2 Conditions for orthogonal

↳ Neutural
↳ Mutal exclusive terms

* K-MAP (konaurgh MaP) L-20

- Boolean variable → symbol which can take value 0 or 1

  Ex $x \begin{cases} \to 0 \\ \to 1 \end{cases}$

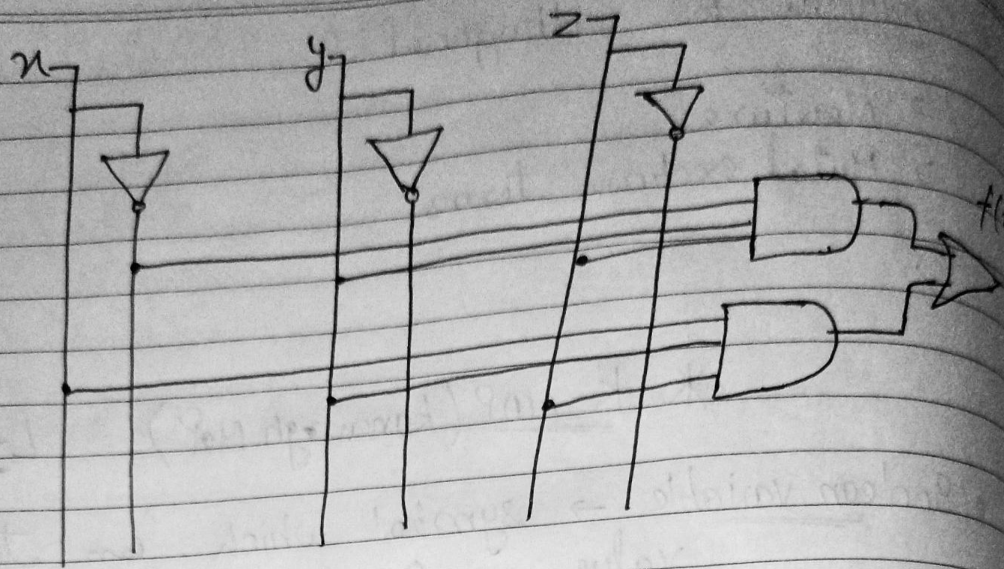
- Literal → use of variable or its complement in an expression

$$\underbrace{f(x, y)}_{\text{2 variables}} = \underbrace{\bar{x}y + x\bar{y}}_{\text{4 Literals}}$$

* Implement the following function

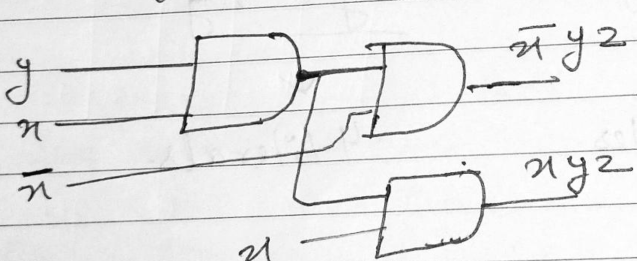
$$f(x, y, z) = \bar{x}yz + xyz$$

4



2 AND gate (3 I/P)
1 OR gate
1 Not gate

* Another way to implement:-



- **Minimization**

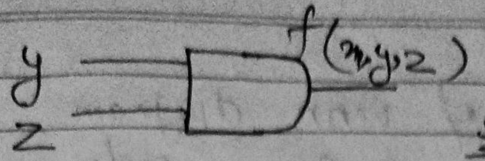
$$f(x,y,z) = \bar{x}yz + xyz$$

$$yz(x+\bar{x})$$

$\downarrow$ complement law

$$yz(1)$$

$$yz$$



Ans

There are two way to minimize an expression

1) Boolean laws 2) ~~kara~~ Karnaugh Map

Summary :-

→ before implementing the function by logic gates we must first minimize it

→ for minimization we can apply boolean laws on identities. But some time its difficult to minimize expression by laws like:

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

$\downarrow$ $1 \cdot BC$ (crucial step) identity law

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

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

$AB + \bar{A}C$

Hence better option is Karnaugh Map.

K-Map

→ Application of venn diagram
→ based on gray code
→ Minimum possible k map is for 1 var & max for n variable
→ for "n" var boolean f^n we've to make 2^n minterms & for each minterm we have cell in K-Map

Hence total no. of cells $= 2^n$ (for n variable)

Q 4 var k map has no. of cells $\Rightarrow 2^4 = 16$

Q $f(A,B,C,D) = \Sigma m(0,1,13,15)$

CD \ AB	00	01	11	10
00	m0	m4	m12	m8
01	m1	m5	m13	m9
11	m3	m7	m15	m11
10	m2	m6	m14	m10

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m13

2 way to make ~~ma~~ K-Map

Size of rectangle
1
2
4
8
16
32

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

CD \ AB	00	01	11	10
00	1			
01	1		1	
11			1	
10				

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

$2^n \times 2^m = 1 \times 2$
$n = 0, m = 1$

$f(A, B, C, D) = \Sigma m(0, 7, 8, 15)$

CD \ AB	00	01	11	10
00	1_0	4	$\bullet_{12}$	1_8
01	1	5	13	9
11	2	1_7	1_{15}	11
10	3	6	14	10

$BCD + \bar{B}\bar{C}\bar{D}$

$f(A, B, C, D) = \Sigma m(0, 2, 12, 14)$

CD \ AB	00	01	11	10
00	1_0	4	1_{12}	8
01	1	5	13	9
11	3	7	15	11
10	1_2	6	1_{14}	10

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

$f(A, B, C, D) = \Sigma m(3, 5, 6, 15)$

CD \ AB	00	01	11	10
00				
01		1		
11	1		1	
10		1		

$\bar{A}BCD + ABCD + \bar{A}BC\bar{D} + \bar{A}\bar{B}CD$

$f(A, B, C, D) = \Sigma m(0, 1, 2, 3)$

CD \ AB	00	01	11	10
00	1			
01	1			
11	1			
10	1			

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

Size of rectang → literal

1 → 4

2 → 3

4 → 2

Q $f(A,B,C,D) = \Sigma m(5, 7, 13, 15)$

CD \ AB	00	01	11	10
00				
01		1	1	
11		1	1	
10				

BD

Ans

Q $f(A,B,C,D) = \Sigma m(0, 1, 2, 3, 4, 5)$

CD \ AB	00	01	11	10
00	1	1		
01	1	1		
11	1			
10	1			

Q $f(A,B,C,D) = \Sigma m(5,7,13,15)$

CD \ AB	00	01	11	10
00				
01		1	1	
11		1	1	
10				

BD

Ans

Q $f(A,B,C,D) = \Sigma m(0,1,2,3,4,5)$

CD \ AB	00	01	11	10
00	1	1		
01	1	1		
11	1			
10	1			

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

Ans

Q $f(A,B,C,D) = \Sigma m(0,1,2,3,10,11)$

CD \ AB	00	01	11	10
00	1			
01	1			
11	1			1
10	1			1

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

Ans

Q $f(A,B,C,D) = \Sigma m(0,2,4,6,8,10,12,14)$

CD \ AB	00	01	11	10
00	1	1	1	1
01				
11				
10	1	1	1	1

$\bar{D}$

Ans

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Que $f(A,B,C,D) = \Sigma m(0,2,5,7,13,15,8,10)$

CD \ AB	00	01	11	10
00	1			1
01		1	1	
11		1	1	
10	1			1

$BD + \overline{B}\,\overline{D}$

Ans

Que $f(A,B,C,D) = \Sigma m(0,1,2,3,4,6,8,9,10,11,12,14)$

CD \ AB	00	01	11	10
00	1	1	1	1
01	1			1
11	1			1
10	1	1	1	1

$\overline{D} + \overline{B}$

Ans

Que $f(A,B,C,D) = \Sigma m(0,1,2,3,4,5,10,11)$

CD \ AB	00	01	11	10
00	1	1		
01	1	1		
11	1			1
10	1			1

$\overline{A}\overline{B} + \overline{A}\,\overline{C} + \overline{C}\,\overline{B}$ X

$\overline{A}\,\overline{C} + \overline{B}C$

Ans

Que $f(A,B,C,D) = \Sigma m(1,4,6,9,11,15)$

CD \ AB	00	01	11	10
00		1		
01	1			1
11			1	1
10		1		

$\bar{B}\bar{C}D + ACD + \bar{A}B\bar{D}$ Ans

Que $f(A,B,C,D) = \Sigma m(0,1,2,3 \ldots 15)$

CD \ AB	00	01	11	10
00	1	1	1	1
01	1	1	1	1
11	1	1	1	1
10	1	1	1	1

1 Ans

if every cell is present then ans will always be "1" and literal count is "zero"

Proof :

Make 2 boxes of 8 – 8 cells

$\bar{A} + A$

↓

"1" Ans

Size of box	→ literal Count
1	→ 4
2	→ 3
4	→ 2
8	→ 1
16	→ 0

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"n" Variable K-MAP

Rectangle	Literal count
1	n
2	$n-1$
4	$n-2$
8	$n-3$
16	$n-4$
32	$n-5$
2^x	$n-x$

* **Cover**

Consider 2 sets f & g we say f covers g if $g \subseteq f$

Q

A	B	f1	f2
0	0	0	0
0	1	1	1
1	0	1	1
1	1	0	1

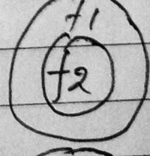
$f_1 = \Sigma m(1, 2)$

$f_2 = \Sigma m(1, 2, 3)$

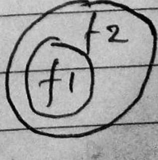
Since the element in f_1 is also present in f_2, means f_2 covers f_1

a. f_1 covers f_2
b. f_2 covers f_1 ✓
c. both
d. none

f_1 cover f_2 →



f_2 cover f_1 →



- In logic/B.A we say f covers g means $g \rightarrow f$ is a tautology

$g \Rightarrow f$

g implies in f

A	B	f_1	f_2	$f_1 \to f_2$
0	0	0	0	1
0	1	1	1	1
1	0		1	1
1	1	0	1	1

implies Truth table

P	Q	$P \to Q$
0	0	1
0	1	1
1	0	0
1	1	1

f_2 covers f_1 $\therefore$ $f_1 \to f_2$ is tautology

* Implicant:

given 2 functions f_1 & f_2 s.t $f_1 \subseteq f_2$ then f_1 is called implicant of f_2 i.e $f_1 \longrightarrow f_2$ is tautology

Simply we can say that every subset of boolean f^n is an implicant

Ex $f(A,B) = \Sigma(1,2)$

$f_1(A,B) = \phi$
$f_2(A,B) = \Sigma(1)$
$f_3(A,B) = \Sigma(2)$
$f_4(A,B)\ \Sigma(1,2)$

All function from f_1 to f_4 are implicant of $f(A,B) = \Sigma m(1,2)$

If f^n 'f' has n minterms then how many implicant?

2^n Ans

Q If f^n 'f' of n var has 'x' minterms then how many ~~implicants~~ functions can cover f?

$n \rightarrow 2^n$ = minterms

$2^n - x = 2^{(2^n - x)}$

Q $f(A,B,C) = AB + BC \rightarrow$ SOP

How many functions can cover f?

$f(A,B,C) = \Sigma m(6,7,3)$

$8 - 3 = 5 = 2^5 \rightarrow 32$ Ans

"3" are always present rest 5 having "2" possibilite they can be or can be present

for (6, 7, 3, 0) and so on...

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Q If f^n 'f' of n var has 'x' minterms then how many ~~implicants~~ functions can cover f?

$n \rightarrow 2^n$ = minterms

$2^n - x = 2^{(2^n - x)}$

Q $f(A,B,C) = AB + BC \rightarrow$ SOP

How many functions can cover f?

$f(A,B,C) = \Sigma m(6,7,3)$

$8 - 3 = 5 = 2^5 \Rightarrow 32$ Ans

"3" are always present rest 5 having "2" possibilites they can be or can be present

for $(6,7,3,0)$ and so on...

Q How to visualize implicants in K-map?

$f(A,B,C) = \Sigma m(1,5,7,8,13,15)$

$\Sigma m(1)$

CD \ AB	00	01	11	10
00				1
01	1	1	1	
11		1	1	
10				

$f_1 \rightarrow f$

$f_1(A,B,C,D) = \Sigma m(7,8,15)$

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- We have f^n 'f' of 'n' variable & to minimize it we have designed K-Map
- This K-Map will contain 1s in those cells whose corresponding minterms are present in f^n
- Hence take any single 1 or group of 1s from the the K-Map & it is called implicant of the f^n for which K-MAp is designed

Def^n of Implicant :-
Any single 1 or group of 1s in K-Map is called implicant.

* Prime implicant → A prime implicant is an implicant that can not be covered by more $\underbrace{\text{reduced}}$ implicant
↓
Implicant with less literal count than the given implicant

$f(A,B,C,D) = \Sigma m(0,1,2,3)$

$f_1(A,B,C,D) = (0,1)$ → is it Prime implicant?

$(0,1) \Rightarrow \bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D$
$\bar{A}\bar{B}\bar{C}$ we need find a function ~~which~~ who is super set of (0,1) and its literal count is less

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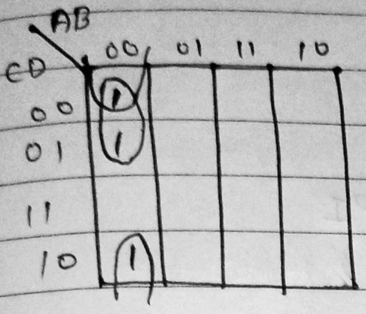
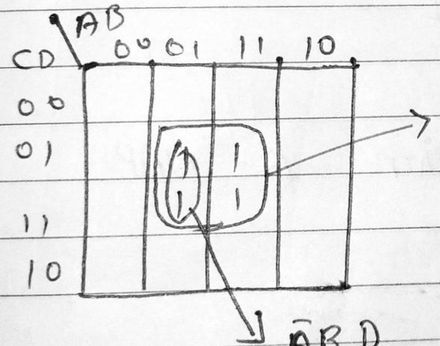
than $\bar{A}\bar{B}\bar{C}$

(0, 1, 2) $\Rightarrow$ $\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}\bar{D}$ ✗
(0, 1, 3) $\Rightarrow$ $\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}D$ ✗



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

Q How to visulize Prime implicant in K-MAP?
A Any single 1 or group of 1 that can't be inculded in bigger rectangle in K-MAP?



BD is a prime implicant

$\bar{A}BD$ is not a prime implicant

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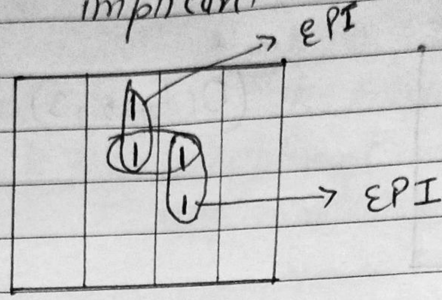
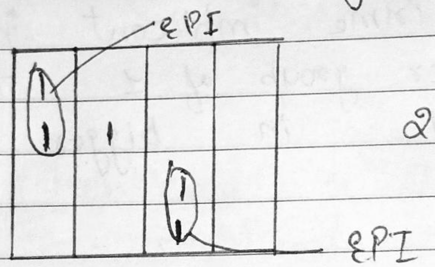
* Essential Prime Implicant

Those prime implicant which contain at least 1 minterm which is not included in any other implicant

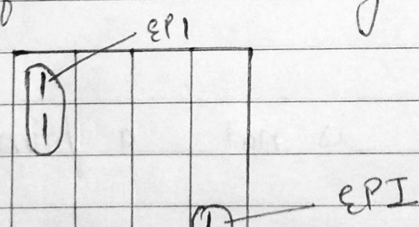


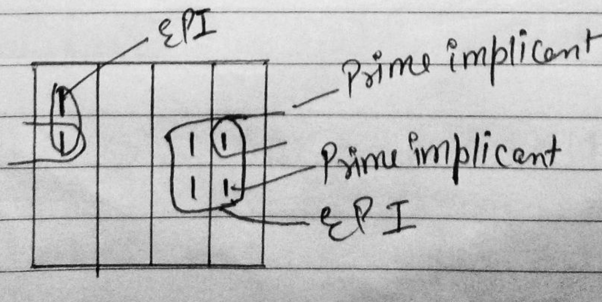
- No. of EPI in given K-MAP ?



2 EPI

- No of EPI in given K-MAP





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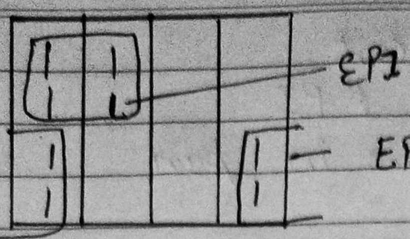
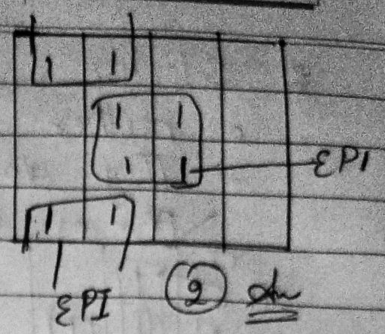
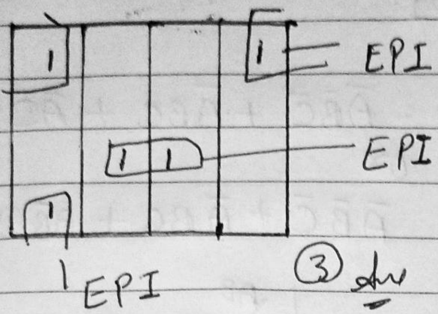


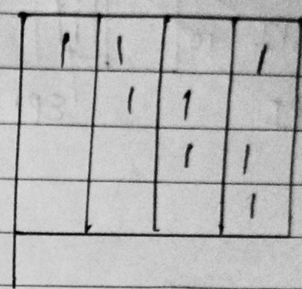
(2) Ans



(2) Ans



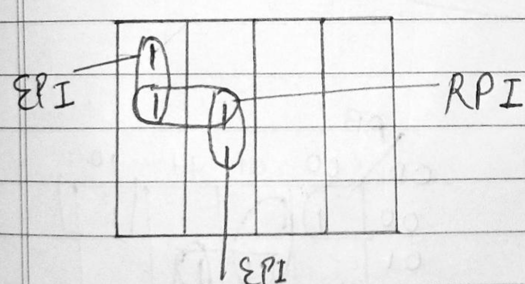
(3) Ans

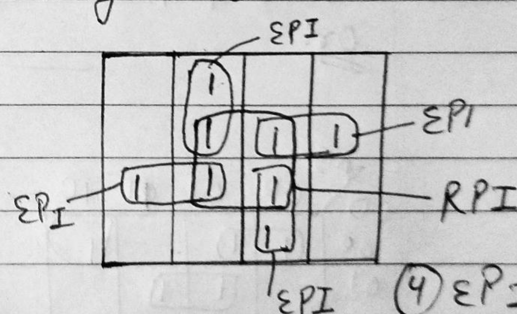


0 EPI

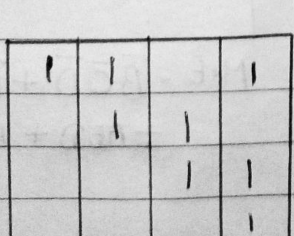
* Redundant Prime Implicant

A prime implecant in which ~~which~~ each of its minterm is coverd by some other EPI





(4) EPI



0 EPI
0 RPI

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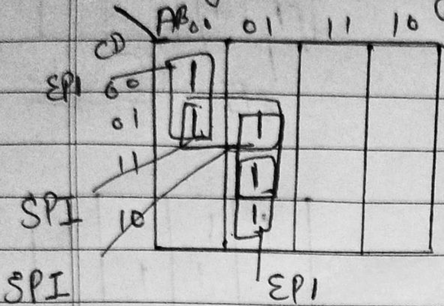
* Selective Prime implicant

- neither EPI nor RPI
- They ~~do~~ alway accurs in pain



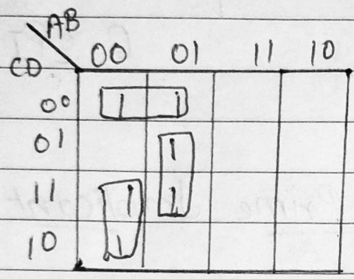
② EPI

② SPI

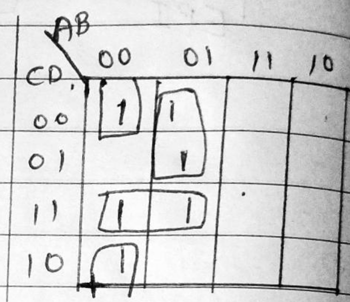
$M.E = \bar{A}\bar{B}\bar{C} + \bar{A}BC + \bar{A}\bar{C}D$

or

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



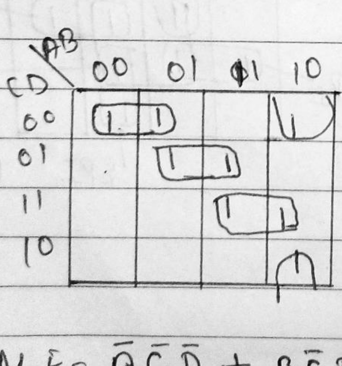
6 SPI



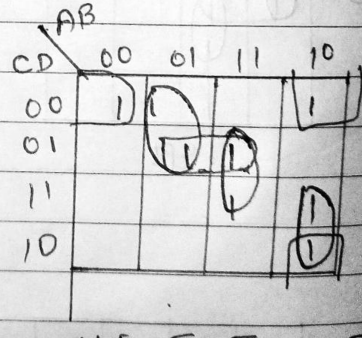
$M.E = \bar{A}\bar{C}\bar{D} + \bar{A}BD + \bar{A}\bar{B}C$

or

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



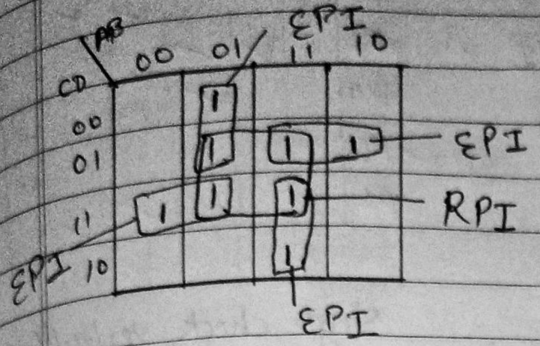
or



$M.E = \bar{A}\bar{C}\bar{D} + B\bar{C}D + ACD + A\bar{B}\bar{D}$

$M.E = \bar{B}\bar{C}\bar{D} + \bar{A}B\bar{C} + ABD + A\bar{B}C$

* Practice Question EPI, RPI & SPI and minimized expression?



using PI chart

	3	4	5	7	9	13	14	15
P1		✓	✓					
P2					✓	✓		
P3							✓	✓
P4	✓			✓				
P5			✓	✓		✓		✓

$M.E = \bar{A}B\bar{C} + A\bar{C}D + ABC + \bar{A}CD$

Ans

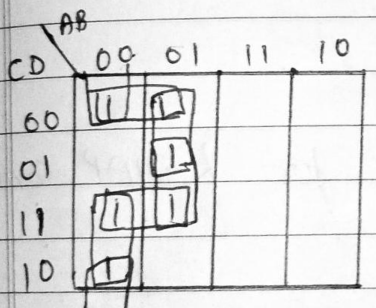
P1 --- P4 = 4 EPI

P = 1 RPI

4 EPI

1 RPI

0 SPI



using PI chart

	0	2	3	4	5	7
P1	✓			✓		
P2				✓	✓	
P3					✓	✓
P4			✓			✓
P5		✓	✓			
P6	✓	✓				

0 EPI

6 SPI

$M.E = \bar{A}\bar{C}D + \bar{A}BD + \bar{A}\bar{B}C$

or

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

Ans

P1 .... P6 = 6 SPI

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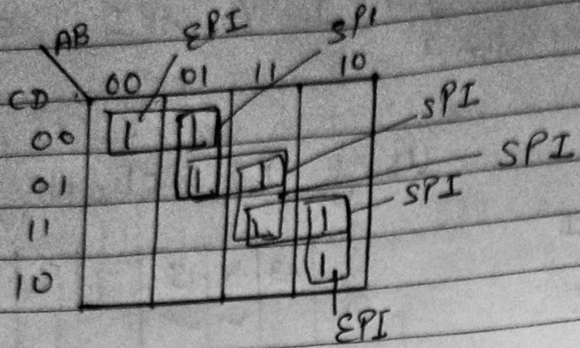


EPI	0	4	5	10	11	13
✓ P1	✓	✓				
P2				✓	✓	
P3		✓	✓			
P4			✓			✓
EPI ✓ P5						✓
P6				✓	✓	

2 EPI
4 SPI

$M.E = \bar{A}\bar{C}D + B\bar{C}D + ABD + A\bar{B}C$

Single check vertically = 2 EPI
4 SPI

or

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

or

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

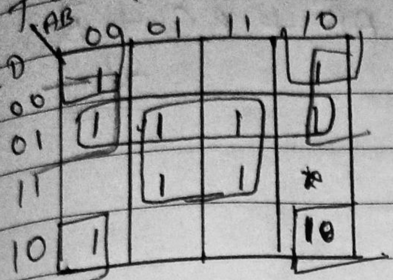
Ans

* Note → Minimize expression for K-MAP contain

all EPI
No RPI
Some but not all SPI

* Minimized expression

(1) $f(A, B, C, D) = \Sigma m(0,1,2,5,7,8,9,10,13,15)$



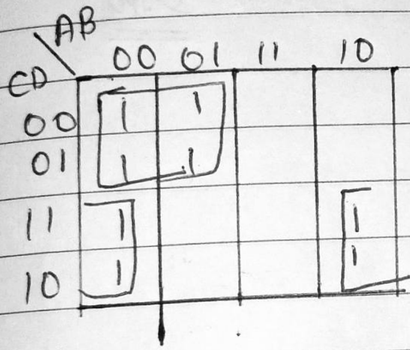
$\bar{B}\bar{D} + BD + \bar{C}D$

Ans

or $\bar{B}\bar{D} + BD + \bar{B}\bar{C}$

Ans

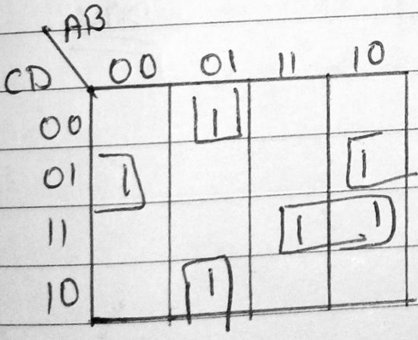
(2)



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

Ans

(3)



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

CD \ AB	00	01	11	10
00	1			1
01	1	1		1
11	1	1		1
10	1			

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

Ans

CD \ AB	00	01	11	10
00	1	1	1	1
01			1	1
11		1	1	
10				

$\bar{C}\bar{D} + A\bar{C} + BCD$

Ans

CD \ AB	00	01	11	10
00	1	1		
01	1	1	1	
11		1	1	1
10	1	1		

$\bar{A}\bar{D} + \bar{A}\bar{C} + ACD + BC$

Ans

CD \ AB	00	01	11	10
00	1	1		1
01				1
11	1			
10	1		1	1

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

Ans

CD \ AB	00	01	11	10
00		1		1
01	1		1	
11		1		1
10	1		1	

$A \oplus B \oplus C \oplus D$

Ans

If we ~~aren't~~ ain't able to make any cell then it ~~would~~ will be XOR or ~~XOR~~ XNOR

XOR → Gives ~~true~~ '1' if odd no of literals are true.

XNOR → Gives '1' when even no. of literals are false.

Proof why it is XOR using boolean law

$A \oplus B \oplus C \oplus D$

M.E

$$\overset{1}{\bar{A}\bar{B}\bar{C}D} + \overset{3}{\bar{A}\bar{B}C\bar{D}} + \overset{4}{\bar{A}B\bar{C}\bar{D}} + \overset{7}{\bar{A}BCD} + \overset{13}{AB\bar{C}D} + \overset{14}{ABC\bar{D}}$$
$$+ \underset{8}{A\bar{B}\bar{C}\bar{D}} + \underset{11}{A\bar{B}CD}$$

* K-MAP representation in POS

① $f(A,B,C,D) = \pi m(1,2,3,4,5)$

- means given minterms are "absent." rest everyone is "present"

CD \ AB	00	01	11	10
00		0		
01	0	0		
11	0			
10	0			

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

or

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

Ans

Note: 0 means as it is
1 means bar

② $f(A,B,C,D) = \pi M(0,1,2,5,7,8,9,10,14,15)$

CD \ AB	00	01	11	10
00	0			0
01	0	0		0
11	0	0	0	
10	0		0	0

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

Ans

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Q $f(A,B,C,D) = \Sigma m(0,1,2,3,8,9,10,11,13,15)$
minimized expression

a) $(A+\bar{B})\cdot(\bar{B}+D)$ ✓
b) $(A+B)\cdot(\bar{B}+D)$
c) $(A+B)\cdot(\bar{B}+\bar{D})$
d) $(A+\bar{B})\cdot(B+D)$

Ans is given POS and minterm is given in SOP.
will write those terms which are absent

$f(A,B,C,D) = \pi M(4,5,6,7,12,14)$

CD \ AB	00	01	11	10
00		0	0	
01		0		
11		0		
10		0	0	

$(\bar{B}+D)\cdot(A+\bar{B})$
Ans

or it will be → in SOP $\bar{B}+A\cdot D$
Ans

Q $f(w,x,y,z) = \Sigma m(0,1,2,5,8,9,10)$

a) $(\bar{w}+\bar{x})\cdot(\bar{y}+\bar{z})\cdot(\bar{x}+\bar{z})$
b) $(w+\bar{x})\cdot(y+\bar{z})\cdot(x+\bar{z})$
c) $(w+x)\cdot(y+z)\cdot(x+\bar{z})$
d None ✓

in POS $= \pi M(3,4,6,7,11,12,13,14,15)$

yz \ wx	00	01	11	10
00		0	0	
01			0	
11	0	0	0	0
10		0	0	

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

✓ The Good Paper

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$f(A,B,C,D) = \pi M(0,1,2,3 \text{ --- } 15)$

-

CD \ AB	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	0	0	0	0
10	0	0	0	0

Ans → 0
proof by makin 2 8-8 cells

$(A \cdot \bar{A}) = 0$
Literal Count 0 Ans

Similarly in SOP ans will = 1
$A + \bar{A} = 1$ Ans

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

CD \ AB	00	01	11	10
00	1		1	1
01	1		1	1
11	1			1
10	1			1

$\bar{B} + A\bar{C}$ → SOP
or $(\bar{B} + A) \cdot (\bar{B} + \bar{C})$ → POS

$f(A,B,C,D) = \pi M(0,1,2,3 \ldots 15)$

○

CD \ AB	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	0	0	0	0
10	0	0	0	0

Ans $\rightarrow 0$
proof by makin 2 8-8 cells

$(A \cdot \bar{A}) = 0$
Literal Count 0 Ans

Similarly in SOP ans will $= 1$
$A + \bar{A} = 1$ Ans

○ $f(A,B,C,D) = A\bar{B} + \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C} + A\bar{C}D + AC\bar{D}$

CD \ AB	00	01	11	10
00	1		1	1
01	1		1	1
11	1			1
10	1			1

$\bar{B} + A\bar{C} \longrightarrow$ SOP
or $(\bar{B}+A) \cdot (\bar{B}+\bar{C}) \rightarrow$ POS

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

CD \ AB	00	01	11	10
00	1	1		1
01		1	1	1
11				
10	1			

① EPI

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

$\Sigma m(0, 3, 4, 5, 8, 9, 13)$

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

CD \ AB	00	01	11	10
00	1			1
01	1	1		
11	1	1		
10	1			1

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

Ans

- $f(P,Q,R,S) = R + \bar{P}Q + \bar{R}S$
- $f2(P,Q,R,S) = PQ\bar{R}\bar{S} + \bar{P}\bar{Q}\bar{R}\bar{S} + P\bar{Q}\bar{R}\bar{S}$
- $f3(P,Q,R,S) = RS + PR + P\bar{Q} + \bar{P}\bar{Q}$
- $f4(P,Q,R,S) = R + S + PQ + \bar{P}\bar{Q}\bar{R} + P\bar{Q}\bar{S}$

f1

CD \ AB	00	01	11	10
00		1		
01	1	1	1	1
11	1	1	1	1
10	1	1	1	1

f2

RS \ PQ	00	01	11	10
00	1		1	1
01				
11				
10				

f3

RS \ PQ	00	01	11	10
00		1	1	
01		1	1	
11	1	1	1	1
10		1		

RS \ PQ	00	01	11	10
00		1		
01	1	1	1	1
11	1	1	1	1
10	1	1	1	1

$f1 = f4, \quad f2 = \bar{f1}, \quad f2 = \bar{f4}$ Ans

Q In a prime implicant chart representation a boolean exp $f(w, x, y, z)$ columns represent minterms & rows represent P.I . identify P, Q, R, S, a, b

	0	4	5	7	8	a	b
P	✓	✓					
Q	✓				✓		
R		✓	✓				
S			✓	✓	x	✓	✓

Sol

yz \ wx	00	01	11	10
00	1	1		1
01		1	1	
11		1	1	
10				

$P \to \bar{w}\bar{y}\bar{z}$

$Q \to \bar{x}\bar{y}\bar{z}$

$R \to \bar{w}x\bar{y}$

$S \to xz$

$a \to 13$

$b \to 15$

Ans

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