+1)(0+0+0)+(0+0+0)$

$= M_2 \cdot M_3 \cdot M_0 \cdot M_4$

$= \Pi M(0,2,3,4)$

Q Express given equation in standard POS form
$F(A,B,C) = \Pi M(0,2,5,7)$

$$F(A,B,C) = \Pi M(0,2,5,7)$$
$$= M_0 + M_2 \cdot M_5 \cdot M_7$$
$$= (0+0+0)\cdot(0+1+0)\cdot(1+0+1)\cdot(1+1+1)$$
$$= (A+B+C)\,(A+\bar{B}+C)\,(\bar{A}+B+\bar{C})\,(\bar{A}+\bar{B}+\bar{C})$$

$$F = (A+B+C)\,(A+\bar{B}+C)\,(\bar{A}+B+\bar{C})\,(\bar{A}+\bar{B}+\bar{C})$$

<u>SOP</u>

$$F(A,B,C) = \Pi M(0,2,5,7)$$
$$= \Sigma m(1,3,4,6)$$

K-Map

Karnaugh map is a method used to simplify the algebric expression in Boolean function without having complex theorem.

K-map is a graphical or pictorial method used to simplify Boolean expressions.

This method was invented by E.W. Veitch in 1952, In 1953 M. Karnaugh modified this graphical method of simplification. Hence it is called Karnaugh map.

A Kmaps comprises of boxes/squares called "cells".

Construction of K-map

1 variable Kmap consists of
$2^1 = 2$ cells.

2 Variable Kmap consists of
$2^2 = 4$ cells

3 Variable Kmap consists of
$2^3 = 8$ cells

4 variable K-map consists of
$2^4 = 16$ cells

Kmap for one variable

$2^1 = 2$ cells

A	
0	
1	

$\bar{A}$	0
A	1

$\bar{A}$ 0	A 1

Kmap for two variable

$2^2 = 4$ cell

A\B		
	0	1
	2	3

A\B		
	00	01
	10	11

$\bar{A}\bar{B}$	$\bar{A}B$
$A\bar{B}$	AB

A\B	$\bar{B}$	B
$\bar{A}$	0	1
A	2	3

00	01
10	11

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

A\B	B	$\bar{B}$
A		
$\bar{A}$		

Kmap for 3 variable

$2^3 = 8$ cells

A\BC				
	0	1	3	2
	4	5	7	6

A\BC				
	000	001	011	010
	100	101	111	110

A\BC				
	$\bar{A}\bar{B}\bar{C}$	$\bar{A}\bar{B}C$	$\bar{A}BC$	$\bar{A}B\bar{C}$
	$A\bar{B}\bar{C}$	$A\bar{B}C$	ABC	$AB\bar{C}$

A\BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	0	1	3	2
A	4	5	7	6

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Q Plot the Boolean expression $Y = AB + \bar{A}\bar{B}$ on k-map

$$Y = AB + \bar{A}\bar{B}$$
$$= 11 + 00 = m_3 + m_0$$
$$= \Sigma m(0,3)$$

A \ B	$\bar{B}$	B
$\bar{A}$	1 (0)	(1)
A	(2)	1 (3)

Q Plot the Boolean expression on K-map
$Y = (A+B) \cdot (A+\bar{B})$

$$Y = (A+B)\,(A+\bar{B})$$
$$= (0+0)\quad(0+1)$$
$$= M_0 \cdot M_1$$
$$= \Pi M(0,1)$$
$$= \Sigma m(2,3)$$

A \ B	B	$\bar{B}$
A	0 (0)	0 (1)
$\bar{A}$	1 (2)	1 (3)

Q Plot the Boolean expression on K-map
$Y = \bar{A}\bar{B}\bar{C} + \bar{A}BC + A\bar{B}C + AB\bar{C}$

$$= 000 + 011 + 101 + 110$$
$$= m_0 + m_3 + m_5 + m_6$$
$$= \Sigma m(0,3,5,6)$$

A \ B	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1 (0)	(1)	1 (3)	(2)
A	(4)	1 (5)	(7)	1 (6)

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Q Plot the Boolean expression on Kmap

$$Y = (A+\bar{B}+C)\cdot(A+\bar{B}+\bar{C})\,(A+B+C)\,(A+B+\bar{C})$$
$$= (0+1+0)\,(0+1+0)\,(0+0+0)\,(0+0+1)$$
$$= M_2 \cdot M_3 \cdot M_0 \cdot M_1$$
$$= \prod M(2,3,0,1)$$

A \ B	BC	$B\bar{C}$	$\bar{B}\bar{C}$	$\bar{B}C$
A	0 [0]	0 [1]	0 [3]	0 [2]
$\bar{A}$	1 [4]	1 [5]	1 [7]	1 [6]

Kmap for 4 variable

$2^4 = 16$ cells

AB \ CD				
	0	1	3	2
	4	5	7	6
	12	13	15	14
	8	9	11	10

0000	0001	0011	0010
0100	0101	0111	0110
1100	1101	1111	1110
1000	1001	1011	1010

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	$\bar{A}\bar{B}\bar{C}\bar{D}$	$\bar{A}\bar{B}\bar{C}D$	$\bar{A}\bar{B}CD$	$\bar{A}\bar{B}C\bar{D}$
$\bar{A}B$	$\bar{A}B\bar{C}\bar{D}$	$\bar{A}B\bar{C}D$	$\bar{A}BCD$	$\bar{A}BC\bar{D}$
AB	$AB\bar{C}\bar{D}$	$AB\bar{C}D$	$ABCD$	$ABC\bar{D}$
$A\bar{B}$	$A\bar{B}\bar{C}\bar{D}$	$A\bar{B}\bar{C}D$	$A\bar{B}CD$	$A\bar{B}C\bar{D}$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	0	1	3	2
$\bar{A}B$	4	5	7	6
AB	12	13	15	14
$A\bar{B}$	8	9	11	10

Q Plot the Boolean expression

$$Y = (A+B+C+D)(A+\bar{B}+C+\bar{D})(\bar{A}+\bar{B}+\bar{C}+\bar{D})(\bar{A}+C+B+\bar{D})$$

$$= (0+0+0+0)\ (0+1+0+1)\ (1+1+1+1)\ (1+0+0+1)$$

$$= M_0 \cdot M_5 \cdot M_{15} \cdot M_9$$

$$= \Pi M (0, 5, 9, 15)$$

0 (0)	(1)	(3)	(2)
(4)	0 (5)	(7)	(6)
(12)	(13)	0 (15)	(14)
(8)	0 (9)	(11)	(10)

Q Plot the Boolean expression

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

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

$$= 0100 + 1010 + 1111 + 1100$$

$$= m_4 + m_{10} + m_{15} + m_{12}$$

$$\Sigma m (4, 10, 12, 15)$$

(0)	(1)	(3)	(2)
1 (4)	(5)	(7)	(6)
1 (12)	(13)	1 (15)	(14)
(8)	(9)	(11)	1 (10)

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Grouping

Pair, Quad, Octet, Single

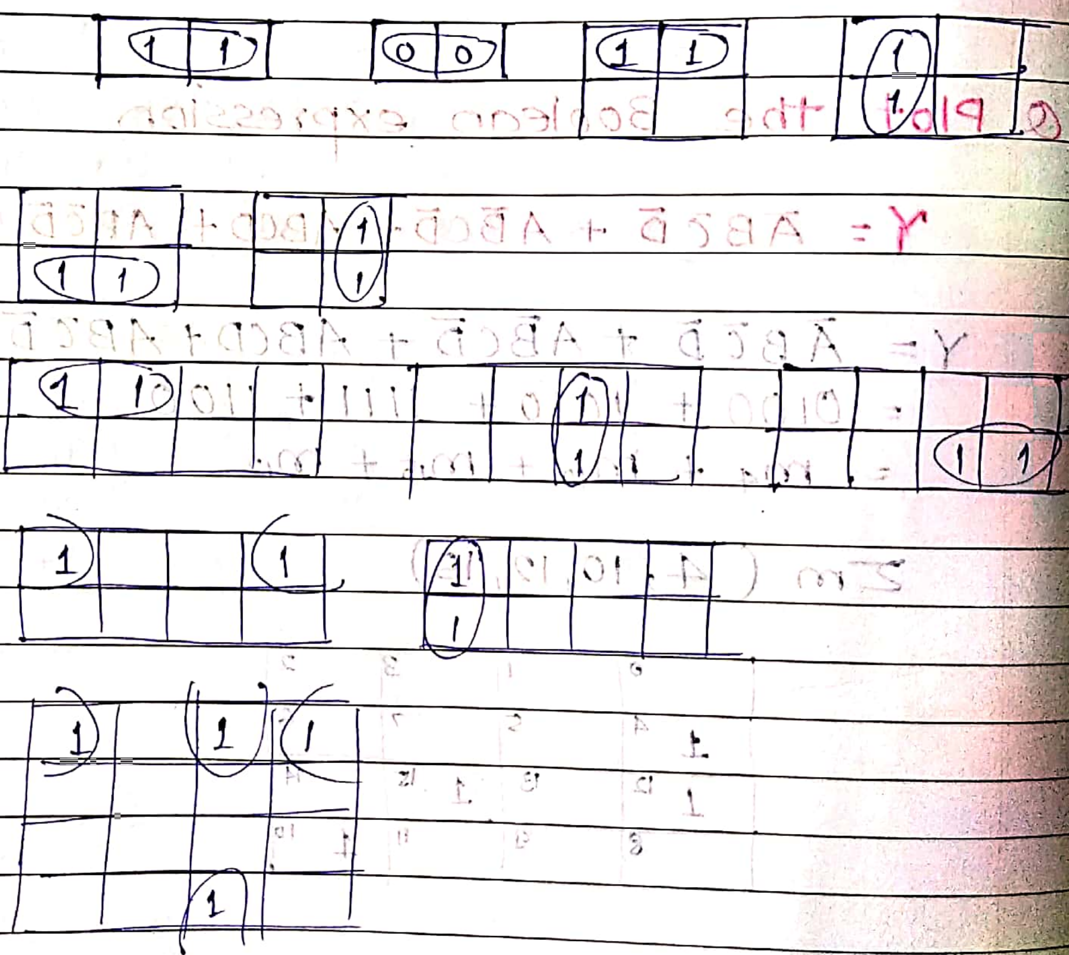
Quad

Single

The single 0 or 1 is comes under the single group.

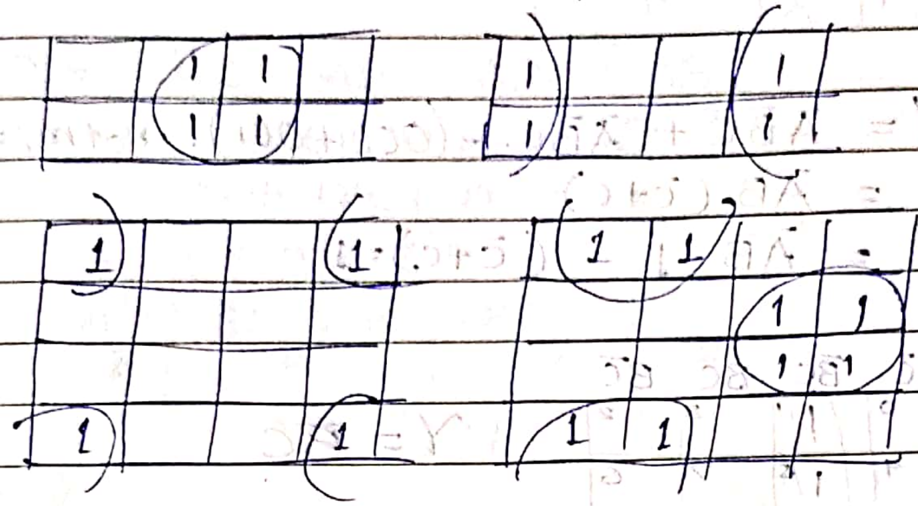
Pair

A group of two adjacent 1's or 0's is called as a pair



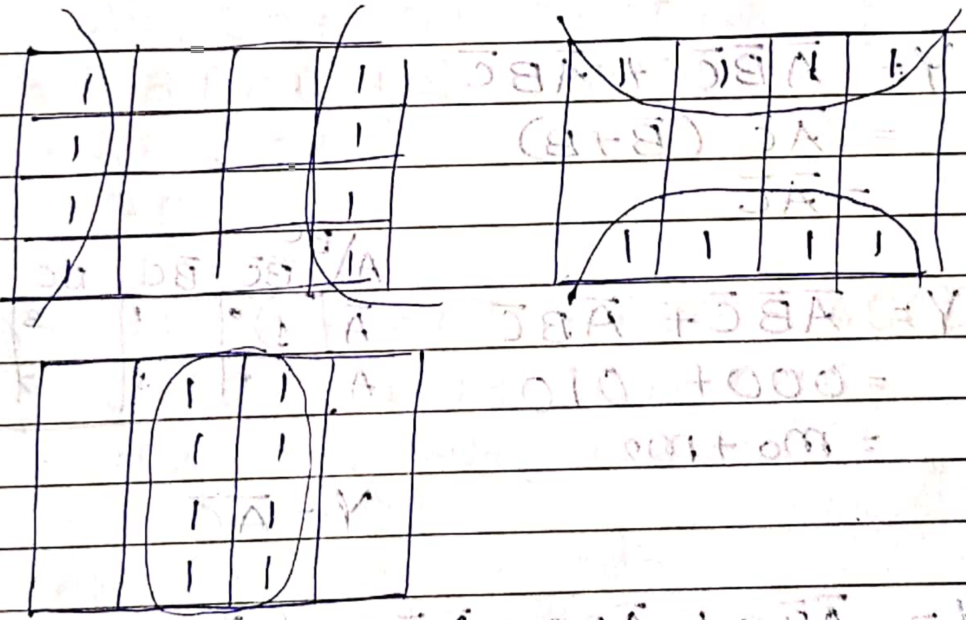
Quad

A group of four adjacent 1's or 0's is called as a quad.



Octate

A group of Eight adjacent 1's or 0's is called as a octate.



(1)

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1		
A				

$Y = \bar{A}\bar{B}$

$Y = \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C = (000 + 001) = m_0 + m_1 = (0,1)$

$= \bar{A}\bar{B}.(\bar{C}+C)$

$= \bar{A}\bar{B} \cdot 1 \quad (\bar{C}+C) = 1$

(2)

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1		
A		1		

$Y = \bar{B}C$

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

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

$= \bar{B}C$

(5) $Y = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C}$

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

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

3 $Y = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C}$

$= 000 + 010$

$= m_0 + m_2$

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1			1
A				

$Y = \bar{A}\bar{C}$

(4) $Y = \bar{A}\bar{B}C + \bar{A}BC + \bar{A}\bar{B}C + A\bar{B}C$

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

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

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1	1	
A		1		

$Y = 001 + 011 + 001 + 101$

$= m_1 + m_3 + m_1 + m_5$

$= (1,3,5)$

$Y =$ (1) $\bar{A}C$ (2) $\bar{B}C$

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

①

$A \backslash BC$	$\bar B\bar C$	$\bar B C$	BC	$B\bar C$
$\bar A$	1 0	1 1	3	2
A	4	5	7	6

$Y = \bar A\bar B$

$Y = \bar A\bar B\bar C + \bar A\bar B C - (000 + 001) : m_0 + m_1 = (0,1)$

$= \bar A\bar B \cdot (\bar C + C)$

$= \bar A\bar B \cdot 1 \quad (\bar C + C) = 1$

②

$A \backslash BC$	$\bar B\bar C$	$\bar B C$	BC	$B\bar C$
$\bar A$	0	1 1	3	2
A	4	1 5	7	6

$Y = \bar B C$

$Y = \bar A\bar B C + A\bar B C$

$= \bar B C(\bar A + A)$

$= \bar B C$

③ $Y = \bar A\bar B\bar C + \bar A B\bar C$

$= \bar A\bar C\,(\bar B + B)$

$= \bar A\bar C$

3 $Y = \bar A\bar B\bar C + \bar A B\bar C$

$= 000 + 010$

$= m_0 + m_2$

$A \backslash BC$	$\bar B\bar C$	$\bar B C$	BC	$B\bar C$
$\bar A$	1 0	1	3	1 2
A	4	5	7	6

$Y = \bar A\bar C$

④ $Y = \bar A\bar B C + \bar A B C + \bar A\bar B C + A\bar B C$

$= \bar A C(\bar B + B) + \bar B C(\bar A + A)$

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

$A \backslash BC$	$\bar B\bar C$	$\bar B C$	BC	$B\bar C$
$\bar A$	0	1 1	1 3	2
A	4	1 5	7	6

$Y = 001 + 011 + 001 + 101$

$= m_1 + m_3 + m_1 + m_5$

$= (1, 3, 5)$

$Y = ①\ \bar A C \quad ②\ \bar B C$

$Y = \bar A C + \bar B C$

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⑤ $Y = \bar{A}\bar{B}C + \bar{A}BC + ABC + AB\bar{C}$

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

$= \bar{A}C + AB$

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

$= 001 + 011 + 111 + 110$

$= m_1 + m_3 + m_7 + m_6$

$= (1,3,6,7)$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	(0)	1 (1)	1 (3)	(2)
A	(4)	(5)	1 (7)	1 (6)

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

⑥ $Y = \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}BCD + \bar{A}BC\bar{D}$

$= \bar{A}B(\bar{C}\bar{D} + \bar{C}D + CD + C\bar{D})$

$= \bar{A}B(\bar{C}(\bar{D}+D) + C(D+\bar{D}))$

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

$= \bar{A}B$

$Y = \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}BCD + \bar{A}BC\bar{D}$

$= 0100 + 0101 + 0111 + 0110$

$= m_4 + m_5 + m_7 + m_6$

$= (4,5,6,7)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	(0)	(1)	(3)	(2)
$\bar{A}B$	1 (4)	1 (5)	1 (7)	1 (6)
AB	(12)	(13)	(15)	(14)
$A\bar{B}$	(8)	(9)	(11)	(10)

$Y = \bar{A}B$

⑦ $Y = \bar{A}B\bar{C}\bar{D} + AB\bar{C}\bar{D} + \bar{A}BC\bar{D} + ABC\bar{D}$

$= 0100 + 1100 + 0110 + 1110$

$= m_4 + m_{12} + m_6 + m_{14}$

$= (4, 6, 12, 14)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	0	1	3	2
$\bar{A}B$	1 (4)	5	7	1 (6)
AB	1 (12)	13	15	1 (14)
$A\bar{B}$	8	9	11	10

$Y = B\bar{D}$

⑧ $\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}C\bar{D} + A\bar{B}\bar{C}\bar{D} + A\bar{B}C\bar{D}$

$= 0000 + 0010 + 1000 + 1010$

$= m_0 + m_2 + m_8 + m_{10}$

$= (0, 2, 8, 10)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1 (0)	1	3	1 (2)
$\bar{A}B$	4	5	7	6
AB	12	13	15	14
$A\bar{B}$	1 (8)	9	11	1 (10)

$Y = \bar{B}\bar{D}$

$Y = \sum m(4, 5, 6, 7, 13, 14, 15)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	0	1	3	2
$\bar{A}B$	1 (4)	1 (5)	1 (7)	1 (6)
AB	12	1 (13)	1 (15)	1 (14)
$A\bar{B}$	8	9	11	10

$Y = \bar{A}B + BD + BC$

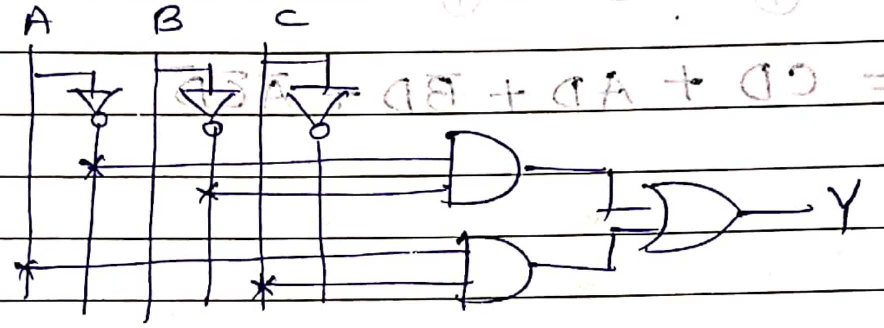
Q $f(A,B,C) = \Sigma m(1,3,5,7)$

$f(A,B,C) = m_0, m_1, m_5, m_7$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1 (0)	1 (1)	(3)	(2)
A	(4)	1 (5)	1 (7)	(6)

$Y = \bar{A}\bar{B} + AC$

1



Q Minimize the equation using K-Map

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

$= 011 + 101 + 100 + 000$

$= m_3 + m_5 + m_4 + m_0$

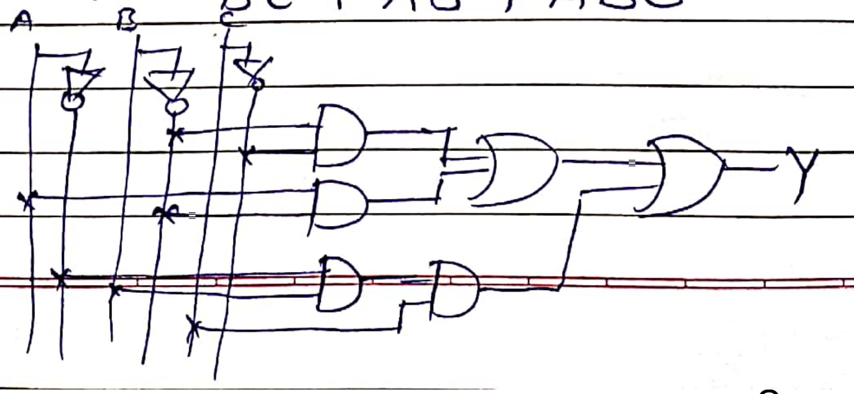
$= \Sigma m(0,3,4,5)$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1 (0)	(1)	1 (3)	(2)
A	1 (4)	1 (5)	(7)	(6)

1 2 3

2

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



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Q Minimize KMap using K-Map

$F(A,B,C,D) = \Sigma m(0,1,3,4,7,9,11,13,15)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1^{0}	1^{1}	1^{3}	^{2}
$\bar{A}B$	1^{4}	^{5}	1^{7}	^{6}
AB	^{12}	1^{13}	1^{15}	^{14}
$A\bar{B}$	^{8}	1^{9}	1^{11}	^{10}

4 2 1 3

$Y = CD + AD + \bar{B}D + \bar{A}\bar{C}\bar{D}$

Q $F(A,B,C,D) = \Sigma m(3,4,5,7,9,13,14,15)$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	
AB		1	1	1
$A\bar{B}$		1		

$Y = \bar{A}B\bar{C} + A\bar{C}D + \bar{A}CD + ABC$

Q $F(A,B,C,D) = \Sigma m(0,1,2,3,4,6,7,8,9,11,12,13)$

4 quad

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

Q $F(A,B,C) = \Sigma m(0,1,3,4,6)$

1	1	1	
1			1

3 3 pairs

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

$F(A,B,C,D) = \Sigma m(0,1,3,5,7,8,9,11,13,15)$

4

1	1	1	
	1	1	
	1	1	
1	1	1	

$Y = \bar{B}\bar{C} + D$

5

$F(A,B,C,D) = \Sigma m(0,3,5,8,11,13)$

1 (0)	(1)	1 (3)	(2)
(4)	1 (5)	(7)	(6)
(12)	1 (13)	(15)	(14)
1 (8)	(9)	1 (11)	(10)

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K-Map using Don't care Condition

If the input combinations of the value of Boolean expression are not specified called as Don't care condition.

'X' - for Don't care

$F(A,B,C) = \Sigma m(1,2,4) + d(5,6,7)$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	^{0}	1^{1}	^{3}	1^{2}
A	1^{4}	X^{5}	X^{7}	X^{6}

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

② $F(A,B,C) = \Sigma m(0,1,6,7) + \Sigma d(3,5)$

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1^{0}	1^{1}	X^{3}	^{2}
A	^{4}	X^{5}	1^{7}	1^{6}

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

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$$F(A,B,C) = \Sigma m(1, \cancel{2}, 5, 7) + \Sigma d(0, 2, 4, 6)$$

X (0)	1 (1)	(3)	X (2)
X (4)	1 (5)	1 (7)	X (6)

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

$$F(A,B,C) = A + \bar{B} + \bar{C}$$

Q $F(A,B,C,D) = \Sigma m(0,5,9,12,13,14,15) + d(1,2,3,4)$

1 (0)	X (1)	X (3)	X (2)
X (4)	1 (5)	(7)	(6)
1 (12)	1 (13)	1 (15)	1 (14)
(8)	1 (9)	(11)	(10)

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$F(A,B,C,D) = \Sigma m(1,3,7,11,15) + d(0,2,5)$

X [0]	1 [1]	1 [3]	X [2]
[4]	X [5]	1 [7]	[6]
[12]	[13]	1 [15]	[14]
[8]	[9]	1 [11]	[10]

$F(A,B,C,D) = \overline{A}D + CD$

$F(A,B,C,D) = \Sigma m(1,3,4,6,8,11,15) + d(0,5,7)$

Simplification of POS form using K-Map ~~up~~

Q Minimize the expression

$$Y = (A+B+\bar{C})(A+\bar{B}+\bar{C})(\bar{A}+B+C)(\bar{A}+\bar{B}+\bar{C})(A+B+C)$$

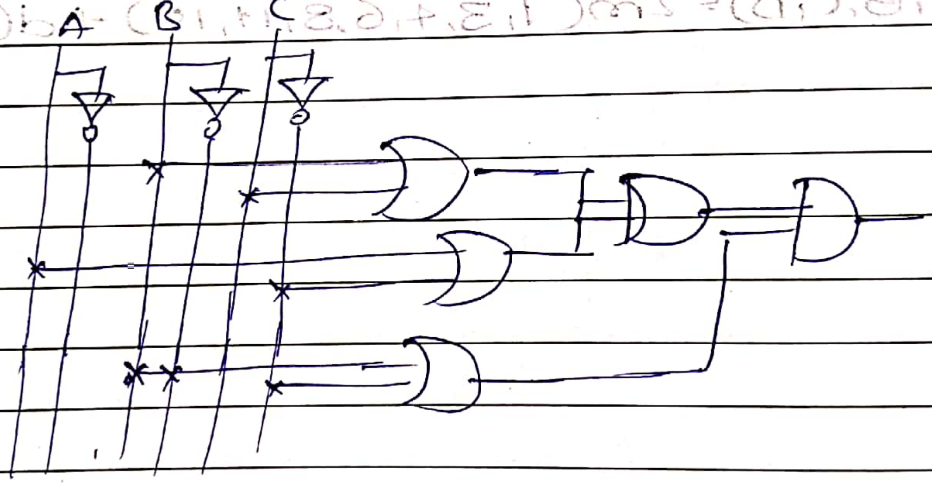
$$= (001)(011)(100)(111)(000)$$

$$= M_0 \cdot M_1 \cdot M_3 \cdot M_4 \cdot M_7$$

	$B+C$	$B+\bar{C}$	$\bar{B}+\bar{C}$	$\bar{B}+C$
A	0 (0)	0 (1)	0 (3)	(2)
$\bar{A}$	0 (4)	(5)	0 (7)	(6)

1 2 3

$$Y = (B+C)(A+\bar{C})(\bar{B}+\bar{C})$$



Minimized Boolean Expression by Quine McCluskey Method or Tabular Method

① $f(A,B,C,D) = \Sigma m(0,2,3,6,7,8,10,12,13)$

Minterm	A	B	C	D	
m_0	0	0	0	0	✓
m_2	0	0	1	0	✓
m_3	0	0	1	1	✓
m_6	0	1	1	0	✓
m_7	0	1	1	1	✓
m_8	1	0	0	0	✓
m_{10}	1	0	1	0	✓
m_{12}	1	1	0	0	✓
m_{13}	1	1	0	1	✓

Group	Minterm	A	B	C	D
0	m_0 ✓	0	0	0	0
1	m_2 ✓	0	0	1	0
	m_8 ✓	1	0	0	0
2	m_3 ✓	0	0	1	1
	m_6 ✓	0	1	1	0
	m_{10} ✓	1	0	1	0
	m_{12} ✓	1	1	0	0
3	m_7 ✓	0	1	1	1
	m_{13} ✓	1	1	0	1

Group	Minterm	A	B	C	D	
0	m_0m_2	0	0	X	0	✓
	m_0m_8	X	0	0	0	✓
1	m_2m_3	0	0	1	X	✓
	m_2m_6	0	X	1	0	✓
	m_2m_{10}	X	0	1	0	✓
	m_8m_{10}	1	0	X	0	✓
	m_8m_{12}	1	X	0	0	$A\bar{C}\bar{D}$
2	m_3m_7	0	X	1	1	✓
	m_6m_7	0	1	1	X	✓
	$m_{12}m_{13}$	1	1	0	X	$AB\bar{C}$

Group	Minterm	A	B	C	D	
0	$m_0m_2m_8m_{10}$	X	0	X	0	- $\bar{B}\bar{D}$
	$m_0m_8m_2m_{10}$	X	0	X	0	
1	$m_2m_3m_6m_7$	0	X	1	X	$\bar{A}C$
	$m_2m_6m_3m_7$	0	X	1	X	

Group

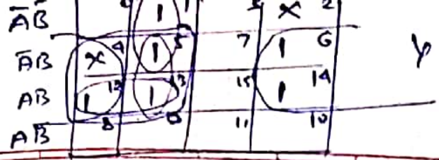
Prime Implicants		m_0	m_2	m_3	m_6	m_7	m_8	m_{10}	m_{12}	m_{13}
$A\bar{C}\bar{D}$	$m_8 m_{12}$						X		X	
✓ $AB\bar{C}$	$m_{12} m_{13}$								X	X
✓ $\bar{B}\bar{D}$	$m_0 m_2 m_8 m_{10}$	X	X				X	X		
✓ $\bar{A}C$	$m_2 m_3 m_6 m_7$		X	X	X	X				

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

$\Sigma m(0, 2, 3, 6, 7, 8, 10, 12, 13)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1 (0)	(1)	1 (3)	1 (2)
$\bar{A}B$	(4)	(5)	1 (7)	1 (6)
AB	1 (12)	1 (13)	(15)	(14)
$A\bar{B}$	1 (8)	(9)	(11)	1 (10)

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



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

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$F(A,B,C,D) = \sum m(1,5,6,12,13,14) + d(2,4)$

Minterm	A	B	C	D	
m_1	0	0	0	1	✓
m_5	0	1	0	1	✓
m_6	0	1	1	0	✓
m_{12}	1	1	0	0	✓
m_{13}	1	1	0	1	✓
m_{14}	1	1	1	0	✓
m_2	0	0	1	0	✓
m_4	0	1	0	0	✓

Group	Minterm	A	B	C	D	
1	m_1	0	0	0	1	✓
	m_2	0	0	1	0	✓
	m_4	0	1	0	0	✓
2	m_5	0	1	0	1	✓
	m_6	0	1	1	0	✓
	m_{12}	1	1	0	0	✓
3	m_{13}	1	1	0	1	✓
	m_{14}	1	1	1	0	✓

Group	Minterm	A	B	C	D	
1	$m_1 m_5$	0	X	0	1	PI - $\bar{A}\bar{C}D$
	$m_2 m_6$	0	X	1	0	PI - $\bar{A}C\bar{D}$
	$m_4 m_5$	0	1	0	X	✓
	$m_4 m_6$	0	1	X	0	✓
	$m_4 m_{12}$	X	1	0	0	✓
2	$m_5 m_{13}$	X	1	0	1	✓
	$m_6 m_{14}$	X	1	1	0	✓
	$m_{12} m_{13}$	1	1	0	X	✓
	$m_{12} m_{14}$	1	1	X	0	✓

Group	Minterm	A	B	C	D	
1	$m_4 m_5 m_{12} m_{13}$	X	1	0	X	← $B\bar{C}$
	$m_4 m_6 m_{12} m_{14}$	X	1	X	0	← $B\bar{D}$
	$m_4 m_{12} m_5 m_{13}$	X	1	0	X	← $B\bar{C}$
	$m_4 m_{12} m_6 m_{14}$	1	X	X	0	← $B\bar{D}$

PI	Minterm	m_1	m_5	m_6	m_{12}	m_{13}	m_{14}
$\bar{A}\bar{C}D$	$m_1 m_5$	X	X				
$\bar{A}CD$	$m_2 m_6$			X			
$B\bar{D}$	$m_4 m_6 m_{12} m_{14}$			X	X		X
$B\bar{C}$	$m_4 m_5 m_{12} m_{13}$		X		X	X	

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

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$Y(A,B,C,D) = \sum m(0,1,2,3,5,7,8,9,11,14)$

Minterm	A	B	C	D	
	Binary Representation				
m_0	0	0	0	0	✓
m_1	0	0	0	1	✓
m_2	0	0	1	0	✓
m_3	0	0	1	1	✓
m_5	0	1	0	1	✓
m_7	0	1	1	1	✓
m_8	1	0	0	0	✓
m_9	1	0	0	1	✓
m_{11}	1	0	1	1	✓
m_{14}	1	1	1	0	✓

Group	Minterm	Representation				
0	m_0	0	0	0	0	✓
1	m_1	0	0	0	1	✓
	m_2	0	0	1	0	✓
	m_8	1	0	0	0	✓
2	m_3	0	0	1	1	✓
	m_5	0	1	0	1	✓
	m_9	1	0	0	1	✓
3	m_7	0	1	1	1	✓
	m_{11}	1	0	1	1	✓
	m_{14}	1	1	1	0	PI $ABC\bar{D}$

Group	Minterm	Representation				
0	$m_0 m_1$	0	0	0	X	✓
	$m_0 m_2$	0	0	X	0	✓
	$m_0 m_8$	X	0	0	0	✓
1	$m_1 m_3$	0	0	X	1	✓
	$m_1 m_5$	0	X	0	1	✓
	$m_1 m_9$	X	0	0	1	✓
	$m_2 m_3$	0	0	1	X	✓
	$m_8 m_9$	1	0	0	X	✓
2	$m_3 m_7$	0	X	1	1	✓
	$m_3 m_{11}$	X	0	1	1	✓
	$m_5 m_7$	0	1	X	1	✓
	$m_9 m_{11}$	1	0	X	1	✓

Group	Minterm	A	B	C	D	
0	$m_0 m_1 m_2 m_3$	0	0	X	X	$\bar{A}\bar{B}$
	$m_0 m_2 m_1 m_3$	0	0	X	X	
	$m_0 m_2 m_1 m_3$	0	0	X	X	
	$m_0 m_8 m_1 m_9$	X	0	0	X	$\bar{B}\bar{C}$
1	$m_1 m_3 m_5 m_7$	0	X	X	1	$\bar{A}D$
	$m_1 m_9 m_3 m_{11}$	X	0	X	1	
	$m_1 m_5 m_3 m_7$	0	X	X	1	$\bar{B}D$
	$m_1 m_9 m_3 m_{11}$	X	0	X	1	

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$AB C\bar{D}$

$\bar{A}\bar{B}$

$\bar{A}D$

$\bar{B}\bar{C}$

$\bar{B}D$

Q $F(A,B,C,D) = \Sigma m(0,1,2,5,6,7)$

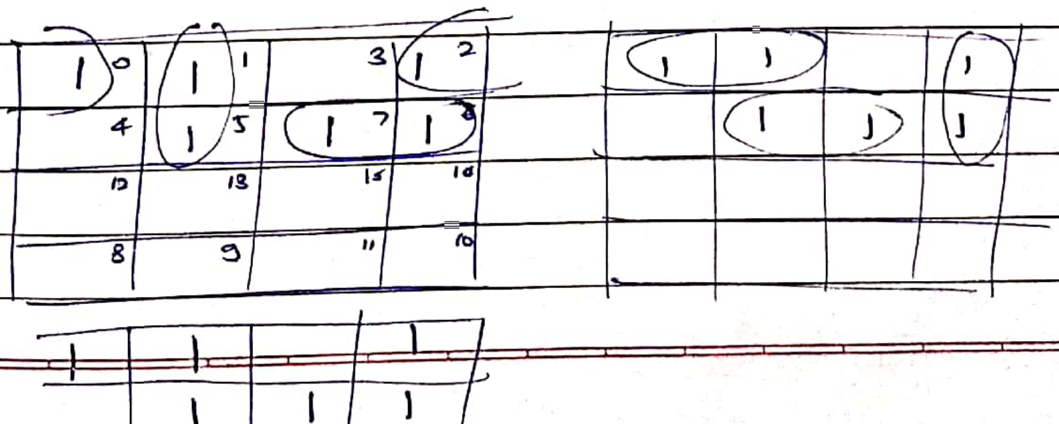
Minterm	Binary Representation				
m_0	0	0	0	0	✓
m_1	0	0	0	1	✓
m_2	0	0	1	0	✓
m_5	0	1	0	1	✓
m_6	0	1	1	0	✓
m_7	0	1	1	1	✓

Group	Minterm	A	B	C	D	
0	m_0	0	0	0	0	✓
1	m_1	0	0	0	1	✓
	m_2	0	0	1	0	✓
2	m_5	0	1	0	1	✓
	m_6	0	1	1	0	✓
3	m_7	0	1	1	1	✓

Group	Minterm	Representation				
1	$m_0 m_1$	0	0	0	x	$\bar{A}\bar{B}\bar{C}$
	$m_0 m_2$	0	0	x	0	$\bar{A}\bar{B}\bar{D}$
2	$m_1 m_5$	0	x	0	1	$\bar{A}\bar{C}D$
	$m_2 m_6$	0	x	1	0	$\bar{A}C\bar{D}$
3	$m_5 m_7$	0	1	x	1	$\bar{A}BD$
	$m_6 m_7$	0	1	1	x	$\bar{A}BC$

PI	Minterm	m_0	m_1	m_2	m_5	m_6	m_7
$\bar{A}\bar{B}\bar{C}$ ✓	$m_0 m_1$	X	X				
$\bar{A}\bar{B}\bar{D}$	$m_0 m_2$	X		X			
$\bar{A}\bar{C}D$	$m_1 m_5$		X		X		
$\bar{A}C\bar{D}$ ✓	$m_2 m_6$			X		X	
$\bar{A}BD$ ✓	$m_5 m_7$				X		X
$\bar{A}BC$	$m_6 m_7$					X	X

$$Y = \bar{A}\bar{B}\bar{C} + \bar{A}C\bar{D} + \bar{A}BD$$



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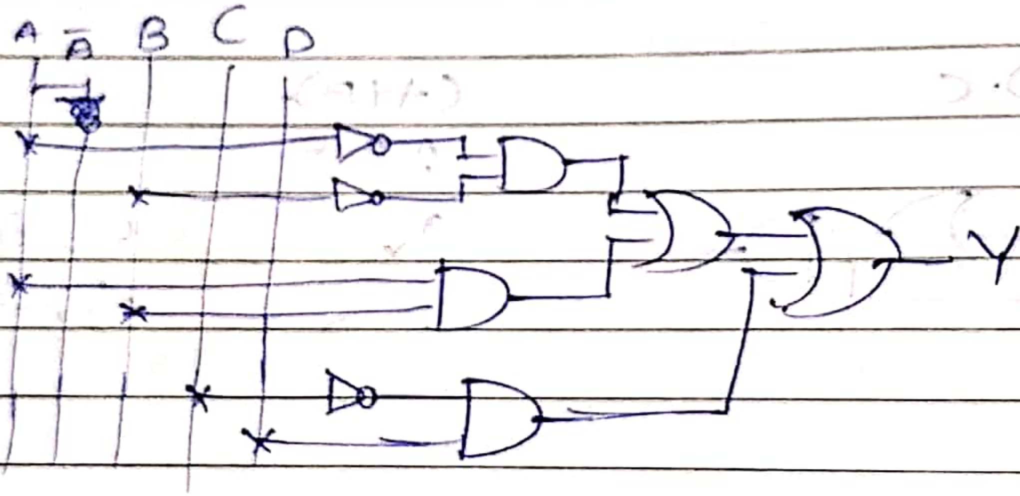
Minimize
Implement boolean expression using K-Map
design using NAND gate only

$F = \sum m(0,5,9,12,13,14,15) + d(1,2,3,4)$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1 ⁰	X ¹	X ³	X ²
$\bar{A}B$	X ⁴	1 ⁵	⁷	⁶
AB	1 ¹²	1 ¹³	1 ¹⁵	1 ¹⁴
$A\bar{B}$	⁸	1 ⁹	¹¹	¹⁰

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



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

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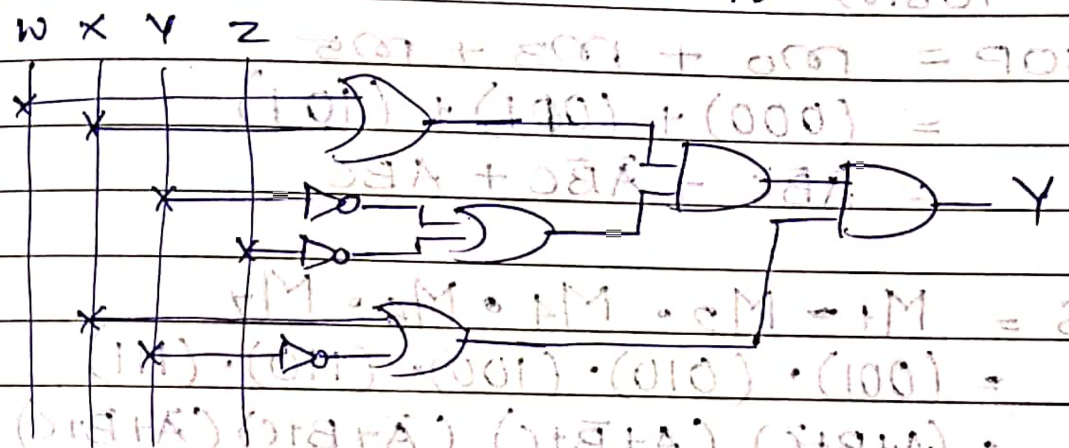
Simplify following logic function & realize using NOR gates

$f(W,X,Y,Z) = \prod M(1,2,3,7,10,11) + d(0,15)$

	$C+D$	$C+\bar{D}$	$\bar{C}+\bar{D}$	$\bar{C}+D$
$A+B$	X 0	0 1	0 3	0 2
$A+\bar{B}$	4	5	0 7	6
$\bar{A}+\bar{B}$	12	13	X 15	14
$\bar{A}+B$	8	9	0 11	0 10

$$Y = (A+B)(\bar{C}+\bar{D})(B+\bar{C})$$
$$= (W+X)(\bar{Y}+\bar{Z})(X+\bar{Y})$$



Write standard SOP & POS expression

A	B	C	function	Minterm	Maxterm
0	0	0	1	m_0	
0	0	1	0		M_1
0	1	0	0		M_2
0	1	1	1	m_3	
1	0	0	0		M_4
1	0	1	1	m_5	
1	1	0	0		M_6
1	1	1	0		M_7

SOP form

$$SOP = m_0 + m_3 + m_5$$
$$= (000) + (001) + (101)$$
$$= \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + A\bar{B}C$$

$$POS = M_1 \cdot M_2 \cdot M_4 \cdot M_6 \cdot M_7$$
$$= (001) \cdot (010) \cdot (100) \cdot (110) \cdot (111)$$
$$= (A+B+\bar{C})\ (A+\bar{B}+C)\ (\bar{A}+B+C)\ (\bar{A}+\bar{B}+C)\ (\bar{A}+\bar{B}+\bar{C})$$

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