

## Synthesis techniques

i/p o/p ग्राम में से कौन सा फंक्शन एक्ट सिंथेसीस → विनियोग

1) Minterms  $\rightarrow$  SOP

2) Maxterms  $\rightarrow$  POS

3) K-Map

4) Multiplexers  $\rightarrow$  Simple / Naive way  $\rightarrow$  i/p  $\Sigma(0,1)$  select pin  
 $\rightarrow$  o/p to ip of MUX  $\Sigma(0,1)$

$\rightarrow$  Smart way  $\rightarrow$  take MSB of the i/p's as select pin  
(use Shanon expansion theorem and derive expressions of the select pin)

5) Decoders

SOP      POS implement

6) Use CPLD, FPGA etc boards.

7) Use RAM, ROM chips.

8)

(3)

## Boolean synthesis

Synthesis → finding the network that performs certain functional behaviour.

Minterm →

- complemented if 0
- uncomplemented if 1

Maxterm →

- complemented if 1
- uncomplemented if 0

$x_1$	$x_2$	$x_3$	$f$
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

→ synthesis of  
for the given i/p's  
and outputs  
↓  
design the network.

SOP → Sum of Products: → use Minterms

$f = 1$  (?) corresponding value 2(?) for 1,

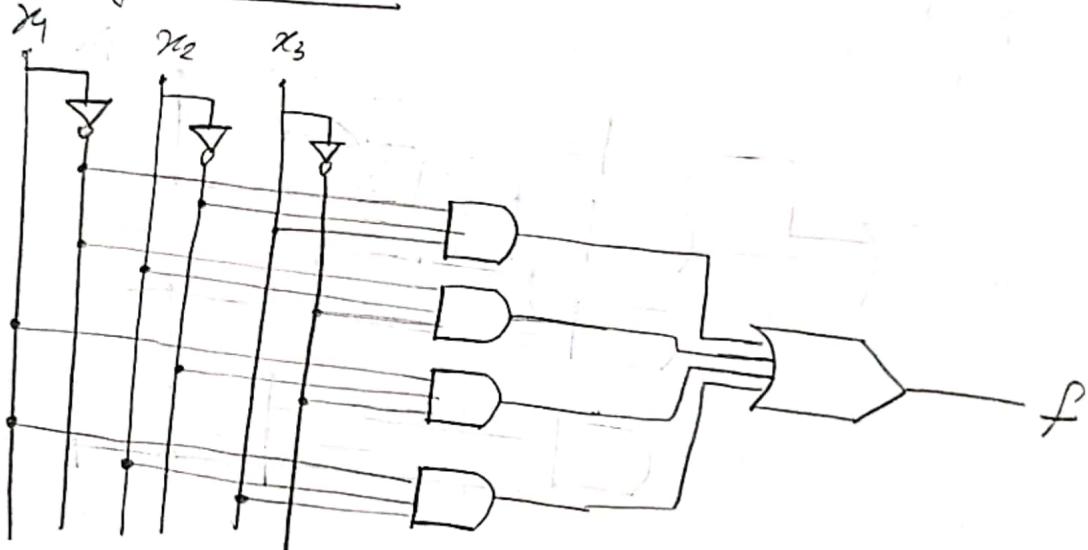
$$f = f(x_1, x_2, x_3) = \bar{x}_1 \bar{x}_2 x_3 + \bar{x}_1 x_2 \bar{x}_3 + x_1 \bar{x}_2 \bar{x}_3 + x_1 x_2 x_3$$
$$= m_1 + m_2 + m_4 + m_7$$

POS (Product of Sums): use Minterms

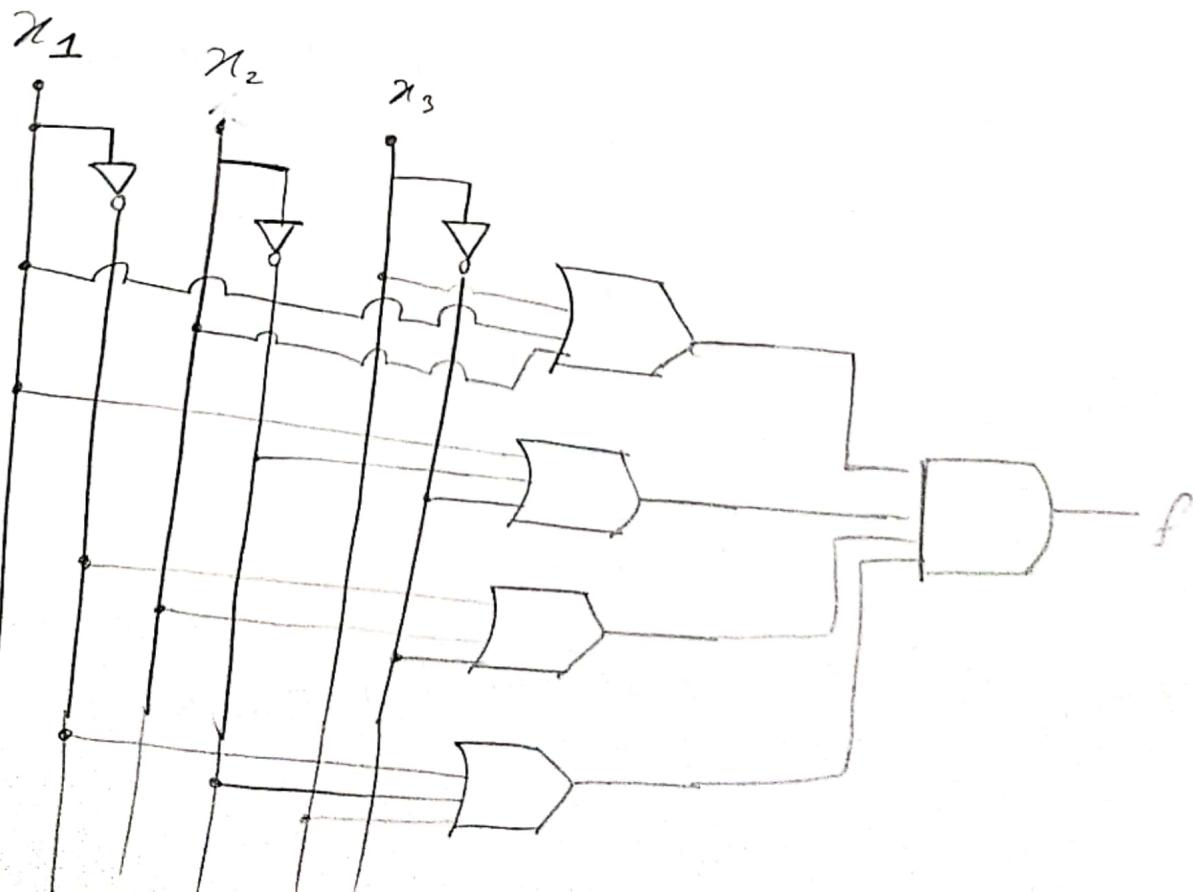
$$f = M_0 \cdot M_3 \cdot M_5 \cdot M_6 \rightarrow f=0 \text{ at respective terms}$$

$$= (x_1 + x_2 + x_3) \cdot (\bar{x}_1 + \bar{x}_2 + \bar{x}_3) \cdot (\bar{x}_1 + x_2 + \bar{x}_3) \cdot (\bar{x}_1 + \bar{x}_2 + x_3)$$

Using SOP results:



Using POS:

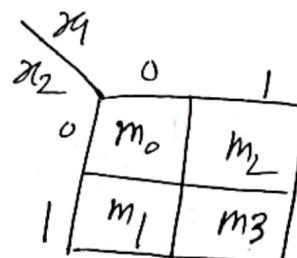


## Logic Circuit Minimization

Karnaugh Map → to produce min. cost logic expression.

for  $\rightarrow$

$x_1$	$x_2$	f	
0	0	$m_0$	1
0	1	$m_1$	1
1	0	$m_2$	0
1	1	$m_3$	1



for 3 variables  $\rightarrow$

$x_3$	$x_2$	00	01	11	10
0	$x_1$	$m_0$	$m_2$	$m_6$	$m_4$
1	$x_1$	$m_1$	$m_3$	$m_7$	$m_5$

for 4 variables :

$x_3$	$x_2$	00	01	11	10
0	$x_1$	00	01	11	10
1	$x_1$	00	01	11	10

for

$x_1$	$x_2$	f
0	0	0
0	1	0
1	0	1
1	1	1

K-map

$x_2$	0	1
0	0	0
1	1	1

$$SOP \rightarrow f = \bar{x}_1 \bar{x}_2 + x_1 x_2 = x_1$$

$$POS \rightarrow f = (x_1 + x_2) \cdot (\bar{x}_1 + \bar{x}_2) = x_1$$

f value  $x_1$  dependent  $\rightarrow$

$x_1$  change  $\exists (2^1)$  f changes.  
 $x_2$  change  $\exists (2^1)$  f = no change.

SOP to largest chain of 1 select  
 POS ( ) " " " 0 "

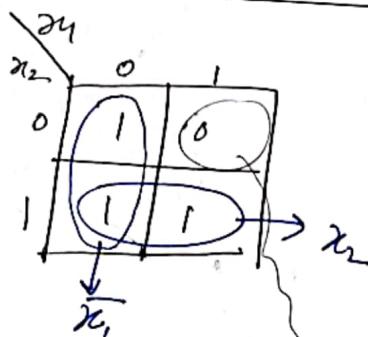
$$2^n$$

where  $n = 0, 1, 2, \dots$

element no. total in the chain on rectangle

MSF / chain size

$x_1$	$x_2$	f
0	0	1
0	1	1
1	0	0
1	1	1

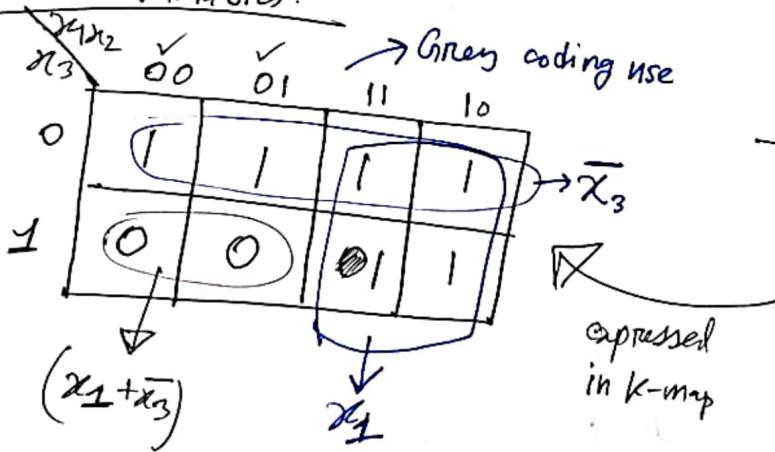


$$\therefore \text{SOP} = \bar{x}_1 + x_2$$

$2^1 = 2$  elements in the chain

POS F  $\rightarrow$  take chain of 0  $\rightarrow (\bar{x}_1 + x_2)$

for 3 variables:



$x_1$	$x_2$	$x_3$	f
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	1
1	1	1	1

SOP  $\rightarrow$  find chain of 1 (largest one)  $\rightarrow$  the rectangle  $\rightarrow (\bar{x}_1 + x_3) = f$

diagonal chain not allowed.

POS  $\rightarrow$  chain of 0 find  $\rightarrow f = (x_1 + \bar{x}_3)$

## useful info for verification

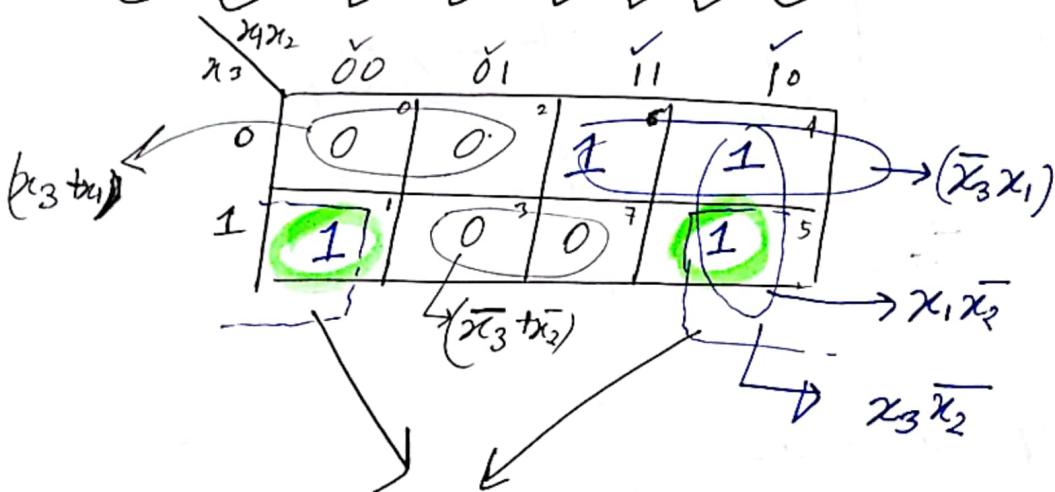
chain size =  $2^2 = 4$  for sop and variable no. = 3 for

so  $\therefore$  per chain  $\Rightarrow$  variable count =  $4 - 3 = 1$  for var.

$x_1$  and  $\bar{x}_3$

$\uparrow$

# find k-map for  $\Sigma_m(1, 4, 5, 6)$ :



$\therefore \exists_1$  connected as 00 and 10  $\Rightarrow$  difference  $\Rightarrow$  180°  
in grey code hence  $\exists_1$  chain  $\Rightarrow$   $\exists_1$   $\exists_2$ ,  
as grey code = cyclic

$$\therefore SOP \rightarrow f = x_1 \bar{x}_3 + x_3 \bar{x}_2 \quad (\text{here, } x_4 \bar{x}_2 \text{ is redundant.})$$

$$POS \rightarrow f = (x_4 + x_3) \cdot (\bar{x}_3 + \bar{x}_2) = x_1 \bar{x}_3 + x_4 \bar{x}_2 + x_3 \bar{x}_2$$

for 4 variables  $\rightarrow$  find POS and SOP from k-map

	$x_1x_2$	$x_3x_4$	00	01	11	10	
$(x_1+x_3)$	00	00	0	0	0	0	$(x_3+x_4)$
01	0	0	1	1	1	1	$x_1\bar{x}_3x_4$
11	1	0	0	0	1	1	
10	1	0	0	0	1	1	$x_1\bar{x}_2\bar{x}_4$
							$(\bar{x}_2+\bar{x}_3)$

invalid as  
 $1 \oplus 3 \neq 0$   
 $\neq 2^n; n=0, 1, 2, \dots$

redundant term

$$SOP = (\bar{x}_1\bar{x}_3x_4 + \bar{x}_2x_3 + \cancel{x_1\bar{x}_2x_4})$$

rectangle chain exists due to  
cyclic gray code  $\rightarrow \bar{x}_2x_3$

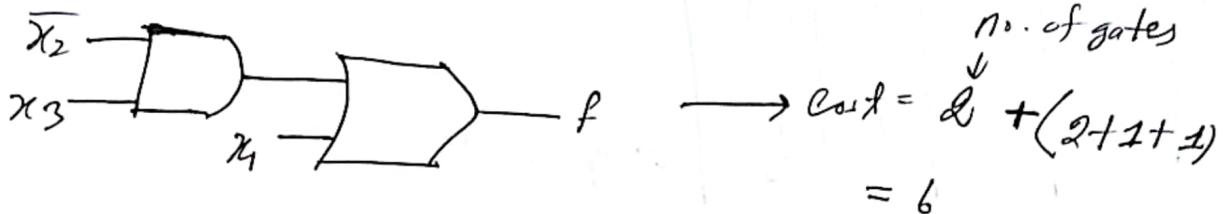
$$\begin{aligned}
 POS &= (x_1+x_3)(x_3+x_4)(\bar{x}_2+\bar{x}_3) \\
 &= (x_1x_3 + x_4x_4 + x_3x_4)(\bar{x}_2\bar{x}_3) \\
 &= (\cancel{\bar{x}_1\bar{x}_2\bar{x}_3} + x_1\bar{x}_2x_4 + x_1\bar{x}_3x_4 + (\bar{x}_2x_3 + x_2\bar{x}_3x_4)) \\
 &= \cancel{\bar{x}_2x_3}(1+x_1+x_4) + x_2\bar{x}_2x_4 + x_4\bar{x}_3x_4 \\
 &= SOP \text{ same}
 \end{aligned}$$

## Cost Function

Cost = (# gates) + (# total inputs to all the gates)

Ex:  $x_1 + \bar{x}_2 x_3$

$x_2, \bar{x}_2$  cost same hence →  
for input variables



Ex:

	00	01	11	10
00	0	0	0	0
01	0	0	1	1
11	1	1	1	1
10	1	1	1	1

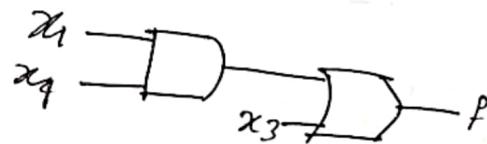
$x_1 x_3$

$(x_1 + x_3)$

$x_1 x_4$

$x_3$

SOP →  $f = x_1 x_4 + x_3$



Cost = 2 + (2 + 1 + 1) = 6

POS →  $f = (x_1 + x_3)(x_3 + x_4)$

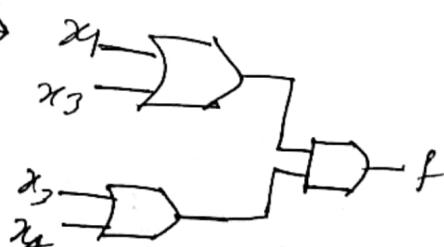
$x_1 x_3 + x_2 x_4 + x_3 + x_2 x_4$

$= x_3(1 + x_1 + x_2 + x_1 x_2)$

$= SOP \quad 2(1/3) \quad 25$  formst

→ SOP formst, not POS formst

hence POS  $\overline{GTR}(f = (x_1 + x_3)(x_3 + x_4))$  or  
WRT f → Cost too 25 formst



Cost = 3 + 6 = 9

↑  
3 T gates  
OR

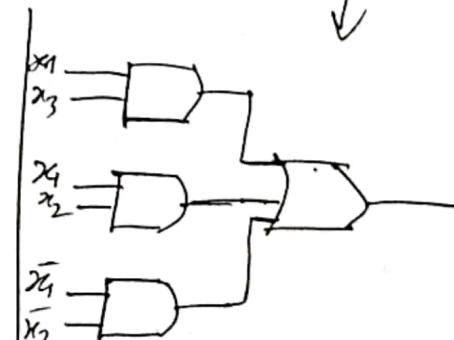
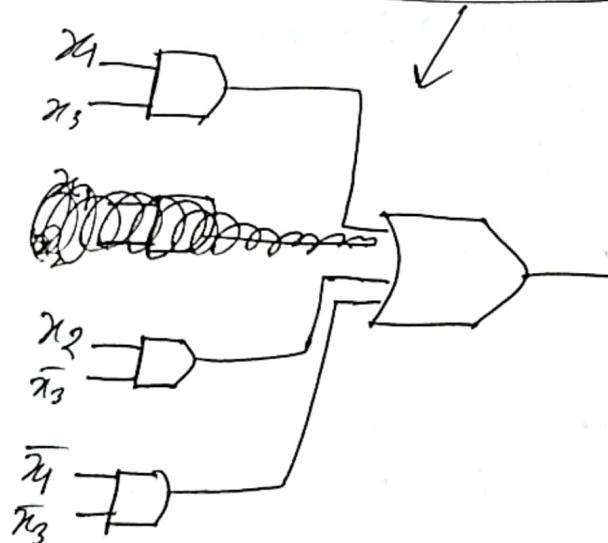
Ex: find cost in SOP and POS format and find the min. cost.

	$\bar{x}_1 \bar{x}_2$	$x_1 \bar{x}_2$	$x_1 x_2$	
$\bar{x}_3 \bar{x}_4$	00	01	11	10
00	1	1	1	0
01	1	1	1	0
11	0	0	1	1
10	0	0	1	1

as for 1  $\oplus$  chain have and  
 $b \neq 2^n$  where,  $n=0, 1, 2, 3, \dots$   
∴ invalid chain for

In SOP  $f = (\bar{x}_1 x_2 + x_1 \bar{x}_2 + \bar{x}_1 \bar{x}_2)$

highlighted (1) to include  
either chain or  
 $\frac{\partial f}{\partial x_1 x_3} + \frac{\partial f}{\partial x_1 \bar{x}_2}$   
 $+ \bar{x}_1 x_2 + \bar{x}_1 \bar{x}_2$



Cost = 4 + 9 = 13 = same

Cost = 4 + (9) = 13

PTO,

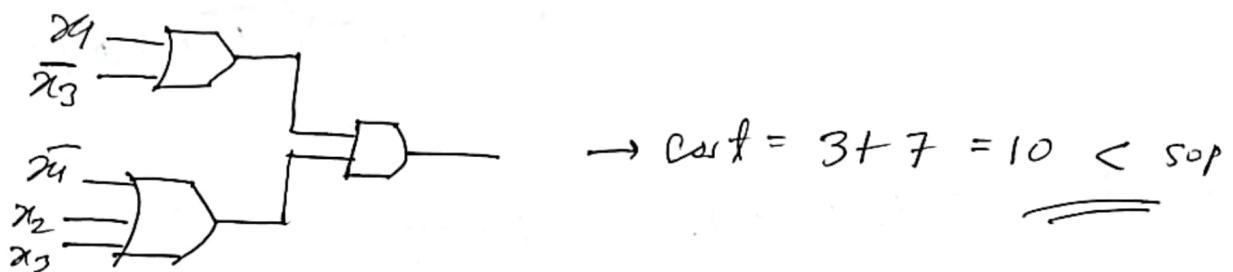
the

for POS format:

$\bar{x}_2 \bar{x}_3$	00	01	11	10
$x_2 x_3$	1	1	1	0
00	1	1	1	0
01	1	1	1	0
11	0	0	1	1
10	0	0	1	1

$(\bar{x}_1 + x_2 + x_3)$

$$f = (\bar{x}_1 + \bar{x}_3) \cdot (\bar{x}_1 + x_2 + x_3)$$



Ex:

$\bar{x}_2 \bar{x}_3$	00	01	11	10
$x_2 x_3$	0	0	0	0
00	0	0	1	1
01	0	1	1	0
11	1	1	0	1
10	1	1	1	1

$\bar{x}_4 x_3$

$x_3 \bar{x}_4$

$\bar{x}_2 x_3$

$$\text{SOP } \omega \rightarrow f = (\bar{x}_4 x_3 + x_3 \bar{x}_4 + \bar{x}_2 x_3 + x_2 \bar{x}_3 x_4)$$

in pos:

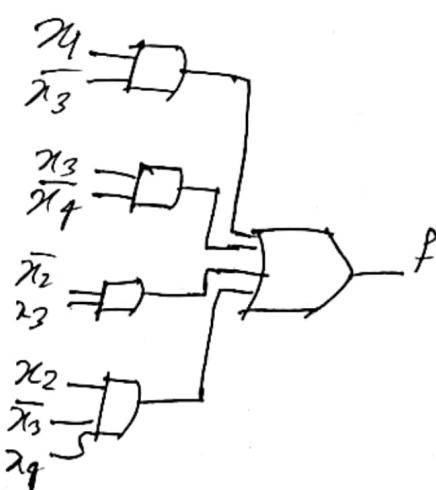
$\bar{x}_4 \bar{x}_3$	00	01	11	10
$x_4 x_3$	0	0	0	0
$\bar{x}_4 x_3$	0	1	1	0
$x_4 \bar{x}_3$	1	1	0	1
$x_4$	1	1	1	1

pos  $\rightarrow f = (\bar{x}_3 + x_4)(x_2 + x_3) \cdot (\bar{x}_4 + \bar{x}_2 + \bar{x}_3 + x_4)$

nr. minterms =  $4 - 0 = 4$

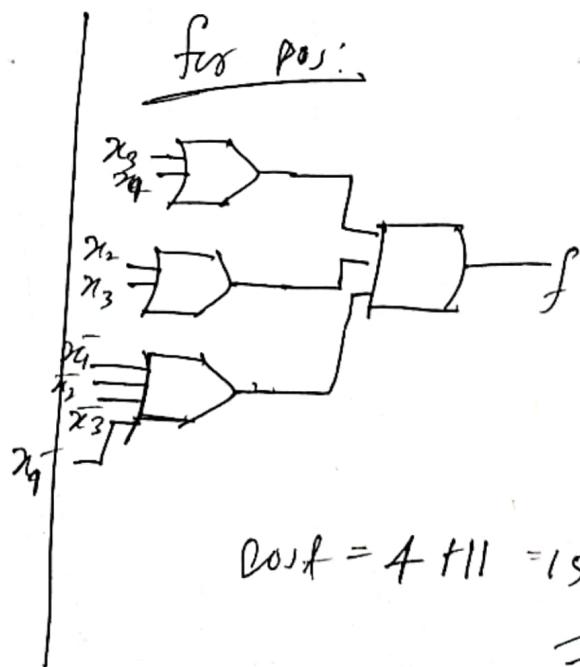
$2^{\circ} = 1$

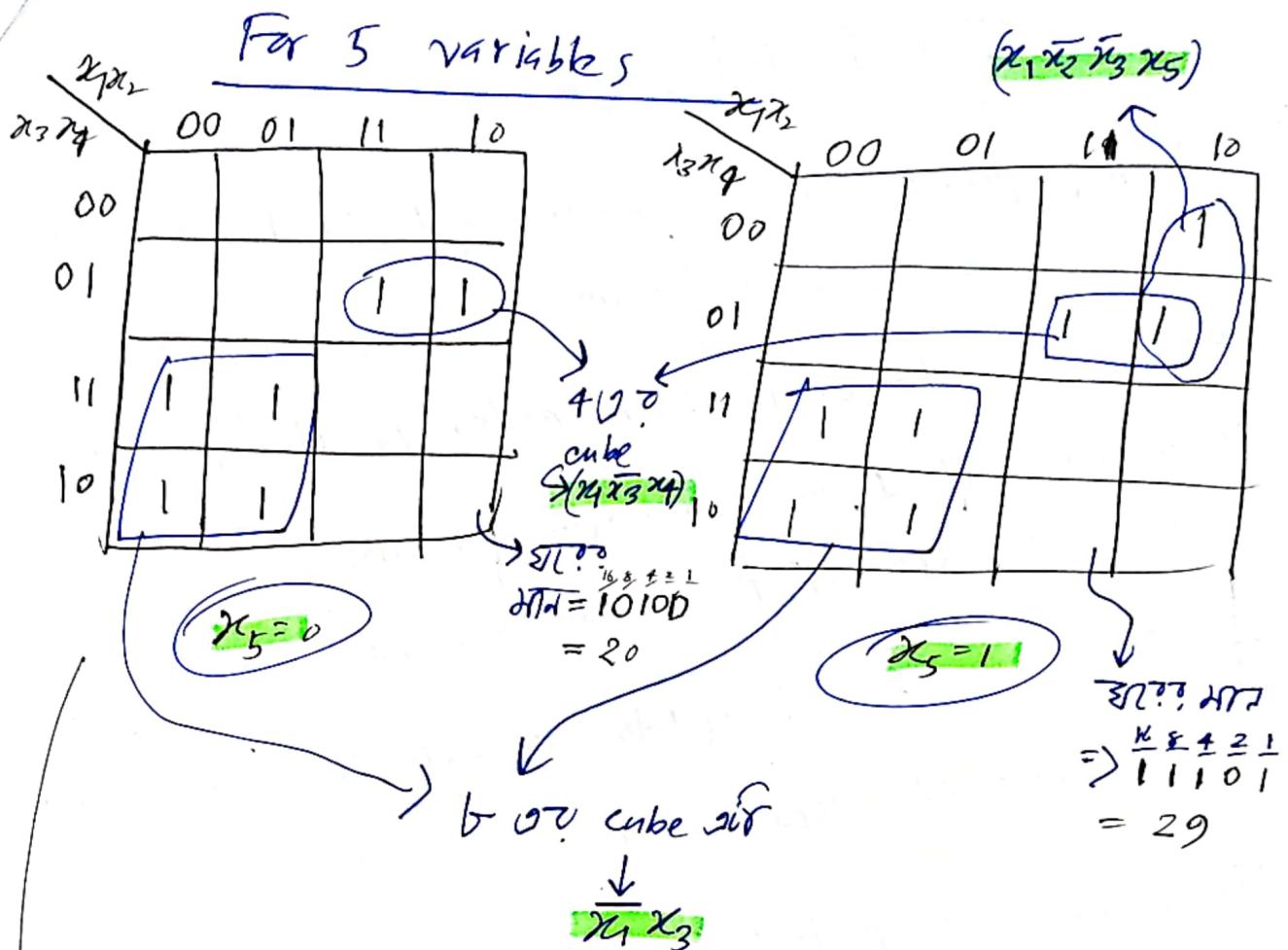
elementary



$$\text{Cost } f = 5 + 13 = 18$$

for sop =





$$\therefore SOP \rightarrow f = (\bar{x}_4 x_3 + x_4 \bar{x}_3 \bar{x}_4 + x_1 \bar{x}_2 \bar{x}_3 x_5)$$

5<sup>th</sup> block गले आरोग्यदाता कृषि अकड़ in 3D.

## Things to Note

- 1) K-map provides the minimized SOP or POS version but not the most minimized form.
- 2) If a bit changes, it doesn't matter. If it stays same, it matters.
- 3) include all 1's for SOP  $\rightarrow$  use Minterm  
" " 0's for POS  $\rightarrow$  use Maxterm
- 4) Select largest chain (lateral or vertical) or rectangle, with size  $= 2^n$  where  $n = 0, 1, 2, 3, \dots$  etc.
- 5) Chains may partially overlap
- 6) Grey coding is cyclic hence ends are connected.

## K-Map - Part - 2

Literal: each appearance of a variable either uncomplemented or complemented.

Ex:

$$x_1 \bar{x}_2 \text{ literal} = 2$$

$$x_1 x_3 \bar{x}_4 \text{ " " } = 3$$

$$x_1 \bar{x}_4 x_2 \text{ " " } = \text{not } 2 \text{ as result } = 0 \quad \bar{x}_1 x_2 \bar{x}_3$$

Implicant:  $x_1 \bar{x}_2$  product

Ex:  $x_1 \bar{x}_2$  form 3 stor 1 face on. not store 2 stor for implicant.

$x_3$	00	01	11	10
0	1 1	1 1	0	0
1	1 1	1 1	1 1	0

$\therefore$  total = 11 by implicant  $\rightarrow$  not 12 ie  $\bar{x}_1 x_2$  3 for 1 go see video. now why as  $3 \neq 2^n$ .

$n=0, 1, 2, \dots$   
etc.

Prime implicant:

Other implicants  $\bar{x}_1 x_2$  etc  $x_1 \bar{x}_2$ ,  $x_1 x_2$ ,  $x_1 \bar{x}_3$ ,  $x_1 x_3$ ,  $x_2 \bar{x}_3$ ,  $x_2 x_3$

$x_3$	00	01	11	10
0	1 1	1 1	0	0
1	1 1	1 1	1 1	0

$\therefore$  total = 2 by

Cover: SOP ( $\Sigma$ ) implicants sum of 1's in minterm map or total

SOP ( $\Sigma$ ) minterm or function expression (SOP)  $\Sigma$ ,

	$x_2$	00	01	11	10
$x_3$		0	1	0	0
	1	1	1	0	

SOP form

$$f = \bar{x}_1 \bar{x}_2 x_3 + \bar{x}_1 \bar{x}_2 \bar{x}_3 + x_1 \bar{x}_2 \bar{x}_3 + \bar{x}_1 x_2 x_3 + x_1 x_2 \bar{x}_3$$

$$= \bar{x}_1 \bar{x}_3 + \bar{x}_1 x_2 + x_2 x_3$$

$$= \bar{x}_1 + x_2 x_3 \rightarrow \text{SOP (GATE) cover} = 2$$

$\Sigma$  ( $\Sigma$ )  
cover  
 $= 5$

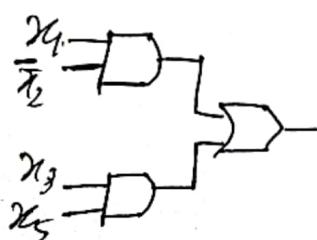
Cost

- Cost = (#gates) + (#total i/p to all gates)
- i/p side

a) complement, uncomplemented same cost OR  
 $x_2, \bar{x}_2$  same OR, extra NOT gate cost OR

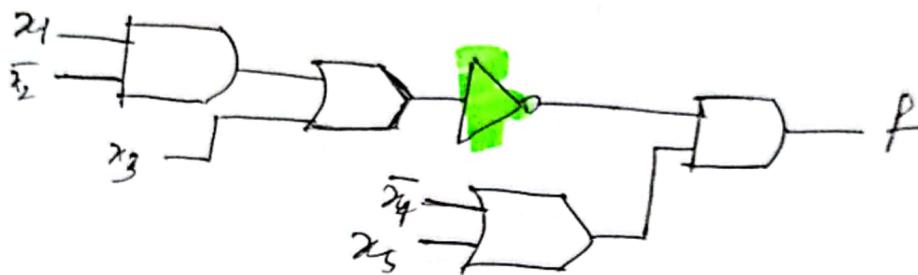
b) But, if inversion needed inside a ckt, not at i/p side then  
 NOT gate and its i/p cost included.

$$f = \bar{x}_1 \bar{x}_2 + x_3 x_5$$



$$\text{Cost} = 3 + (4) = 9$$

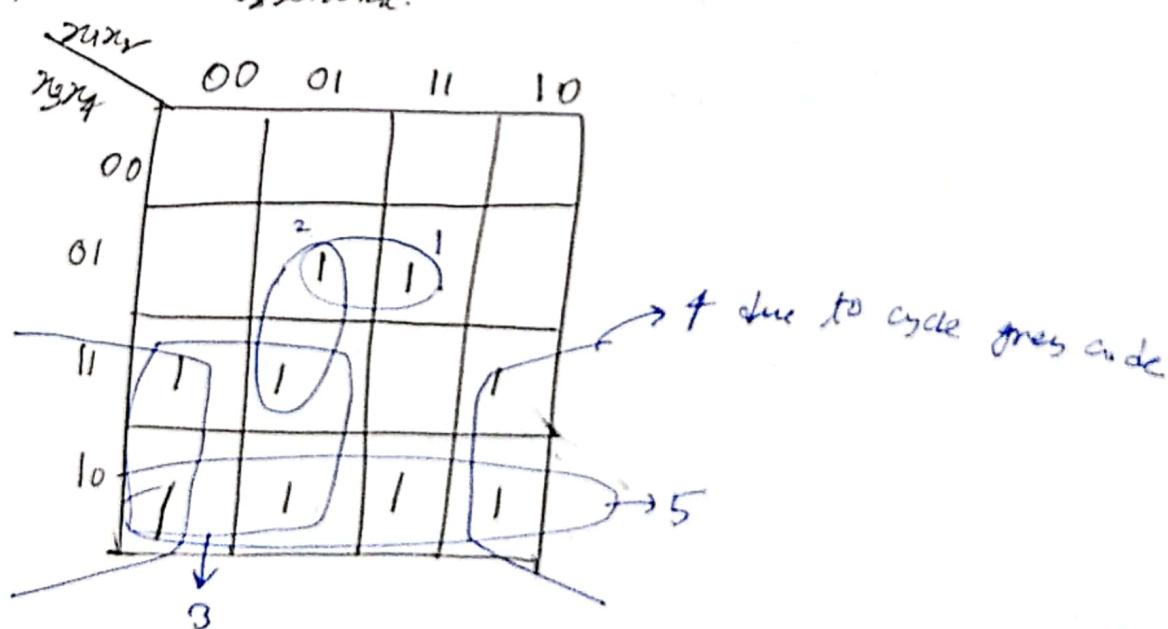
$$f = \overline{x_1 \bar{x}_2 + x_3} \cdot (\bar{x}_4 + x_5)$$



$$\begin{aligned} \text{Cost} &= \# \text{gates} + \# \text{total ips to all gates} \\ &= 5 + \{9\} = 14 \end{aligned}$$

✓ Essential Prime Implicant

prime implicant  $\bar{x}_1 \bar{x}_2 x_3$  is ~~not~~ covered by any other prime implicant if  $\bar{x}_1 \bar{x}_2 x_3$  is covered by another prime implicant then that prime implicant is essential.



1 no. prime implicant ~~on left~~ left side of  $\bar{x}_1$  OR 2 no. prime implicant = 2 no. exists but Right side of  $\bar{x}_1$  OR 0 no. prime hence 1 no. prime implicant is essential  $\rightarrow \bar{x}_1 \bar{x}_2 x_3$

5 no also essential prime implicant as 5 no. minterm

M2(0 or 1) or diff. term implicant of T2,  $\rightarrow \bar{x}_3 \bar{x}_4$

4 no. also essential as (3, 4) ⊂ minterm 1 so diff. term prime implicant of minterm 1 →  $\bar{x}_2 x_3$

Diff. of 2 no. and 3 no. prime implicants = not essential.

Non-essential  $\Rightarrow$  take the largest prime implicant i.e. the 3 no.  $\rightarrow \bar{x}_1 x_3 \rightarrow$  get minimized result.

$$\therefore f = SOP = (\bar{x}_2 \bar{x}_3 \bar{x}_4 + x_3 \bar{x}_4 + \bar{x}_2 x_3 + \bar{x}_1 x_3)$$

		MSB				
		$\bar{x}_3 \bar{x}_4$				grey coding
		00	01	11	10	
$\bar{x}_2$	$x_3 \bar{x}_4$	1	1	1	1	1 no. prime implicant of M2 for 1 or M1 (T2)
00				1	2 $\Rightarrow x_1 x_3 \bar{x}_4$	
01				1	3 $\Rightarrow x_1 x_2 x_4$	
11			1	1	4 $\Rightarrow x_1 x_3 x_4$	
10				1	5 $\Rightarrow x_1 \bar{x}_2 x_3$	

total 6 prime implicants present. Only 1 no. = essential. Others

1 or 2 or 3 or prime implicant  $\Rightarrow$  diff. minterms

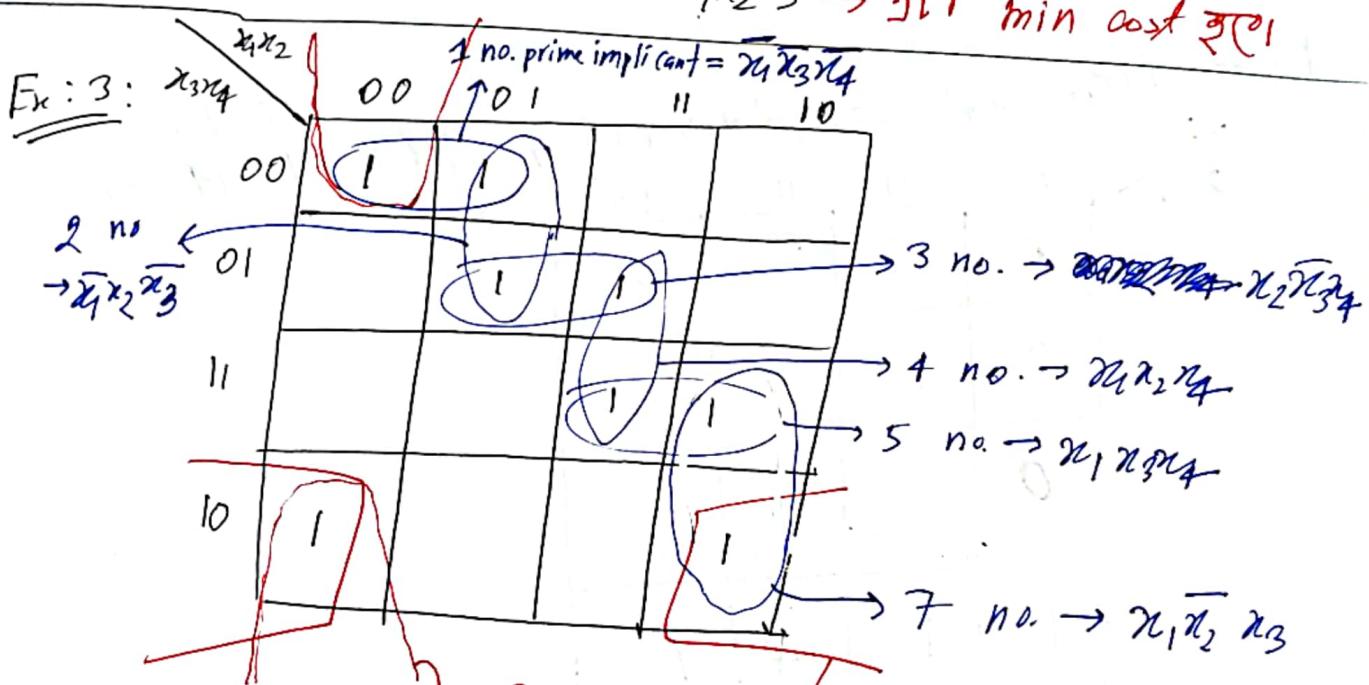
$\bar{x}_1 \bar{x}_2 \bar{x}_4$

मिनी सेल एवं न्यूनतम असेट:

Way-1:  $f = SOP = \text{essential} + 2 \text{ no.} + 4 \text{ no.} \rightarrow 10 \text{ minterms} + 4 \text{ no.} + 5 \text{ no.}$

$$= \bar{x}_3 \bar{x}_4 + x_1 x_2 \bar{x}_3 + x_1 x_3 x_4 + x_2 \bar{x}_2 x_3$$

Way-2:  $f = 1 \text{ no.} + 3 \text{ no.} + 5 \text{ no.} \rightarrow 1 \text{ prime implicant covers 1 cover}$   
 $= \bar{x}_3 \bar{x}_4 + x_1 x_2 x_3 + x_2 \bar{x}_2 x_3 \rightarrow \text{for min cost इसी}$



ग्राफ तथा essential prime implicant के बारे में 180, 120 रुपये

→ Way-1:

$$f = 1 \text{ no.} + 3 \text{ no.} + 5 \text{ no.} + 6 \text{ no.} = \bar{x}_1 \bar{x}_3 \bar{x}_4 + x_2 \bar{x}_3 x_4 + x_1 x_2 x_4 + \bar{x}_2 x_3 \bar{x}_4$$

Way-2:  $f = 7 \text{ no.} + 2 \text{ no.} + 4 \text{ no.} + 7 \text{ no.}$

$$= \bar{x}_1 \bar{x}_2 \bar{x}_4 + \bar{x}_1 x_2 \bar{x}_3 + x_1 x_2 x_4 + x_2 \bar{x}_2 x_3$$

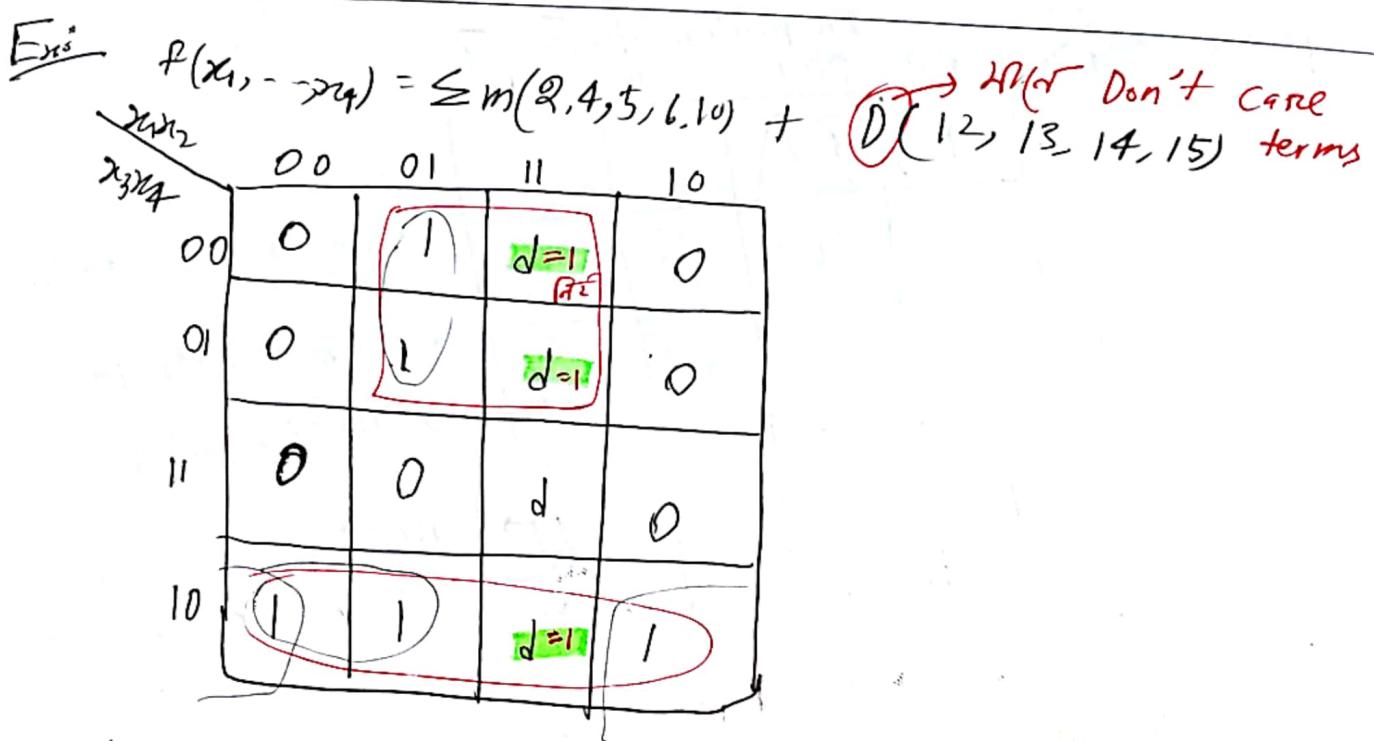
Both same cost

## K-Map → Part 3

✓ In completely specified function case → K-map :

A function that has don't care condition(s) is incompletely specified func.

Ex: if two switch are such that both can't be closed simultaneously then only allowed ip are 00, 01, 10 ; 11 ip is invalid hence don't care state.



don't care term at 1110 → so  $f = \bar{x}_1 x_2 \bar{x}_3 + \bar{x}_1 x_3 \bar{x}_4 + \bar{x}_2 x_3 \bar{x}_4$

As don't care term 1110 is all hence answer  $d=1$  for 1110 or if then →  
 $f = x_2 \bar{x}_3 + x_3 \bar{x}_4$   
 $\downarrow$   
 $\Rightarrow d=0-3$  for 1110

Much minimized form of 1110

# Note that  $d$  is a cycle factor so it is constant

1 cover  $d$  terms  $d=1$  ~~for~~ chain terms

		pos form				
		00	01	11	10	
$x_1x_2$	$x_3x_4$	00	0	1	$d$	0
		01	0	1	$d$	0
11		0	0	$d$	0	
10		1	1	$d$	1	

(1)  $\rightarrow (x_2 + x_3)$

(2)  $\rightarrow (x_2 + \bar{x}_3 + \bar{x}_4)$

(3)  $\rightarrow (x_1 + \bar{x}_3 + \bar{x}_4)$

don't care term  $\rightarrow f = pos$

$$= (x_1 + x_3)(x_1 + \bar{x}_3 + \bar{x}_4)(x_2 + \bar{x}_3 + \bar{x}_4)$$

if  $d$  are considered now:

		00	01	11	10
		$x_1x_2$	$x_3x_4$		
00	0	0	1	$d$	0
01	0	1	$d$	0	
11	0	0	$d=0$	0	
10	1	1	$d$	1	

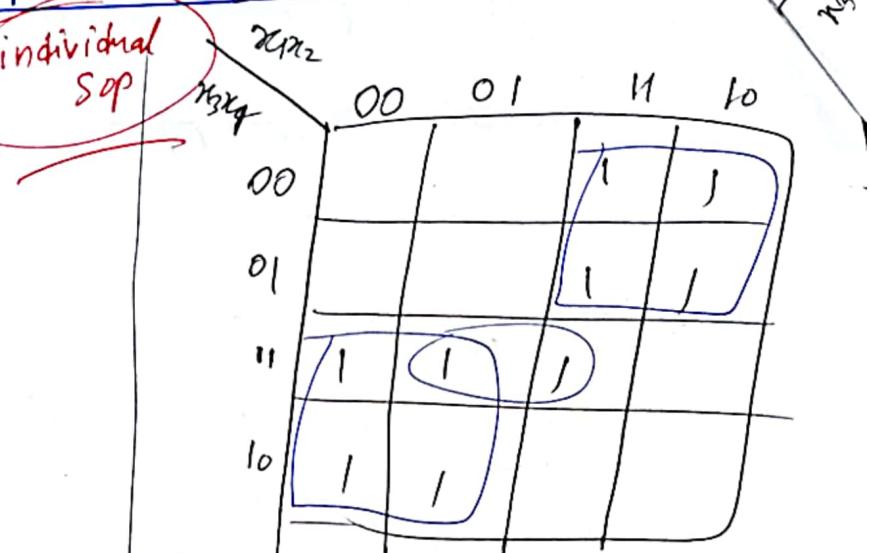
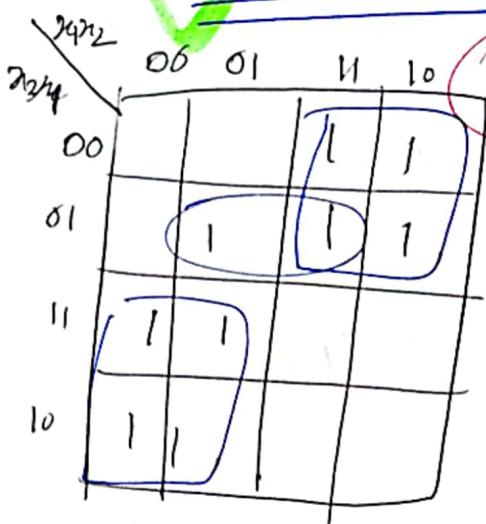
(4)  $\rightarrow (x_2 + x_3)$

(5)  $\rightarrow (\bar{x}_3 + \bar{x}_4)$

$$f = pos = (x_2 + x_3) \cdot (\bar{x}_3 + \bar{x}_4)$$

more cost efficient

## Multiple Output Ckt Case



(a) function  $f_1$

$$f_1 = \cancel{x_4 x_3} + \cancel{\bar{x}_1 x_3} + x_2 \bar{x}_3 x_4$$

$\downarrow$

$C_{1Sf} = 14$

(b) function  $f_2$

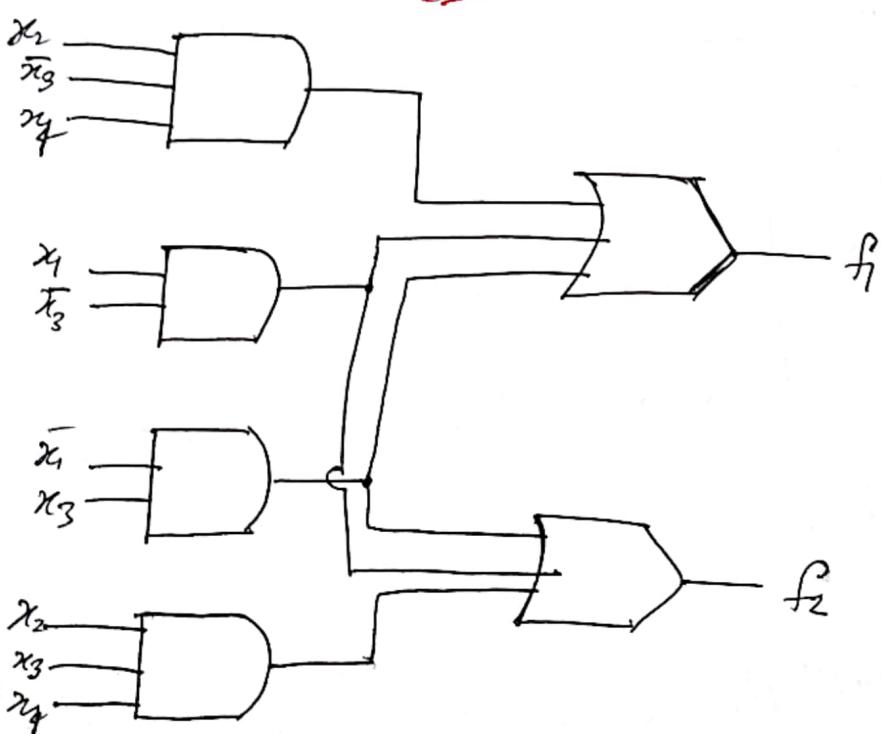
$$f_2 = \cancel{\bar{x}_4 x_3} + \cancel{x_4 \bar{x}_3} + x_2 x_3 x_4$$

$\downarrow$

$C_{1Sf} = 14$

$\text{total cost} = 14 + 14 = 28$

Combined SOP



$C_{1Sf} = 6 + 16$

$= 22$

Using Pos

$x_1x_2$	00	01	11	10
$x_3x_4$	00	0	1	1
00	0	0		
01	0	1	1	1
11	1	1	0	0
10	1	1	0	0

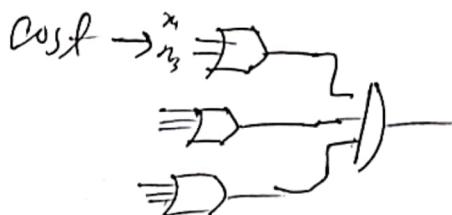
$x_1x_2$	00	01	11	10
$x_3x_4$	00	0	1	1
00	0	0		
01	0	0	1	1
11	1	1	1	0
10	1	1	0	0

$$f_1 = \cancel{(x_1 + x_2 + x_3 + x_4)} \cdot (x_1 + x_3 + x_4) \cdot \\ (x_4 + x_2 + x_3) \cdot (\bar{x}_1 + \bar{x}_3)$$

$$\text{Cost} = 4(3+3+2+3) \\ = 15$$

*total = 30*

$$f_2 = (x_1 + x_3)(\bar{x}_1 + x_2 + \bar{x}_3) \\ (\bar{x}_1 + \bar{x}_3 + x_4)$$



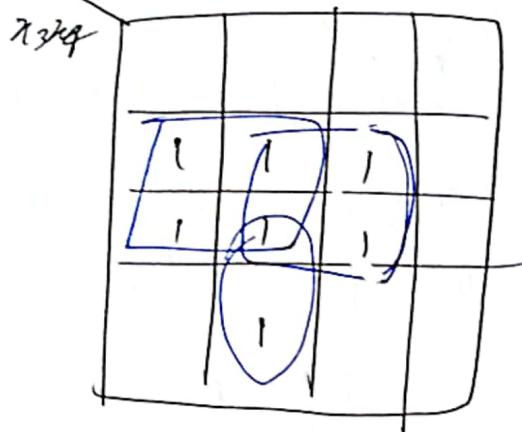
*total = 15*

### Combined Fct

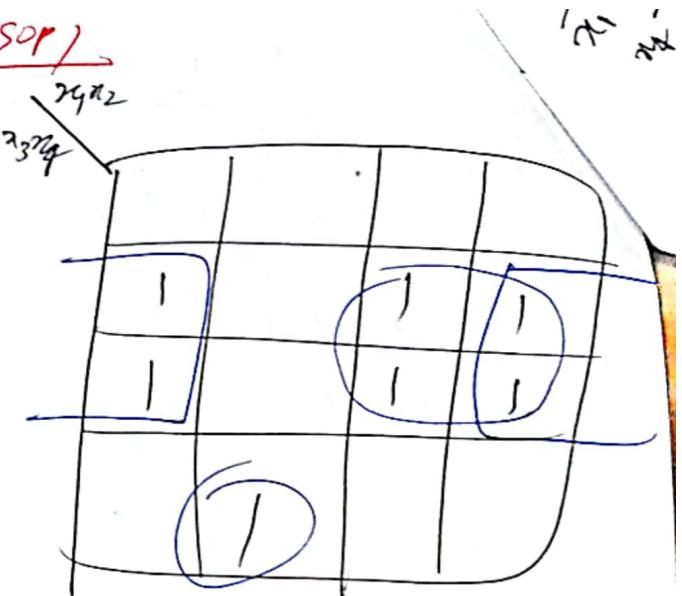
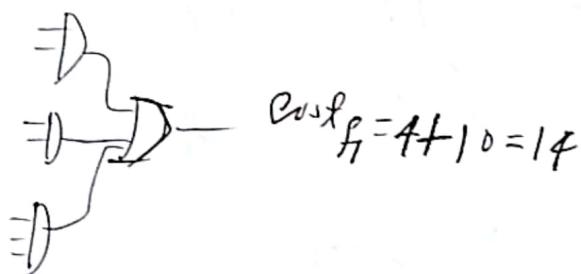
No common parts. Other 2 ckt.  $\text{Out} > 30$   $\text{Fct}$   
एक एक

En: 2

### Way - 1: (individual SOP)



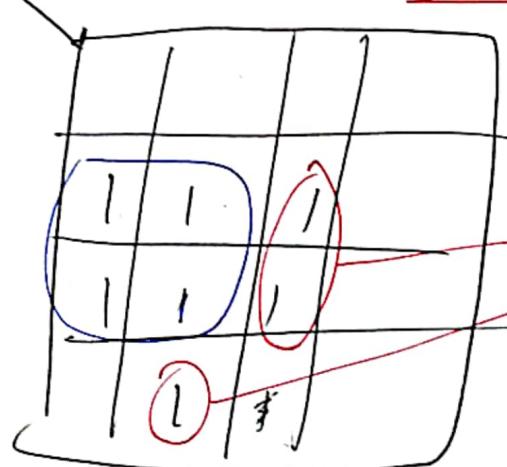
$$f_1 = \bar{x}_1 x_2 + x_2 x_3 + \bar{x}_1 \bar{x}_2 x_3$$



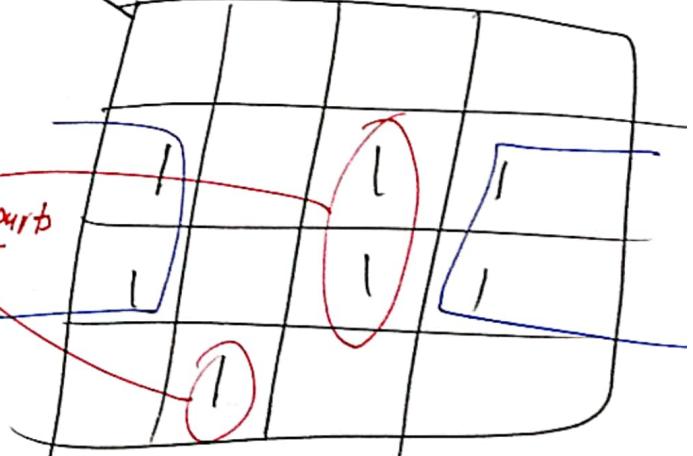
$$f_2 = x_1 x_2 + \bar{x}_1 x_2 + \bar{x}_1 \bar{x}_2 x_3 - \\ \Rightarrow \text{Cost} = 15$$

$$\text{Total Cost} = 14 + 15 = 29$$

### Combined SOP Form!

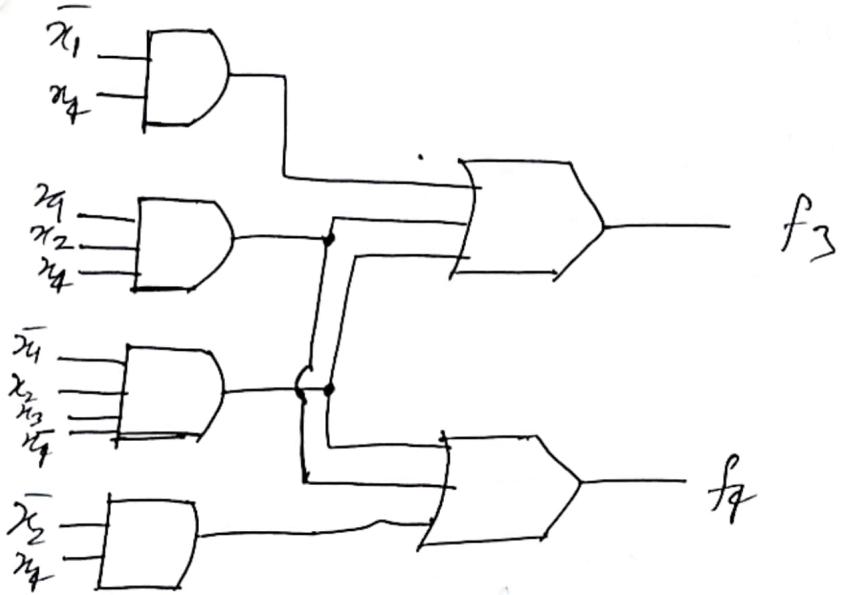


Common part  
Filter

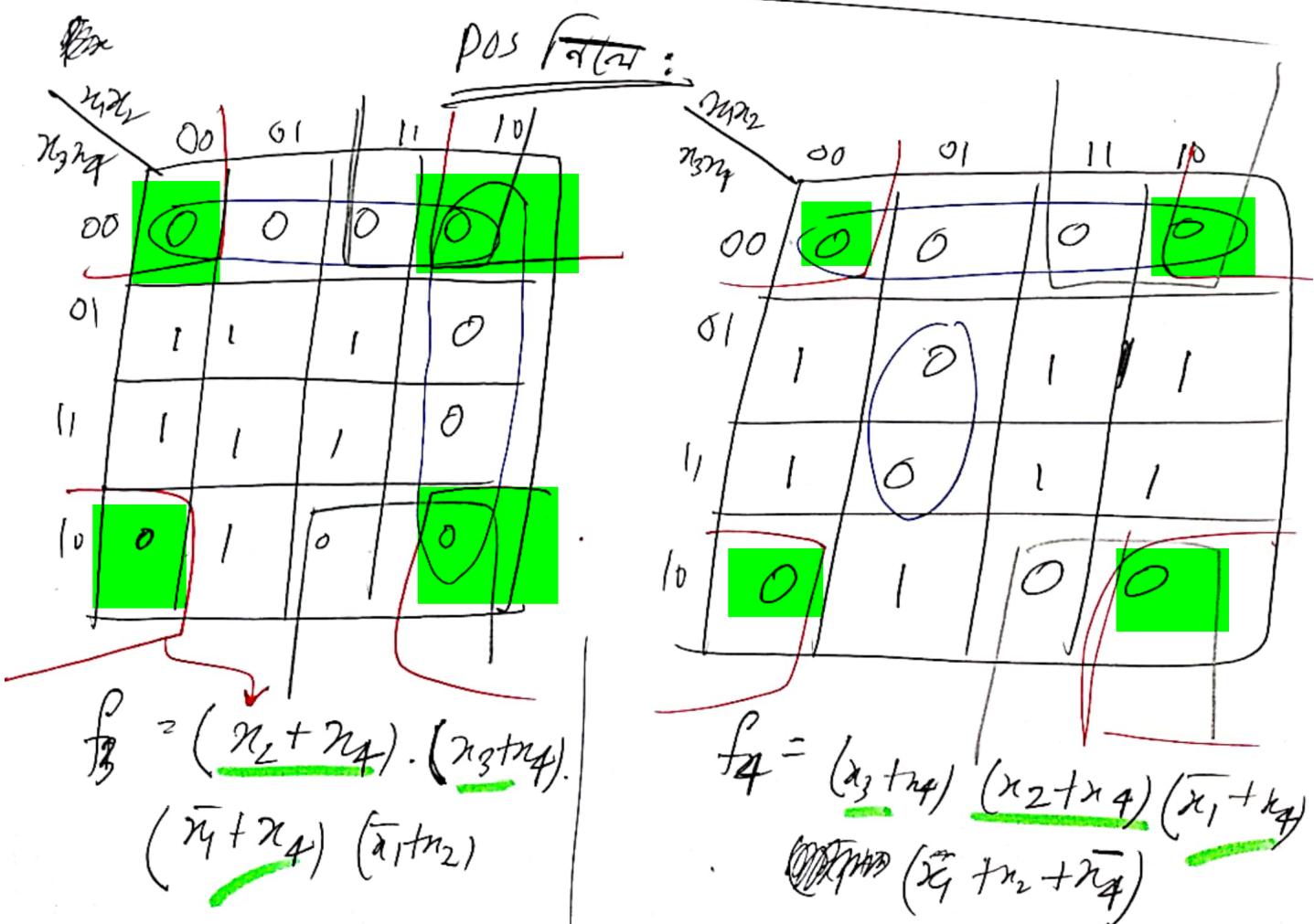


$$f_3 = x_1 x_2 x_4 + \bar{x}_1 x_2 x_3 \bar{x}_4 \\ + \bar{x}_1 \bar{x}_4$$

$$f_4 = x_1 x_2 x_4 + \bar{x}_1 x_2 x_3 \bar{x}_4 \\ + \bar{x}_2 x_4$$



$$\text{Cost in combined} = 6 + 17 = \underline{\underline{23}} \rightarrow \text{Min}$$



Watch out for corner elements as well

$$f_3 \text{ cost} \rightarrow 5 + 12 = 17$$

$$f_4 \rightarrow 5 + 13 = 18$$

$$\text{Total} = 35$$

Combined Pos

Common F0 F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F30 F31 F32 F33 F34 F35 F36 F37 F38 F39 F40 F41 F42 F43 F44 F45 F46 F47 F48 F49 F50 F51 F52 F53 F54 F55 F56 F57 F58 F59 F60 F61 F62 F63 F64 F65 F66 F67 F68 F69 F70 F71 F72 F73 F74 F75 F76 F77 F78 F79 F80 F81 F82 F83 F84 F85 F86 F87 F88 F89 F90 F91 F92 F93 F94 F95 F96 F97 F98 F99 F100 F101 F102 F103 F104 F105 F106 F107 F108 F109 F110 F111 F112 F113 F114 F115 F116 F117 F118 F119 F120 F121 F122 F123 F124 F125 F126 F127 F128 F129 F130 F131 F132 F133 F134 F135 F136 F137 F138 F139 F140 F141 F142 F143 F144 F145 F146 F147 F148 F149 F150 F151 F152 F153 F154 F155 F156 F157 F158 F159 F160 F161 F162 F163 F164 F165 F166 F167 F168 F169 F170 F171 F172 F173 F174 F175 F176 F177 F178 F179 F180 F181 F182 F183 F184 F185 F186 F187 F188 F189 F190 F191 F192 F193 F194 F195 F196 F197 F198 F199 F199 F200 F201 F202 F203 F204 F205 F206 F207 F208 F209 F210 F211 F212 F213 F214 F215 F216 F217 F218 F219 F220 F221 F222 F223 F224 F225 F226 F227 F228 F229 F229 F230 F231 F232 F233 F234 F235 F236 F237 F238 F239 F239 F240 F241 F242 F243 F244 F245 F246 F247 F248 F249 F249 F250 F251 F252 F253 F254 F255 F256 F257 F258 F259 F259 F260 F261 F262 F263 F264 F265 F266 F267 F268 F269 F269 F270 F271 F272 F273 F274 F275 F276 F277 F278 F279 F279 F280 F281 F282 F283 F284 F285 F286 F287 F288 F289 F289 F290 F291 F292 F293 F294 F295 F296 F297 F298 F298 F299 F299 F300 F300 F301 F302 F303 F304 F305 F306 F307 F308 F309 F309 F310 F311 F312 F313 F314 F315 F316 F317 F318 F319 F319 F320 F321 F322 F323 F324 F325 F326 F327 F328 F329 F329 F330 F331 F332 F333 F334 F335 F336 F337 F338 F339 F339 F340 F341 F342 F343 F344 F345 F346 F347 F348 F349 F349 F350 F351 F352 F353 F354 F355 F356 F357 F358 F359 F359 F360 F361 F362 F363 F364 F365 F366 F367 F368 F369 F369 F370 F371 F372 F373 F374 F375 F376 F377 F378 F379 F379 F380 F381 F382 F383 F384 F385 F386 F387 F388 F389 F389 F390 F391 F392 F393 F394 F395 F396 F397 F398 F398 F399 F399 F400 F400 F401 F402 F403 F404 F405 F406 F407 F408 F409 F409 F410 F411 F412 F413 F414 F415 F416 F417 F418 F419 F419 F420 F421 F422 F423 F424 F425 F426 F427 F428 F429 F429 F430 F431 F432 F433 F434 F435 F436 F437 F438 F439 F439 F440 F441 F442 F443 F444 F445 F446 F447 F448 F449 F449 F450 F451 F452 F453 F454 F455 F456 F457 F458 F459 F459 F460 F461 F462 F463 F464 F465 F466 F467 F468 F469 F469 F470 F471 F472 F473 F474 F475 F476 F477 F478 F479 F479 F480 F481 F482 F483 F484 F485 F486 F487 F488 F489 F489 F490 F491 F492 F493 F494 F495 F496 F497 F498 F498 F499 F499 F500 F500 F501 F502 F503 F504 F505 F506 F507 F508 F509 F509 F510 F511 F512 F513 F514 F515 F516 F517 F518 F519 F519 F520 F521 F522 F523 F524 F525 F526 F527 F528 F529 F529 F530 F531 F532 F533 F534 F535 F536 F537 F538 F539 F539 F540 F541 F542 F543 F544 F545 F546 F547 F548 F549 F549 F550 F551 F552 F553 F554 F555 F556 F557 F558 F559 F559 F560 F561 F562 F563 F564 F565 F566 F567 F568 F569 F569 F570 F571 F572 F573 F574 F575 F576 F577 F578 F579 F579 F580 F581 F582 F583 F584 F585 F586 F587 F588 F589 F589 F590 F591 F592 F593 F594 F595 F596 F597 F598 F598 F599 F599 F600 F600 F601 F602 F603 F604 F605 F606 F607 F608 F609 F609 F610 F611 F612 F613 F614 F615 F616 F617 F618 F619 F619 F620 F621 F622 F623 F624 F625 F626 F627 F628 F629 F629 F630 F631 F632 F633 F634 F635 F636 F637 F638 F639 F639 F640 F641 F642 F643 F644 F645 F646 F647 F648 F649 F649 F650 F651 F652 F653 F654 F655 F656 F657 F658 F659 F659 F660 F661 F662 F663 F664 F665 F666 F667 F668 F669 F669 F670 F671 F672 F673 F674 F675 F676 F677 F678 F679 F679 F680 F681 F682 F683 F684 F685 F686 F687 F688 F689 F689 F690 F691 F692 F693 F694 F695 F696 F697 F698 F698 F699 F699 F700 F700 F701 F702 F703 F704 F705 F706 F707 F708 F709 F709 F710 F711 F712 F713 F714 F715 F716 F717 F718 F719 F719 F720 F721 F722 F723 F724 F725 F726 F727 F728 F729 F729 F730 F731 F732 F733 F734 F735 F736 F737 F738 F739 F739 F740 F741 F742 F743 F744 F745 F746 F747 F748 F749 F749 F750 F751 F752 F753 F754 F755 F756 F757 F758 F759 F759 F760 F761 F762 F763 F764 F765 F766 F767 F768 F769 F769 F770 F771 F772 F773 F774 F775 F776 F777 F778 F779 F779 F780 F781 F782 F783 F784 F785 F786 F787 F788 F789 F789 F790 F791 F792 F793 F794 F795 F796 F797 F798 F798 F799 F799 F800 F800 F801 F802 F803 F804 F805 F806 F807 F808 F809 F809 F810 F811 F812 F813 F814 F815 F816 F817 F818 F819 F819 F820 F821 F822 F823 F824 F825 F826 F827 F828 F829 F829 F830 F831 F832 F833 F834 F835 F836 F837 F838 F839 F839 F840 F841 F842 F843 F844 F845 F846 F847 F848 F849 F849 F850 F851 F852 F853 F854 F855 F856 F857 F858 F859 F859 F860 F861 F862 F863 F864 F865 F866 F867 F868 F869 F869 F870 F871 F872 F873 F874 F875 F876 F877 F878 F879 F879 F880 F881 F882 F883 F884 F885 F886 F887 F888 F889 F889 F890 F891 F892 F893 F894 F895 F896 F897 F898 F898 F899 F899 F900 F900 F901 F902 F903 F904 F905 F906 F907 F908 F909 F909 F910 F911 F912 F913 F914 F915 F916 F917 F918 F919 F919 F920 F921 F922 F923 F924 F925 F926 F927 F928 F929 F929 F930 F931 F932 F933 F934 F935 F936 F937 F938 F939 F939 F940 F941 F942 F943 F944 F945 F946 F947 F948 F949 F949 F950 F951 F952 F953 F954 F955 F956 F957 F958 F959 F959 F960 F961 F962 F963 F964 F965 F966 F967 F968 F969 F969 F970 F971 F972 F973 F974 F975 F976 F977 F978 F979 F979 F980 F981 F982 F983 F984 F985 F986 F987 F988 F989 F989 F990 F991 F992 F993 F994 F995 F996 F997 F998 F998 F999 F999 F1000 F1000

$$\text{Cost} = 7 + 19 = 26$$

Ans