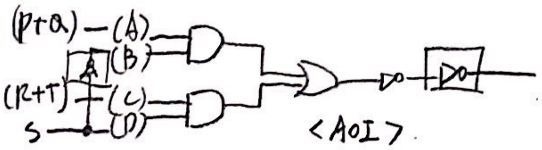
$\boxed{2}$ $Z = \overline{(AB+CD)} \Leftarrow A\cdot O\cdot I$

(a) $f(P,Q,R) = \overline{(PQ+R)} \Leftarrow$ only $\boxed{\text{1 package.}}$

($\because$ by $A=P,\ B=Q,\ C=R,\ D=1$)

(b) $f(\boxed{P,Q},\ \overline{R,S,T}) = (\underset{\sim}{P+Q})S + (\underset{\sim}{R+T})\overline{S}$

→ To make $(P+Q)$ and $(R+T)$,
we need 1 package for each … ①.



→ by using ①, we can make $f(P,Q,R,S,T)$ with using additional 2 inverters.

→ we can make inverter by 1 AoI … ②

$\therefore$ By ① & ②, $1\times2 + 1\times2 + 1 = \boxed{\text{5 packages}}$

(c) $f(P,Q,R,S,T) = PQR + \underset{\sim}{ST}$

→ $(A'+B')' = AB.$

$$f = [(P'+Q'+R')\cdot(S'+T')]' \quad ③$$

$$= [\underbrace{(P'+Q')\cdot\overline{(S'+T')}}_{① = 7\text{ pack.}} + \underbrace{R'\cdot\overline{(S'+T')}}_{② = 4\text{ pack.}}]$$

→ $① = [(P'+Q')' + \underbrace{(S'+T')'}_{③'}]'$

$③' = (\underline{S}'+\underline{T}')' \Leftarrow$ 3 packages (2 for inv.)

$③' \to ①,\ ① \Leftarrow 3+3+1 = \underline{7\text{ packages.}}$

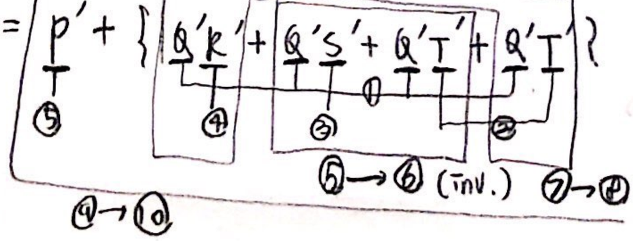
$② = [\underline{R} + \underbrace{(S'+T')'}]' \Leftarrow 1$ package

can use ③' ⤴

$\therefore f(P,Q,R,S,T)$ needs $\boxed{\text{9 packages.}}$

) $f(P,Q,R,S,T) = [P(Q+RST)]'$

$f = P' + \{Q'\cdot(R'+S'+T')\}$



$\therefore \boxed{\text{10 packages}}$??

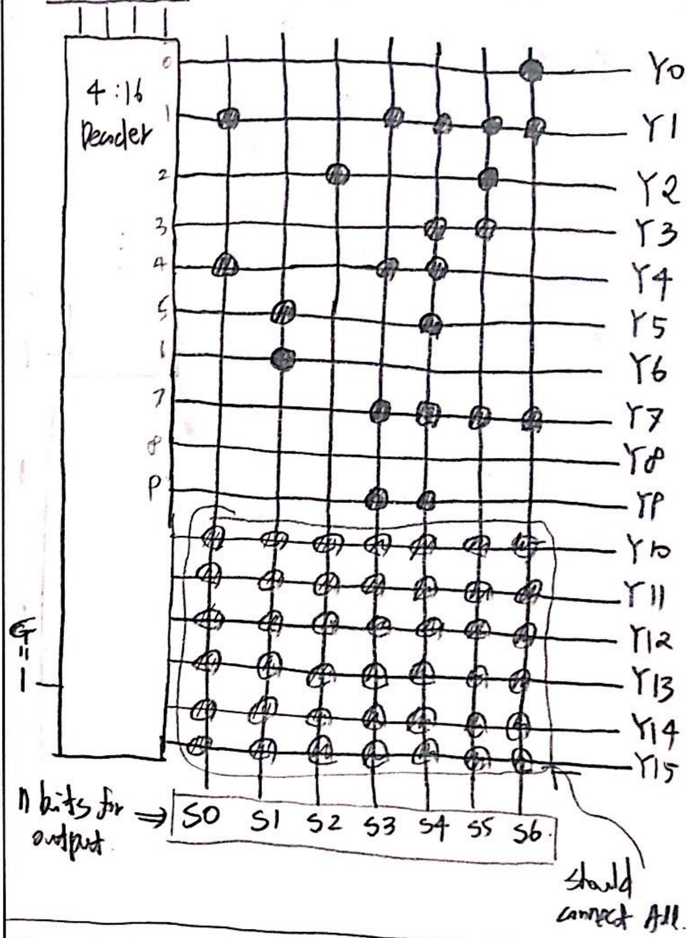
$\boxed{3}$ (min address bits & min bits per word) ROM → $\underline{\text{SSD}}$

→ Assume that ROM uses $\underline{\text{pull-up}}$ resistor.

→ Initially HIGH. DOT = Low. ↳

in	out
0	1
1	0.

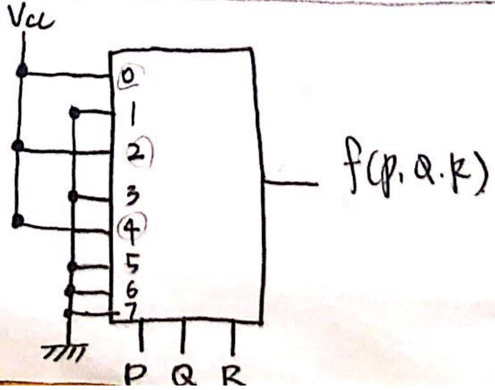
$\boxed{A\ B\ C\ D} \Leftarrow$ 4 bits for address.



$\boxed{7}$ Implement func. using MUX

(a) $f(P,Q,R) = \overline{(PQ+R)} = \Sigma m(0,2,4)$

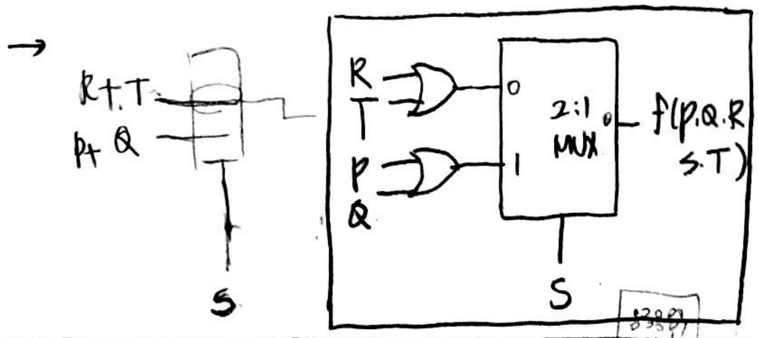
P	Q	R	PQ	R	(PQ+R)	$\overline{(PQ+R)}$ = F	
0	0	0	0	0	0	1	⓪
0	0	1	0	1	1	0	1
0	1	0	0	0	0	1	②
0	1	1	0	1	1	0	3
1	0	0	0	0	0	1	④
1	0	1	0	1	1	0	5
1	1	0	1	0	1	0	6
1	1	1	1	1	1	0.	7



(b) $f(P.Q.R.S.T) = (P+Q)\cdot S + (R+T)\cdot \overline{S}$

using 2:1 MUX, 2 OR

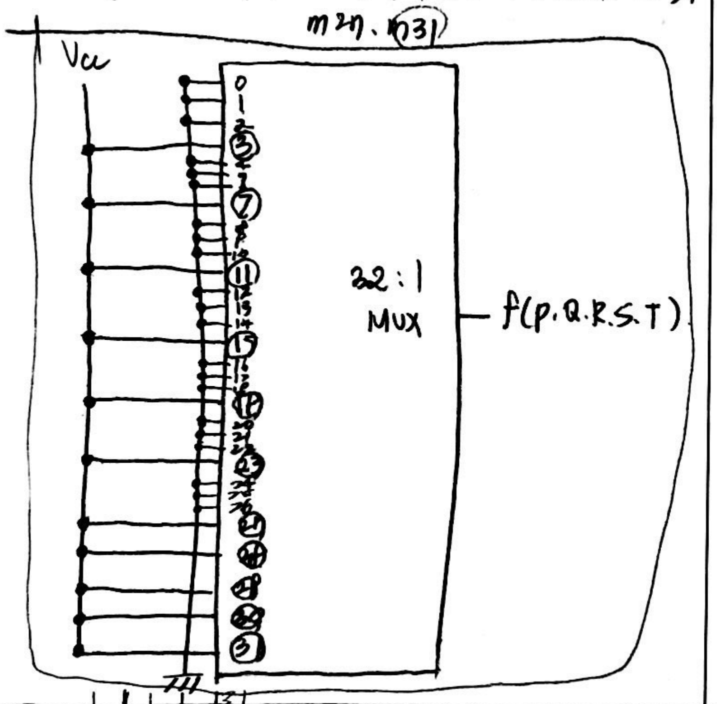
→



(c) $f(P.Q.R.S.T) = \boxed{PQR} + \boxed{ST}$ [0, 31]

→ case for 111-- : m28. m29. m30, m31

case for ---11 : m3, m7, m11. m15. m19. m23. m27. m31



(d) $f(P.Q.R.S.T) = \overline{P(Q+RST)} = \overline{P} + (\overline{Q+RST})$

$= \overline{P} + \overline{Q}\cdot\overline{RST} = \overline{P} + \overline{Q}\cdot(\overline{R}+\overline{S}+\overline{T})$

$= \overline{P} + \overline{Q}\overline{R} + \overline{Q}\,\overline{S} + \overline{Q}\,\overline{T}$ = (0----) + (-00--) + (-0-0-) + (-0--0)

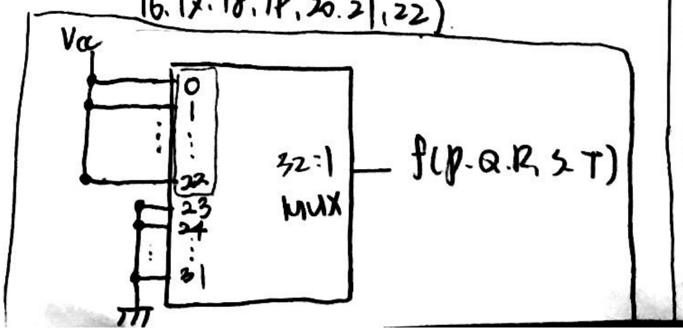
= ~~Σm[0.15]~~ + Σm(~~0, 1, 2, 3,~~ 16, 17, 18, 19) +

Σm(~~0, 1, 4, 5, 16. 17. 20. 21~~) +

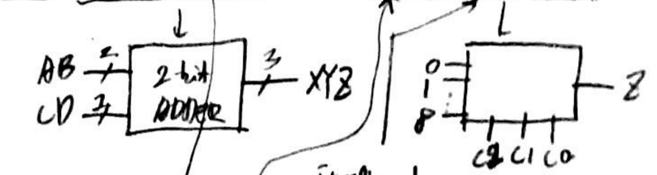
Σm(~~0. 2, 4, 6, 16. 18. 20~~. 22).

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

16. 17. 18. 19, 20. 21, 22)



11 2-bit ADDER using three 8:1 MUX



→ express (i) with three implicant (3 variables.) / or

~~$X = A\cdot C$, $Y = 1$, $Z = B\oplus D.$~~

~~$(B\oplus D)\cdot(A\oplus C) + (B\cdot D)\cdot(A\odot C)$~~

$Z = B\oplus D$

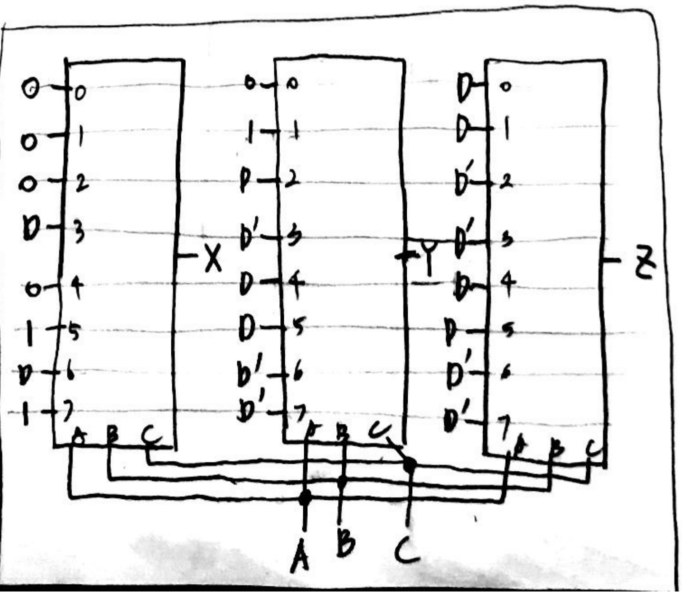
$Y = B\cdot D\,\boxed{A\odot C} + (B\cdot D)'\cdot(A\oplus C)$

$= (BD\oplus(A\oplus C))$

$X = A\cdot C + (A\oplus C)\cdot B\cdot D$

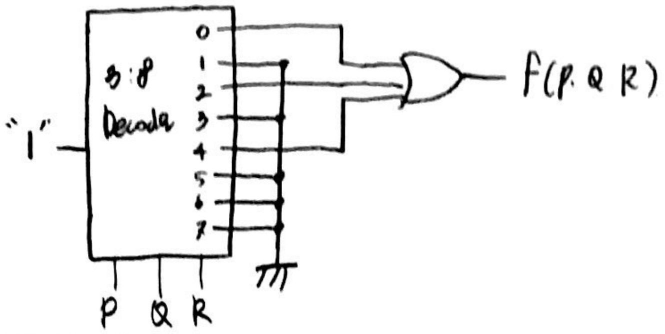
A	B	C	D	X	Y	Z
0	0	0	0	0	0	0
0	0	0	1	0	0	1
0	0	1	0	0	1	0
0	0	1	1	0	1	1
0	1	0	0	0	0	1
0	1	0	1	0	1	0
0	1	1	0	0	1	1
0	1	1	1	1	0	0
1	0	0	0	0	1	0
1	0	0	1	0	1	1
1	0	1	0	1	0	0
1	0	1	1	1	0	1
1	1	0	0	0	1	1
1	1	0	1	1	0	0
1	1	1	0	1	0	1
1	1	1	1	1	1	0

Fix

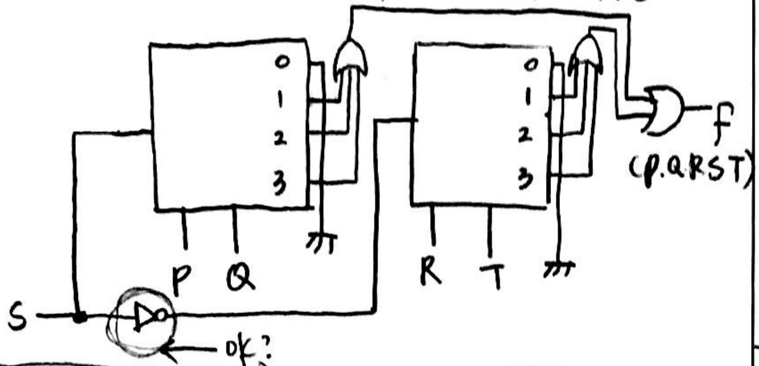


$\boxed{14}$ decoder & n-size OR

(a) $f(p.Q.R) = \overline{(PQ)+R} = \Sigma m(0.2.4)$ (by ∩(a))

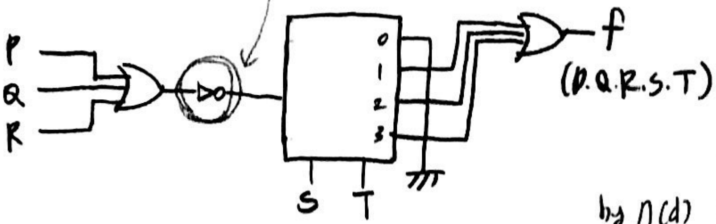


(b) $f(p.Q.R.S.T) = (P+Q)S + (R+T)S'$

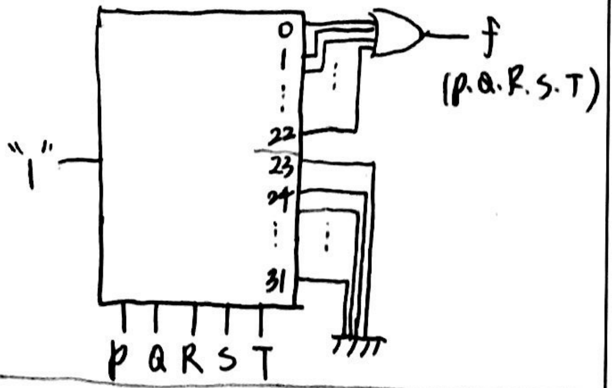


(c) $f(p.Q.R.S.T) = \underline{P'Q'R'}(S+T)$, 2:4 decoder.

$= (P+Q+R)'.(S+T)$

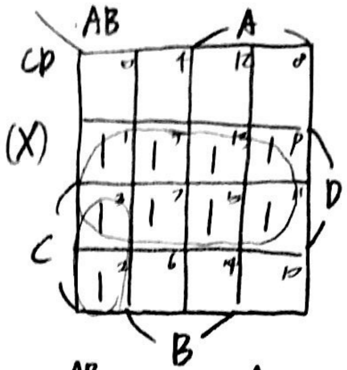


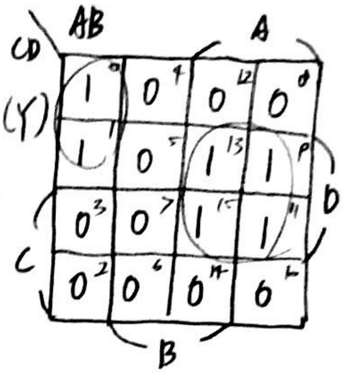
(d) $f(p.Q.R.S.T) = \overline{P(Q+RST)} = \Sigma m(0.1,\cdots,22)$ by ∩(d)

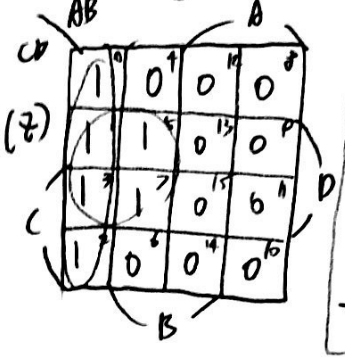


$\boxed{21}$ X.Y.Z (A.B.C.D)

(a) minimum s-o-p







$X = \enclose{circle}{D} + A'B'C$

$Y = A'B'C' + \enclose{circle}{AD}$

$Z = \enclose{circle}{A'D} + A'B'$

⟹ 6 unique terms

(b) Make common terms to implement simultaneously

→ $X = (A+A')D + A'B'C = \underline{\enclose{circle}{AD} + A'D + A'B'C}$

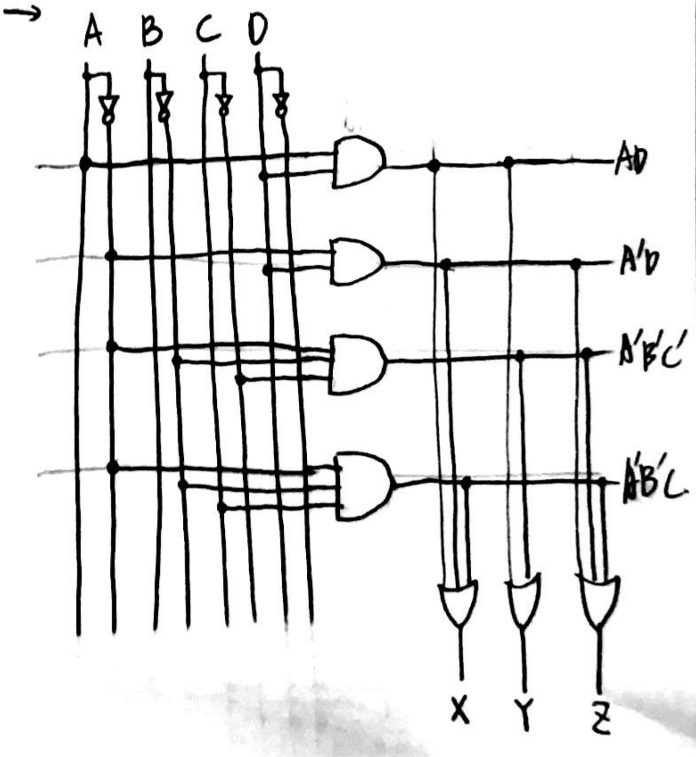
$Y = \underline{\boxed{A'B'C'} + \enclose{circle}{AD}}$

$Z = A'D + A'B'(C+C') = \underline{A'D + A'B'C + \boxed{A'B'C'}}$

⟹ $\boxed{\text{4 unique terms}}$

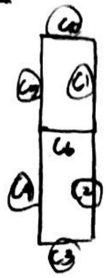
(c) <PLA structure>

→



28 Expand "BCD to SSD" to "0-15 to SSD"

→



$C_0 = \sum m(0,2,3,5,6,7,8,9) + \sum m(10,12,14,15)$

$C_1 = \sum m(0,1,2,3,4,7,8,9) + \sum m(10,13)$

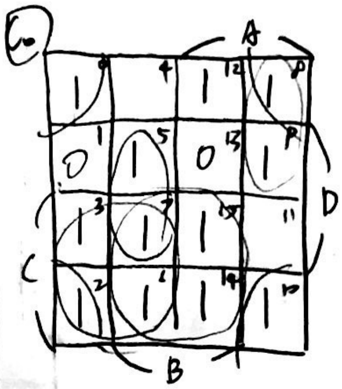
$C_2 = \sum m(0,1,3,4,5,6,7,8,9) + \sum m(10,11,13)$

$C_3 = \sum m(0,2,3,5,6,8,) + \sum m(10,11,12,13,14)$

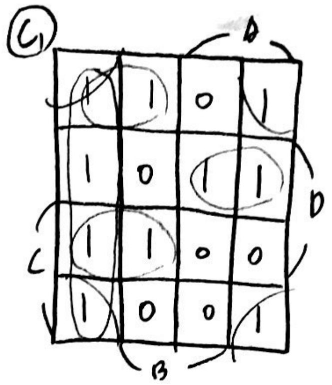
$C_4 = \sum m(0,2,6,8) + \sum m(10,11,12,13,14,15)$

$C_5 = \sum m(0,4,5,6,8,9) + \sum m(11,12,14,15)$

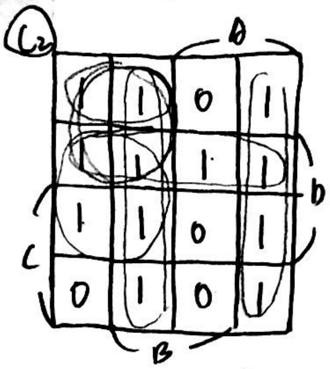
$C_6 = \sum m(2,3,4,5,6,8,9) + \sum m(10,11,13,14,15)$



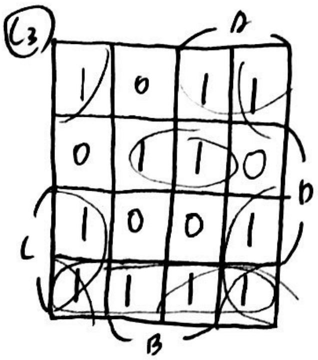
1		1	1
0	1	0	1
1	1	1	
1	1	1	1



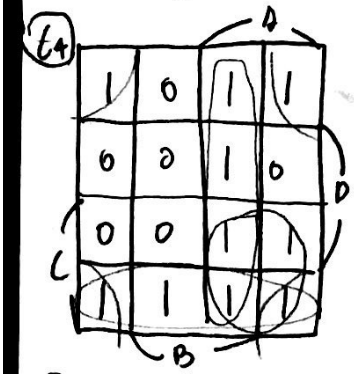
1	1	0	1
1	0	1	1
1	1	0	0
1	0	0	1



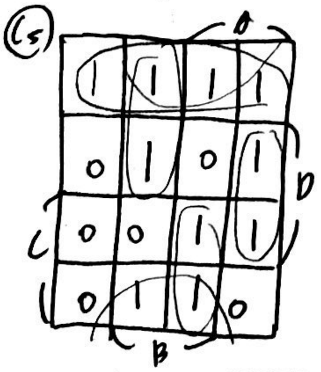
1	1	0	1
1	1	1	1
1	1	0	1
0	1	0	1



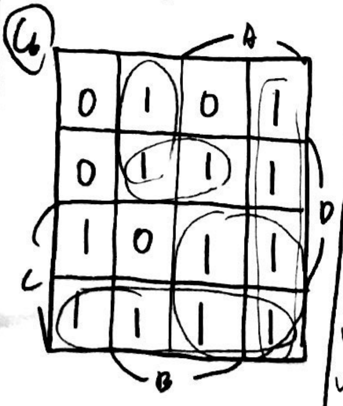
1	0	1	1
0	1	1	0
1	0	0	1
1	1	1	1



1	0	1	1
0	0	1	0
0	0	1	1
1	1	1	1



1	1	1	1
0	1	0	1
0	0	1	1
0	1	1	0



0	1	0	1
0	1	1	1
1	0	1	1
1	1	1	1

$AB'C' + AC'D$

✓ $C_0 = B'D' + BC + A'C + A'BD +$

✓ $C_1 = B'D' + A'B' + A'CD + A'C'D' + AC'D$

✓ $C_2 = A'D + C'D + AB' + A'B + AC'$

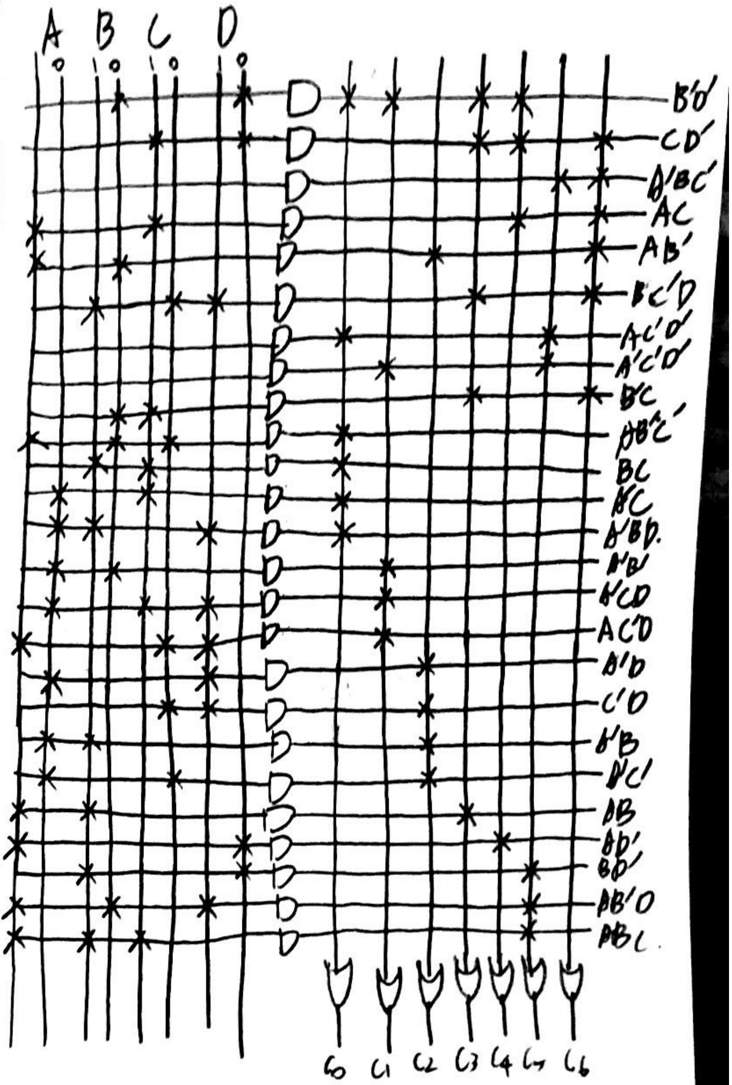
✓ $C_3 = B'D' + CD' + B'C + AD + BC'D$

✓ $C_4 = B'D' + CD' + AB + AC$

✓ $C_5 = \cancel{C} + BD' + AB'D + A'BC' + ABC$

✓ $C_6 = CD' + AC + AB' + BC'D + A'BC'$

$AC'D' + B'C'D' \quad + B'C$



BC .