lecture 3:-

Decimal number system Base = Radix

0 1 2 3 4 5 6 7 8 9

10 symbols.

Every symbol represent some quantity.

$$\left(\overset{1000}{1}\ \overset{100}{2}\ \overset{10}{5}\ \overset{1}{1}\right)_{\text{Base } 10}$$

$$1000 + 200 + 50 + 1$$

$$1 \times 1000 + 2 \times 100 + 5 \times 10 + 1 \times 1$$

$$1 \times 10^3 + 2 \times 10^2 + 5 \times 10^1 + 1 \times \boxed{10^0}$$

151		rotate ten time / increment then return to zero and pass 1 to next multiple
⋮		
159		
160		
161	00	568.23
⋮	⋮	
	09	
	10	$5 \times 10^2 + 6 \times 10^1 + 8 \times 10^0 + 2 \times 10^{-1} + 3 \times$
169	⋮	$500 + 60 + 8 + 0.2 + 0.03$
170	99	
⋮	100	As 10^{-1} in base 10 we also have 2^{-1} in base 2.
⋮	⋮	
	199	
190	200	
⋮	⋮	
	999	
199	1000	
200		

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Binary number system: (Base 2)

→ Two symbol
(0, 1)

Convert Decimal to Binary.

$(7)_{10} \longrightarrow (111)_2$

0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Convert Binary to Decimal.

$(111)_2 \longrightarrow (7)_{10}$

$= 1\times2^2 + 1\times2^1 + 1\times2^0$

$= 4 + 2 + 1$

$= 7$

$(1101)_2 \longrightarrow (13)_{10}$

$= 1\times2^4 + 1\times2^2 + 0\times2^1 + 1\times2^0$

$= 8 + 4 + 0 + 1$

$= 13$

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2^8	2^7	2^6	2^5	2^4	2^3	2^1	2^0	2^9	2^{10}
128	64	32	16	8	4	2	1	256	512

Binary of Dec

1	1	0	1
8	4	2	1

⇒ Only add the weight where 1 is place and ignore the weight of 0 so, its simplify

$$8 + 4 + 1 = 13$$

$$101101 \longrightarrow 32 + 8 + 4 + 1 = 45$$

Dec to Bin.

$$(59)_{10} \longrightarrow (111011)_2$$

64	32	16	8	4	2	1
0	1	1	1	0	1	1

$$\begin{array}{r} 32 \\ 16 \\ \hline 48 \\ 8 \\ \hline 56 \\ 4 \\ \hline 60 \times \end{array} \leftarrow \begin{array}{r} 56 \\ 2 \\ \hline 58 \\ 1 \\ \hline 59 \end{array}$$

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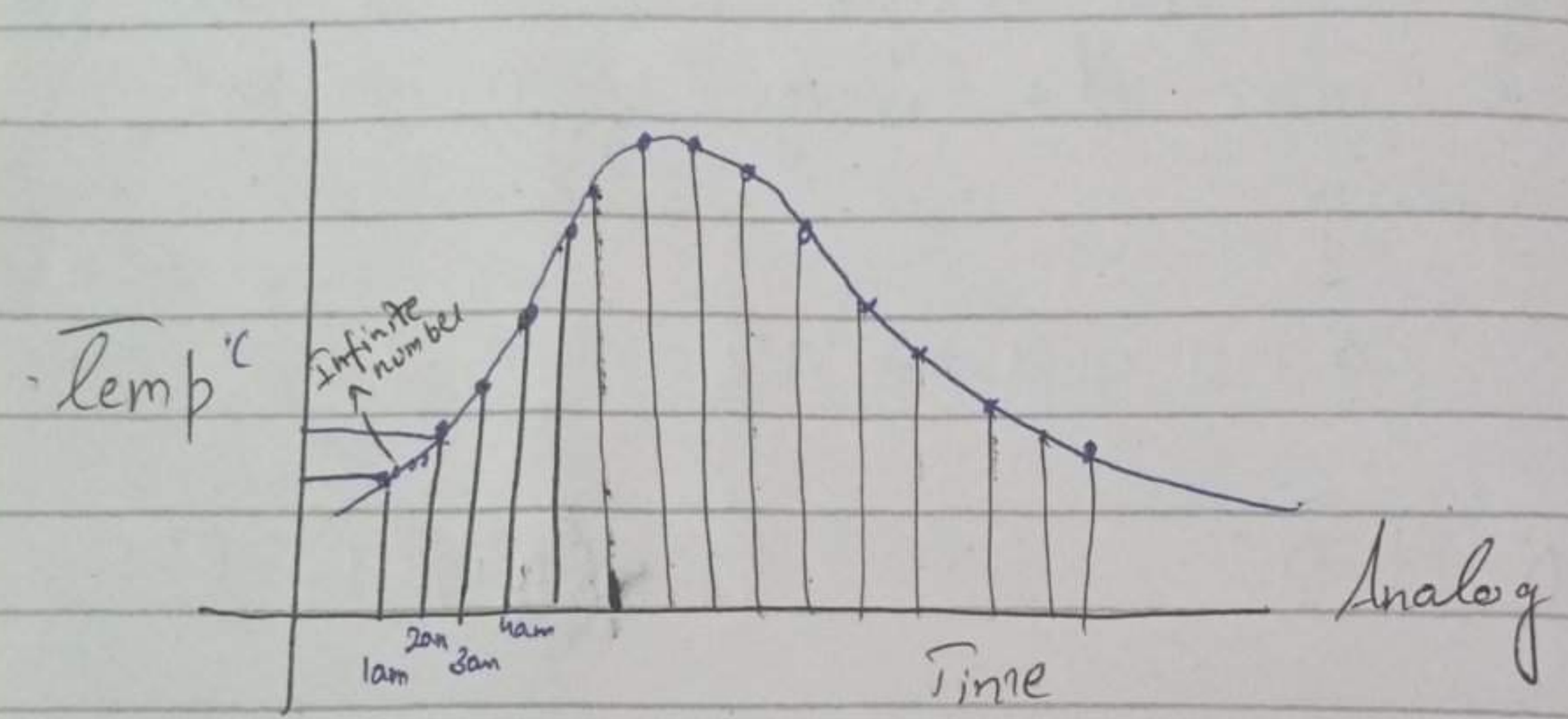
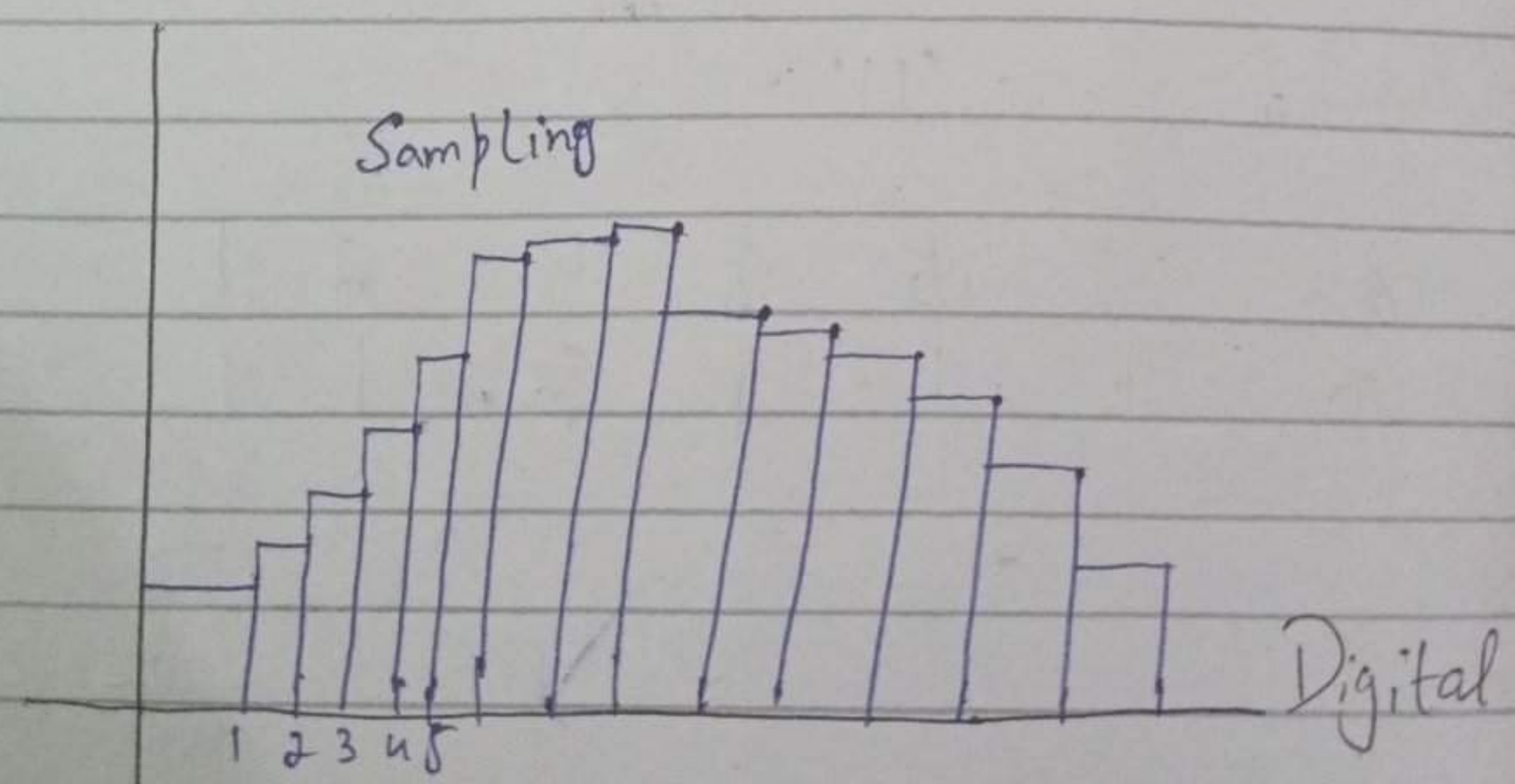
Binary Digits

- Bits (0, 1)
  - 1 → True, Yes
  - 0 → False, No

B = byte = 8 bits

Analogue to Digital





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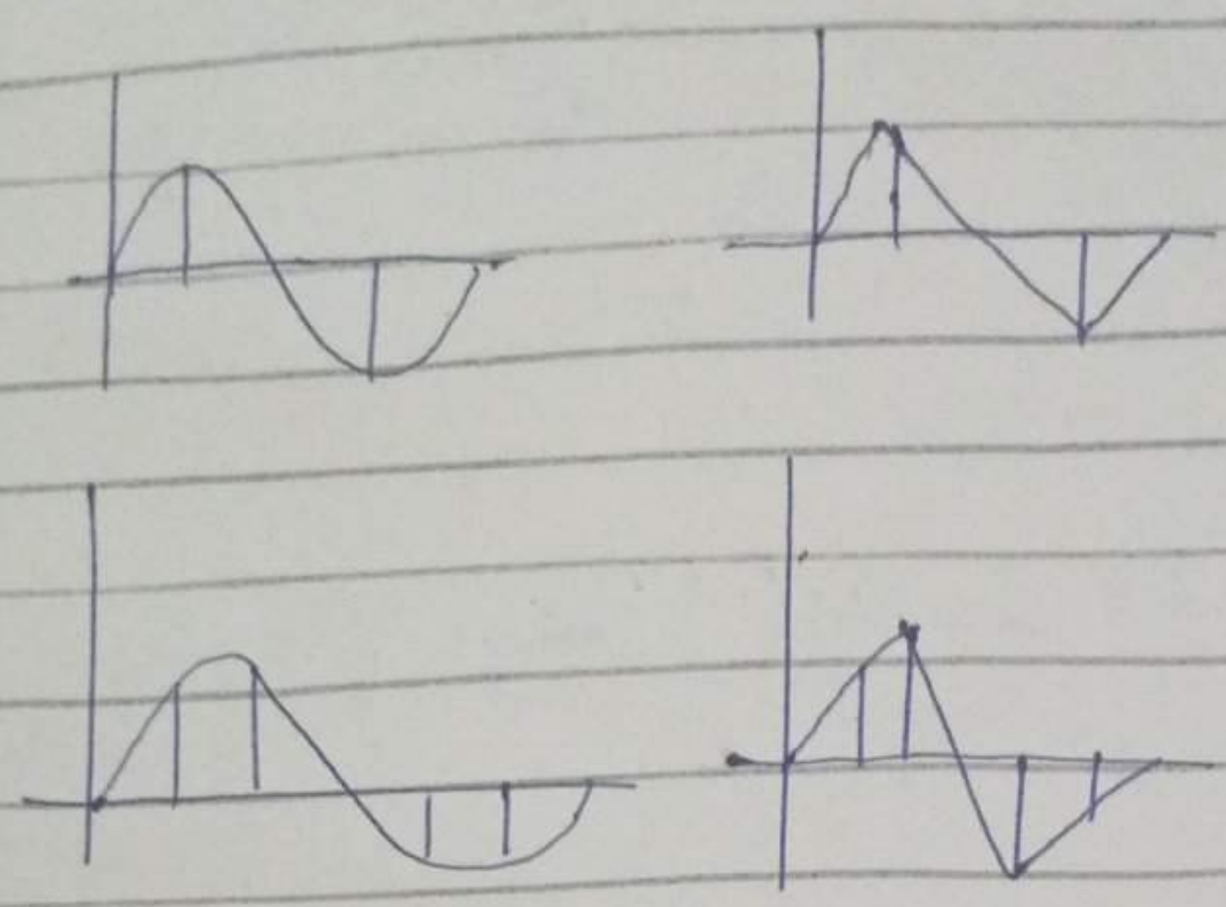
If no of Sample increase, less data loss have more info. but we have more memory to store them



Data loss from A to D

Analog ⟶ Continous

Digital ⟶ Discrete

Error collecting method are apply on Digital., sound noise e.t.c that Damged the data ⟶ Difficult to apply in analog.

Algorithm implement very easy on Digital.

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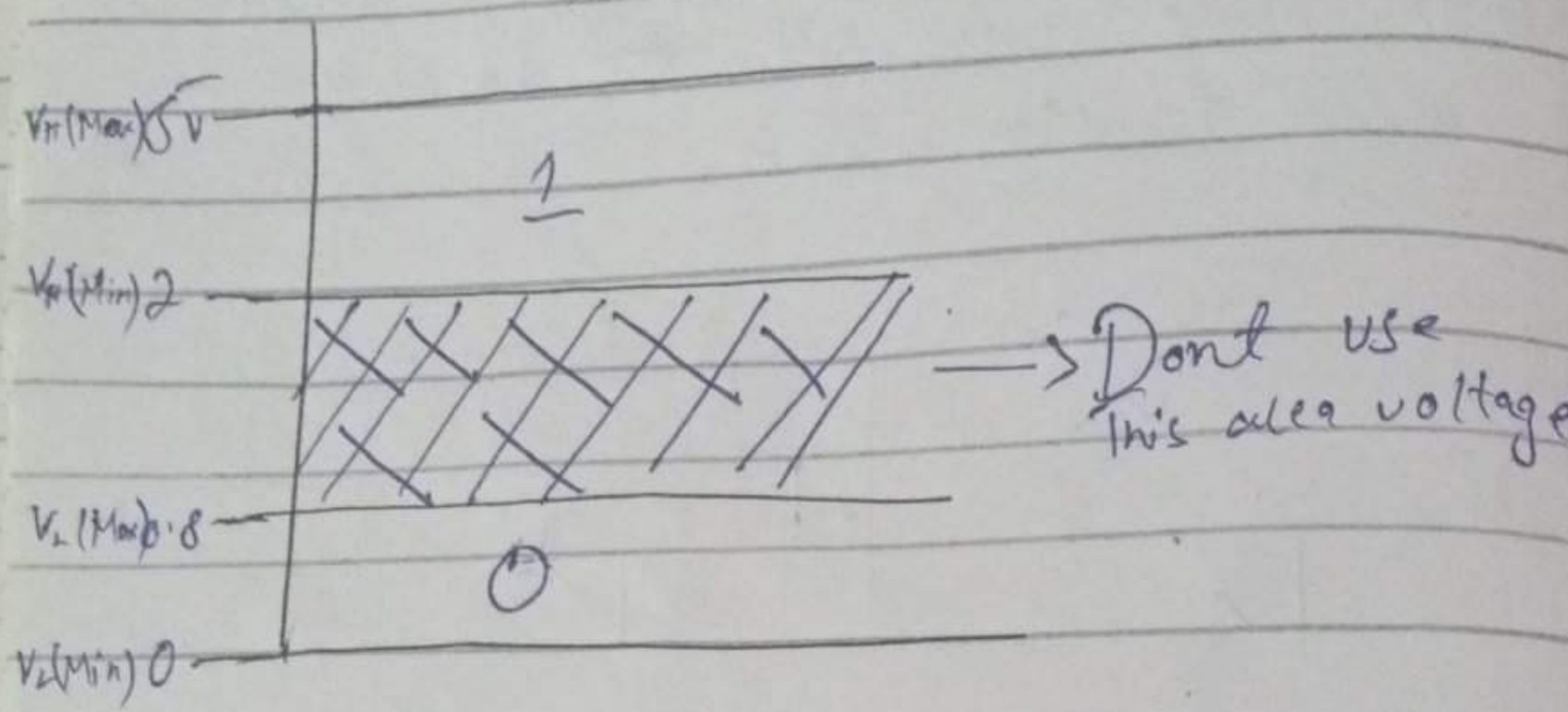
Transistor-Transistor Logic

TTL



$V_{CC} = +5V$ → High(V) Damage the ICs

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Exercise 2-4

B to D

① 0.101 ϕ → Binary

$= 2^{-1} + 2^{-3} + 2^{-4}$

$= 0.5 + 0.125 + 0.0625$

$= 0.6875$ → Decimal

② 10.111

$2^{1} + 2^{-1} + 2^{-2} + 2^{-3}$

$2 + 0.5 + 0.250 + 0.125$

$= 2.878$

③ 101.11101.011

$= 128 + 32 + 16 + 8 + 4 + 2 + 0.25 + 0.125$

$= 189.375$

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DloB

(1) 12

1100

(2) 25

11001

(3) 58

111010

(4) 82

1010010

(5) 125

1111101

(6) 0.625

0.625×2 — 1

1.250×2 — 0

$.50 \times 2$ — 1

1.00

$(0.101)_2$

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Method 2 of D to B Converter

Divide the number by 2 and write the reminder on the right side again divide the divided number by 2 and write reminder on next left Continue until there is 0 quitient

① $19 \xrightarrow{1} 9 \xrightarrow{1} 4 \xrightarrow{0} 2 \xrightarrow{0} 1$

$(19)_2 \longrightarrow (1\ 0\ 0\ 1\ 1)_2$

16 8 4 2 1

② $\frac{45}{2} = 22$ rem $= 1$

$\frac{22}{2} = 11$ rem $= 0$

$\frac{11}{2} = 5$ rem $= 1$

$\frac{5}{2} = 2$ rem $= 1$

$\frac{2}{2} = 1$ rem $= 0$

$\frac{1}{2} = 0$ rem $= 1$

~~101101~~

16 8 4

101101

$(12)_{10} \longrightarrow (\quad)_2$

2	12	
2	6 — 0	L.S.B
2	3 — 0	
	1 — 1	

M.S.B

MSB $\longrightarrow$ L.S.B

(1100)

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Converting Decimal Fraction to Binary.

(1) 23

$23 \xrightarrow{1} 11 \xrightarrow{1} 5 \xrightarrow{1} 2 \xrightarrow{0} 1$

$= 10111$

(2) 57

$57 \xrightarrow{1} 28 \xrightarrow{0} 14 \xrightarrow{0} 7 \xrightarrow{1} 3 \xrightarrow{1} 1 \xrightarrow{1} 0$

$= 111001$

(3) 45.5

$45 \xrightarrow{1} 22 \xrightarrow{0} 11 \xrightarrow{1} 5 \xrightarrow{1} 2 \xrightarrow{0} 1 \xrightarrow{1} 0$

101101.10

$.5 \times 2 = 1.00$

(8) $(110.1101)_2 \rightarrow (\quad)_{10}$

$= 4 + 2 + 0.5 + 0.25 + 0.0625$

$= 6.8125$ Ans.

$(6 \xrightarrow{0} 3 \xrightarrow{1} 1 \xrightarrow{1} 0) . ($

110.1101

$.8125 \times 2 = 1.62$

$.62 \times 2 = 1.24$

$.24 \times 2 = .48$

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(4) 14

$14 \xrightarrow{0} 7 \xrightarrow{1} 3 \xrightarrow{1} 1 \xrightarrow{1} 0$

1110

(5) 21

$21 \xrightarrow{1} 10 \xrightarrow{0} 5 \xrightarrow{1} 2 \xrightarrow{0} 1 \xrightarrow{1} 0$

10101

(6) 0.375

$0.375 \times 2 = 0.75 \mid 0$

$0.75 \times 2 = 1.5 \mid 1$

$1.5 \times 2 = 1.00 \mid \phi$

$.01\phi$

(7) $(0.11101)_2$

$= 2^{-1} + 2^{-2} + 2^{-4}$

$= 0.5 + 0.25 + 0.0625$

$= 0.8125$

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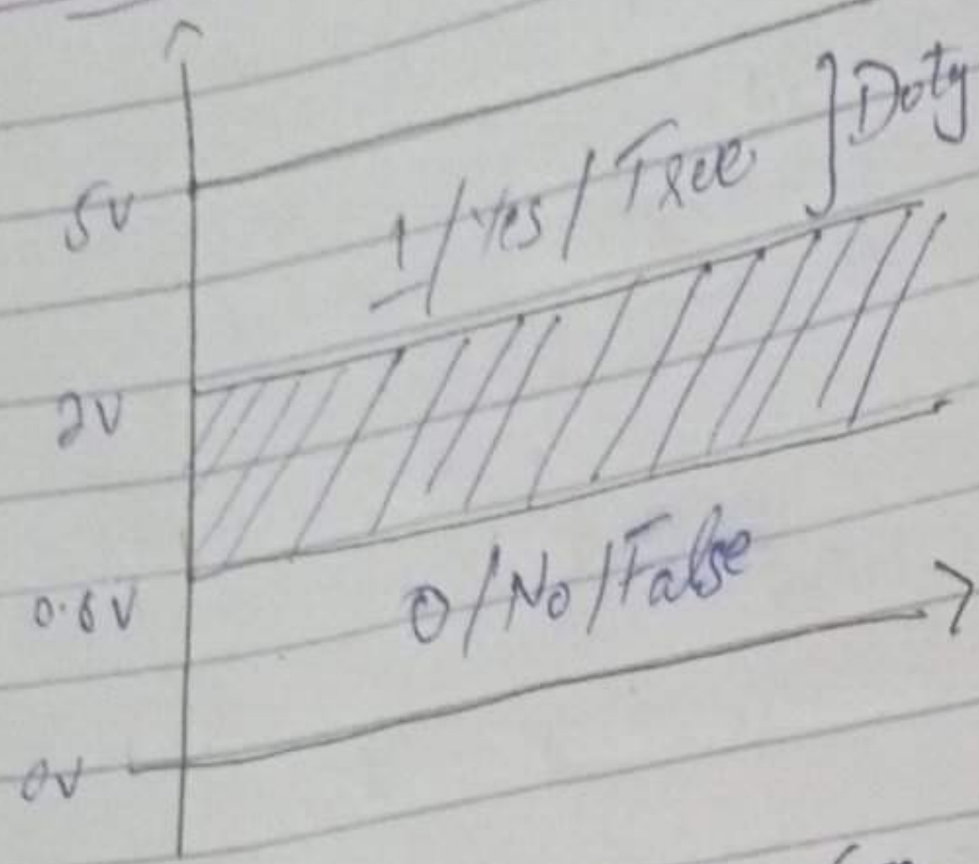
lecture 4:- TTL



Binary Digit : Bits (0, 1)

Voltage level

⏚ -> Ground represent (0)

+Vcc -> Vcc represent (1)

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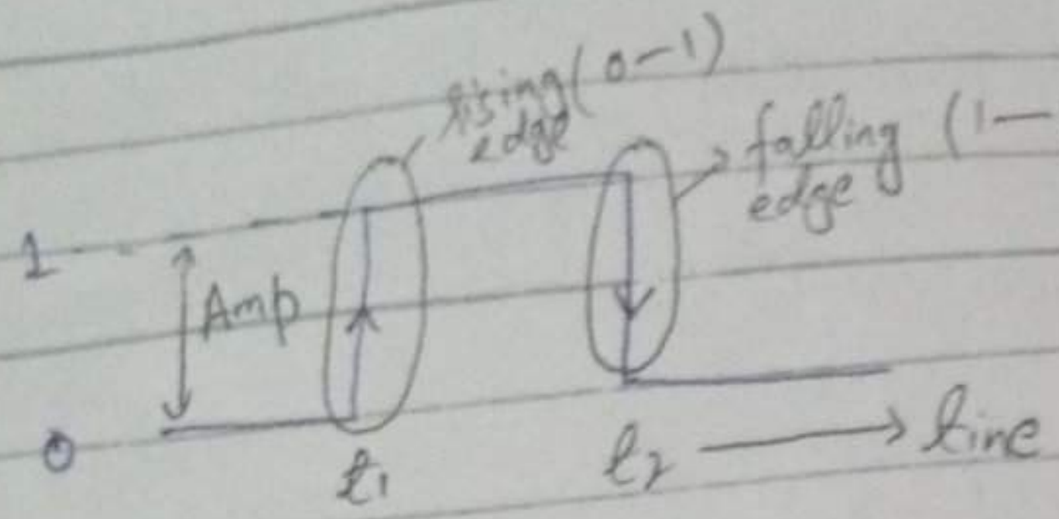
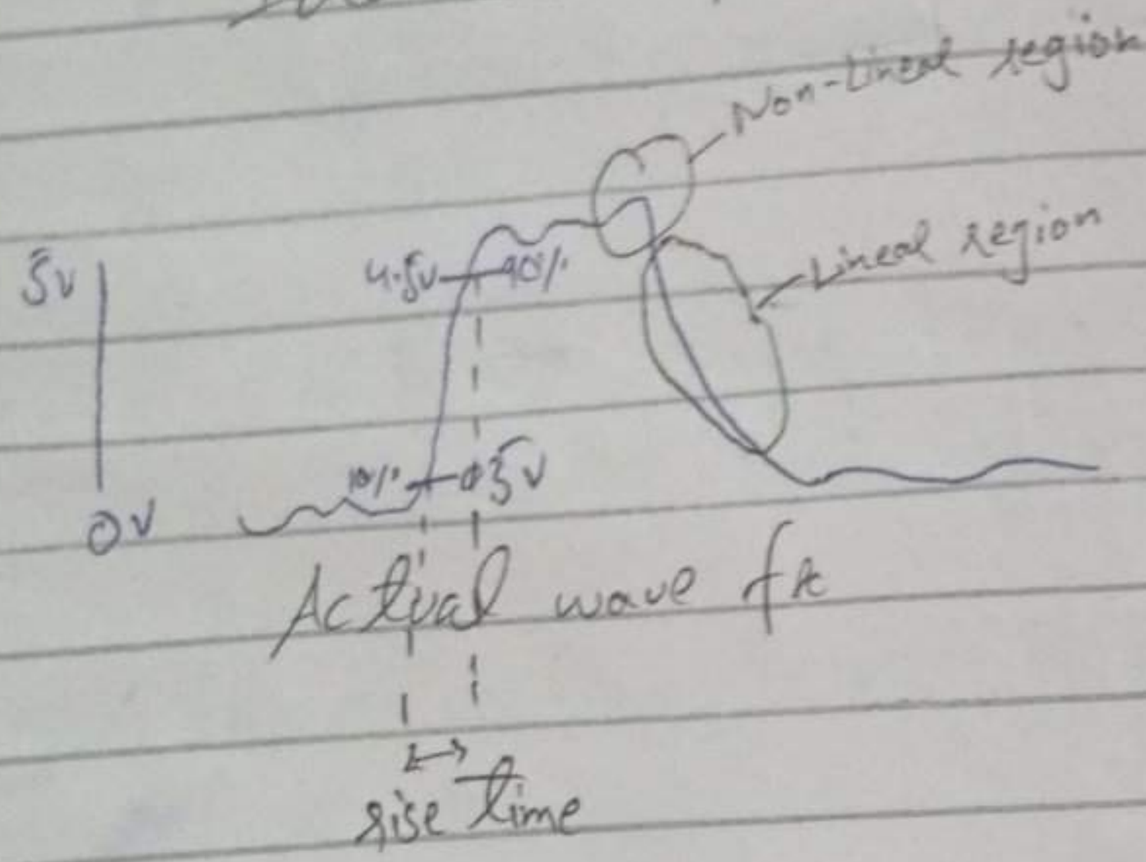


Ideal wave front



Actual wave fn

If rise time is greater our switch can't work properly (slow switching)

Duty Cycle

Ratio of pulse rate

$$\text{Duty cycle} = \frac{t_w}{T} \times 10$$

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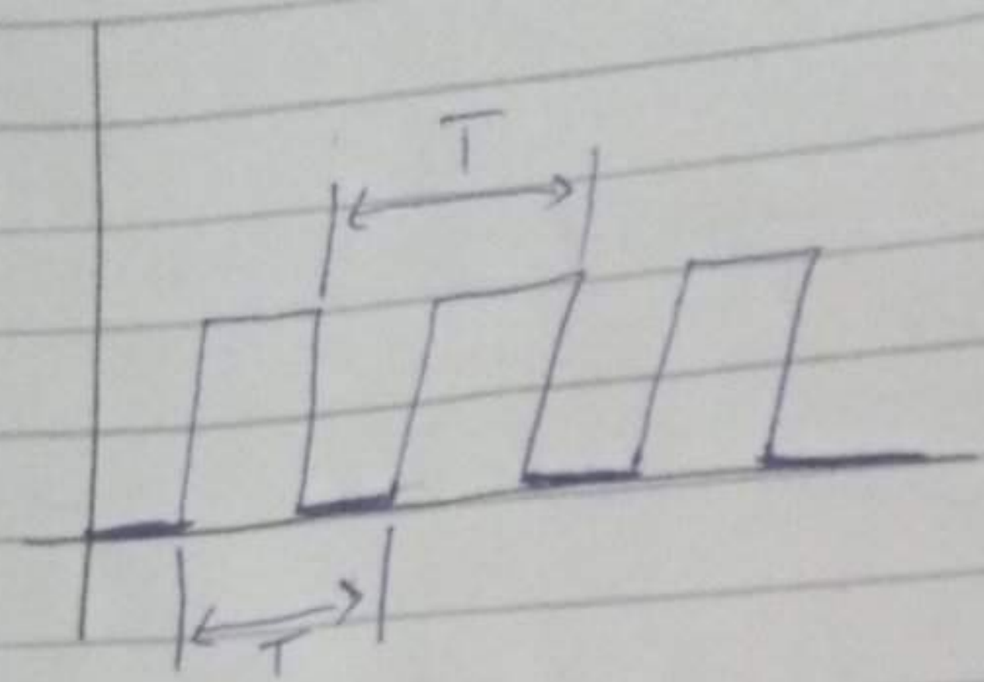
Periodic Signal



In which time signal repeat ~~the~~ its one cycle its called Time period.

frequency

$$F = \frac{1}{T}$$

Measures in hertz (Hz).

$T \uparrow, F \downarrow$

$$T \propto \frac{1}{F}$$

frequency is number of cycle per cycles.

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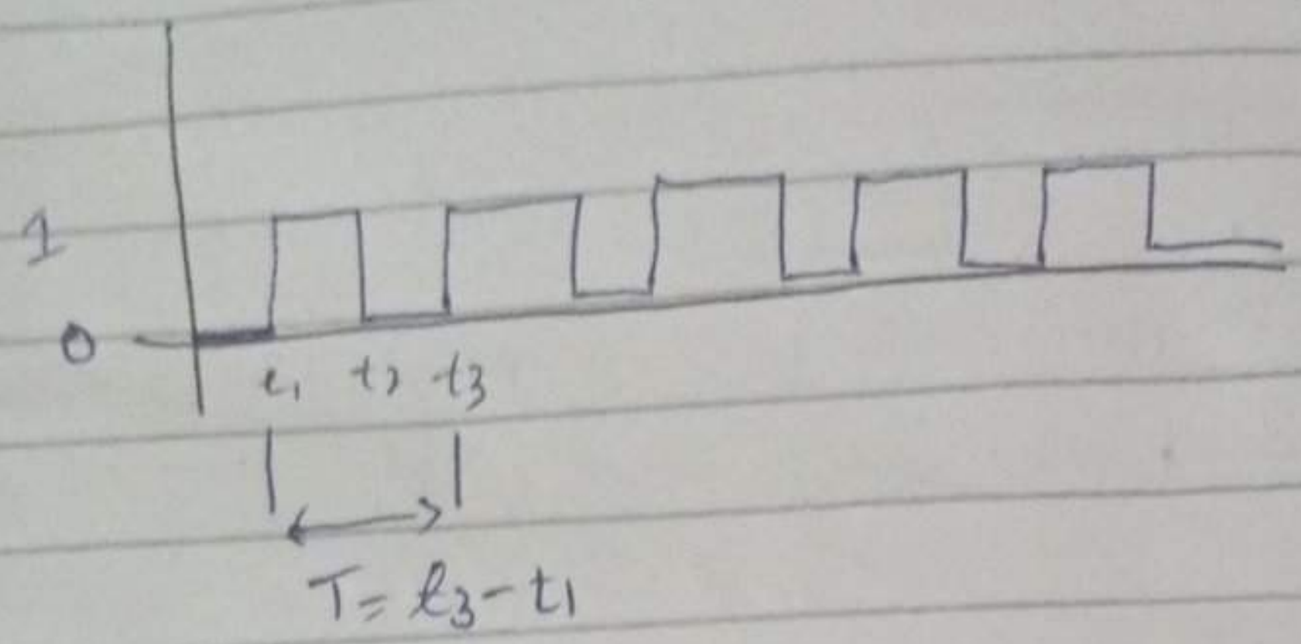
Clock Signal



$f = \frac{1}{T}$, $f = 50MHz$ then $T = 20nS$

=> There is no f and T of non-periodic signal.

=> Edge trigger are much better than Level trigger

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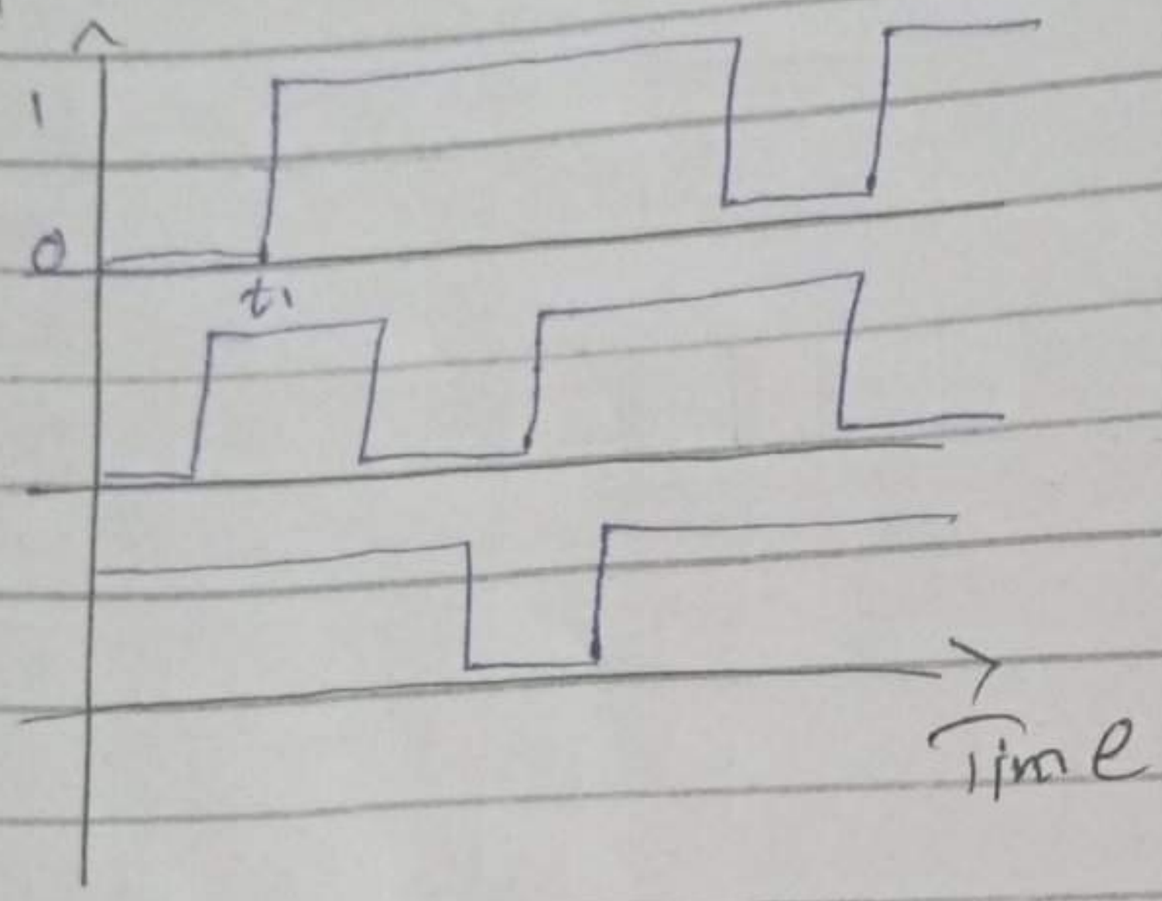
Timing Diagram:-



=> There is no actual ~~signt~~ signal rise to 1 in (0 time).

→ In ideal signal rise to 1 in (0 time).
↳ t_1 rise to 1 from 0 of (0 time)

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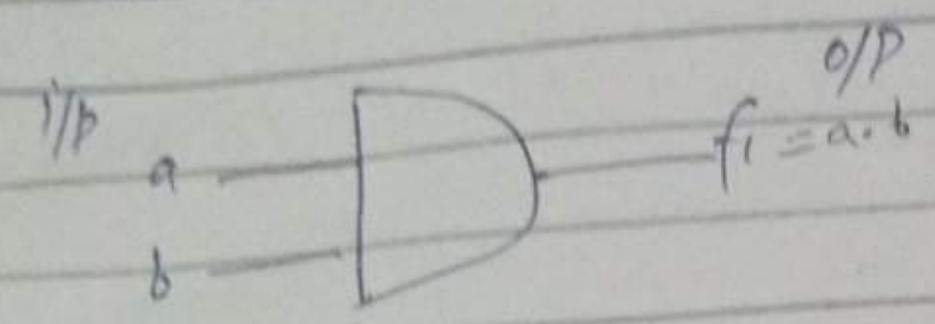
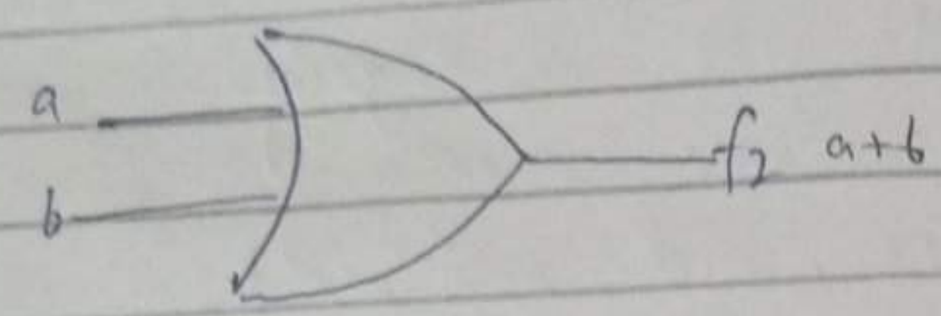
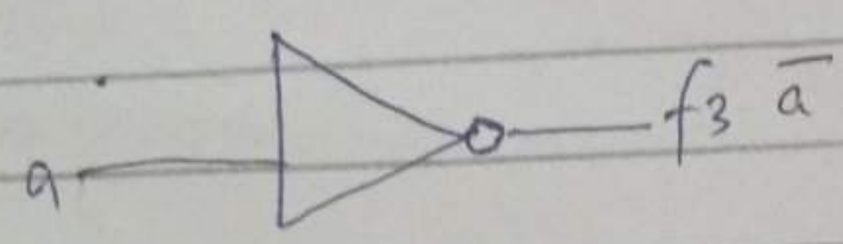
Gate :







a	b	f1	f2	f3
0	0	0	0	1
0	1	0	1	1
1	0	0	1	0
1	1	1	1	0

Truth table

=> In Simple gate we use 2-input gate but we use 3, 4 input gate, But we can't use 5-input gate.

=> If it is necessary to use 5-input gate we make gate as

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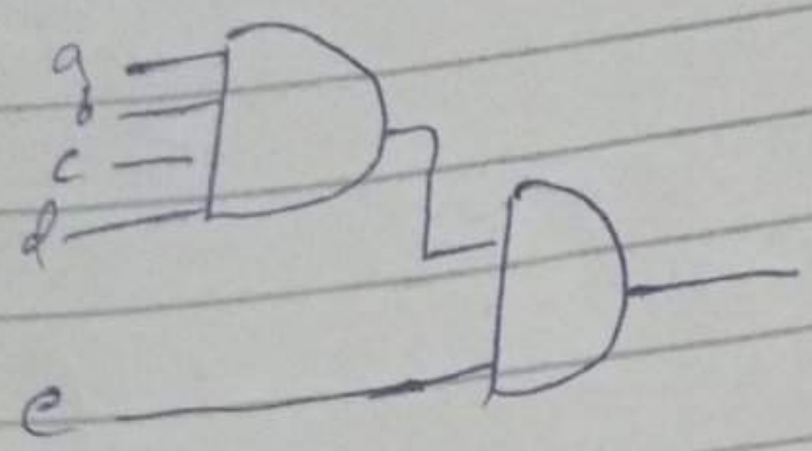

5-input AnD gate

=> Gate doesnot give us energy.
Actually they consume energy.
by ground and +Vcc, and only work
ON and OFF.

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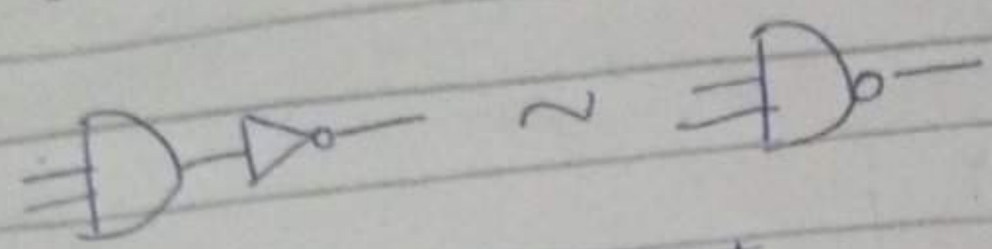
NAND gate

Negation of AND gate

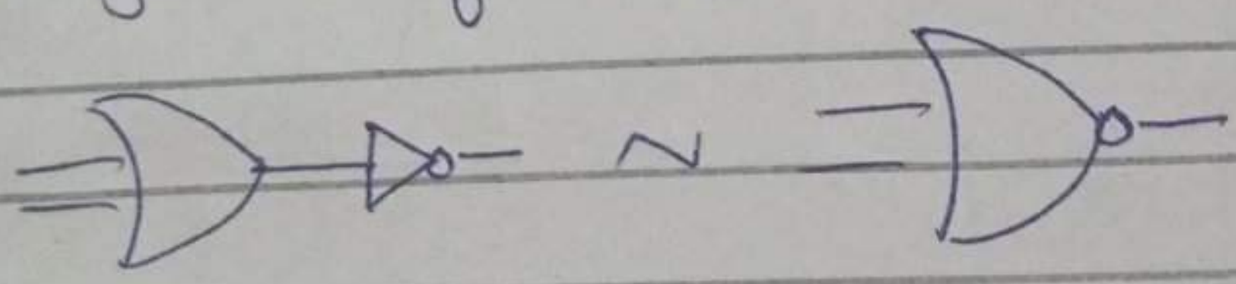


A	B	x
0	0	1
0	1	1
1	0	1
1	1	0

$x = \overline{a \cdot b}$, $(ab)'$

NOR Gate

Negation of OR gate



A	B	x
0	0	1
0	1	0
1	0	0
1	1	0

$x = \overline{a+b}$, $(a+b)'$

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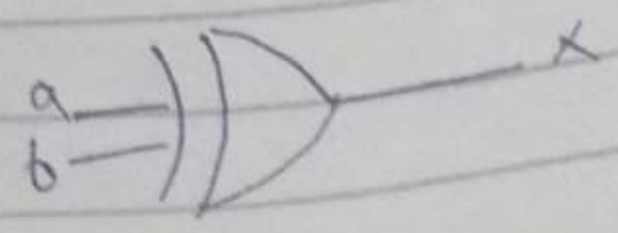
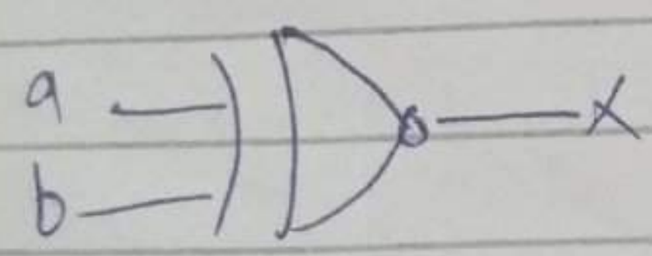
XOR gate.



A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

$X = a'b + ab'$

XNOR gate



A	B	X
0	0	1
0	1	0
1	0	0
1	1	1

$X = a \cdot b + a'b'$

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Boolean Addition

~~Equ~~

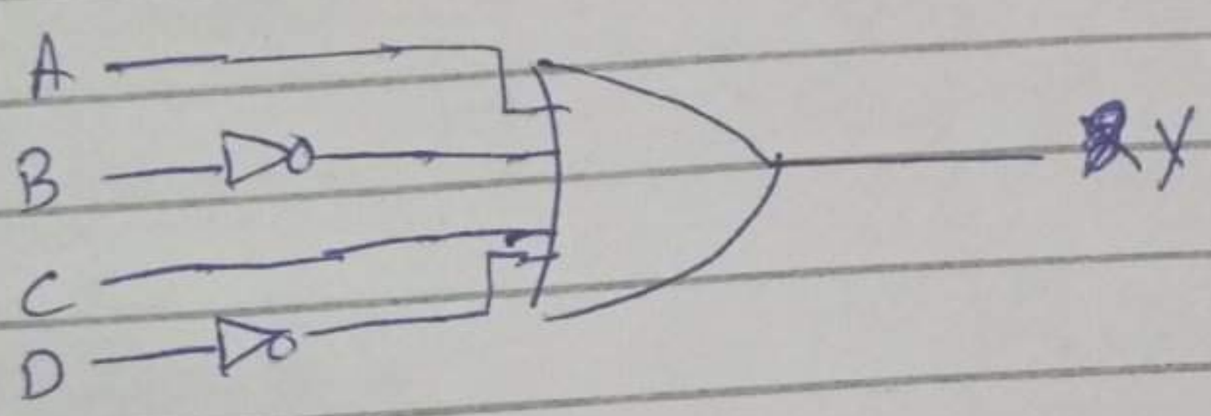
Equivalent to OR gate.

① $Y = A + \bar{B} + C + \bar{D}$ —> Boolean Expression.
(their sum equal to zero)
($Y = 0, A = B = C = D = ?$)

A	$\bar{B}$	C	$\bar{D}$
0,	0	0	0

0	1	0	1
A	B	C	D

$Y = 0101 \longrightarrow (5)_{10}$



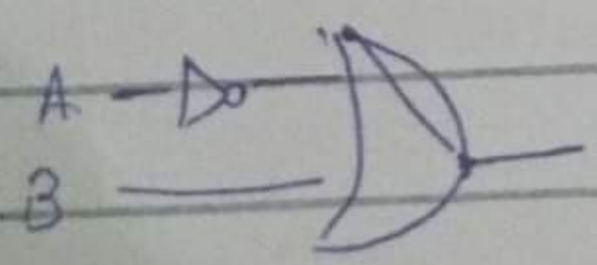
② $X = \bar{A} + B$ $\quad X = 0, A = ?, B = ?$

$\bar{A}$	B
0	0

A	B
1	0

$A = 1, B = 0$

$X = 10 \longrightarrow (2)_{10}$



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(3) $X = \overline{A} + \overline{B} + \overline{C}$ $\qquad X = 0.$

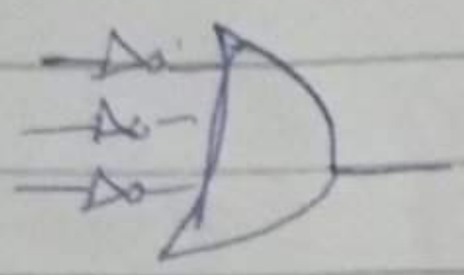
$\overline{A} + \overline{B} + \overline{C}$

0 0 0

A	B	C
1	1	1

$A = 1, B = 1, C = 1$

$X = (111) \longrightarrow (7)$



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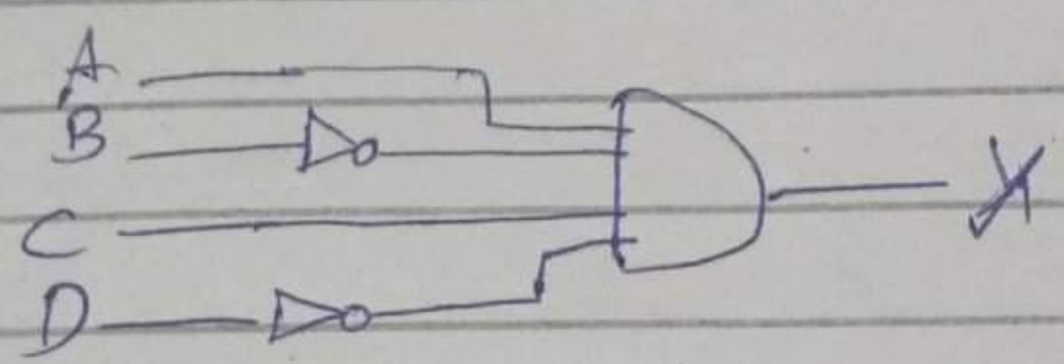
Balean Multiplication.

Equavalent to AND gate.

① $Y = A\bar{B}C\bar{D}$ is ①

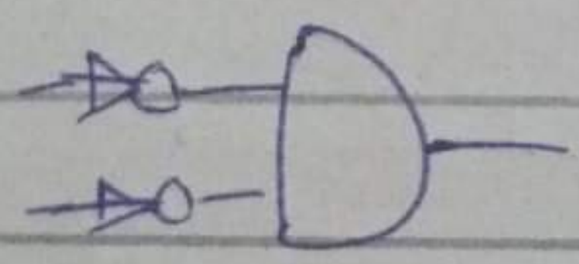
A	$\bar{B}$	C	$\bar{D}$
1	1	1	1
	0	1	0
A	B	C	D

$Y = 1010 \longrightarrow (10)_{10}$



② $X = \bar{A}\bar{B}$ $X = 1, A = ?; B = ?$

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



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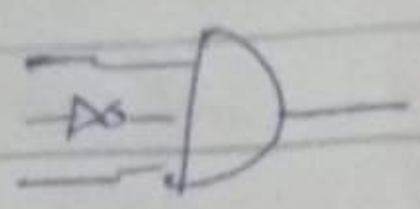
(3) $X = A\bar{B}C$ $\quad X = 1$

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

A	B	C
1	0	1

$A = 1, B = 0, C = 1$

$X = 101 \rightarrow (5)$



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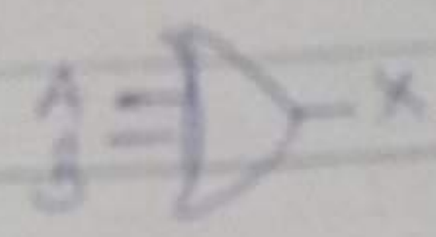
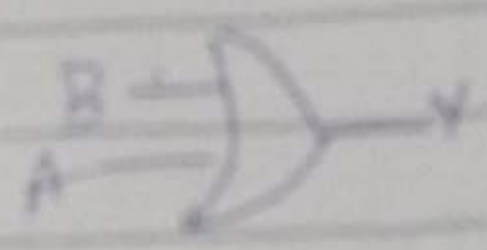
Commutative law of addition

$A+B=B+A$

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



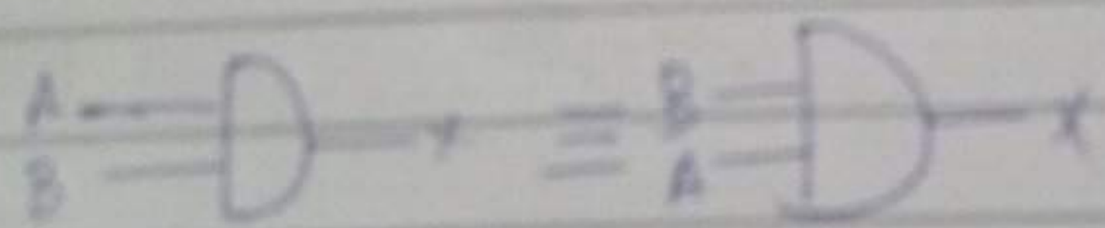
$X=Y$



Commutative law of multiplication

$AB=BA$

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



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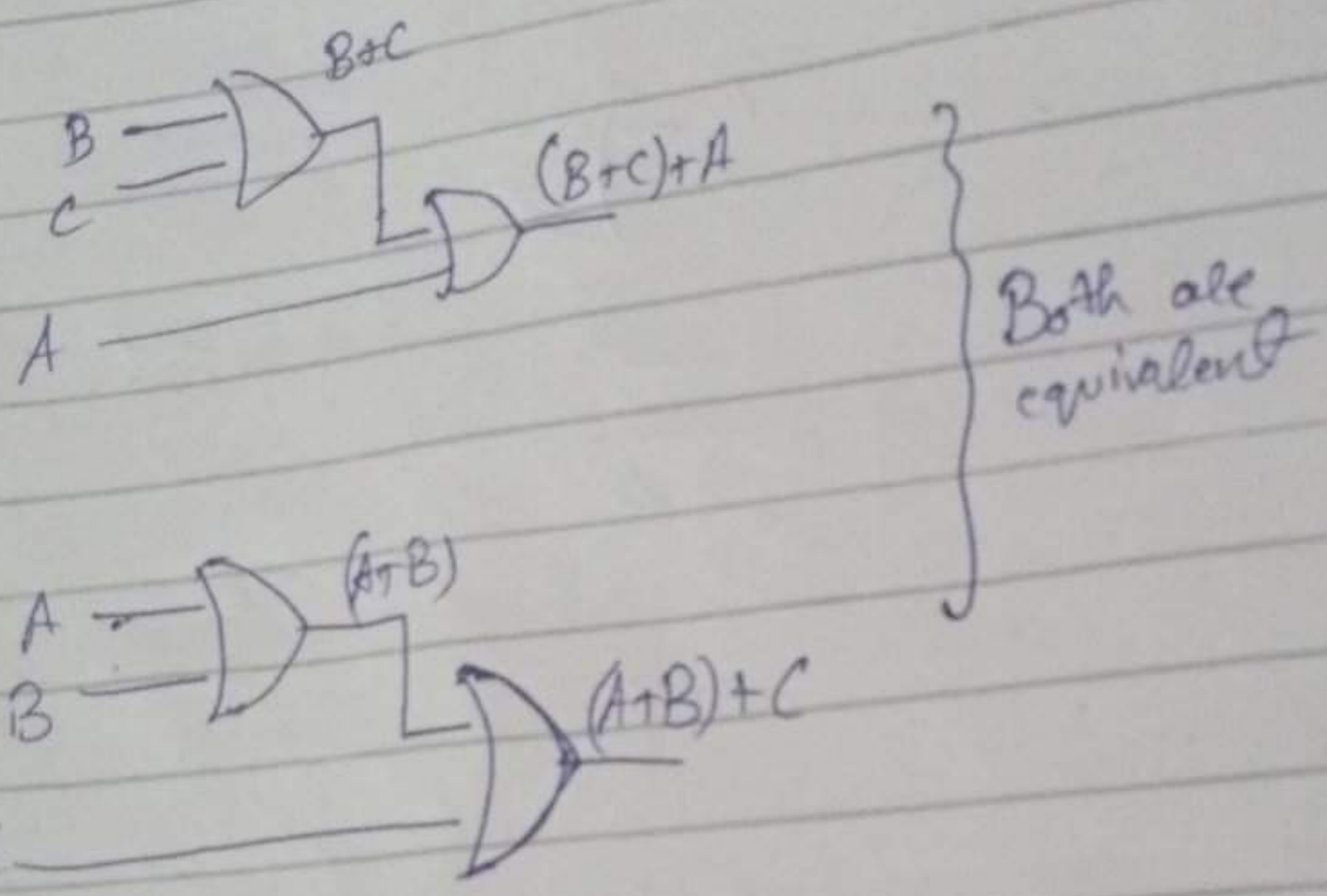
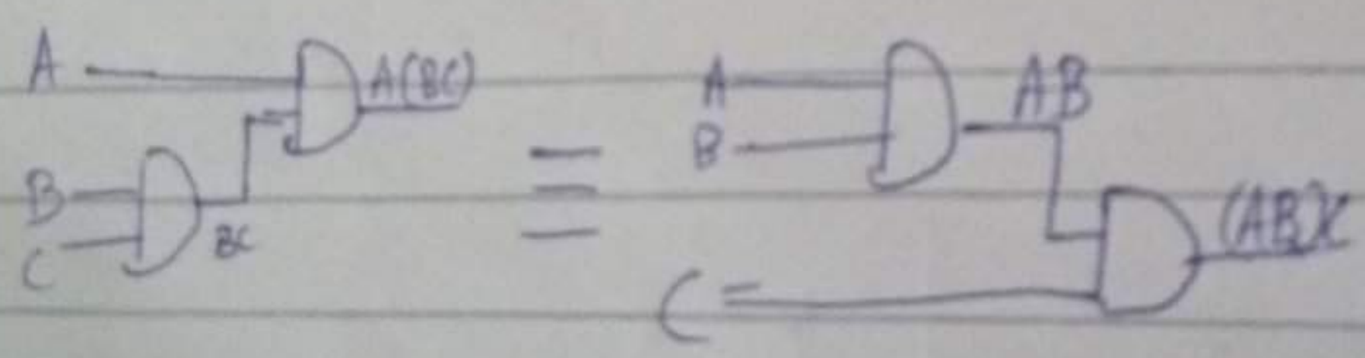
Associative law of addition

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



Associative law of multiplication:

$$A(BC)=(AB)C.$$



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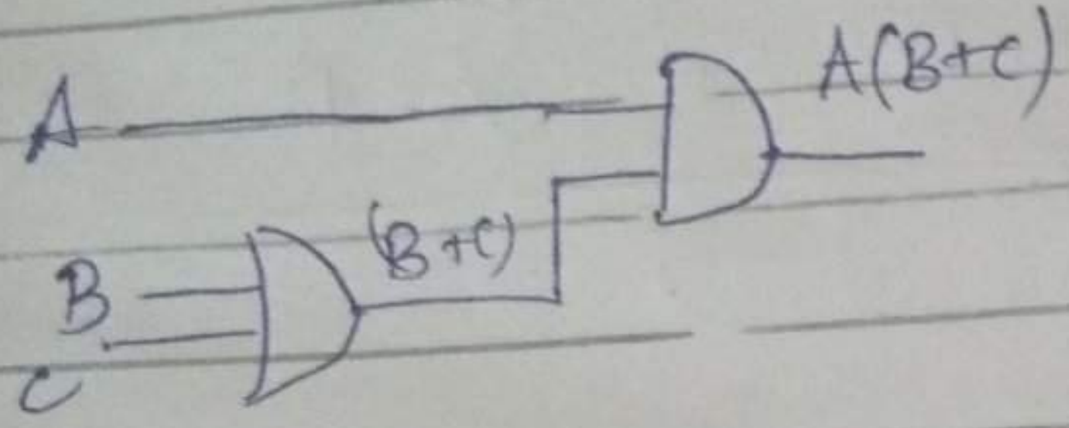
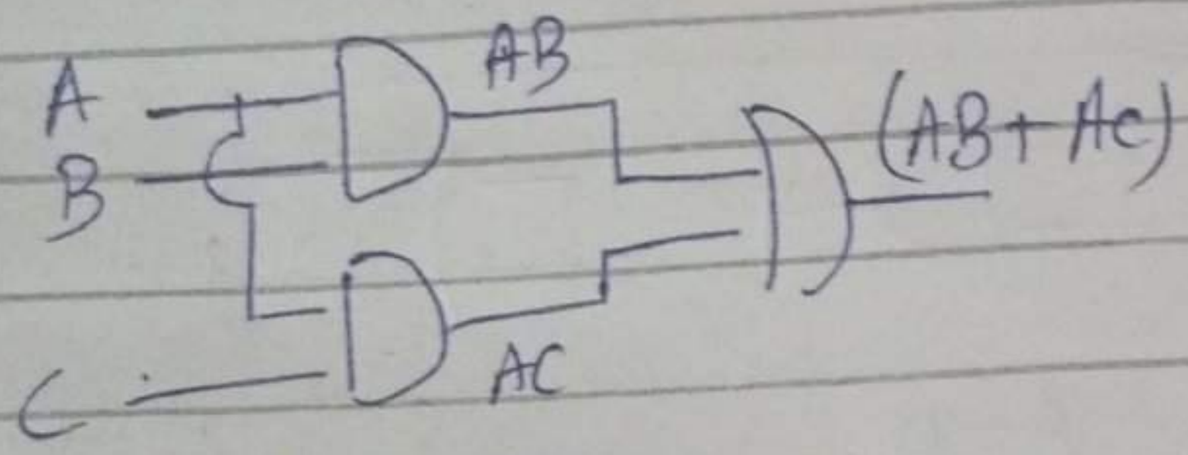
Distributive law.

$$A(B+C) = AB + AC$$





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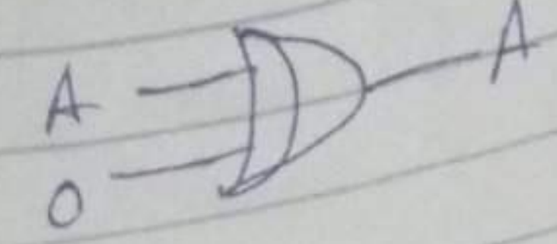
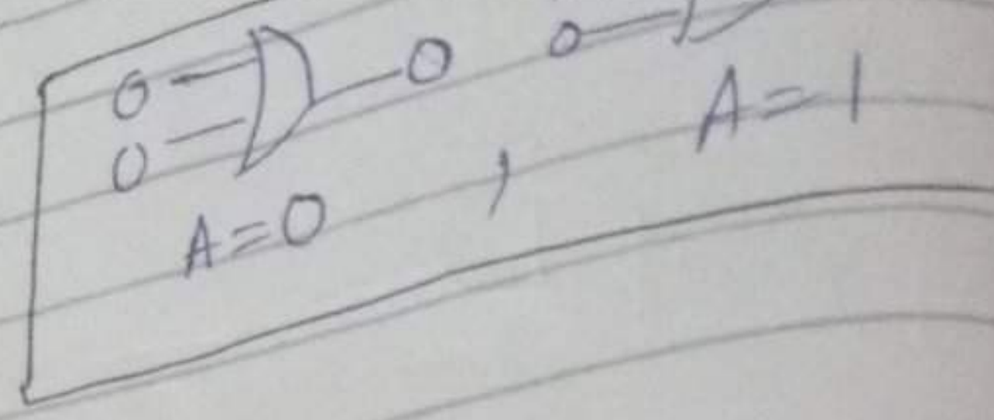
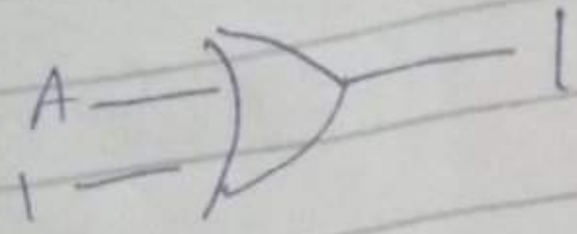
Rule of Boolean Alegebla.

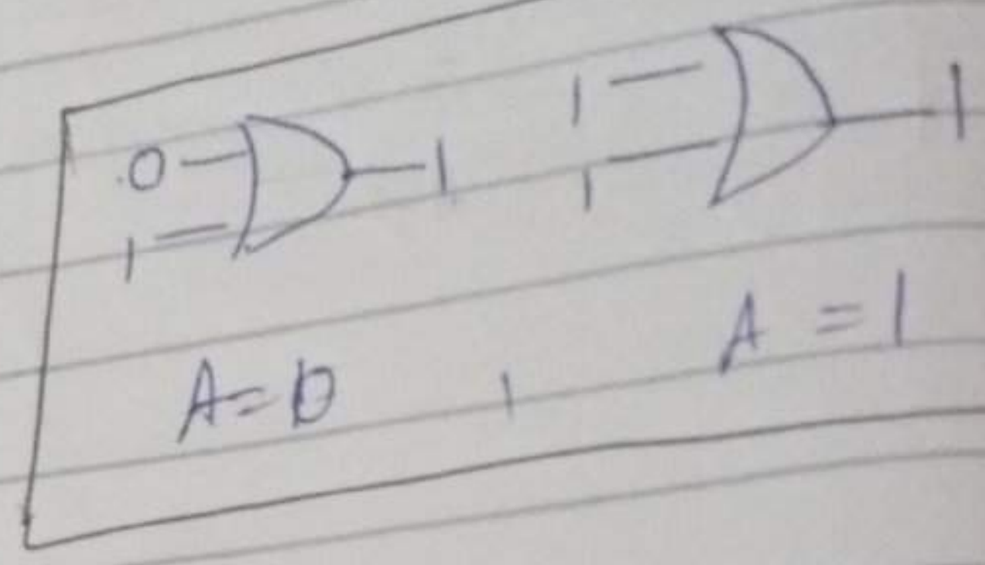
① $A + 0 = A$



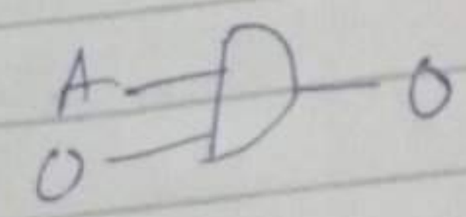


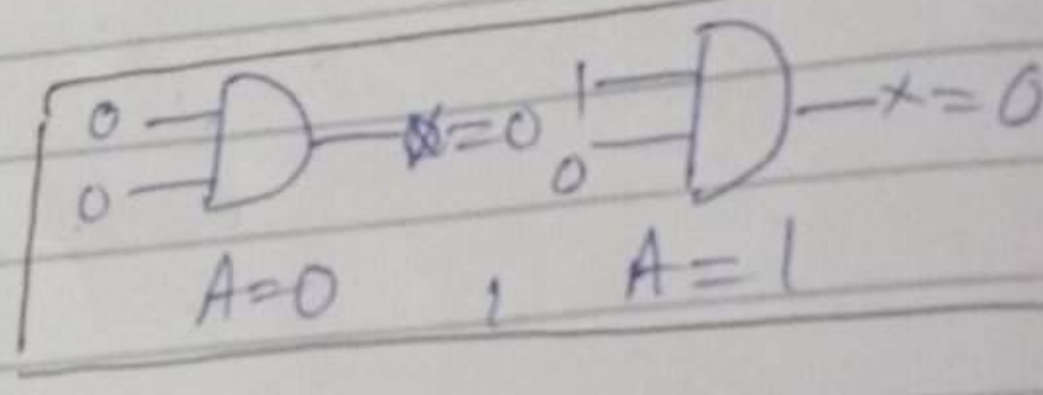
② $A + 1 = 1$



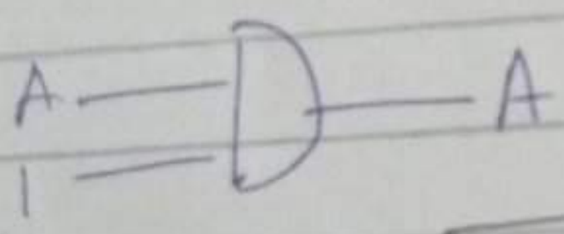


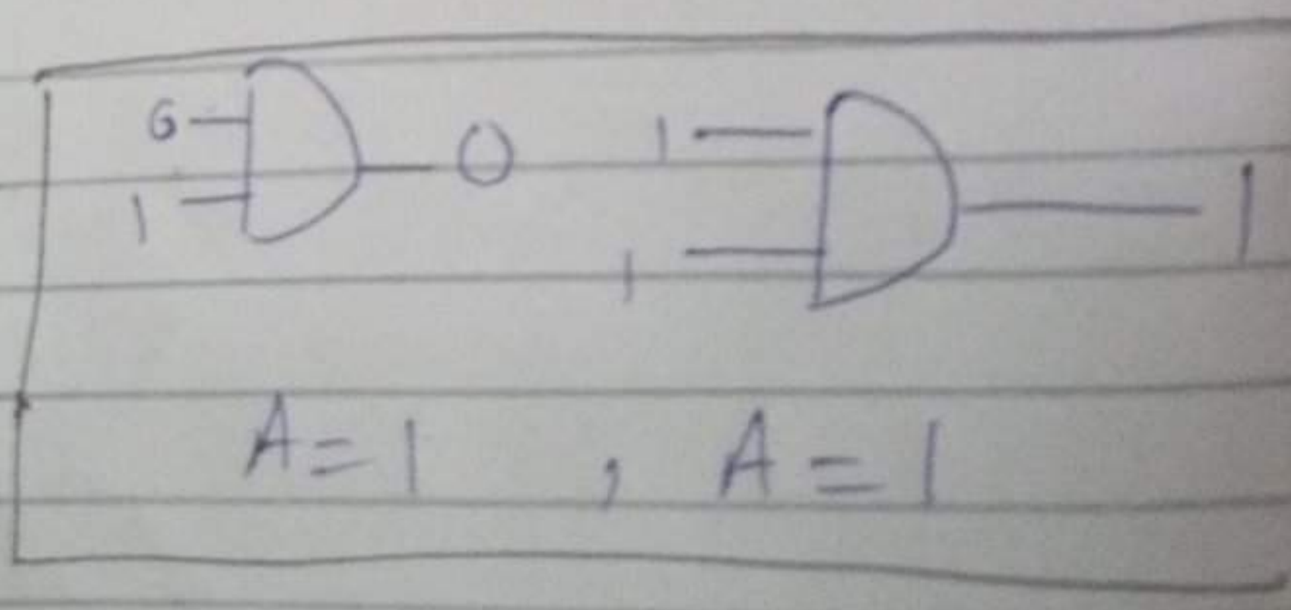
③ $A \cdot 0 = 0$





④ $A \cdot 1 = A$





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$A \cdot (AB + \bar{A}B)$

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

$A \cdot B(1)$

$A \cdot B$

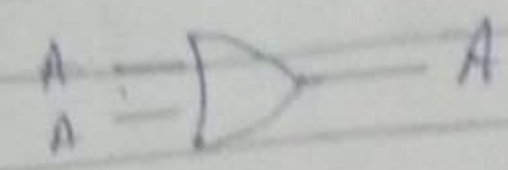
$p \vee (q \wedge r)$

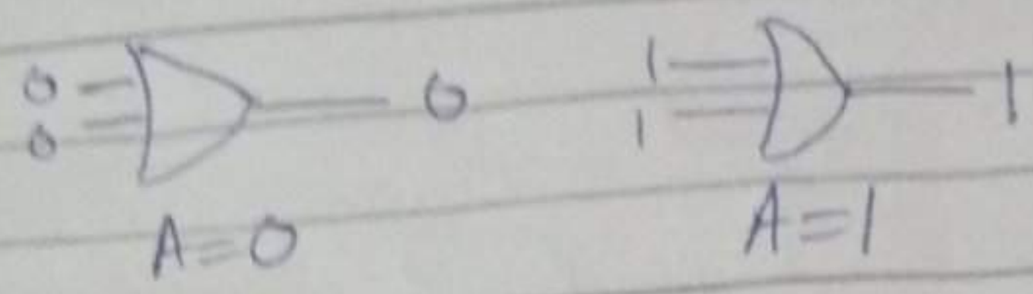
$(p \vee q) \wedge (p \vee r)$

$(p \wedge q) \vee r$

$\sim(p \wedge q) = \sim p \vee \sim q$

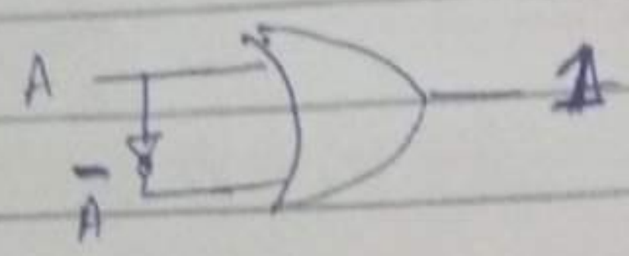
(5) $A + A = A$

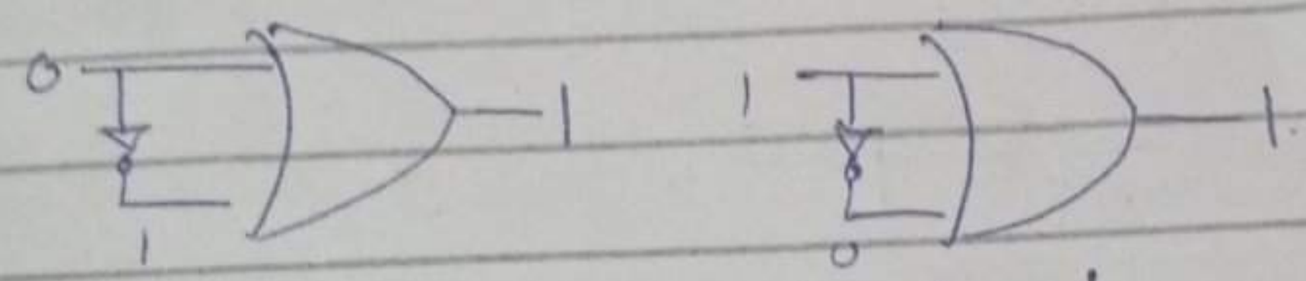




$A = 0$ $A = 1$

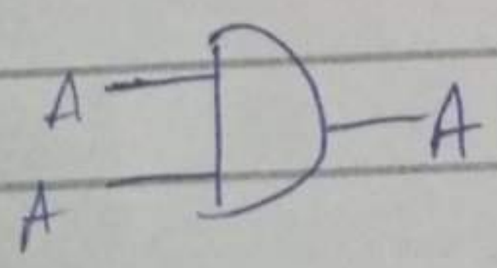
(6) $A + \bar{A} = 1$

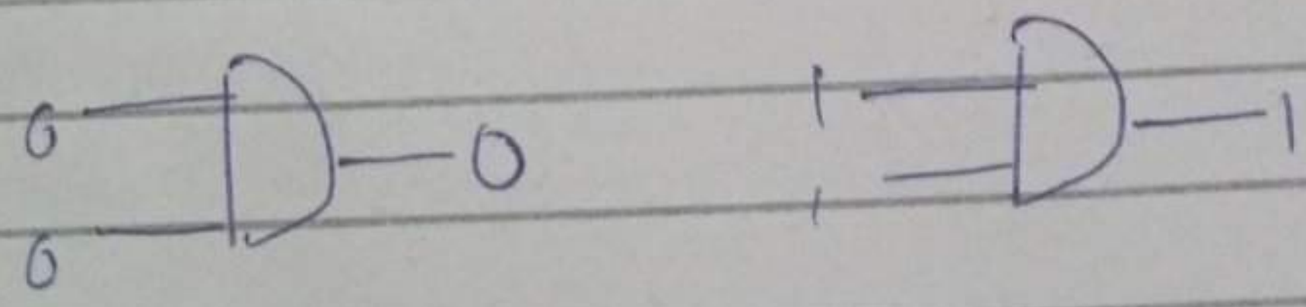




$A = 0$ $A = 1$

(7) $A \cdot A = A$





$A = 0$ $A = 1$

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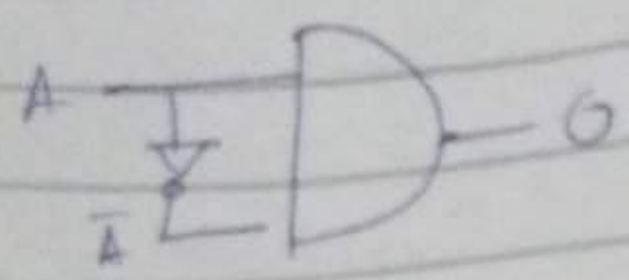
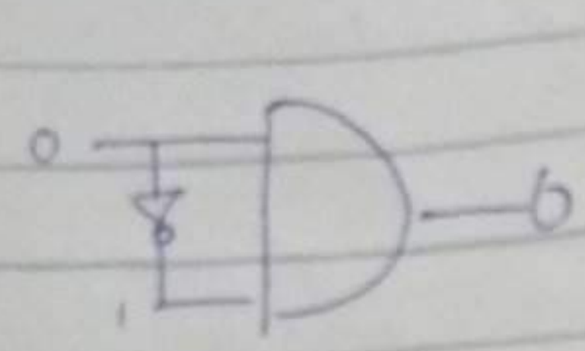
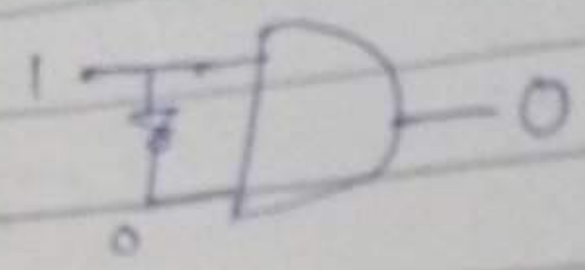
(8) $A \cdot \bar{A} = 0$



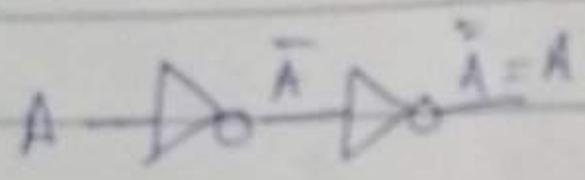


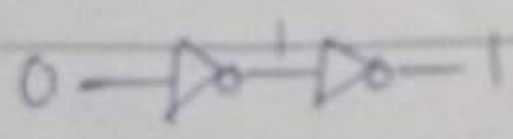
$A=0$



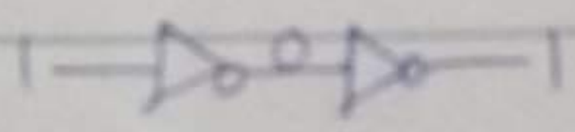
$A=1$

(9) $\bar{\bar{A}} = A$





$A=0$



$A=1$

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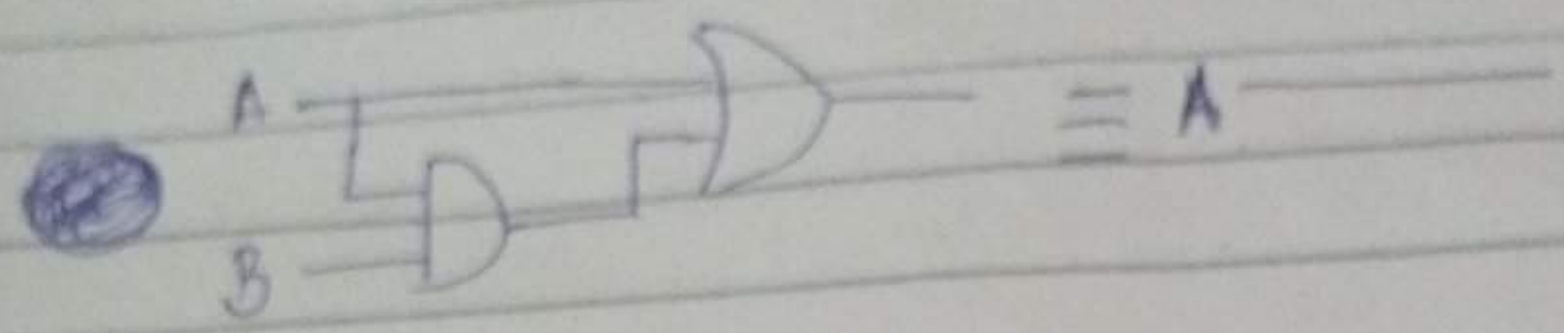
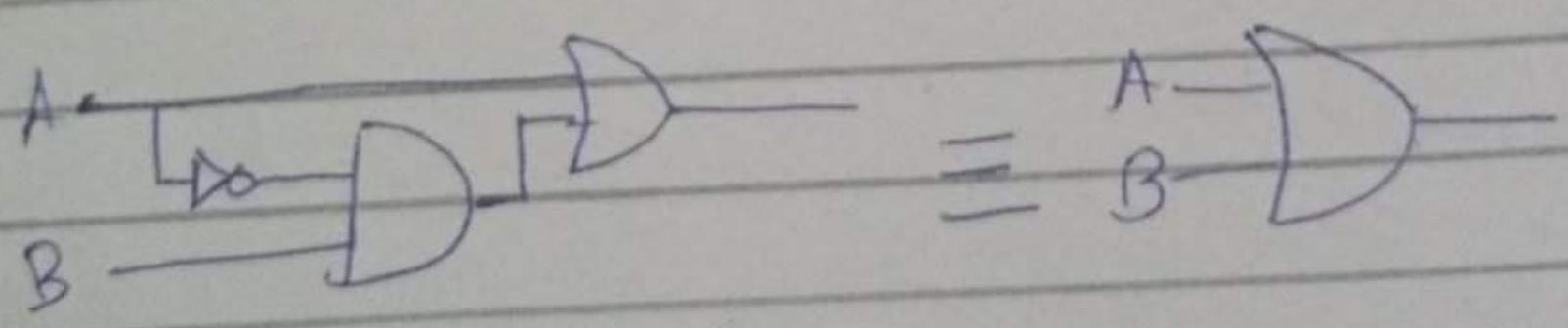
(10) $A + AB = A$

$A(1+B)$	Distributing law:
$A(1)$	Rule 2
A	Rule 4



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

	$A = \bar{A}(A+B)$
$(A + AB) + \bar{A}B$	Rule 10
$A + (AB + \bar{A}B)$	Associative law
$A + B(A + \bar{A})$	Rule 6
$A + B(1)$	Rule 4
$A + B$	



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$(A+B)(B+C)$

Distributive law

$AB+AC+BB+BC$ — Rule 7

$AB+AC+B+BC$ — Rule 10

$AB+AC+B$ — Rule 10

$AC+AB+B$

A

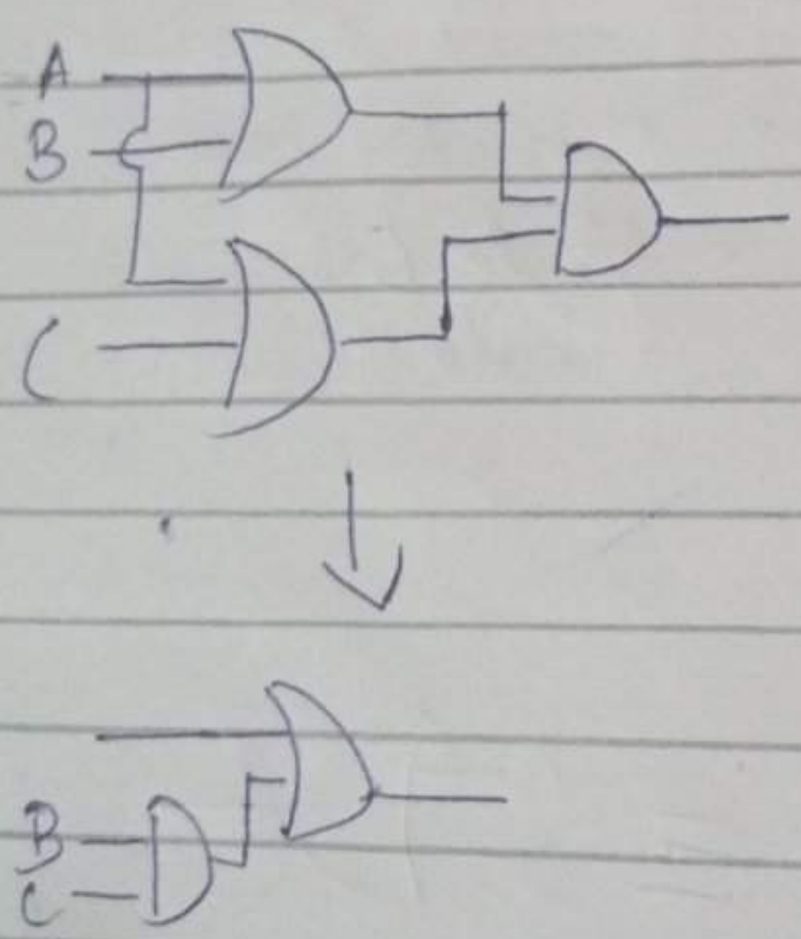
(12) $(A+B)(A+C) = A+BC$

$AA+AC+AB+BC$ — Rule 7

$(A+AC)+AB+BC$ — Rule 10

$A+AB+BC$ — Rule 10

$A+BC$



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Rules:-

1. $A + 0 = A$
2. $A + 1 = 1$
3. $A \cdot 0 = 0$
4. $A \cdot 1 = A$
5. $A + A = A$
6. $A + \bar{A} = 1$
7. $A \cdot A = A$
8. $A \cdot \bar{A} = 0$
9. $\bar{\bar{A}} = A$
10. $A + AB = A$
11. $A + \bar{A}B = A + B$
12. $(A+B)(A+C) = A + BC$

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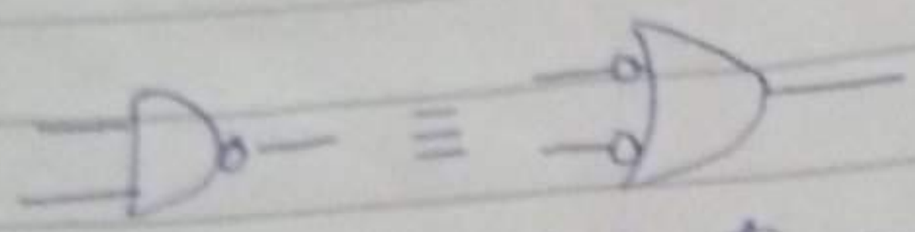
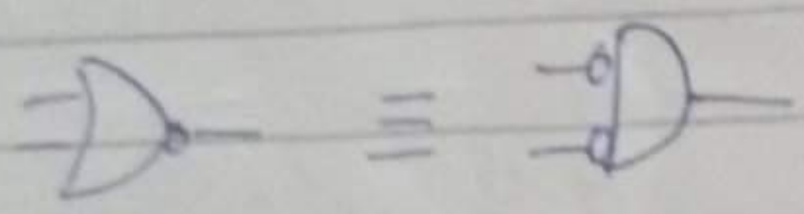
Demorgan theorem

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

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



NAND is equivalent to negative-OR



NOR is equivalent to negative-AND

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Q

① $\overline{\bar{x}+\bar{y}+\bar{z}}$ ①

$= \bar{\bar{x}}\,\bar{\bar{y}}\,\bar{\bar{z}}$

$= x y z$

② $\overline{\bar{w}\,\bar{x}\,\bar{y}\,\bar{z}}$ ②

$\bar{\bar{w}}+\bar{\bar{x}}+\bar{\bar{y}}+\bar{\bar{z}}$

$w+x+y+z$

③ $\overline{((AB)+C)(A+(BC))}$ ③

$\overline{((AB)+C)}+\overline{(A+(BC))}$

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

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

④ $\overline{(A+(B\bar{C}))}+\overline{D(E+\bar{E})}$

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

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

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Q

① $\overline{(A+B+C)D}$

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

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

② $\overline{(ABC)+(DEF)}$

$= \overline{(ABC)} \cdot \overline{(DEF)}$

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

③ $\overline{(A\bar{B})+(\bar{C}D)+(EF)}$

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

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

④ $\overline{(\overline{ABC})+(D)+(E)}$

$\overline{\overline{(ABC)}} \cdot \bar{D} \cdot \bar{E}$

$(ABC) \cdot \bar{D} \cdot \bar{E}$

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Q

① $\overline{(\overline{A+B})+\overline{C}}$

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

$=(A+B)\cdot C$

② $\overline{(\overline{A}+B)+CD}$

$=\overline{(\overline{A}+B)}\cdot\overline{CD}$

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

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

③ $\overline{(A+B)\cdot\overline{C}\cdot\overline{D}+E+\overline{F}}$

$\overline{(A+B)}+\overline{\overline{C}}+\overline{\overline{D}}\cdot\overline{E}\cdot\overline{\overline{F}}$

$(\overline{A+B})+C+D\cdot\overline{E}\cdot F$

$((\overline{A}\cdot\overline{B})+C+D)\cdot\overline{E}\cdot F$

④ $\overline{\overline{A}\cdot B\cdot(C+\overline{D})+E}$

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

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

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

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

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Q.

(1) $\overline{ABC} + (\overline{D+E})$

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

(2) $\overline{(A+B)\cdot C}$

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

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

(3) $\overline{A+B+C}+\overline{\bar{D}E}$

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

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Hexadecimal:- ( )16

Dec	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

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842.

1000.00 → $(8)_{10}$

10000.00 → $(16)_{10}$

100.00 → $(4)_{10}$

<< left shift ×2

>> right shift ÷2

$2^{4} = 16$

↳ # of bits

Binary to Hexadecimal

1100 1010 0101 0111 ← pair start from right

C A 5 7

$(1100101001010111)_2 \longrightarrow (CA57)_{16}$

Hexadecimal to Binary.

$(DF21)_{16} \longrightarrow (1101111100100001)_2$

D F 2 1

1101 1111 0010 0001

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Hexadecimal to Decimal.

① First ~~trans~~ convert from Hexa to Binary, then Binary to Decimal.

$(DA)_{16} \rightarrow (11011010)_2 \rightarrow (218)_{10}$

D A

$(1101 \quad 1010)_2$

128 32 16 8 4 2 1

$(11011010)_2 \longrightarrow (218)$

② Direct

$(DA)_{16} \longrightarrow (218)_{10}$

$D = 13, A = 10$

$13 \times 16^1 + 10 \times 16^0$

$13 \times 16 + 10$

$208 + 10$

$= 218$

16×16

$16^0 \times 13$

16
13
38
16
48
16
208

128
64
192
16
208

64
16
80

128
90
218

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Decimal to Hexa

16 | 650

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Binaly Codded Decimal BCD

0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

9 8 → 1001 1000

3 2 → (0011 0010)$_{BCD}$

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BCD addition

1001 + 0100

```
  1001
+ 0100
 ------
  1101   → Not in range (1—9)
  0110     so add 6
 ------
0001 0011
  1    3
```

13

0011 00111 + 0101 00111

```
 6    7     5    3
```

```
  53
  67
 ----
 120
```

~~0110 0111~~
~~0101 0011~~
~~1011 1010~~
~~0110 0110~~
~~0001 0100 0000~~

```
0110 0111
0101 0011
---------
1011 1010
0110 0110
---------
0001 0100 0000
 1    2    0
```

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Signed

1. Sign magnitude
2. 1's complement
3. 2's complement

1. Sign magnitude

MSB [ ]

↑ Magnitude

Sign

	MSB
-ve	1
+ve	0

$(1\,000)_2$ Sign magnitude.

$(-8)_{10}$

Two zero

⟹ 0 111
+ (7)

1 111
(-) (7)

0 000 → 0

1 000 → 0

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Over flow

$$\begin{array}{r} 5 \\ 4 \\ \hline +9 \end{array}$$

→ 9 is greater than 7 overflow this cause error so, we increase the bit instead 4 we make 5bit then overflow don't.

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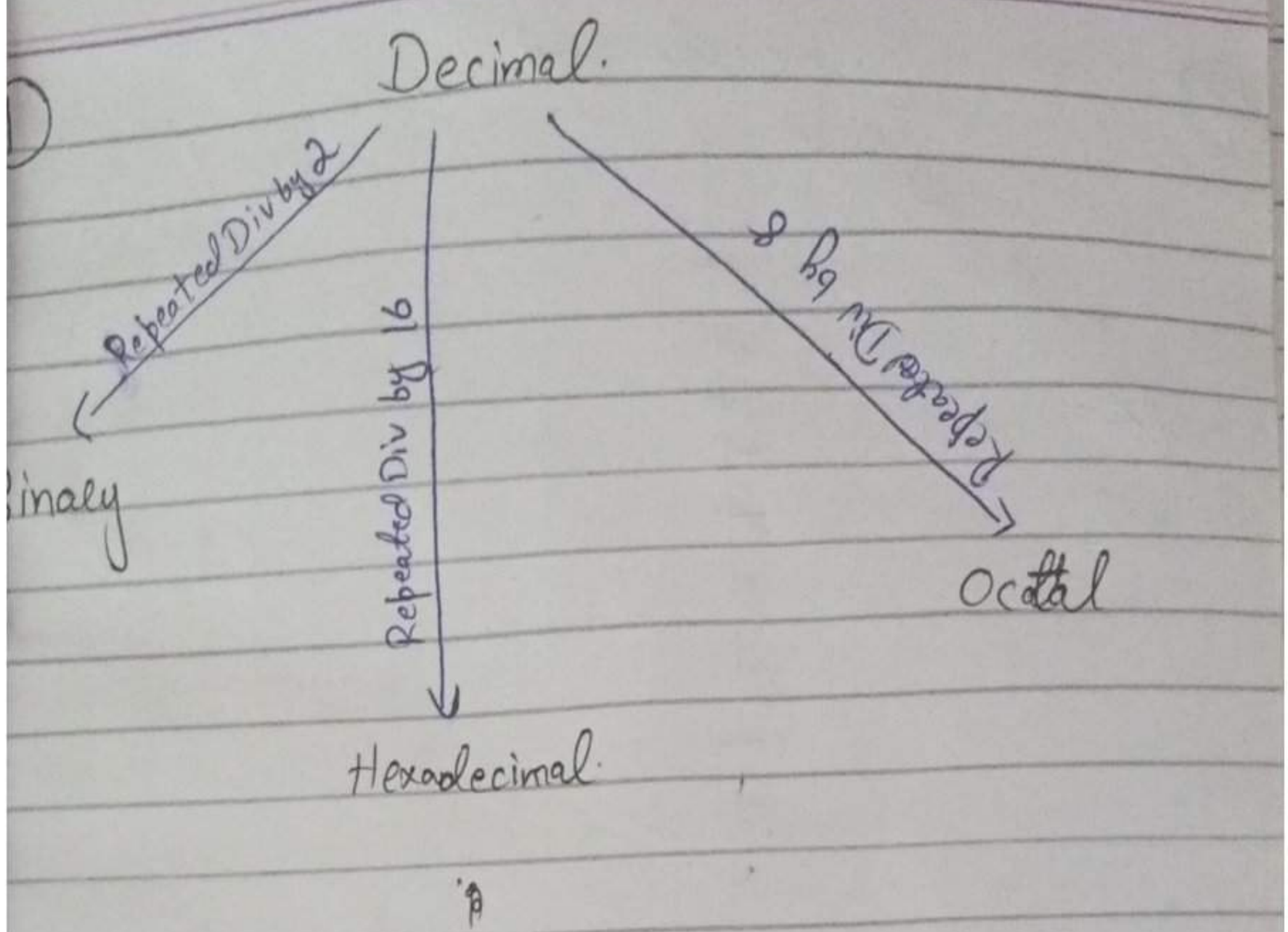
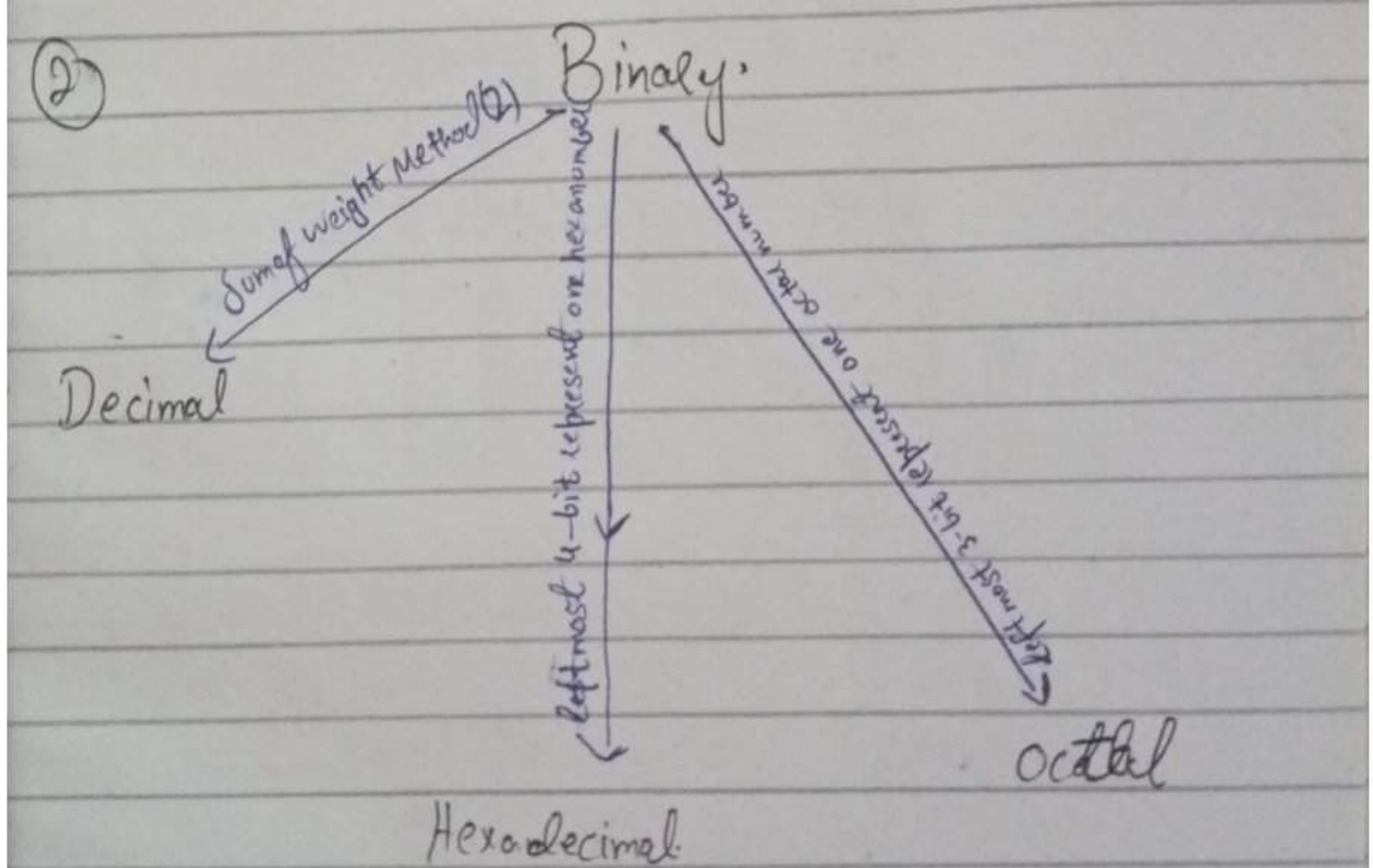
(1)



(2)



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(3) Hexadecimal

Sum of weight method (16)

Decimal

Digit of Hexa code 4 bit of Binary

Binary

(4) Octal

Sum of weight method (8)

Decimal

Digit of octal code 3 bit of Binary

Binary

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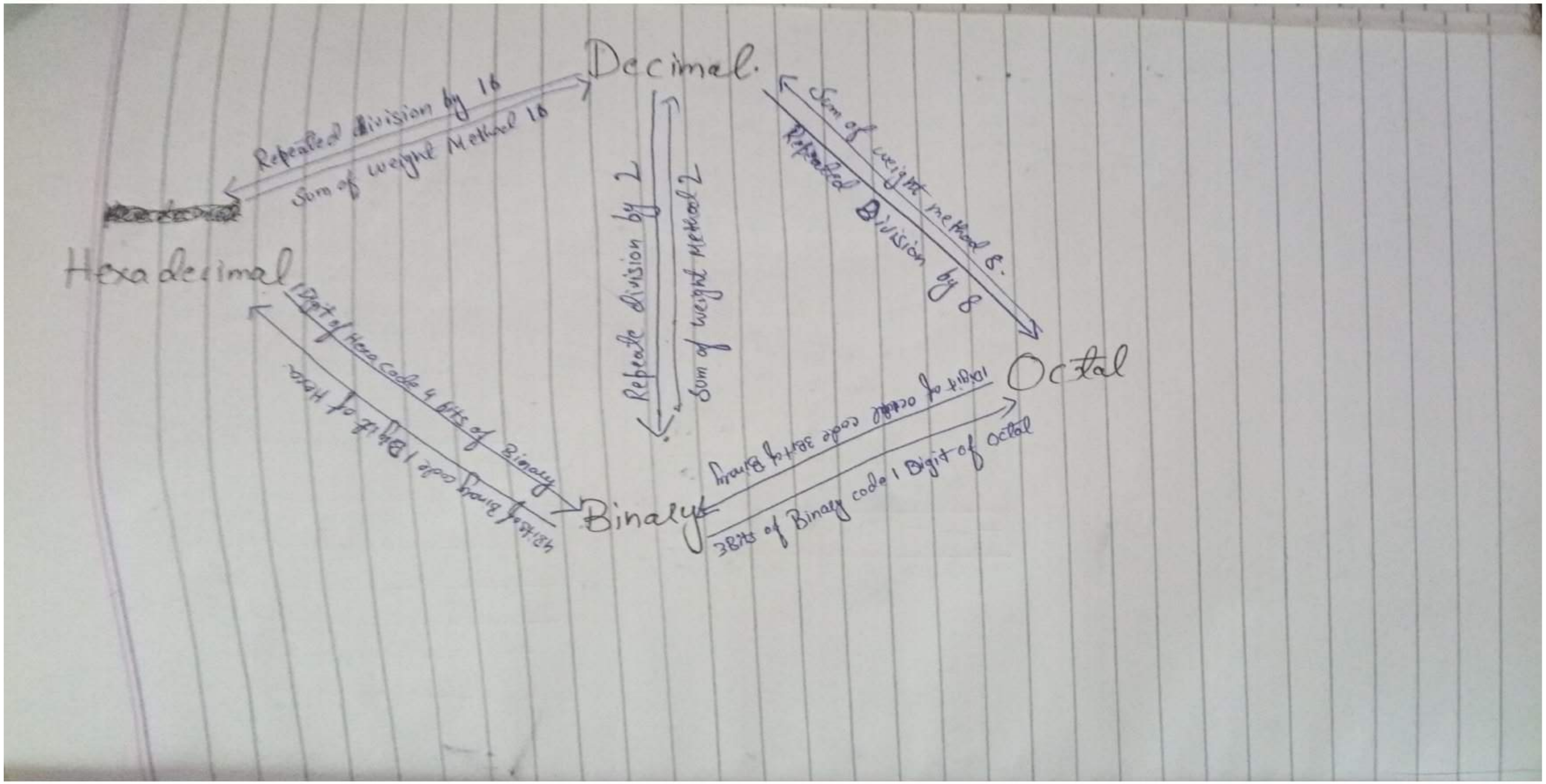

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A	B	C	$\overline{AB}$	$\overline{BC}$									
0	0	0	1	1	1	1	0	0	0	1	0	1	1
0	0	1	1	1	0	1	0	0	0	1	0	1	1
0	1	0	1	1	0	1	0	0	0	1	0	1	1
0	1	1	1	1	0	1	0	0	0	1	0	1	1
1	0	0	1	1	0	1	0	0	0	1	0	1	1
1	0	1	1	0	0	1	0	1	1	0	0	1	1
1	1	0	0	1	0	1	1	0	1	0	0	1	1
1	1	1	0	0	0	0	1	1	1	0	1	0	0

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

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

$\overline{A}+\overline{B}+\overline{C}+(A+B+C)$

$\overline{(\overline{A}\cdot\overline{B}\cdot\overline{C})}\cdot\overline{(A+B+C)}$

$\overline{A}+(\overline{A}(\overline{B}\cdot\overline{C}))+\overline{B}+\overline{C}$

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

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① Simplify $\overline{AB + AC} + \overline{ABC}$

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

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

$= \bar{A} + \bar{B}\bar{C} + \bar{A} + \bar{B} + \bar{C}$ (Rule 12)

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

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

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

$= \bar{A} + (\bar{B} \cdot (1)) + \bar{C}$ (Rule 4)

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

② $\overline{AB} + \overline{AC} + \overline{ABC}$

$(\overline{AB}) \cdot (\overline{AC}) \; (\overline{A + B + C})$

$\overline{(AB)(AC)} + (A + B + C)$

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

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

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

$= (\bar{A} + \bar{A}(\bar{B} \cdot \bar{C})) + \bar{B} + \bar{C}$ Rule 10 $(A + AB) = A$

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

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1s Compliment

+9 0 1001
-9 1 0110

In hardware we use not gate to invert value from (+9) to (-9)

1s Calculate.

-16 8 4 2 1
1 0 1 1 0 = -9

-16 + 6 = -10 (Always answer is less by 1)
+1
-9

(2) +22 16 8 4 2 1
1 0 1 1 0 (1 0 1 0 0 1) -22

Write -9 in sign, 1s

1 1001 Sign 01001
- 9

1 0110 1s compliment
-9

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00001001 (+9)
(11110110) (−9)
(11110110) (−9)

No effect of 1 in 1's compliment.

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

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2's compliment

(a)	0 1 0 0 1
1's com	1 0 1 1 0
	+1
2's comp	1 0 1 1 1

2's comp = 1' comp + 1

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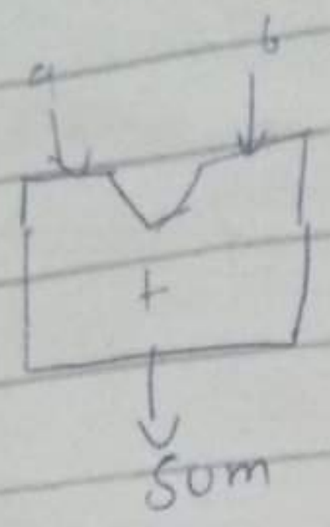
Hardware



(a+b) adder

we we want to calculate a−b use adder

$(a-b) = (a+(-b))$ → $-b = b'+1$

$= a + b' + 1$

Example

5−3 = +2

0101 + (0011)' + 1

0101 + (1100) + 1

0	1	0	1	→ 5
1	1	0	0	−3
0	0	0	1	
1	0	0	1	0	+2

Ignore

Ingnal

+2

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① 22 convert to sign, 1s, 2s.

2	22
2	11 — 0
2	5 — 1
2	2 — 1
	1 — 0

+22 → 010110

(-22)

① singn 110110

② 1s 101001

③ 2s 101010

② 101110

-32 16 8 4 2 1

-32 + 14

14
3
(-18)

Sign
-14

4s
-17

17 →

2	17
2	8 — 1
2	4 — 0
2	2 — 0
	1 — 0

+7 010001

101110

2s
-18

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Ex# 2-14

-39.

2	39
2	19 — 1
2	9 — 1
2	4 — 1
2	2 — 0
	1 — 0

+39 → (100111)

(-39) 1s (1011000)

(-39) 2s (1011001)

Decimal of sign mag 0111 0111

+119

$$\begin{array}{r} 64 \\ 32 \\ 16 \\ 7 \\ \hline 119 \end{array}$$

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Scanned with CamScanner

Practise:-

① 2's compliment of 10110010

256 128 64 32 16 8 4 2 1

01011001 0 → 1's comp

10100110 1

+1

-178 ← 10100110 → 2's comp

② 2's Compliment of 11001011

256 128 64 32 16 8 4 2 1

+203 ← 011001011

100110100 → 1's comp

+1

-203 ← 100110101 → 2's comp

③ Alternate Method.

③ 2's Compliment of 01011000 → 184

-184 ← 101001000 → 2's comp

④ 2's compliment of 011000000 → 192

256 128 64 32 16 8 4 2 1

-192 ← 101000000 → 2's comp

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Scanned with CamScanner

2's comp to binary

101001110 → 2's com

010110001 → inverter

+1

01011001 0 → binary.

(5) 00011010 → 26

11100101 → -27+1 = -26

(6) 011110111 → 247

100001000 → -246+1 => -247

(7) 01000101

10111001 0

(8) 00010110 → 22

11101010 → -22

(9) 011111100 → 252

100000100 → -252

(10) 01001001 → 145

10110111 → -145

Scanned with CamScanner

Scanned with CamScanner

Example 2.14

Express −39 to sign, 1^s, 2^s

2	39
2	19 — 1
2	9 — 1
2	4 — 1
2	2 — 0
	1 — 0

39 → 00100111

Sign — 10100111

1^s — 11011000

2^s — 11011001

Express −19 to sign, 1^s, 2^s.

2	19
2	9 — 1
2	4 — 1
2	2 — 0
	1 — 0

19 → 00010011

Sign → 10010011

1s → 11101100

2s → 11101101

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Ex 2.15 → Sign Magnitude

0 1110111 → convert to decimal

Sign Mag

64+32+16+4+2+1 = 119

0 is sign bit so $\boxed{+119}$

Ex 2.16 → 1s comp

11101011 covert to decimal

-128 64 32 16 8 4 2 1

1 1 1 0 1 0 1 1

Add weight (-128+64+32+8+2+1 = -21)

-21+1 $\boxed{= -20}$

Note

If we have multiple 1 one the left side then remove all and remain only 1 i.e if you have 4, 1 at left side the remove 3.

#101011 = 101011

-32 16 8 4 2 1

1 0 1 0 1 1

Add weight (-32+8+2+1 = -21)

-21+1 $\boxed{= -20}$ Ans same no effect.

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Ex# 2.7 — 2's complement

11.0101.11 convert to decimal.

11010111 = 1010111

-64	32	16	8	4	2	1
1	0	1	0	1	1	1

$-64 + 16 + 4 + 2 + 1 = -41$

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Addition

Ex 2.19

Add 00110011, 10111111, 01100011

128 64 32 16 8 4 2 1

00110011 → 51

+ 10111111 → -65

11110010 → -14

01100011 → 99

Discard → (1) 01010101 → 85

Substraction

Ex 2.20

(a) 00001000 − 00000011

Take 2's comp of 00000011 and add it to 00001000.

So

00000011 → Binary

11111101 → 2's

Add

00001000 → 8

+ 11111101 → -3

Discard → (1) 00000101 → 5

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(b) 00001100 − 11110111

```
  00001100
+ 10001001
  10010101
```

12
−249
−235

(c) 11100111 − 00016011

−128	64	32	16	8	4	2	1	
	1	1	1	0	0	1	1	−25
+	1	1	1	0	1	1	0	−19
(1)	1	1	0	1	0	1	0	−44

Discard

(d) 10001000 − 11100010

```
  10001000
+ 00011110
  10100110
```

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Scanned with CamScanner

(e) - 01000111 + 01011000

128 64 32 16 8 4 2 1

0 1 0 1 1 0 0 0 — 88

+ 1 0 1 1 1 0 0 1 — -71

1 0 0 0 1 0 0 0 1 — +17

Discard

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Gray Code.

Dec	Binary	Gray
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

-> only sigle bit change from code word to next sequence

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Binary to Gray Conversion

10110 to Gray Code

	1	0	1	1	0	Binary
same ←	1	1	1	0	1	Gray.

add this and this

write ans here (discard carry)

Gray to Binary Conversion.

	1	1	1	0	1	Gray
	1	0	1	1	0	Binary.

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Example 2.37

(a) Binary number (11000110) to Gray code.

1 1 0 0 0 1 1 0 Binary

1 0 1 0 0 1 0 1 Gray

Back solve

1 0 1 0 0 1 0 1 Gray

1 1 0 0 0 1 1 0 Binary

(b) Gray code (10101111) to binary

1 0 1 0 1 1 1 1 Grey

1 1 0 0 1 0 1 0 Binary

Back solve

1 1 0 0 1 0 1 0

1 0 1 0 1 1 1 1

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Parity Even | odd

① Parity is used for error detection
② Parity can be attached at beginning at all the end of a code.

BCD	E	O	EParity	OParity
0001	1	0	10001	00001
0011	0	1	00011	10011
0111	1	0	10111	00111
0010	1	0	10010	00010

parity → 1, number → 0010

parity → 0, number → 0010

① In even parity totals 1s is even including parity value
② In odd parity total 1s is odd

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Example 2.39

Add even parity

(a) 1010	01010
(b) 111000	111000
(c) 101101	0101101
(d) 1000111001001	0 1000111001001
(e) 1011010111111	1 1011010111111
(f) 1001011	01001011

Example 2.40

Odd parity code check error.

In odd parity number of 1s in code is odd
So,

(a) No error
(b) No error
(c) error
(d) no error
(e) error
(f) 00110111 → No error.

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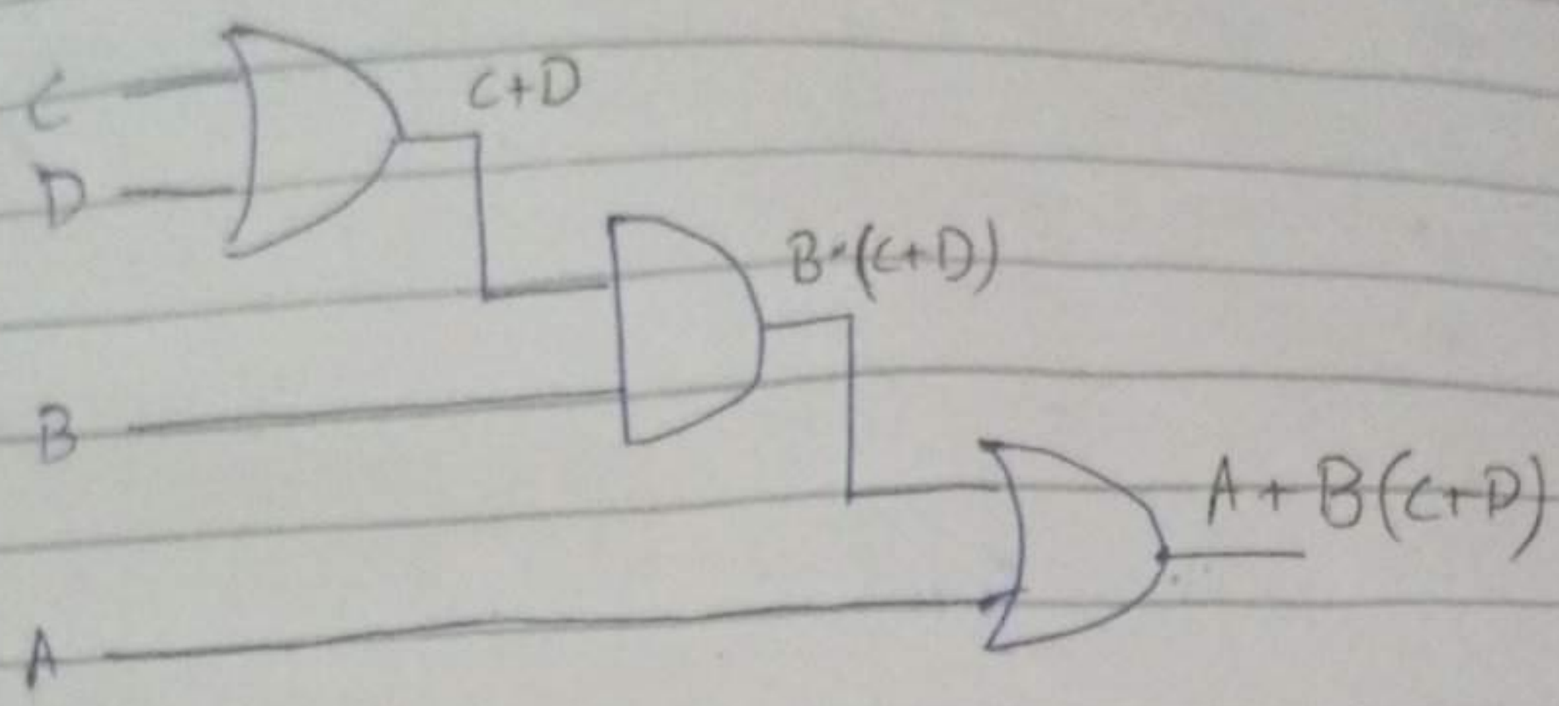
Boolean Expression for logic Circuit.



$X = A + B(C+D)$

Constructing truth table for logic circuit

1. First convert the circuit into boolean exp
2. Find out the variable
3. Calculate possible combination of give variabl

   Formula $= 2^{\text{no of variable}}$

4. Find out the ~~expression~~ all posible values. which make the output 1.

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Example

A	B	C	D	$A+B(C+D)$
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

$A+B(C+D)$

① if $A=1$ regardless of $B(C+D)$ output is 1
so output is 1 where A is 1

② if $A=0$ and $B(C+D)$ is 1 output is 1
$B(C+D)=1$ when $B=1$ and $(C+D)=1$
$C+D=1$ when $\underbrace{C\neq 0 \text{ and } D\neq 0}_{\text{simultaneously}}$

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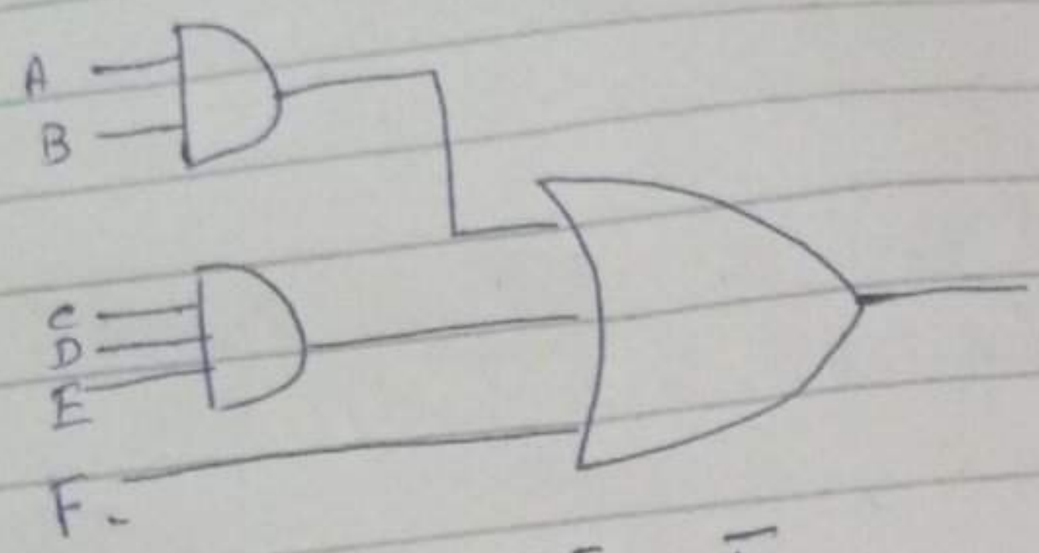
Sum of Product form.

ORing the output of two or more AND gate.



$X = AB + CDE + \overline{F}$

Example 9.12

Convert Boolean expression to SOP form

(a) $AB + B(CD + EF)$ $= AB + BCD + BEF$

(b) $\dfrac{(A+B)(B+C+D)}{(A+B)} + C$ $= AB + AC + AD + BB + BC + BD$

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

(c) $= A\overline{C} + B\overline{C}$

(c) $\overline{A}\,\overline{B}\,\overline{C} + (A+\overline{B})(B+\overline{C}+A\overline{B})$

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

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Standard SOP form.

Standard SOP form is one which contain all the variable in its domain. like.

$A\bar{B}\bar{C} + A\bar{B}CD$ SOP form

↳ D variable is missing.

To convert SOP form to Standard form just multiply (variable + $\overline{\text{variable}}$) with missing term.

$A\bar{B}\bar{C}(B+\bar{D}) + A\bar{B}CD$ $D+\bar{D} = 1$

↳

$A\bar{B}\bar{C}D + A\bar{B}\bar{C}\bar{D} + A\bar{B}CD$ Standard form.

Standard form help us in constructing truth table.

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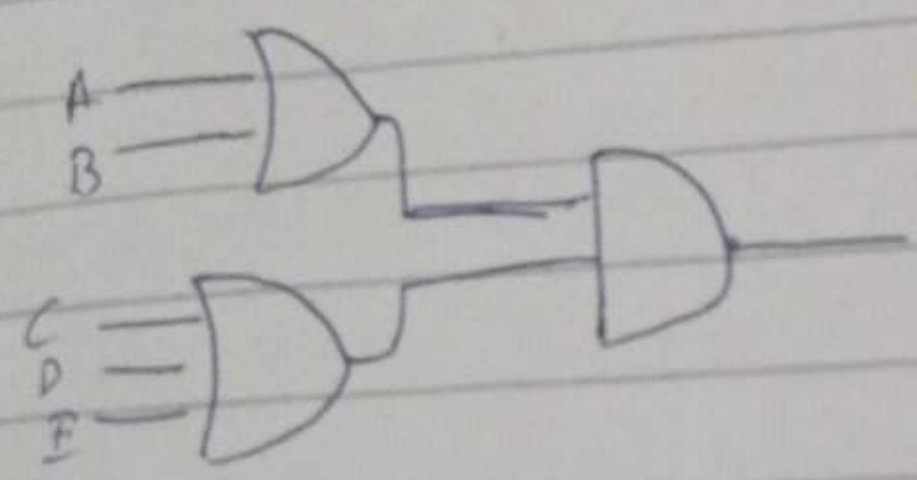
Ex 4.13

$w\bar{x}y + \bar{x}yz + wx\bar{y}$ to Standard form

$w\bar{x}yz + w\bar{x}y\bar{z} + w\bar{x}y\bar{z} + \bar{w}\bar{x}y\bar{z} + wx\bar{y}z + wx\bar{y}\bar{z}$

Product of Sum form :-

ANDing the output of more than two OR gate



$x = (A+B)(C+D+E)$

Standard POS form $(A \cdot \bar{A} = 0)$

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

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

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

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

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Scanned with CamScanner

Construct Truth table from SOP form

$X = x'y'z + x'yz + xy'$

$X = x'z(y+y') + xy'$

$\boxed{X = x'z + xy'}$

→ make expression 1

$x'z = 1$ when $x=0$, $z=1$

$xy' = 1$ when $x=1$, $y=0$

x	y	z		
0	0	0		0
0	0	1	$x'z$	1
0	1	0		0
0	1	1	$x'z$	1
1	0	0	xy'	1
1	0	1	xy'	1
1	1	0		0
1	1	1		0

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Construct truth table from POS

$(x+y+z')(x+y'+z')\cdot(x'+y)$

$(x+y+z')(x+y'+z')(x'+y)$

$(\underbrace{x+z'}_{A}+\underbrace{y}_{B})(\underbrace{x+z'}_{A}+\underbrace{y'}_{C})(x'+y)$ $\quad (A+B)(A+C) = A+BC$

$((x+z')+(y\cdot y'))(x'+y)$

$((x+z')+0)(x'+y)$

$\boxed{X=(x+z')(x'+y)}$

x	y	z		
0	0	0		0
0	0	1	$(x+z')$	1
0	1	0		0
0	1	1	$(x+z')$	1
1	0	0	$x'+y$	1
1	0	1	$x'+y$	1
1	1	0		0
1	1	1		0

$x+z'=0$ when $x=0, z=1$

$x'+y=0$ when $x=1, y=0$

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Q Table:

x	y	z	SOP = 1 (m) small Min Term	POS = 0 (M) capital Max Term	
0	0	0	$x'y'z'$ m_0	$x+y+z$	M_0
0	0	1	$x'y'z$ m_1	$x+y+z'$	M_1
0	1	0	$x'yz'$ m_2	$x+y'+z$	M_2
0	1	1	$x'yz$ m_3	$x+y'+z'$	M_3
1	0	0	$xy'z'$ m_4	$x'+y+z$	M_4
1	0	1	$xy'z$ m_5	$x'+y+z'$	M_5
1	1	0	xyz' m_6	$x'+y'+z$	M_6
1	1	1	xyz m_7	$x'+y'+z'$	M_7

Sum of min term (Product term OR)

product of max term (Sum term AND)

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Scanned with CamScanner

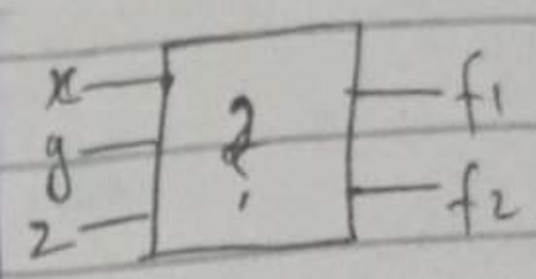
$f_1 = xyz + xyz' + xy'z + xyz' + xy'z' + x'y'z'$

$m_7 + m_6 + m_5 + m_6 + m_4 + m_1$

$f_1 = m_7 + m_6 + m_5 + m_6 + m_4 + m_1$

$f_1 = \Sigma(1, 4, 5, 6, 7)$

Input			Output	
x	y	z	f_1	f_2
0	0	0	0	0
0	0	1	1	0
0	1	0	0	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



$f_1 = x'y'z + x'y'z' + xyz$

$f_1 = m_1 + m_4 + m_7$

$f_1 = \Sigma(1, 4, 7)$

$f_1' = x'y'z' + x'yz' + x'yz + xy'z + xyz'$

Scanned with CamScanner

Scanned with CamScanner

$$(f_1)' = (x'y'z' + x'yz' + x'yz + xy'z + xyz')$$

$$= (\overline{x'y'z'}) \cdot (\overline{x'yz'}) \cdot (\overline{x'yz}) \cdot (\overline{xy'z}) \cdot (\overline{xyz'})$$

$$= (x+y+z)(x+y'+z)(x+y'+z')(x'+y+z')(x'+y'+z$$

$$f_1 = (M_0) \cdot (M_2) \cdot (M_3) \cdot (M_5) \cdot (M_6)$$

$$f_1 = \Pi(0, 2, 3, 5, 6)$$

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Scanned with CamScanner

$f_2 = xyz + xy'z + xyz' + xyz$

$f_2 = m3 + m5 + m6 + m7$

$$\boxed{f_2 = \Sigma(3, 5, 6, 7)}$$

$(f_2') = x'y'z' + x'y'z + x'yz' + xy'z'$

$(f_2')' = \overline{(x'y'z' + x'y'z + x'yz' + xy'z')}$

$f_2 = (\overline{x'y'z'}) \cdot (\overline{x'y'z}) \cdot (\overline{x'yz'}) \cdot (\overline{xy'z'})$

$f_2 = (x+y+z) \cdot (x+y+z') \cdot (x+y'+z) \cdot (x'+y+z)$

$f_2 = (M_0) \cdot (M_1) (M_2) (M$

$$\boxed{f_2 = \Pi(0, 1, 2, 4)}$$

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Scanned with CamScanner

$$F_1 = \overset{BC}{A} + \overset{A}{B'C}$$

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

$$= AB + AB' + AB'C + A'B'C$$

$$= ABC(C+C') + AB'(C+C') + AB'C + A'B'C$$

$$= ABC + ABC' + AB'C + AB'C' + AB'C + A'B'C$$

$$= m_7 + m_6 + m_5 + m_4 + m_5 + m_1$$

$$= m_1 + m_4 + m_5 + m_6 + m_7$$

$$= \Sigma(1, 4, 5, 6, 7)$$

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

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

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$F = XY + X'Z$ ——— Method 1

$XYZ + XYZ' + X'YZ + X'Y'Z$

$m7 + m6 + m3 + m1$

$F = \Sigma(1, 3, 6, 7)$

$F = \Pi(0, 2, 4, 5)$

$(M0)(M2)(M4)(M5)$

$(x+y+z)\cdot(x+y+z')(x'+y+z)(x'+y+z')$

$F = XY + X'Z \longrightarrow$ Method 2

$= (XY + X')(XY + Z)$

$= (X + X')(Y + X')(X + Z)(Y + Z)$

$= (Y + X')(X + Z)(Y + Z)$

$= (X' + Y + Z)\cdot(X' + Y + Z')\cdot(X + Y + Z)\cdot(X + Y' + Z)$

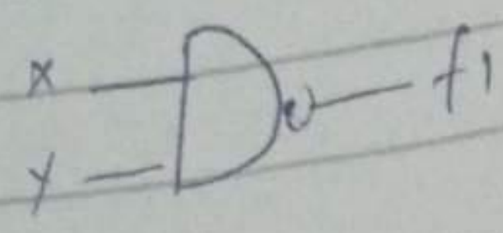
$\cdot(X + Y + Z)(X' + Y + Z)$

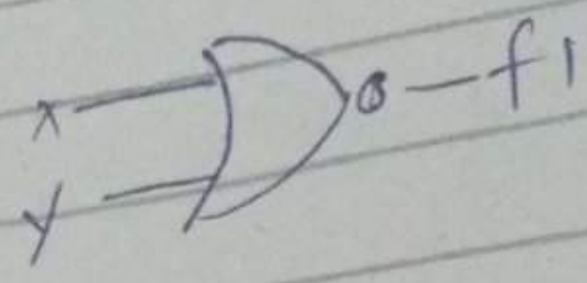
$= (X' + Y + Z)(X' + Y + Z')(X + X + Z)\cdot(X$

Scanned with CamScanner

Scanned with CamScanner

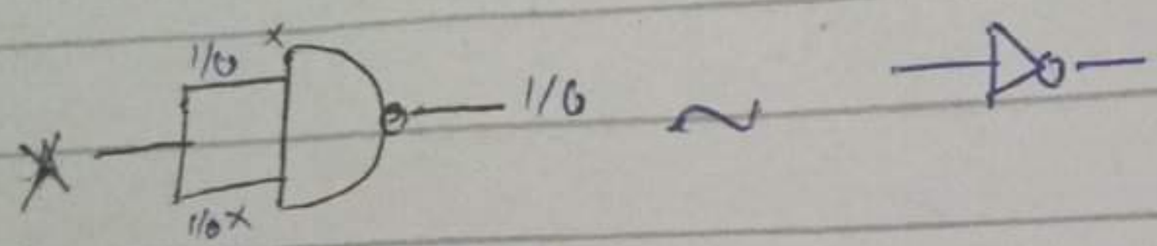
NAND / NOR





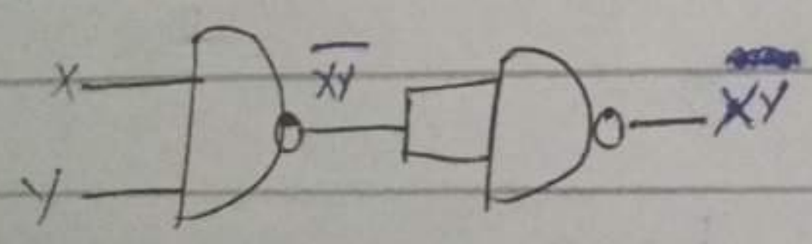
X	X	NAND	NOR
0	0	1	1
0	1	1	0
1	0	1	0
1	1	0	0

NANDto NOT Gate:-



NOT Gate

NAND to AND Gate:-



AND Gate.

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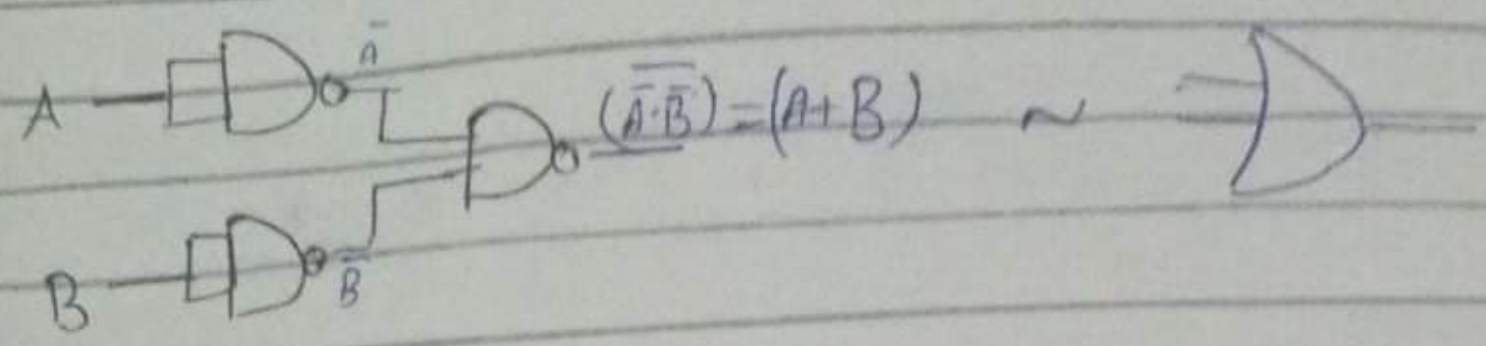
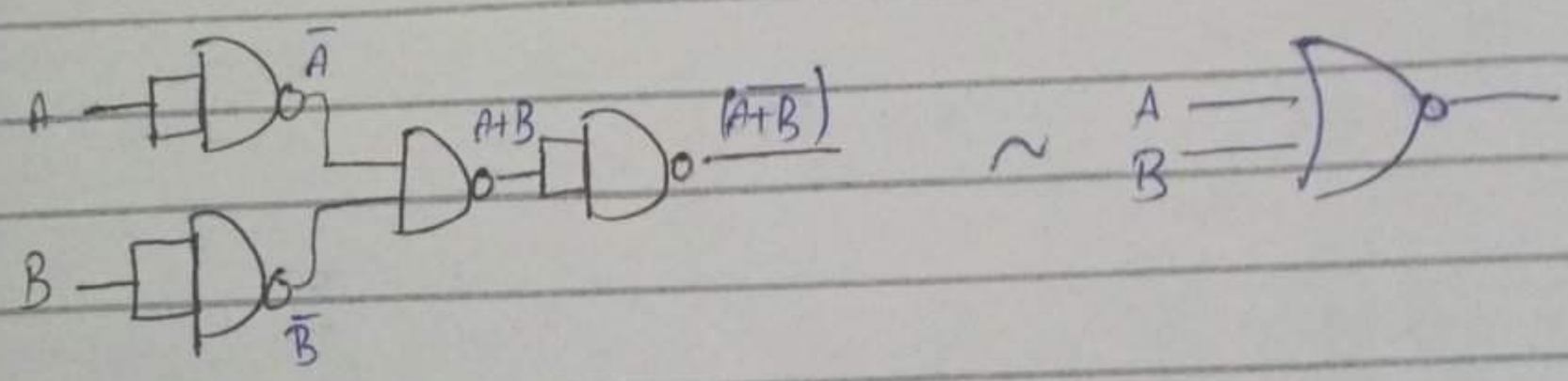
NAND Gate to OR gate :-



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

NAND to NOR gate :-



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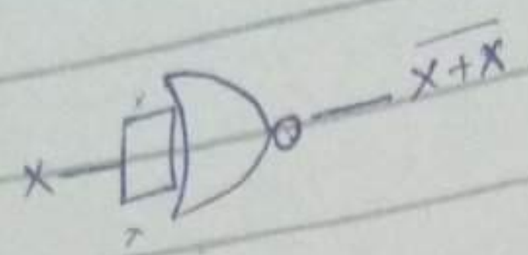
NOR to NOT Gate.

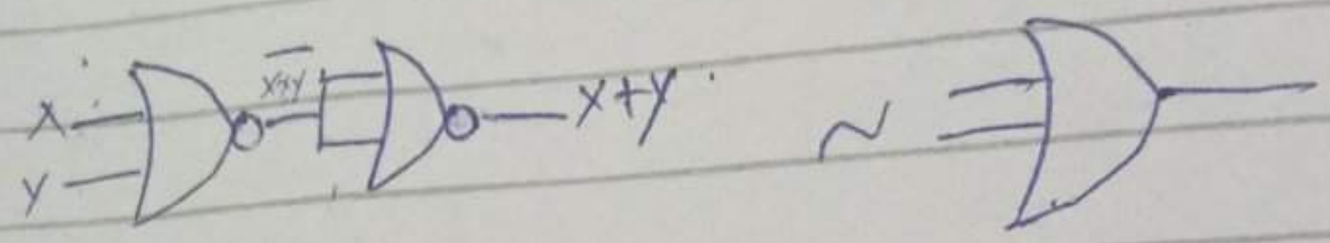


$= \overline{x+x}$

$= \bar{x} \cdot \bar{x}$

$= \bar{x}$

NOR to ~~AND~~ OR Gate.

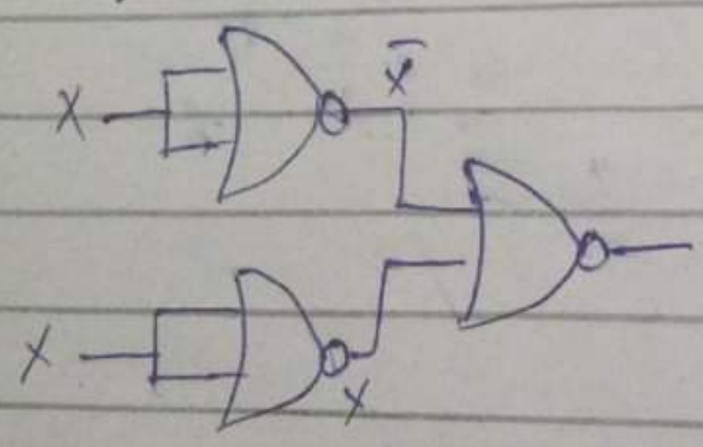


NOR to AND Gate.

$\overline{\bar{x} + \bar{y}}$

$\overline{\bar{y} + \bar{x}}$

$x \cdot y$



$= \overline{\bar{x} + \bar{y}}$

$= \overline{\bar{x}} \cdot \overline{\bar{y}}$

$= x \cdot y$

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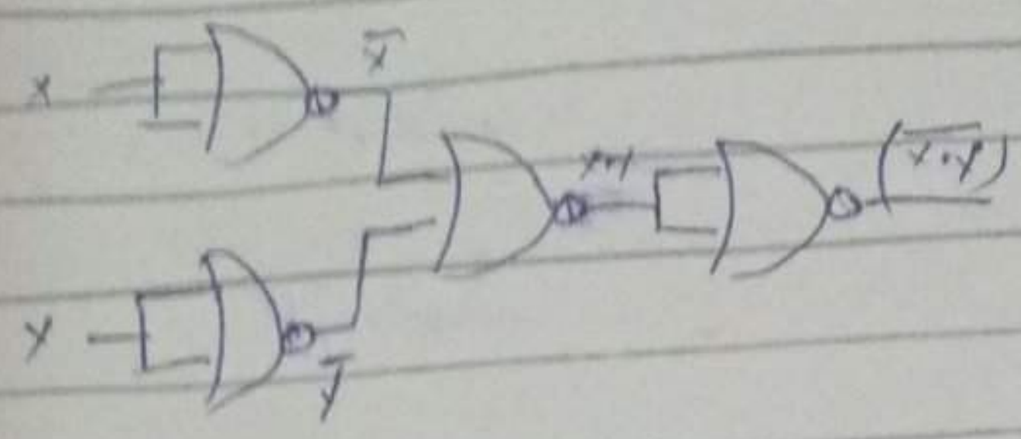
NOR to NAND



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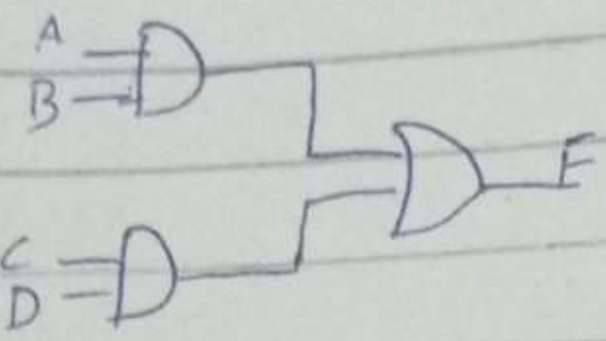
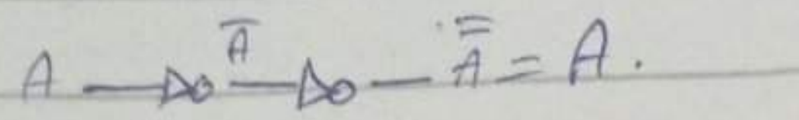
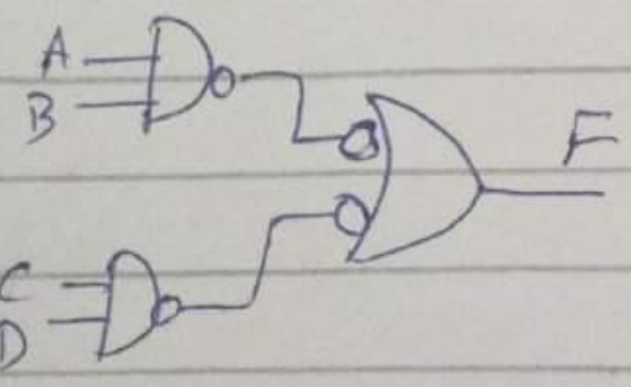
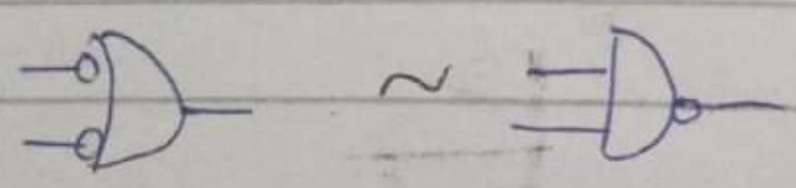
Sum of Product.

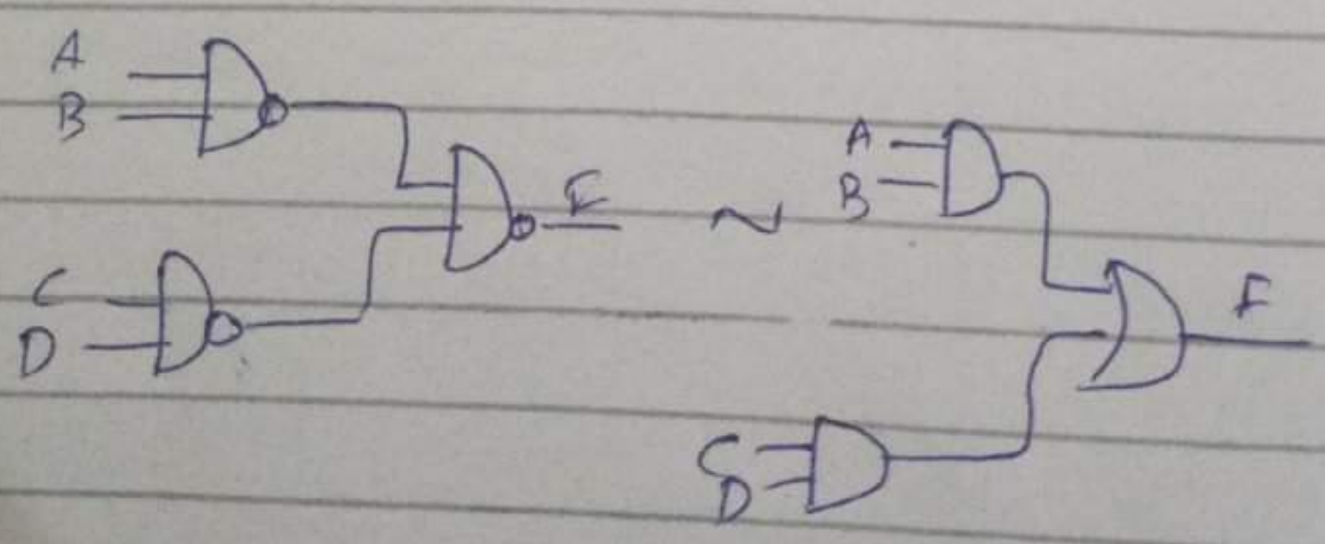




By put double inverter in path then there is no effect in output.







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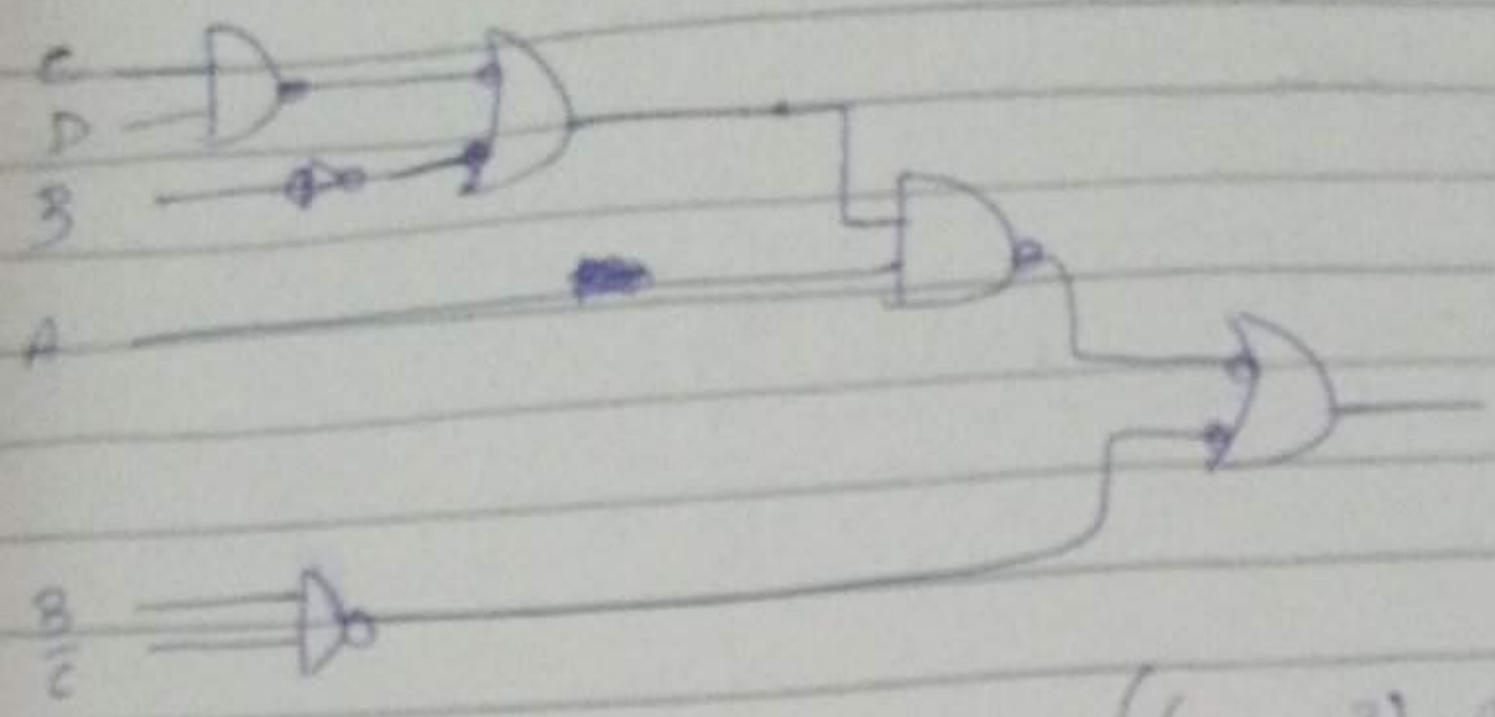
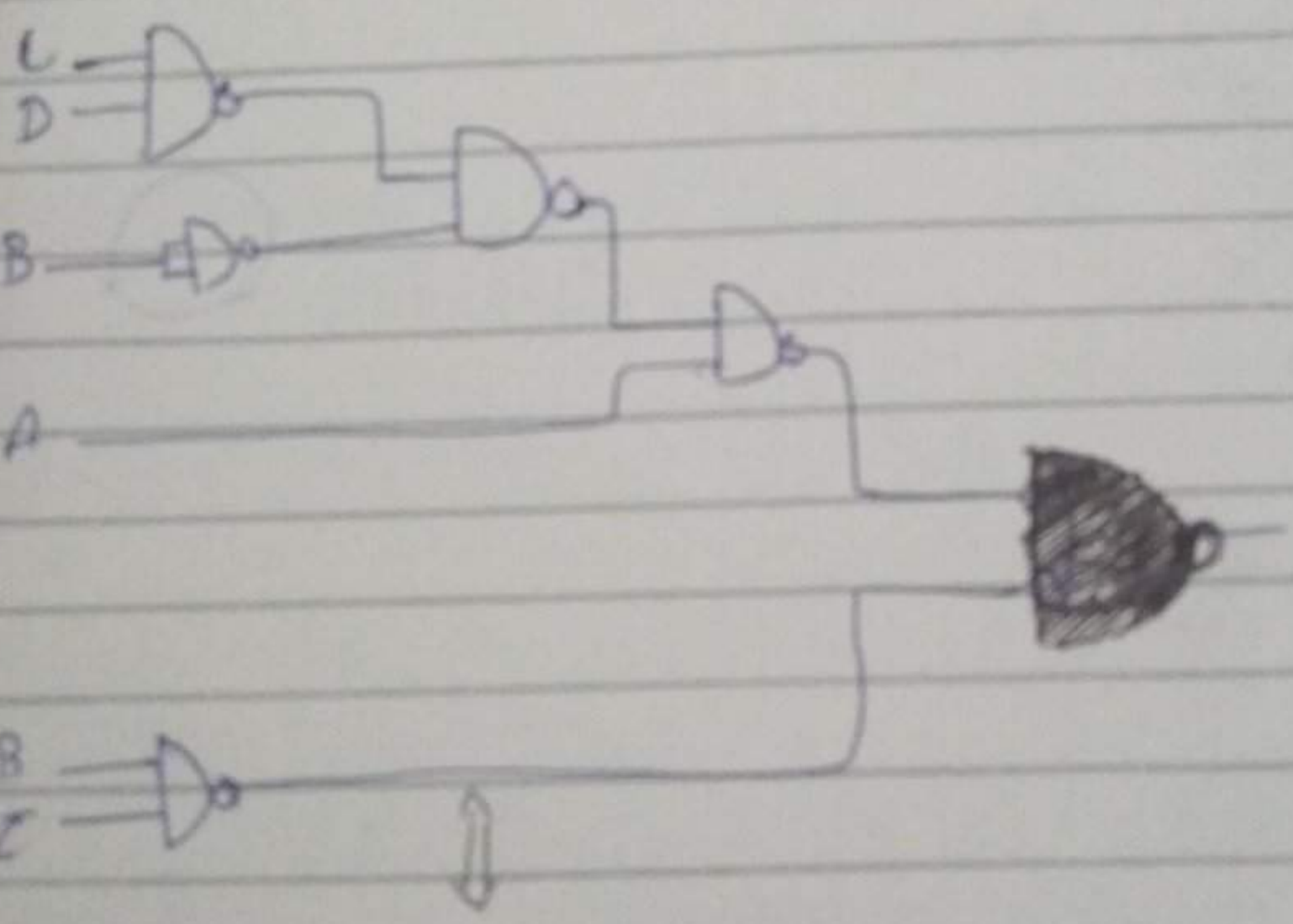
Sum of Product Term Convert

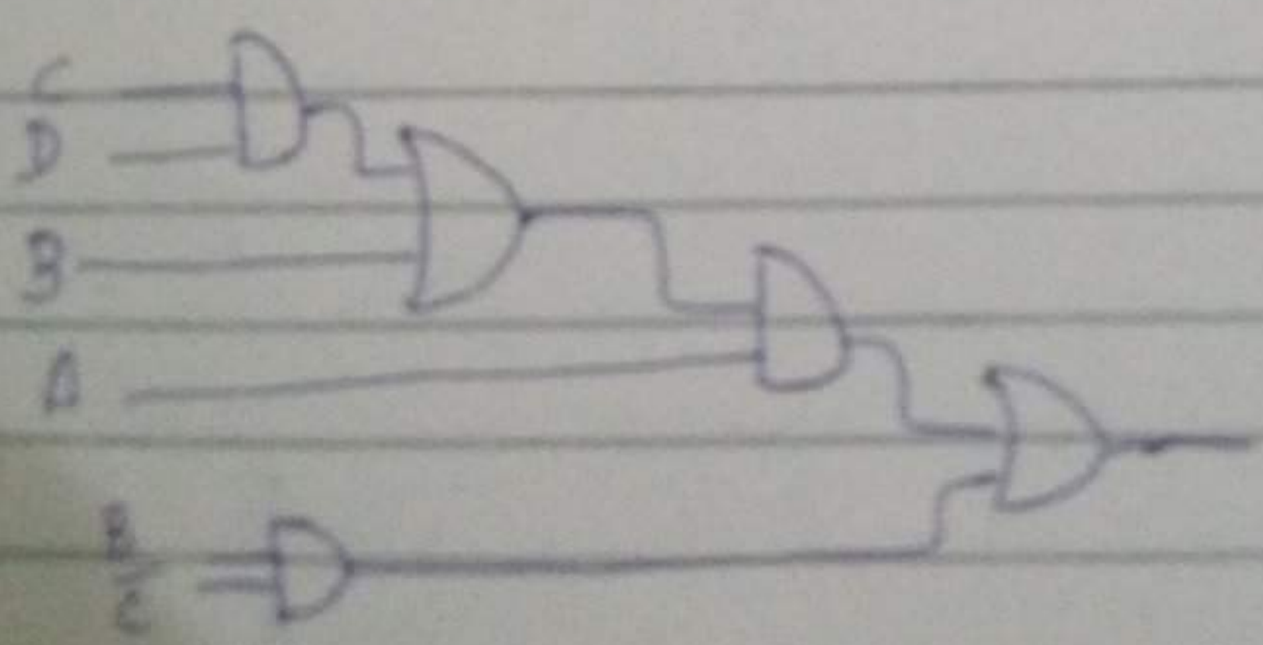
$\overline{\overline{C \cdot B} \cdot \overline{B}}$ $\quad C \cdot B \cdot B$



$$\overline{\overline{((CD + B) \cdot A) + (B \cdot \overline{C})}}$$

$$\overline{((\overline{CD} \cdot \overline{B}) \cdot A) \cdot (\overline{B \cdot C})}$$





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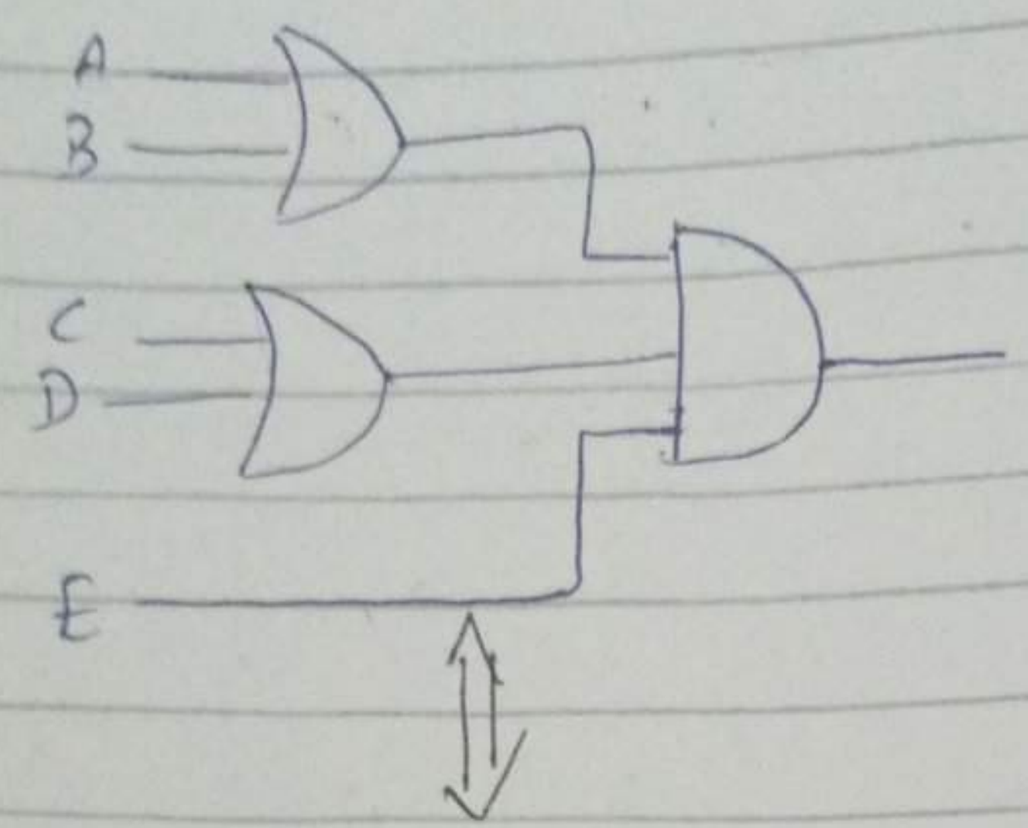
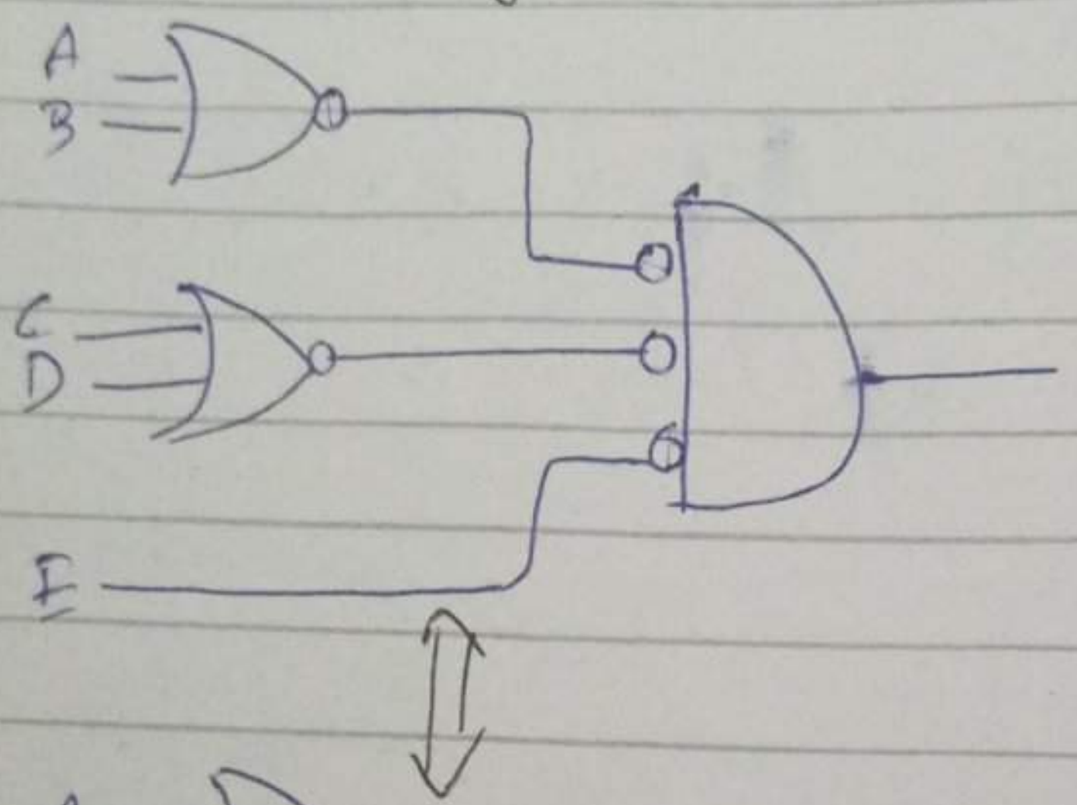
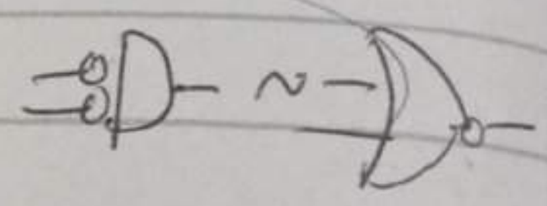
POS term Conver to NOR gate.

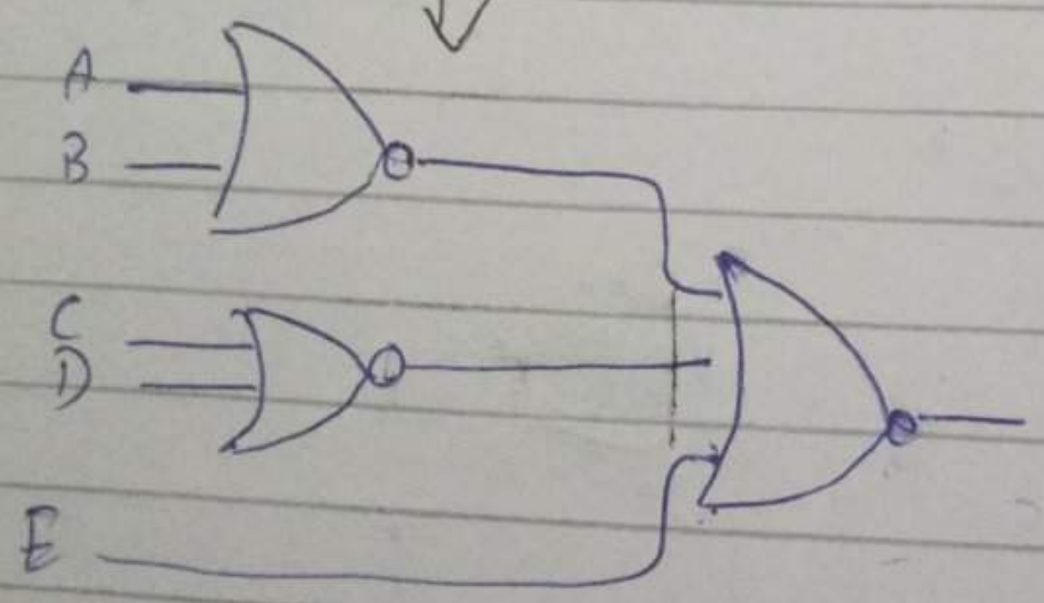


$\bar{A}\,\bar{B}\cdot\bar{C}$

$A+B+C$







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Qu1:

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

SOP to POS

A	B	C	f_1
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

$f_1 = m_0 + m_2 + m_3 + m_5 + m_7$

$f_1 = \Sigma(0, 2, 3, 5, 7)$

$f_1 = \pi(1, 4, 6)$

$f_1 = (M_1)(M_4)(M_6)$

$f_1 = (A+B+\bar{C})(\bar{A}+B+C)(\bar{A}+\bar{B}+C)$

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

POS to SOP.

A	B	C	f_2	
0	0	0	0	0
0	0	1	1	1
0	1	0	0	2
0	1	1	0	3
1	0	0	1	4
1	0	1	0	5
1	1	0	0	6
1	1	1	1	7

$f_2 = (M_0)(M_2)(M_3)(M_5)(M_6)$

$f_2 = \pi(0, 2, 3, 5, 6)$

$f_2 = \Sigma(1, 4, 7)$

$f_2 = m_1 + m_4 + m_7$

$f_2 = (\bar{A}\bar{B}C) + (A\bar{B}\bar{C}) + (ABC)$

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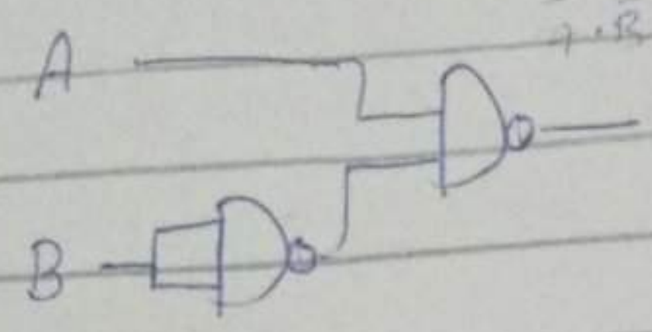
Practise

Sec 5.3

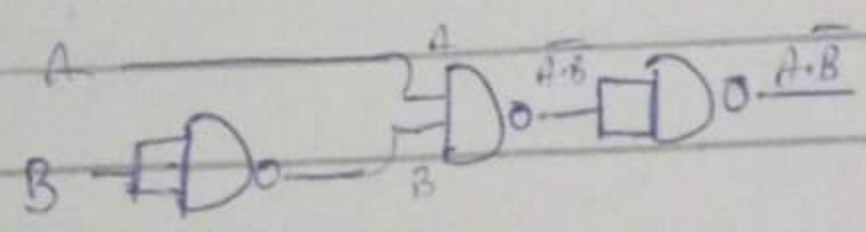
① (a) $Y = \overline{A} + B$



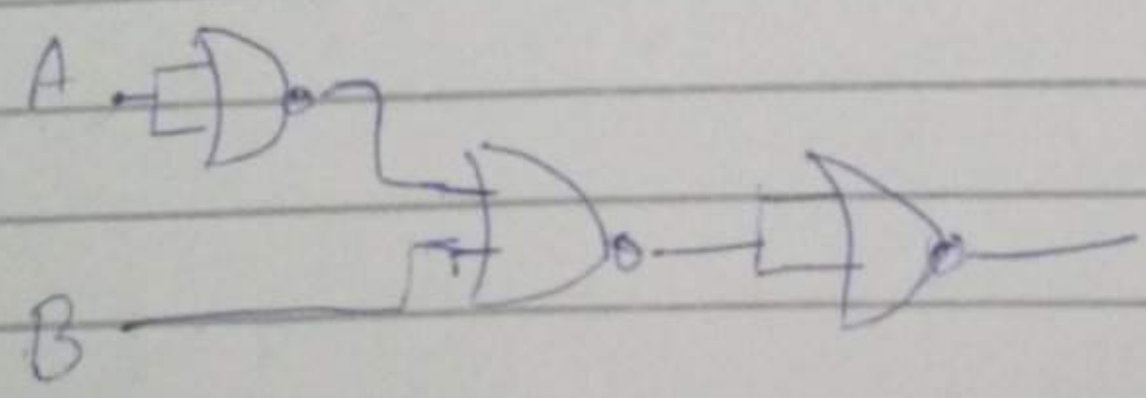
$\overline{\overline{A} + B}$

$A \cdot \overline{B}$

(b) $Y = A\overline{B}$



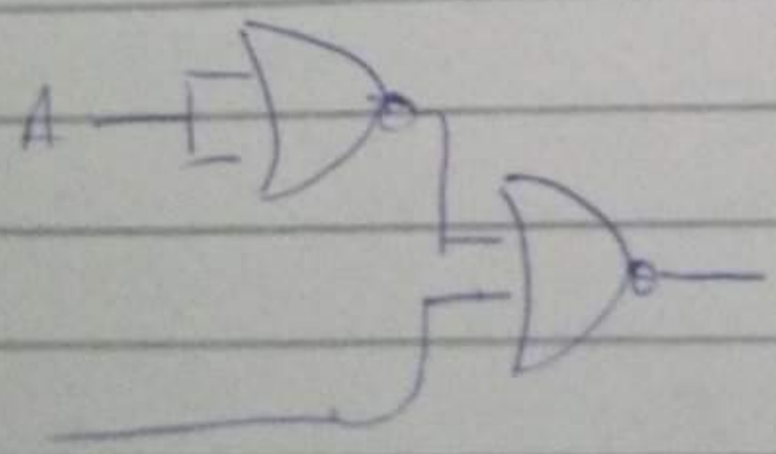
② (a) $Y = \overline{A} + B$



(b) $Y = A\overline{B}$

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

$A \cdot \overline{B}$



$\overline{A} + B$

$A \cdot \overline{B}$

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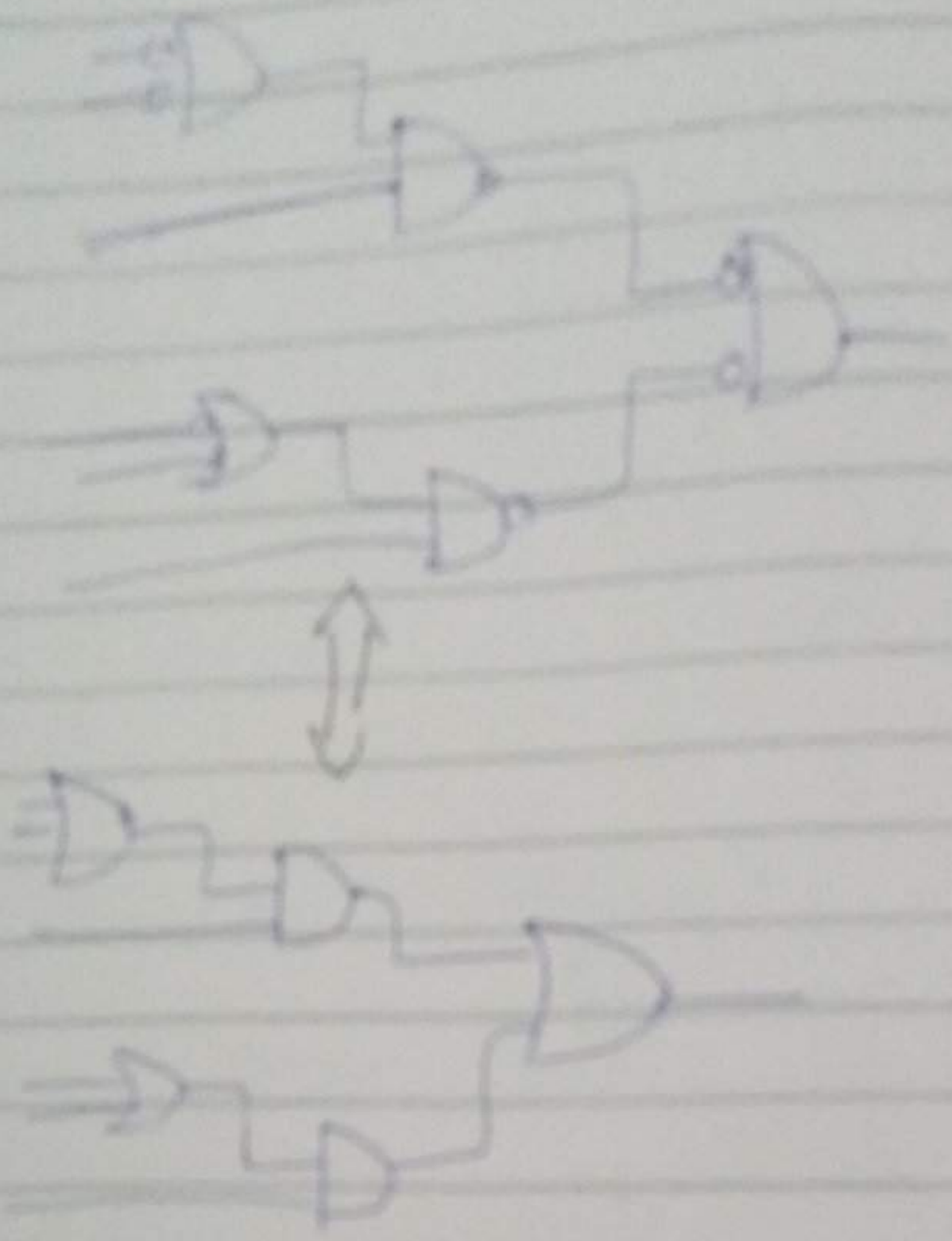
E.5.7



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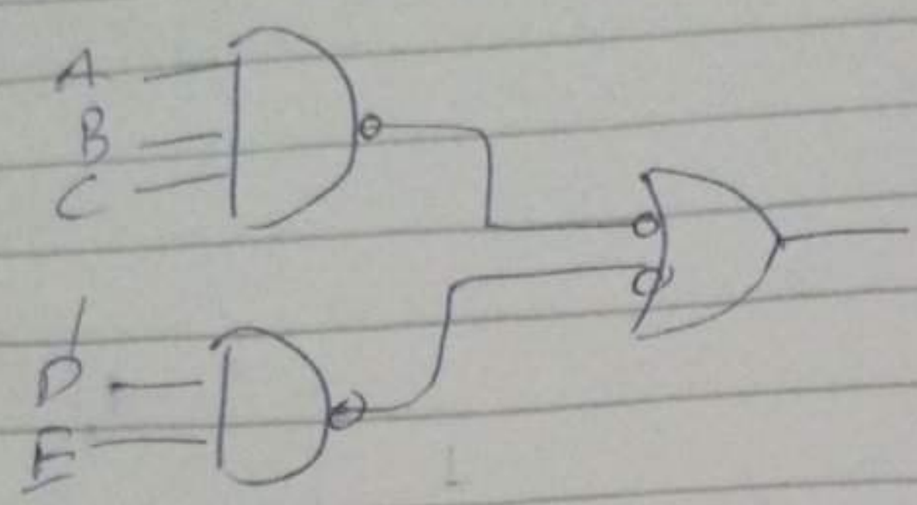
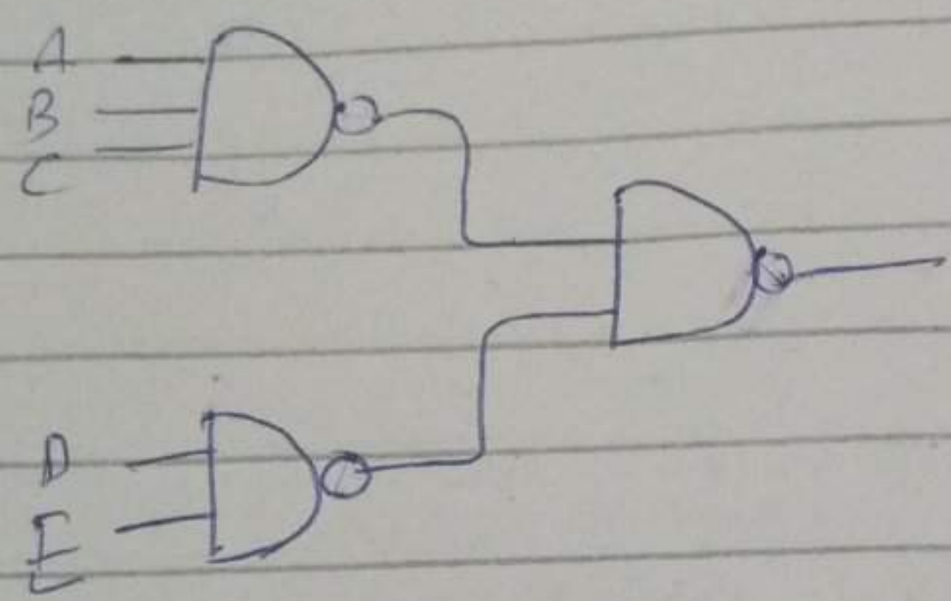
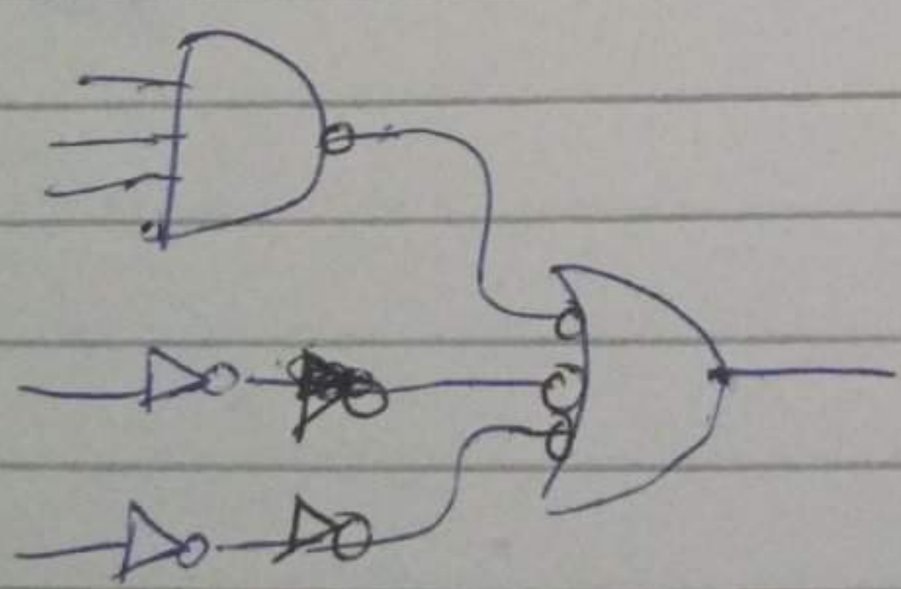
5.8

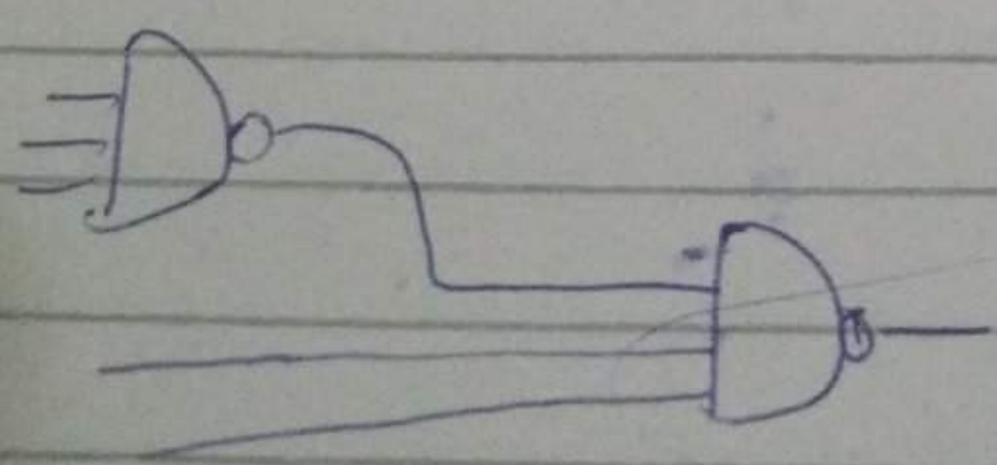
(a) $ABC + DE$





(b) $\overline{ABC + \overline{D} + \overline{E}}$





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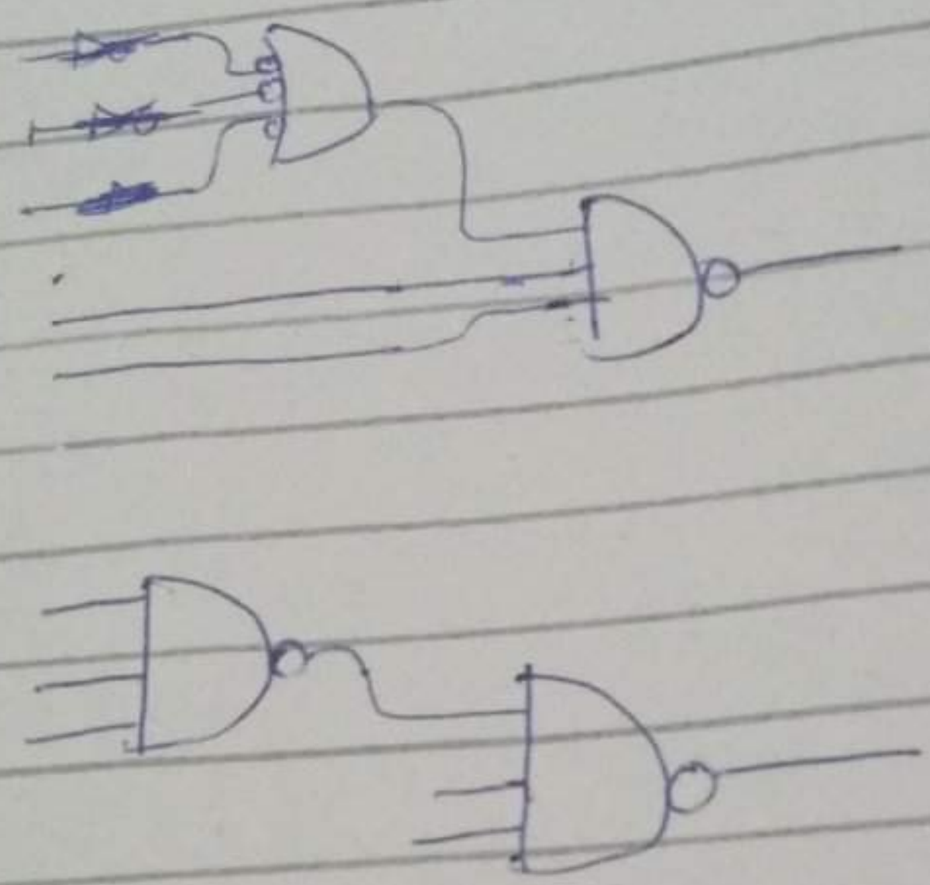
Sec 3.4

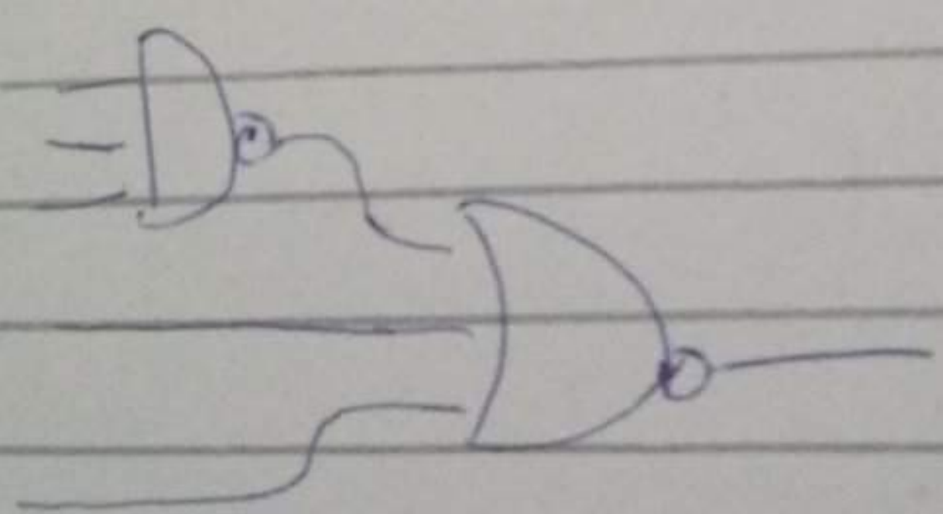
① $X = \overline{(\overline{A}+\overline{B}+\overline{C})\,BE}$

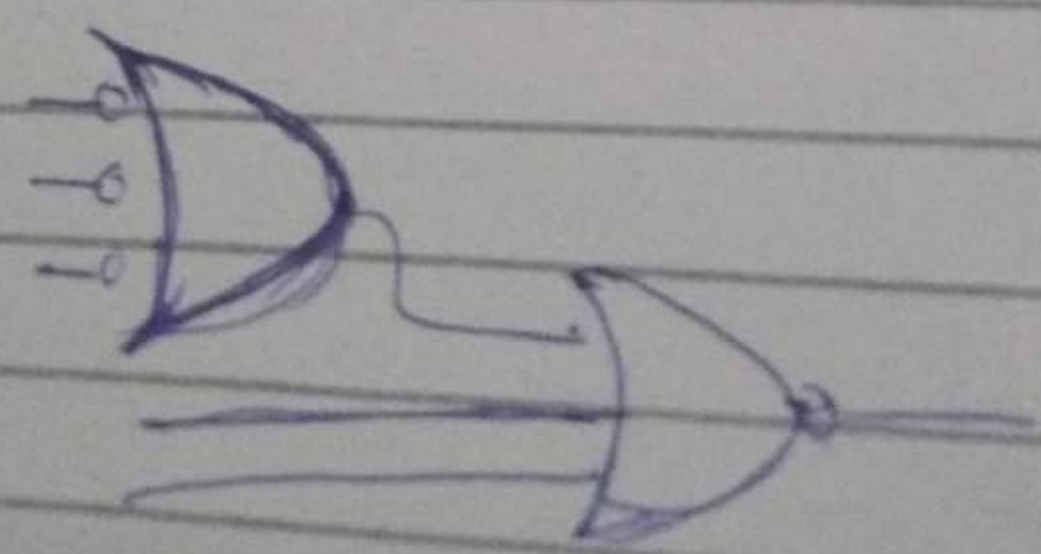
$\overline{A \cdot B \cdot C \cdot D \cdot E}$

Bef. form.



② $X = \overline{ABC + (B+E)}$





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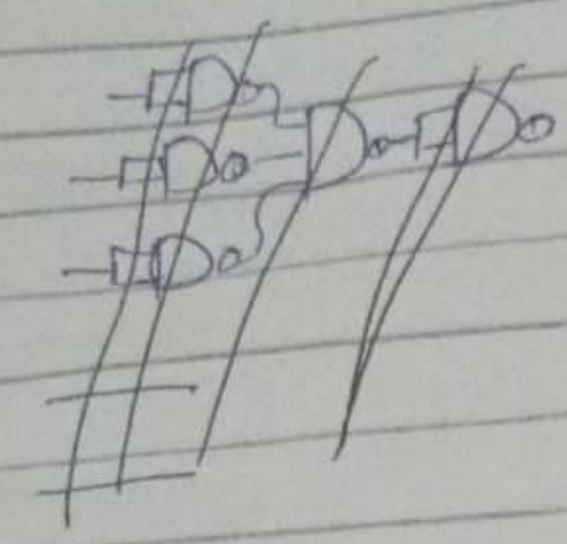
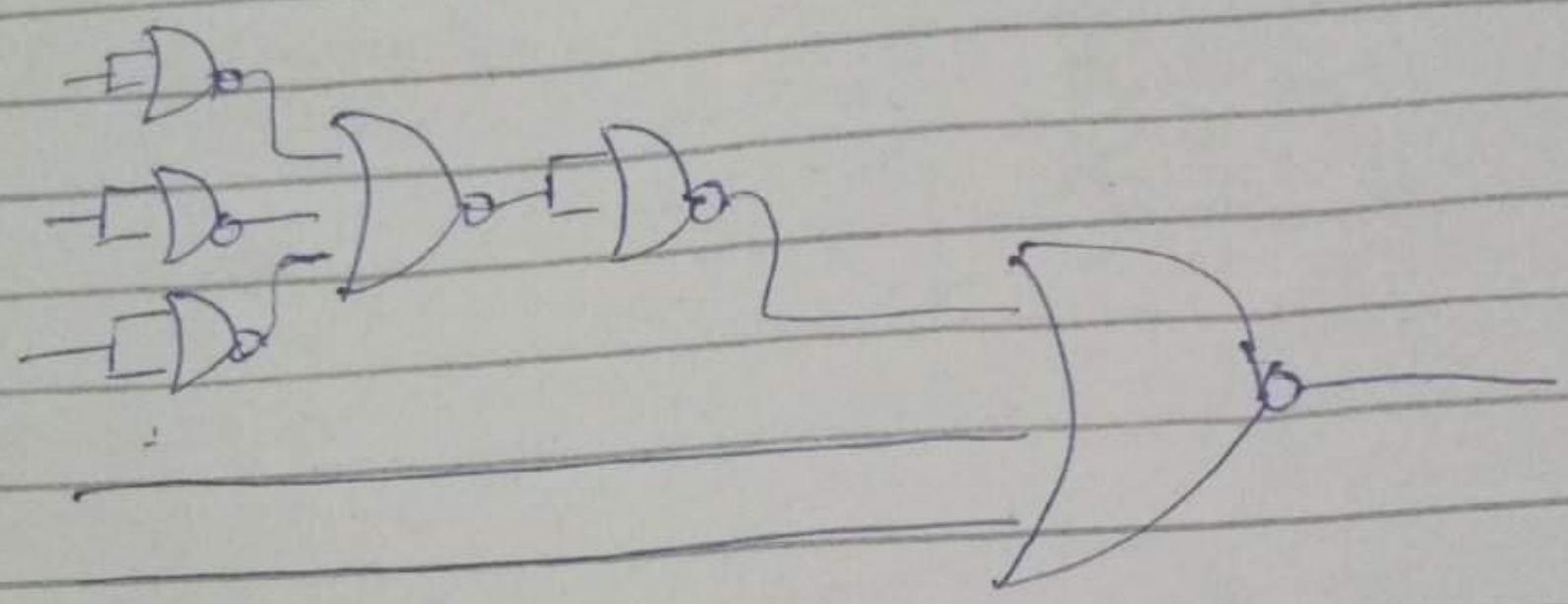


$\overline{\bar{A}+\bar{B}+\bar{C}}$ $\bar{A}+B$



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Karnaugh map (k-map)

$f(x,y) =$

x \ y	y' = 0	y = 1	
0	$x'y'$ m0	$x'y$ m1	x'
1	xy' m2	xy m3	x

x	y	Min term	
0	0	$x'y'$	m0
0	1	$x'y$	m1
1	0	xy'	m2
1	1	xy	m3

x \ y	y'	y
x'	m0	m1
x	m2	m3

$f(x,y) = xy$ (sum of product)

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$f_2(x,y) = x'y + xy' + xy$

$x(y+1)$

$x'y + x$

y

$y + xy'$

x \ y	0	1
0		1
1	1	1

$f_2(x,y) = x + y$

Three variable

x \ yz	00	01	11	10
0	$x'y'z'$ m0	$x'y'z$ m1	$x'yz$ m3	$x'yz'$ m2
1	$xy'z'$ m4	$xy'z$ m5	xyz m7	xyz' m6

$f(x,y,z) = \Sigma(2,3,4,5)$

$= m2 + m3 + m4 + m5$

$= x'yz' + x'yz + xy'z' + xy'z$

x \ yz	00	01	11	10
0	m0	m1	m3	m2
1	m4	m5	m7	m6

$f = x'y + xy'$

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Example

(1)

x \ yz	00	01	11	10
0			1	1
1	1	1	1	

$f = xy' + x'y + yz$

(2)

x \ yz	00	01	11	10
0			1	1
1	1	1	1	

$f = x'y + xy' + xz$

(3)

x \ yz	00	01	11	10
0				1
1	1	1	1	

$f = xy' + xz + x'yz$

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Scanned with CamScanner

(4)

X \ YZ	00	01	11	10
0	1			1
1		1	1	

$f = m_0 + m_2 + m_5 + m_7$

$f_3 = XZ + X'Z'$

(5.1)

X \ YZ	00	01	11	10
0	1			1
1	1			1

$f = Z'$

(5.2)

X \ YZ	00	01	11	10
0		1	1	
1		1	1	

$f = Z$

(6)

X \ YZ	00	01	11	10
0				
1	1	1	1	1

$f = X$

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(7)

X \ X_2	00	01	11	10
0	1	1		
1	1	1	1	1

$f = X + Y'$

$\cancel{Y' + X + (X+}$

$A + B)(A$

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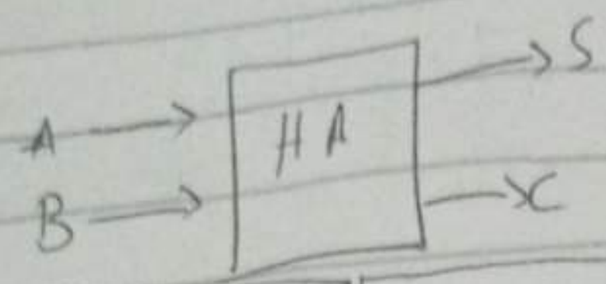
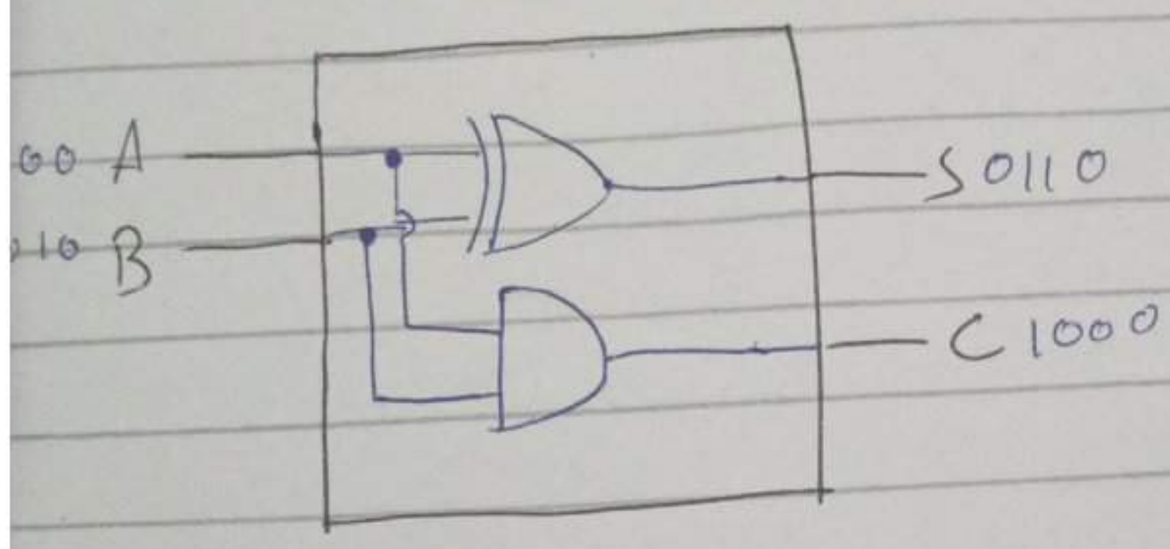
Scanned with CamScanner

Half Adder



input		output	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Exclusive OR — AND Gate



$$C(X,Y) = AB$$

$$S(X,Y) = A'B + AB'$$

$$\Updownarrow$$

$$S(X,Y) = A \oplus B$$

$(A'B+A)(A'B+B')$

$(A+B)(B'+A')$

$(A+B)(A'+B')$

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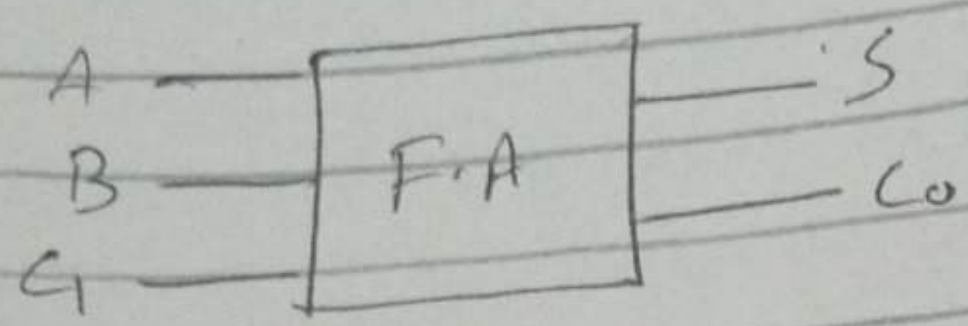
Scanned with CamScanner

Full Adder



A	B	Cı	S	Co
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

$8 + 6 = 14$

$$\begin{array}{r} 1000 \\ 0110 \\ \hline 1110 \end{array} \qquad 0110$$

$8 - 6 = 2$

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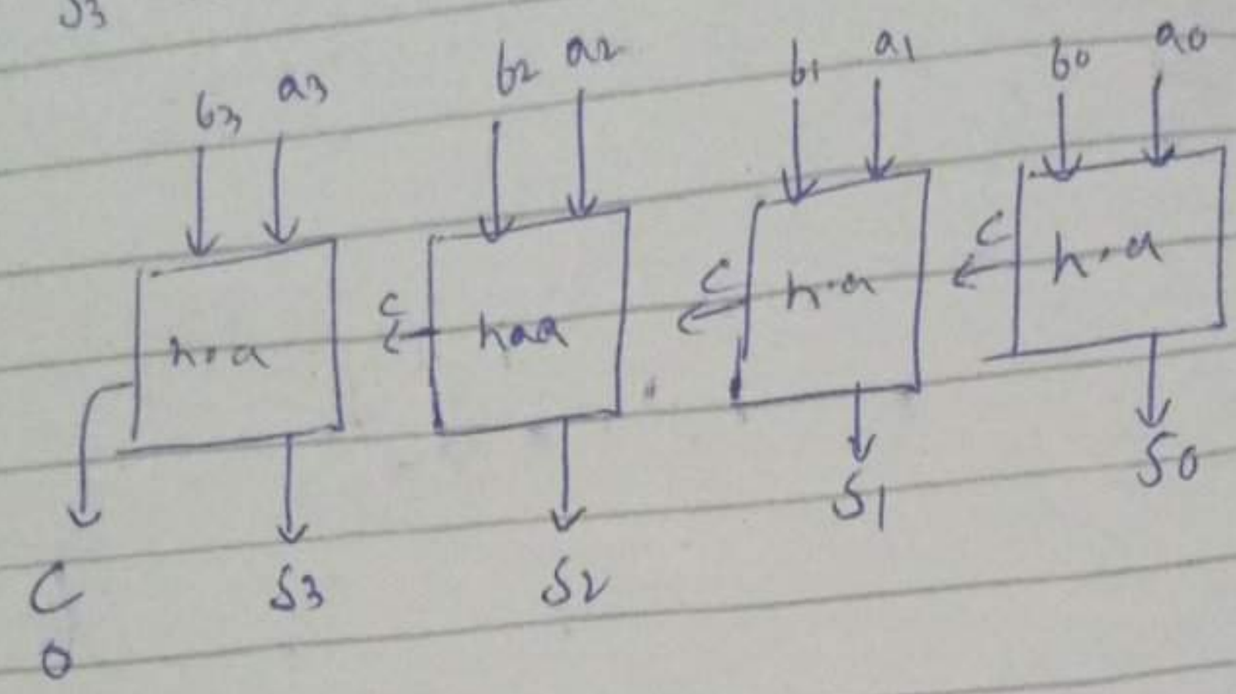
Scanned with CamScanner

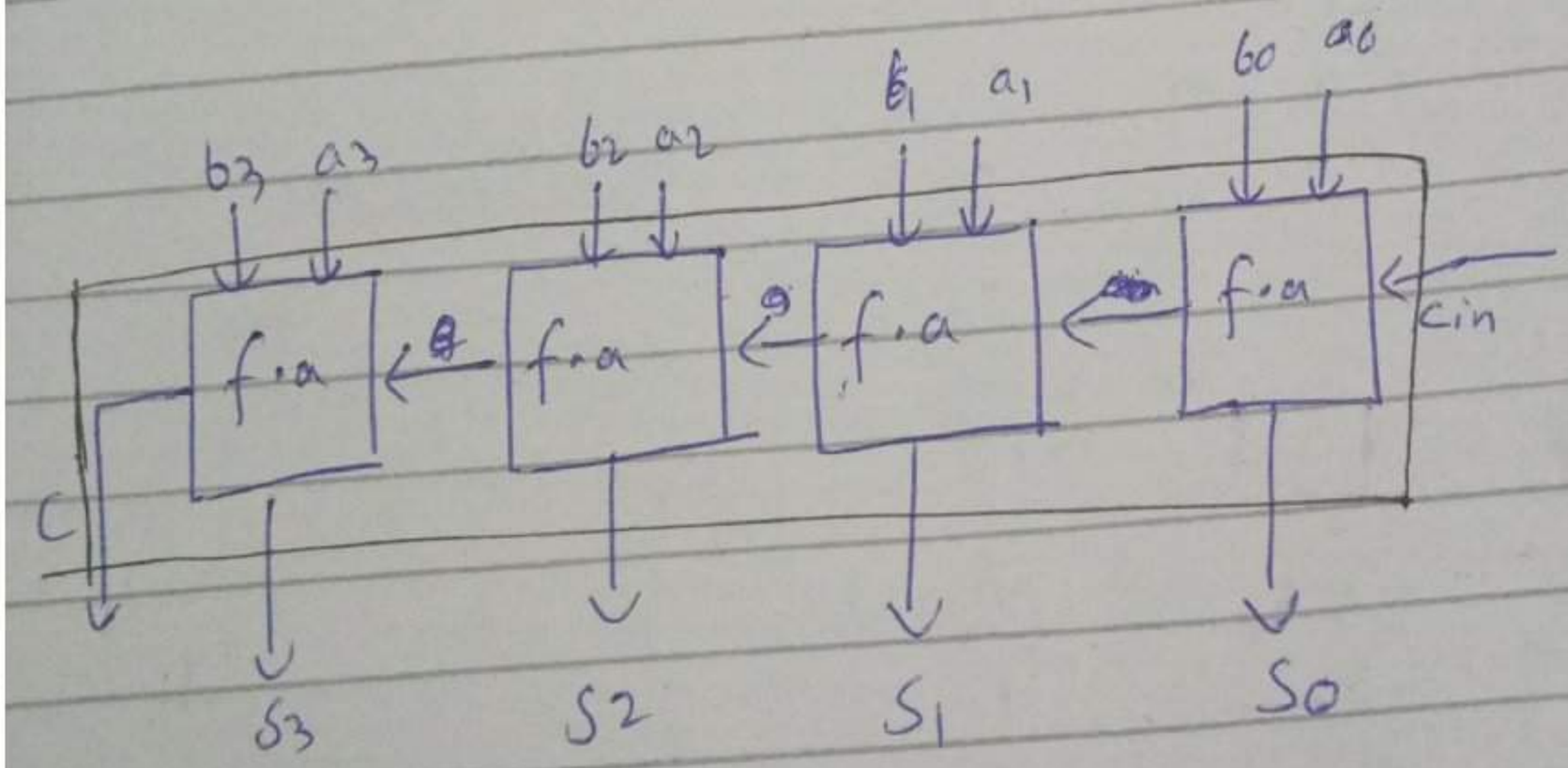
Add four bit values (Half adder)

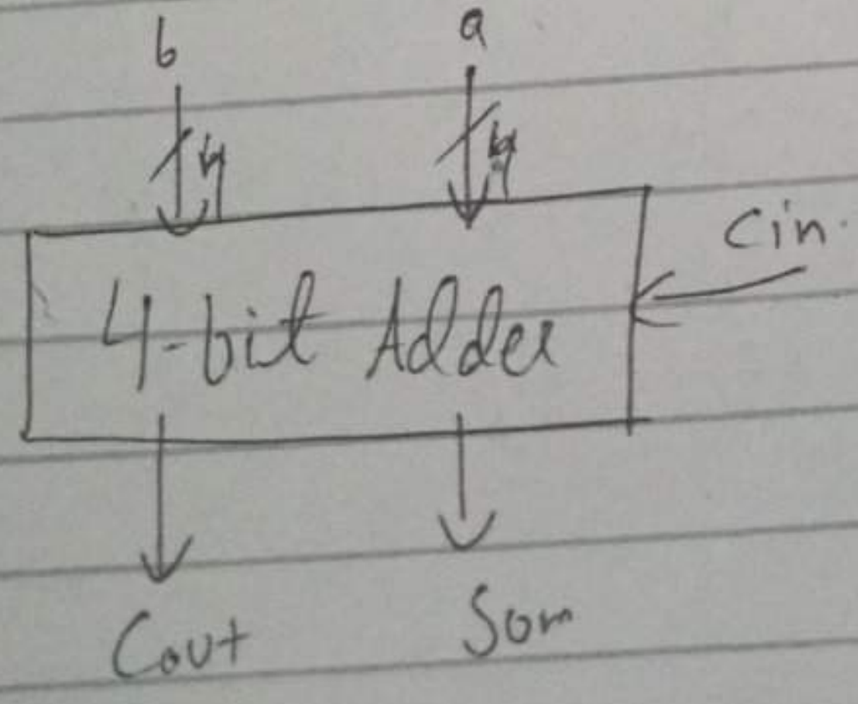
	a_3	a_2	a_1	a_0
A	1	0	1	0
	b_3	b_2	b_1	b_0
B	0	1	0	0
	1	1	1	0
	S_3	S_2	S_1	S_0

$\boxed{c = 0}$



Full Adder (4 bit)





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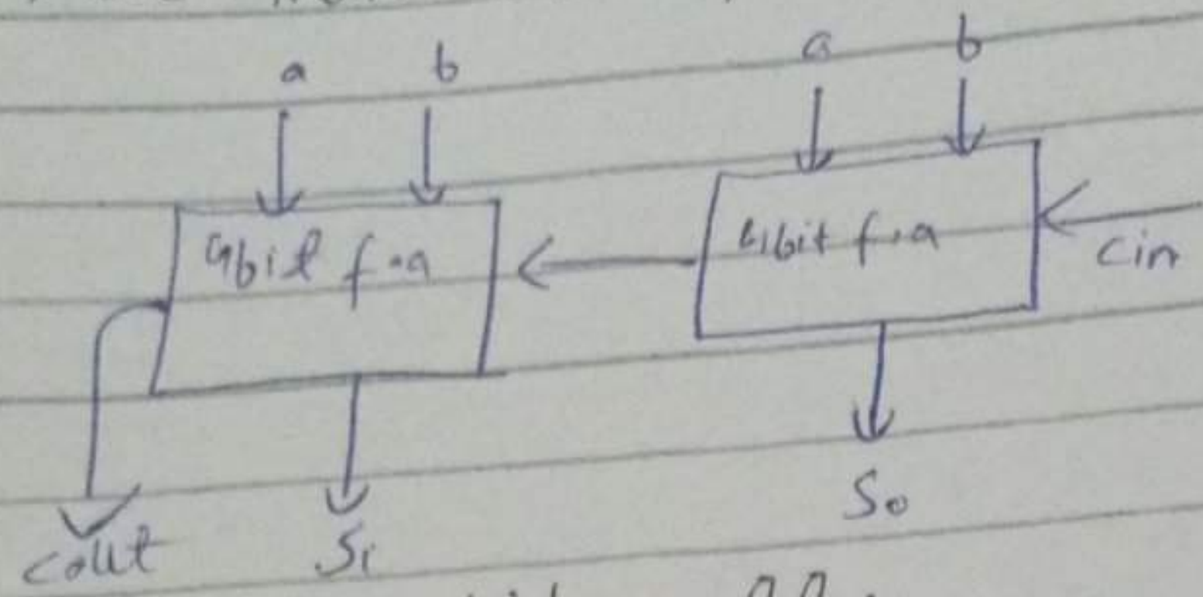
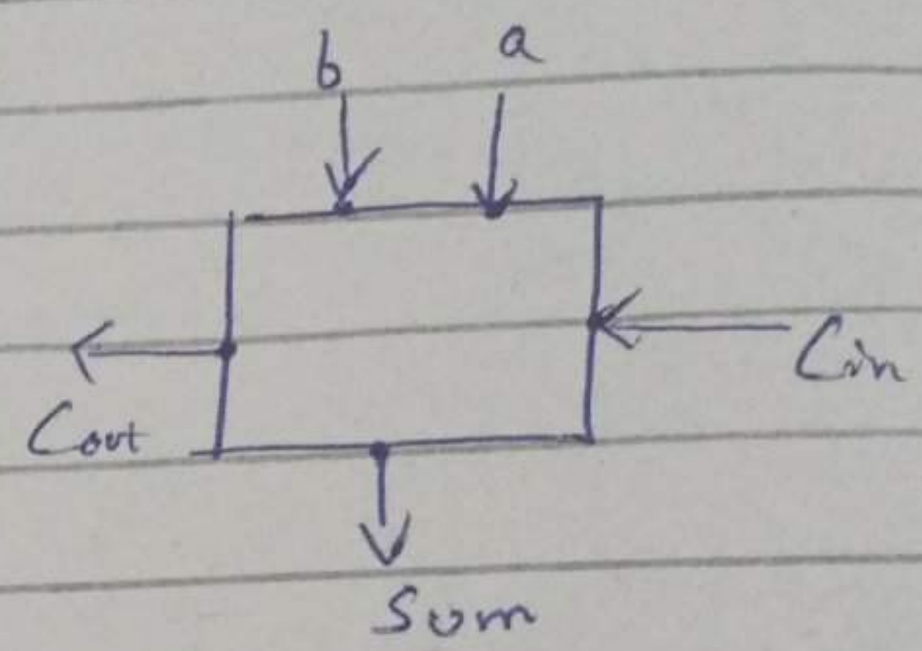
More than 4-bit f.Adder:-

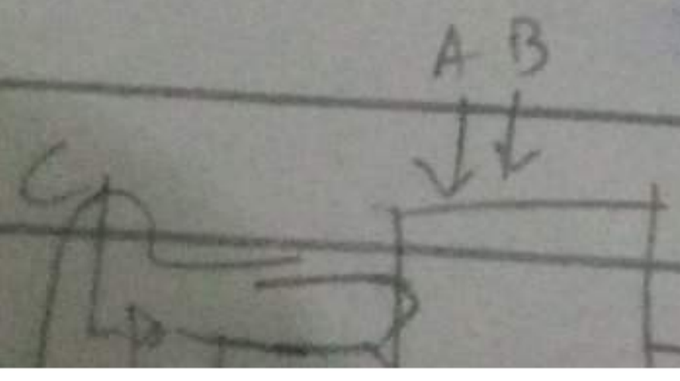


8-bit adder.

Full adder



a	b	Cin	Cout	Sum
0	0	0	0	0
0	0	1	0	1 ✓
0	1	0	0	1 ✓
0	1	1	1	0
1	0	0	0	1 ✓
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1 ✓



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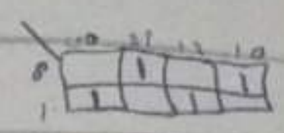
$A'B'C$

$$S = \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + ABC_{in}$$

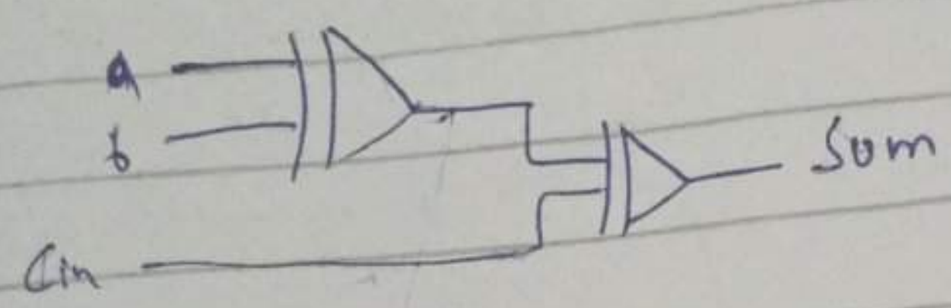
$$C_{out} = \bar{A}BC_{in} + A\bar{B}C_{in} + AB\bar{C}_{in} + ABC_{in}$$



$$S = (\bar{A}\bar{B} + AB)C_{in} + (\bar{A}B + A\bar{B})\bar{C}_{in}$$

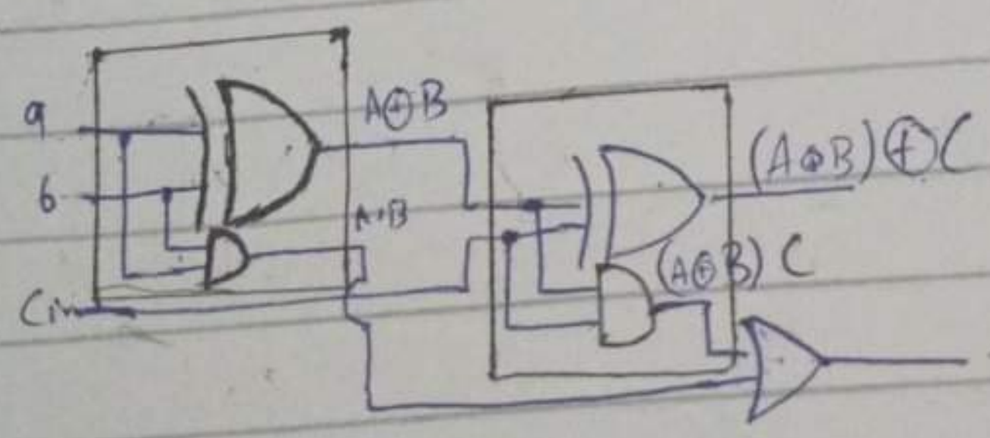
$$S = \overline{(A \oplus B)}C_{in} + (A \oplus B)\bar{C}_{in}$$

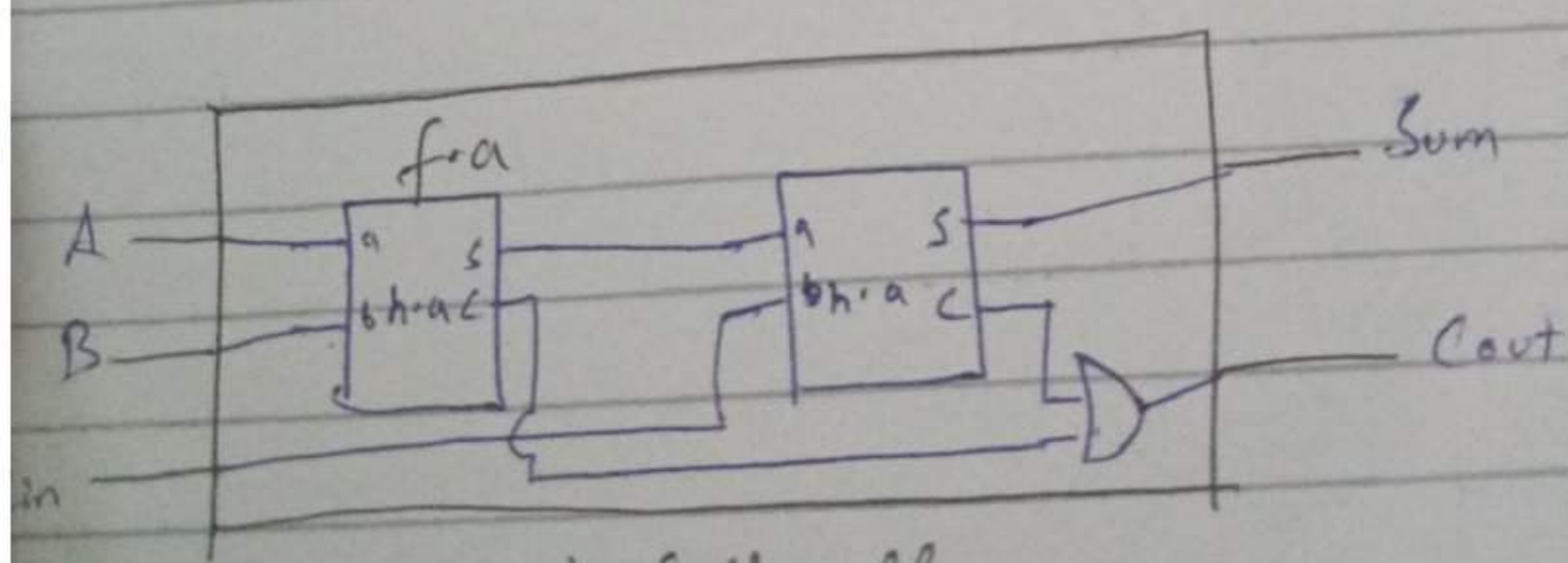
$$S = (A \oplus B) \oplus C_{in}$$



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

$$= (A \oplus B)C + AB$$





1 bit full adder

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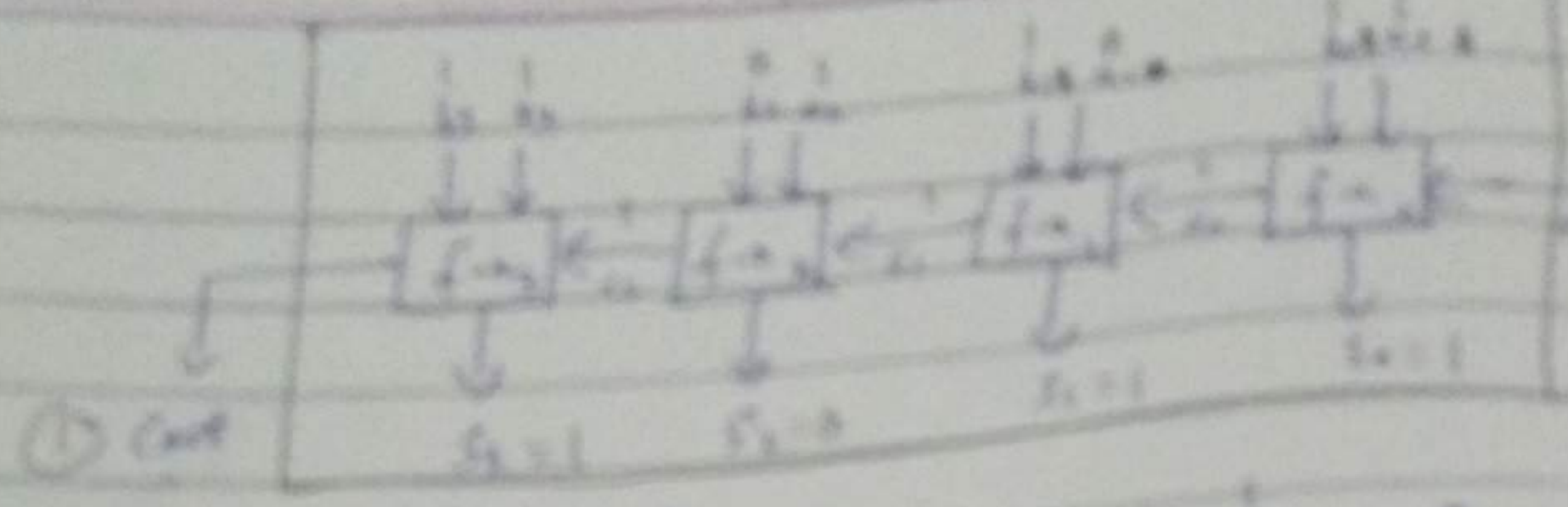
4 bit full adder



① Case

$$A = 1\,1\,0\,0\,1 \qquad\qquad 1\,0\,1\,0$$
$$B = 0\,1\,0\,1\,1 \qquad\qquad +\,0\,0\,1\,1$$
$$1\,1\,0\,0\,0 \qquad\qquad 1\,1\,0\,1$$

O/P is only function of i/p is Combinational circuit

Subtractor

$A - B$

$A + (-B)$

$A + (\bar{B} + 1)$

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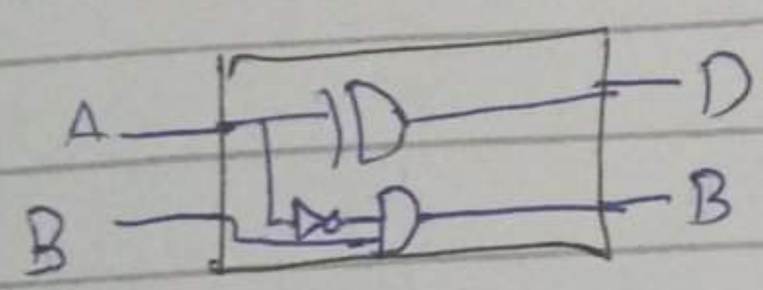
half substractor

A	B	D	B
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

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

$D = A \oplus B$

$B = \bar{A}B$



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full substractor

A	B	C	D	Bin
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

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

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

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

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

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

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

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

Practice

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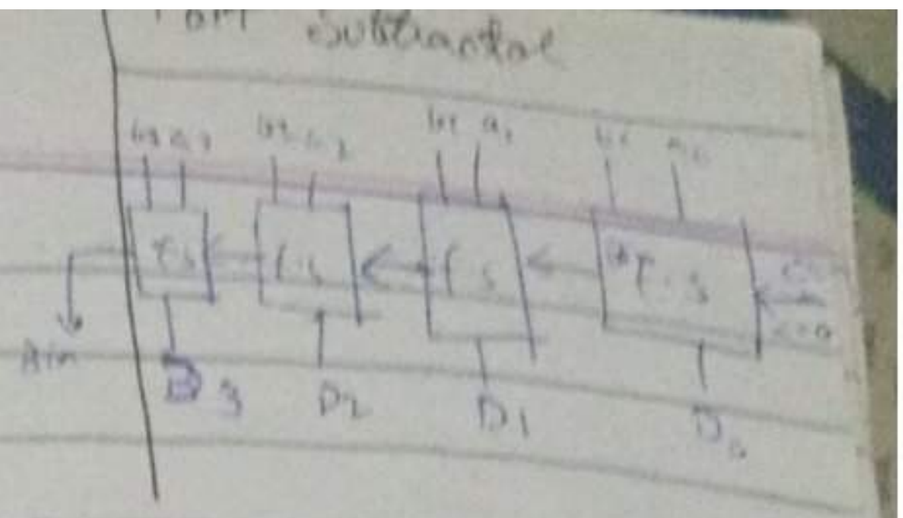

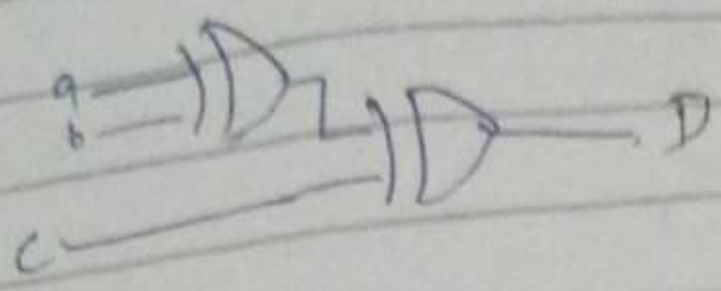

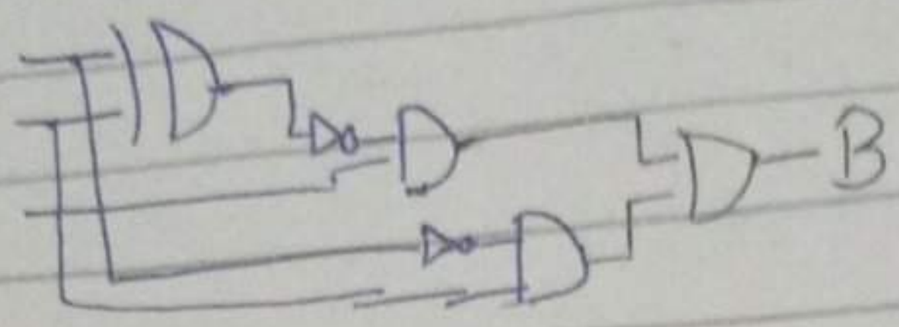

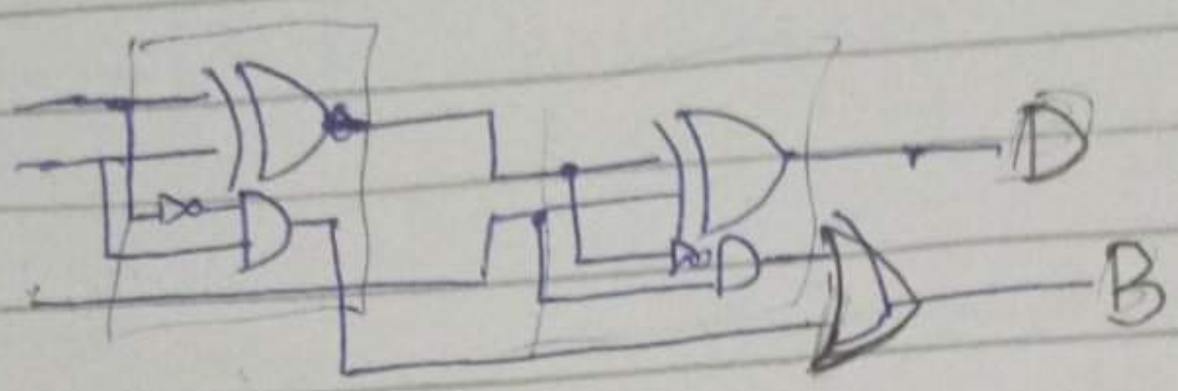

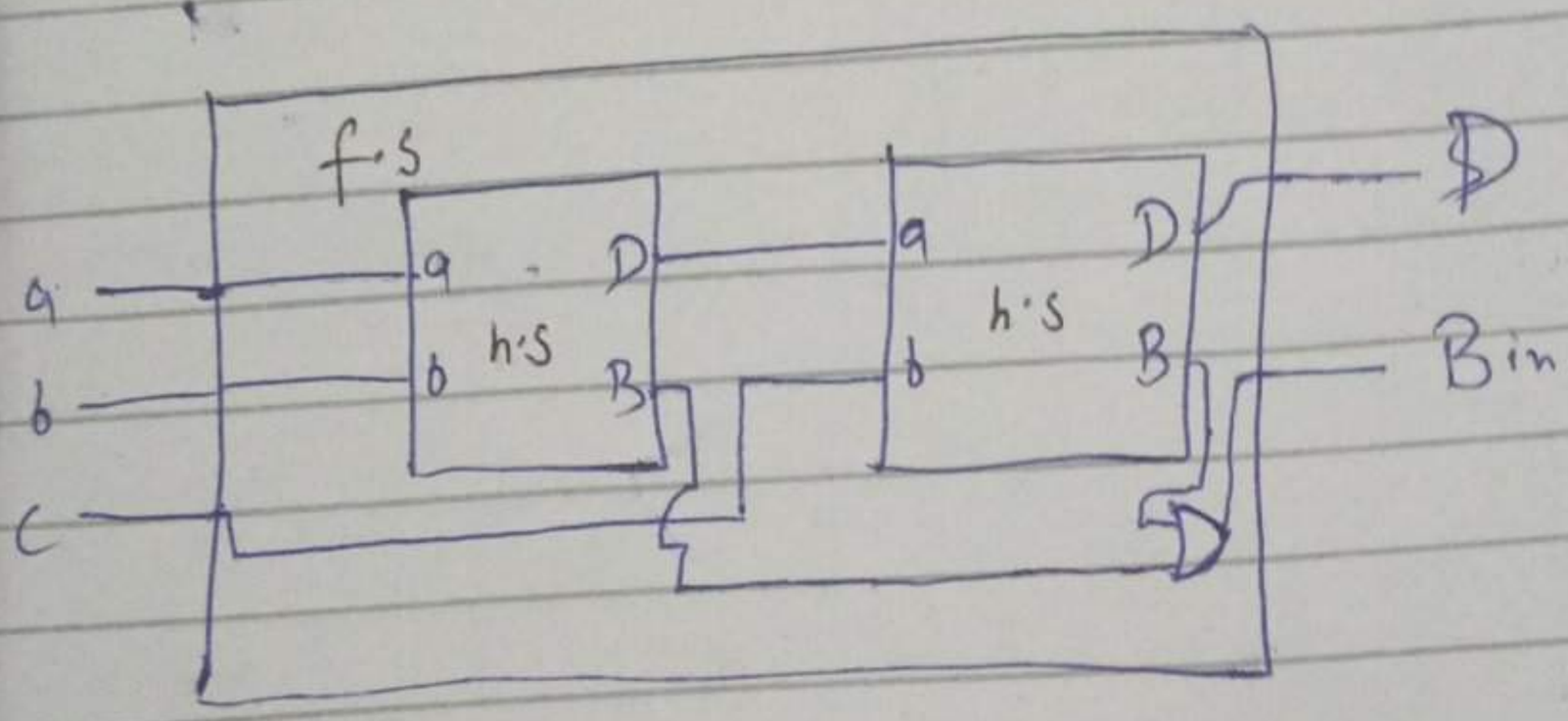

Reaction

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

0 1 1 1 0 ← c
1 1 0 1 0 a
1 0 1 1 1 b
0 0 0 1 1

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

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

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4-variable K-Map

		Col1 $\bar{y}\bar{z}$ 00	Col2 $\bar{y}z$ 01	Col3 yz 11	Col4 $y\bar{z}$ 10
Row1	$\bar{w}\bar{x}$ 00	$\bar{w}\bar{x}\bar{y}\bar{z}$ m0	$\bar{w}\bar{x}\bar{y}z$ m1	$\bar{w}\bar{x}yz$ m3	$\bar{w}\bar{x}y\bar{z}$ m2
Row2	$\bar{w}x$ 01	$\bar{w}x\bar{y}\bar{z}$ m4	$\bar{w}xyz$ m5	$\bar{w}xyz$ m7	$\bar{w}xy\bar{z}$ m6
Row3	wx 11	$wx\bar{y}\bar{z}$ m12	$wx\bar{y}z$ m13	$wxyz$ m15	$wxy\bar{z}$ m14
Row4	$w\bar{x}$ 10	$w\bar{x}\bar{y}\bar{z}$ m8	$w\bar{x}\bar{y}z$ m9	$w\bar{x}yz$ m11	$w\bar{x}y\bar{z}$ m10

Row1 and Row 4 are adjacent

Col1 and Col2 are adjacent.

~~R1C1, R4C1, R1C4, R4C4 are adjacent.~~

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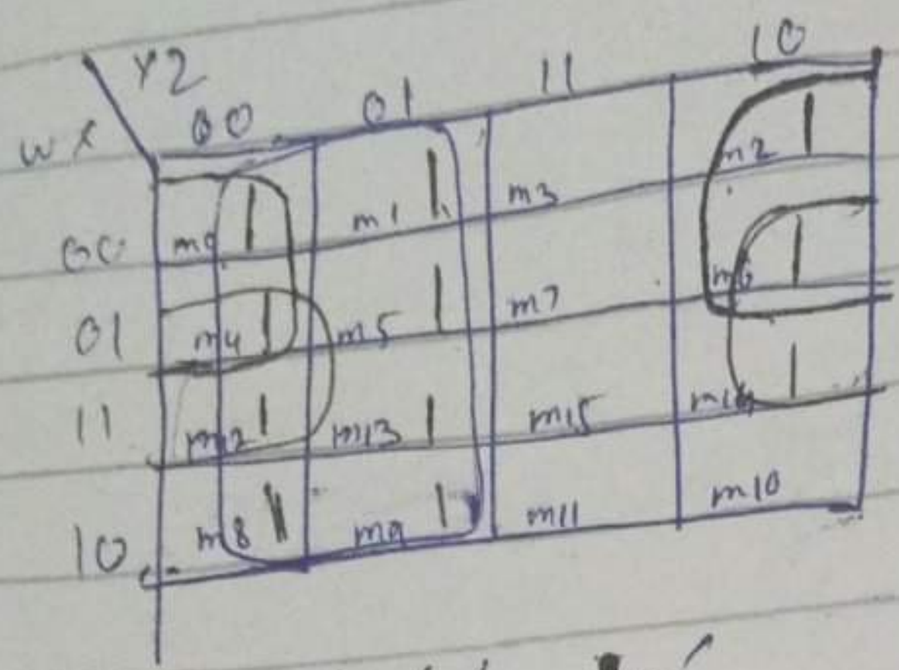
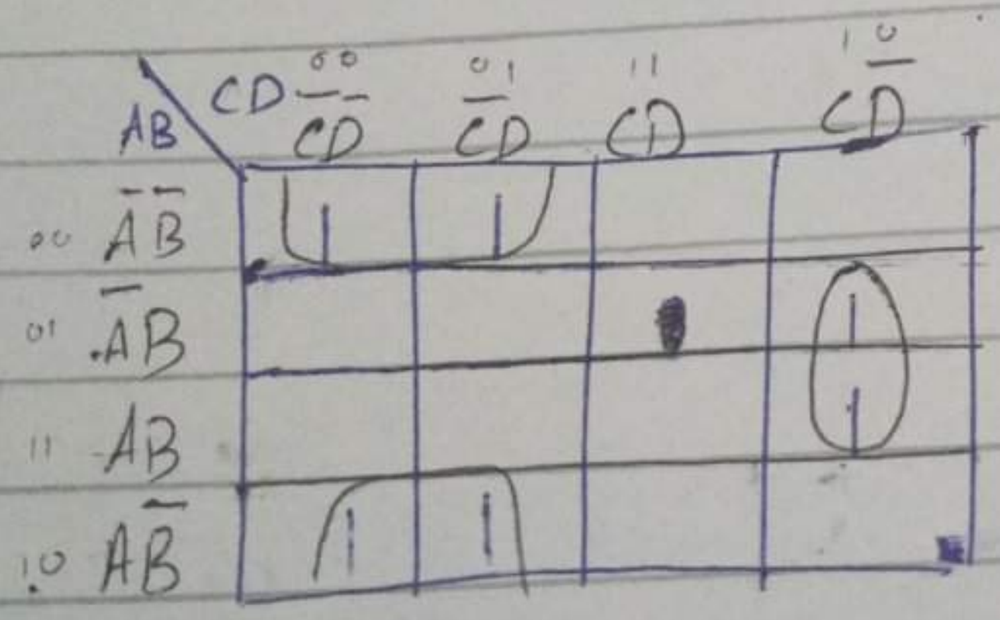
(i) $f(w,x,y,z) = \Sigma(0,1,2,4,5,6,8,9,12,13,14)$



$f = y' + w'z' + x'z'$

(ii) $F = A'B'C' + BCD' + A'B'CD' + AB'C'$

$= A'B'C'D + A'B'C'D' + ABCD' + A'BCD' + A'BCD'$
$+ AB'C'D + AB'C'D'$



$f = BC\bar{D} + \bar{B}\bar{C}$

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(3)

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

$$f_1 = \bar{D} + B\bar{C} + A\bar{B}C$$

(4)

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

$$f_2 = \bar{A}\bar{C} + \bar{A}B + A\bar{B}D$$

(5)

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

$f_3 = \bar{D}$ [illegible] $+ \bar{B}C$

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Dont care condition:—

0	0000	
1	0001	BCD
2	0010	
3	0011	
4	0100	
5	0101	
6	0110	
7	0111	
8	1000	
9	1001	
10	1010	Dont care
11	1011	
12	1100	
13	1101	
14	1110	
15	1111	

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$F(w,x,y,z) = \Sigma(1,3,7,11,15)$

$d(w,x,y,z) = \Sigma(0,2,5)$

$wx \backslash yz$	$y'z'$	$y'z$	yz	yz'
$w'x'$	m_0	m_1	m_3 1	m_2
$w'x$	m_4	m_5	m_7 1	m_6
wx	m_{12}	m_{13}	m_{15} 1	m_{14}
wx'	m_8	m_9	m_{11} 1	m_{10}

$F = yz + w'x'z$

$F_1 = yz + w'x'$
$F_1 = yz + w'z$ } Don't care condition simplify the circuit

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POS K-Map

Map the equation on K-Map

① $F = (\bar{A}+\bar{B}+C+D)(\bar{A}+B+\bar{C}+\bar{D})(A+B+\bar{C}+D)$
$(\bar{A}+\bar{B}+\bar{C}+\bar{D})(A+B+\bar{C}+\bar{D})$

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

② $F = (A+\bar{B}+\bar{C}+D)(A+B+C+\bar{D})(A+B+C+D)(\bar{A}+B+\bar{C}$

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

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③ Simplify the equation

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

$$(\bar{A}+\bar{B}+C) \quad \boxed{2^3 = 8}$$

$$F = \sum(0,1,2,3,6)$$

$$F = \sum(4,5,7)$$

AB \ C	0	1
00	0	0
01	0	0
11	0	1
10	1	1

A \ BC	00	01	11	10
0	0	0	0	0
1	1	1	1	0

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

$$F = (A)(\bar{B}+C) \longrightarrow \text{Simplify by zero } (0)$$

$$F = A\bar{B} + AC \longrightarrow \text{Simplify by one } (1)$$

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

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

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

$$F = (\overset{0}{A}+\overset{0}{B}+\overset{0}{C}+\overset{0}{D})(\overset{1}{\bar{A}}+\overset{0}{B}+\overset{0}{C}+\overset{0}{D})(\overset{0}{A}+\overset{0}{B}+\overset{1}{\bar{C}}+\overset{0}{D})(\overset{0}{A}+\overset{1}{\bar{B}}+\overset{0}{C}+\overset{0}{D})$$

$$(\underset{1}{\bar{A}}+\underset{0}{B}+\underset{0}{C}+\underset{1}{\bar{D}})(\underset{1}{\bar{A}}+\underset{1}{\bar{B}}+\underset{0}{C}+\underset{0}{D})$$

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

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

$$\hookrightarrow = (AC+BC+DC+DA+DB+DA)(\bar{A}+B+C)$$

$$= \cancel{\bar{A}AC} + \bar{A}BC + \bar{A}DC + \cancel{\bar{A}AD} + \bar{A}DB + \bar{A}DA + \cancel{BAC} + \cancel{BB}$$

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

$$F = \bar{A}D + AC + ABD + \bar{A}BC$$

$$= \bar{A}D + BD + BC + AC$$

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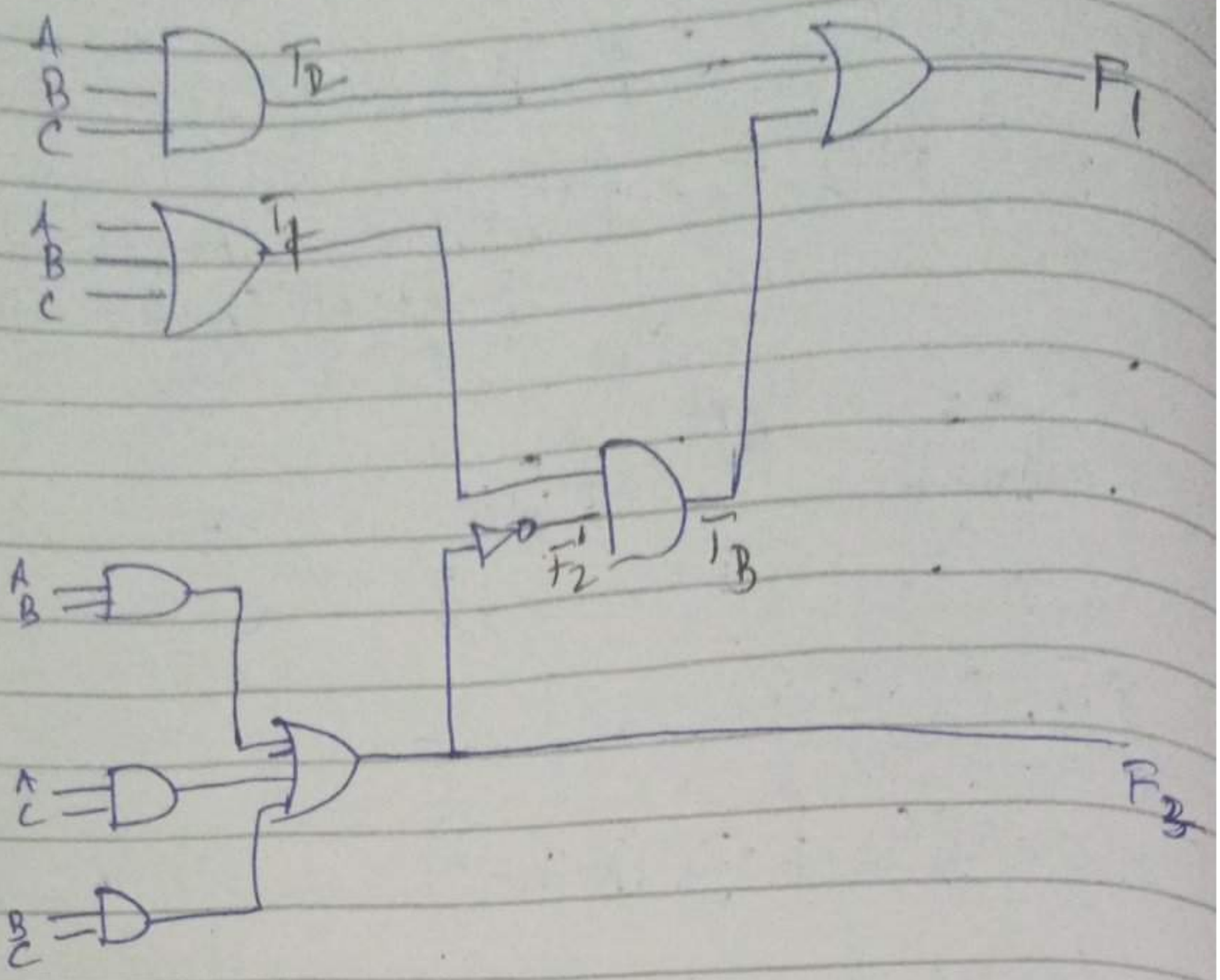
Full adder / Analysis Procedure



$F_2 = AB + AC + BC$ $\quad F_2 \Rightarrow ABC + AB\bar{C} + ABC + A\bar{B}C + ABC + \bar{A}$

$T_1 = A + B + C$ $\quad F_2 \Rightarrow ABC + AB\bar{C} + A\bar{B}C + \bar{A}BC$

$T_2 = ABC$ $\quad F_2 \Rightarrow AB + C(A \oplus B)$

$T_3 = F_2' T_1$

$F_1 = T_3 + T_2$

$F_1 = (F_2' T_1) + ABC$

$F_1 = (AB + AC + BC)' T + ABC$

$F_1 = (AB + AC + BC)'(A + B + C) + ABC$

$F_1 = (\overline{AB})(\overline{AC})(\overline{BC})(A + B + C) + ABC$

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

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

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

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

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

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

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

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

$$\boxed{F_1 = \bar{A}\bar{B}C + \bar{A}\bar{B}\bar{C} + A\bar{B}\bar{C} + ABC} \rightarrow$$

A	B	C	F_1	F_3	$S = A \oplus B \oplus C = F_1$
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	

$$\boxed{\begin{aligned} F_1 &= S \\ F_3 &= Cout \end{aligned}}$$

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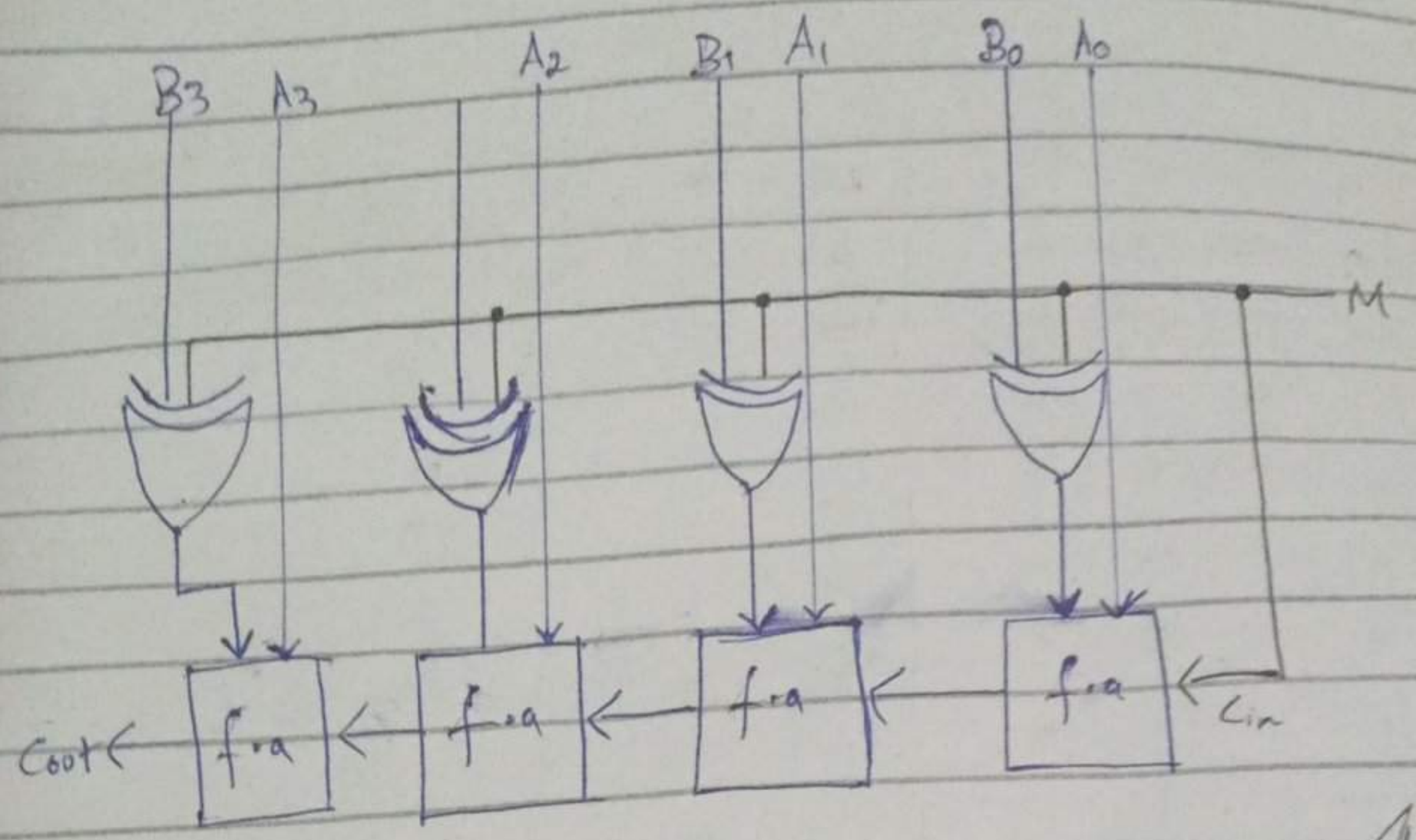

If M = 0 act as adder
If M = 1 act as substractor

When M is 0 then the XOR output is same as B input in circuit.

A	B	F
0	0 → M	0
M ← 0	1	1
1	0 → M	1
1	1	0

→ M =

When M is 1 then the XOR output is compliment of B input in circuit

A	B	F
0	0	0
0	1 → M	1
M ← 1	0	1
M ← 1	1	0

→ M =

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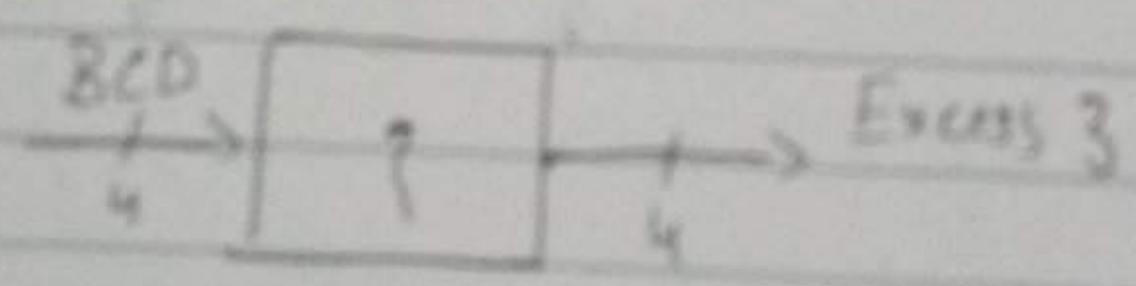
Excess 3

	A	B	C	D	w	x	y	z
0	0	0	0	0	0	0	1	1
1	0	0	0	1	0	1	0	0
2	0	0	1	0	0	1	0	1
3	0	0	1	1	0	1	1	0
4	0	1	0	0	0	1	1	1
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

Code converter:



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

$$W = A + BD + BC$$

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

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

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

$$Y = \bar{C}\bar{D} + CD \Rightarrow \left(\overline{C \oplus D}\right)$$

Scanned with CamScanner

Scanned with CamScanner

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

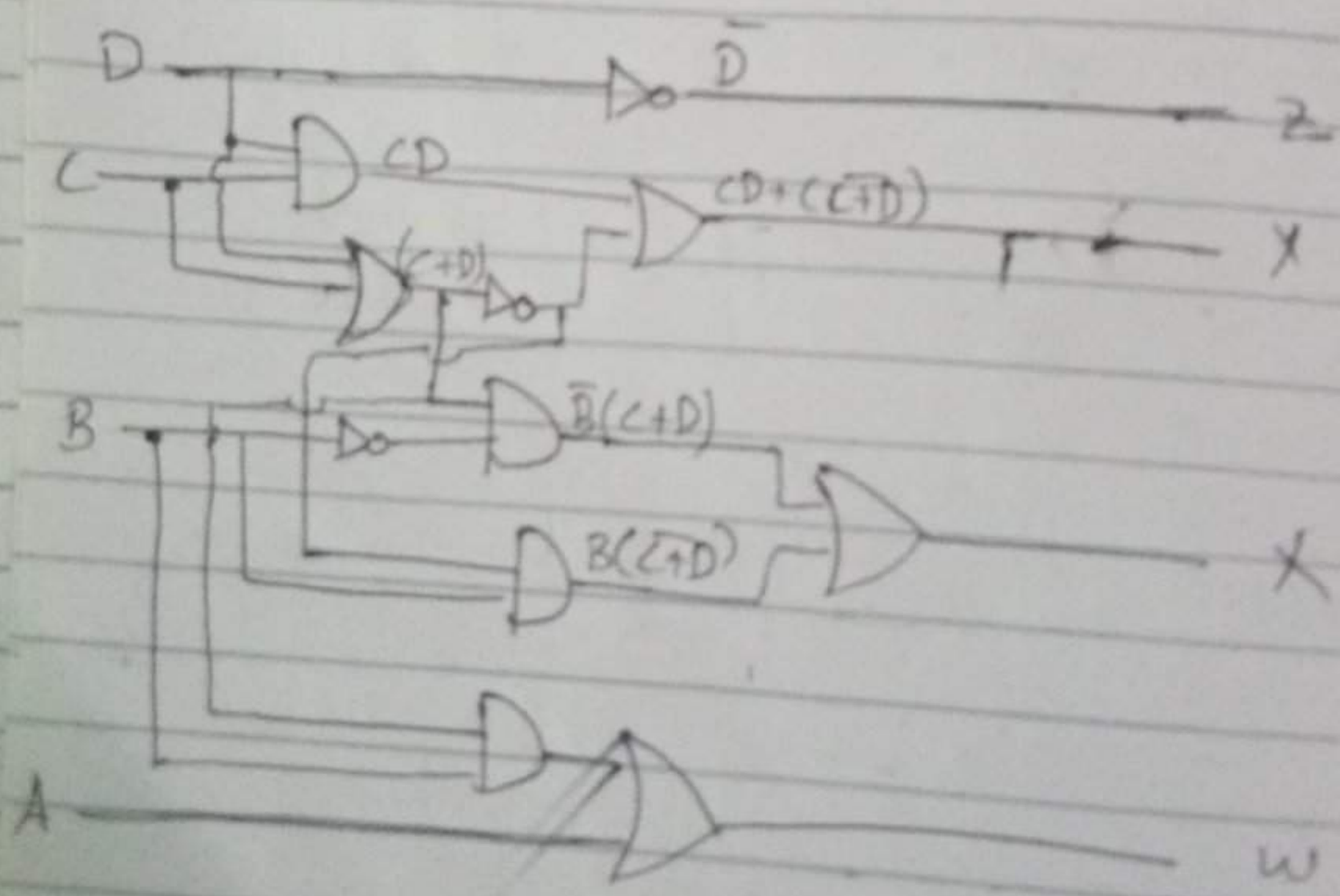
$Z = \overline{D}$

$W = A + B(C+D)$

$X = \overline{B}(C+D) + B\overline{C}\overline{D} \Rightarrow \overline{B}(C+D) + B(\overline{C+D})$

$Y = CD + (\overline{C+D})$

$Z = \overline{D}$



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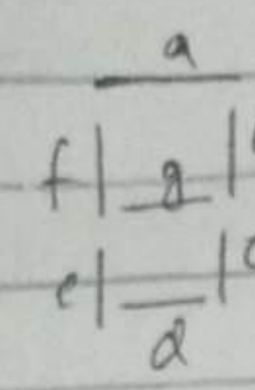
Seven Segment LED



Activelow → LED on
Active High → LED off

BCD to Seven Segment Display.

BCD

w	x	y	z
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
1	0	0	1

a	b	c	d	e	f	g
0	0	0	0	0	0	1
1	0	0	1	1	1	1
0	0	1	0	0	1	0
0	0	0	0	1	1	0
1	0	0	1	1	0	0
0	1	0	0	1	0	0
0	1	0	0	0	0	0
0	0	0	1	1	1	1
0	0	0	0	0	0	0
0	0	0	0	1	0	0

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

$$a = x\bar{y}\bar{z} + \bar{w}\bar{x}\bar{y}z$$

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

$$b = x\bar{y}z + x\bar{y}\bar{z}$$

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

$$c = \bar{x}\bar{y}\bar{z}$$

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

$$d = x\bar{y}\bar{z} + xyz + \bar{w}\bar{x}\bar{y}z$$

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

$$e = x\bar{y} + z$$

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

$$f = yz + \bar{w}\bar{x}z + \bar{w}\bar{x}y$$

w x y z
0 0 1 0

Scanned with CamScanner

Scanned with CamScanner

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

$$g = \bar{w}\bar{x}\bar{y} + xyz$$

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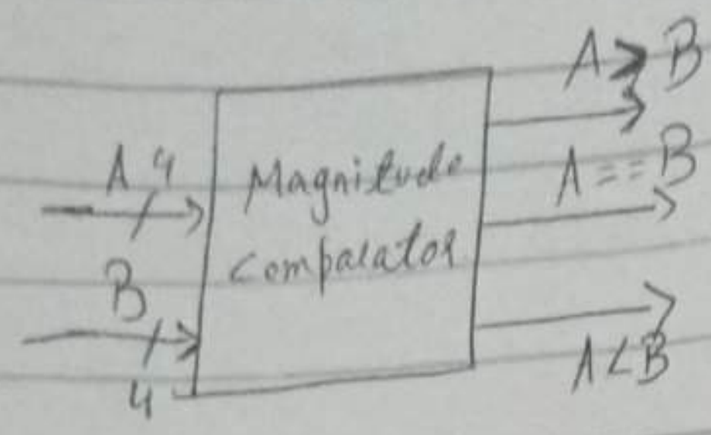
Comparator



Active High.

Equals :—

$A = A_3\ A_2\ A_1\ A_0$

$B = B_3\ B_2\ B_1\ B_0$

$A == B$ $\boxed{\begin{array}{l} A_0 == B_0 \\ A_1 == B_1 \\ A_2 == B_2 \\ A_3 == B_3 \end{array}}$ $\Rightarrow$ $A_i == B_i$, $i = 0, 1, 2, 3$

Exclusive OR Gate / NOR Gate

$A \text{ XOR } B = \bar{A}B + A\bar{B}$

$A \text{ XNOR } B = AB + \bar{A}\bar{B}$

A	B	$A \oplus B$	$\overline{A \oplus B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	1

When Both input are Same XNOR Give us 1

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$x_0 \quad A_0 == B_0$

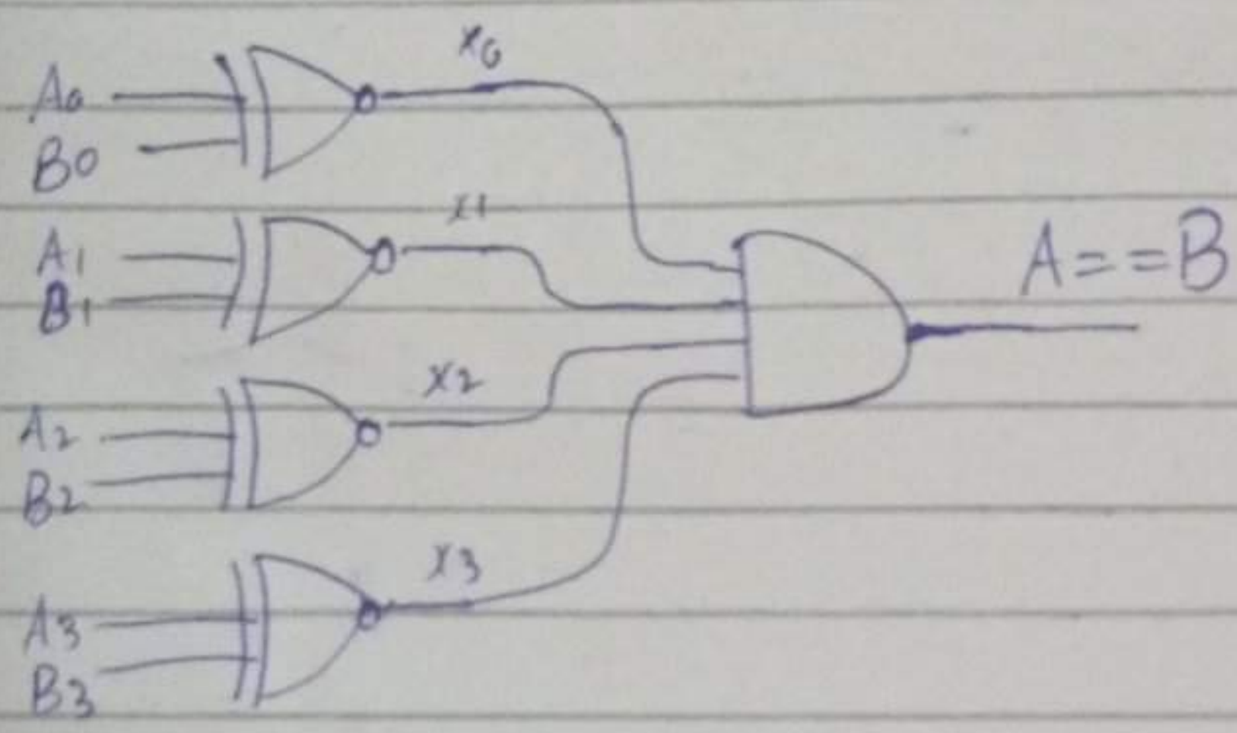
$x_1 \quad A_1 == B_1$

$x_2 \quad A_2 == B_2$

$x_3 \quad A_3 == B_3$

$$x_i = (A_i \oplus B_i)'$$

$(A == B)$ if $x_3 \cdot x_2 \cdot x_1 \cdot x_0$



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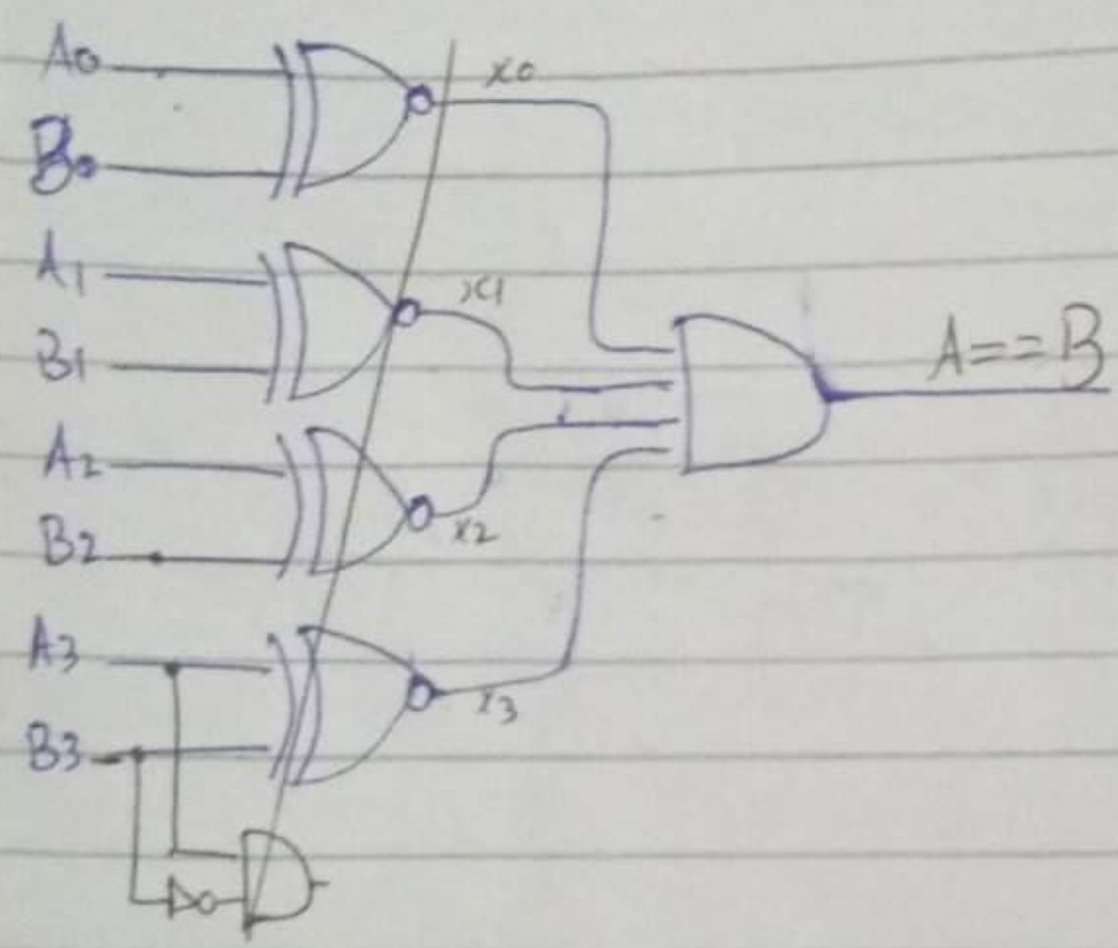
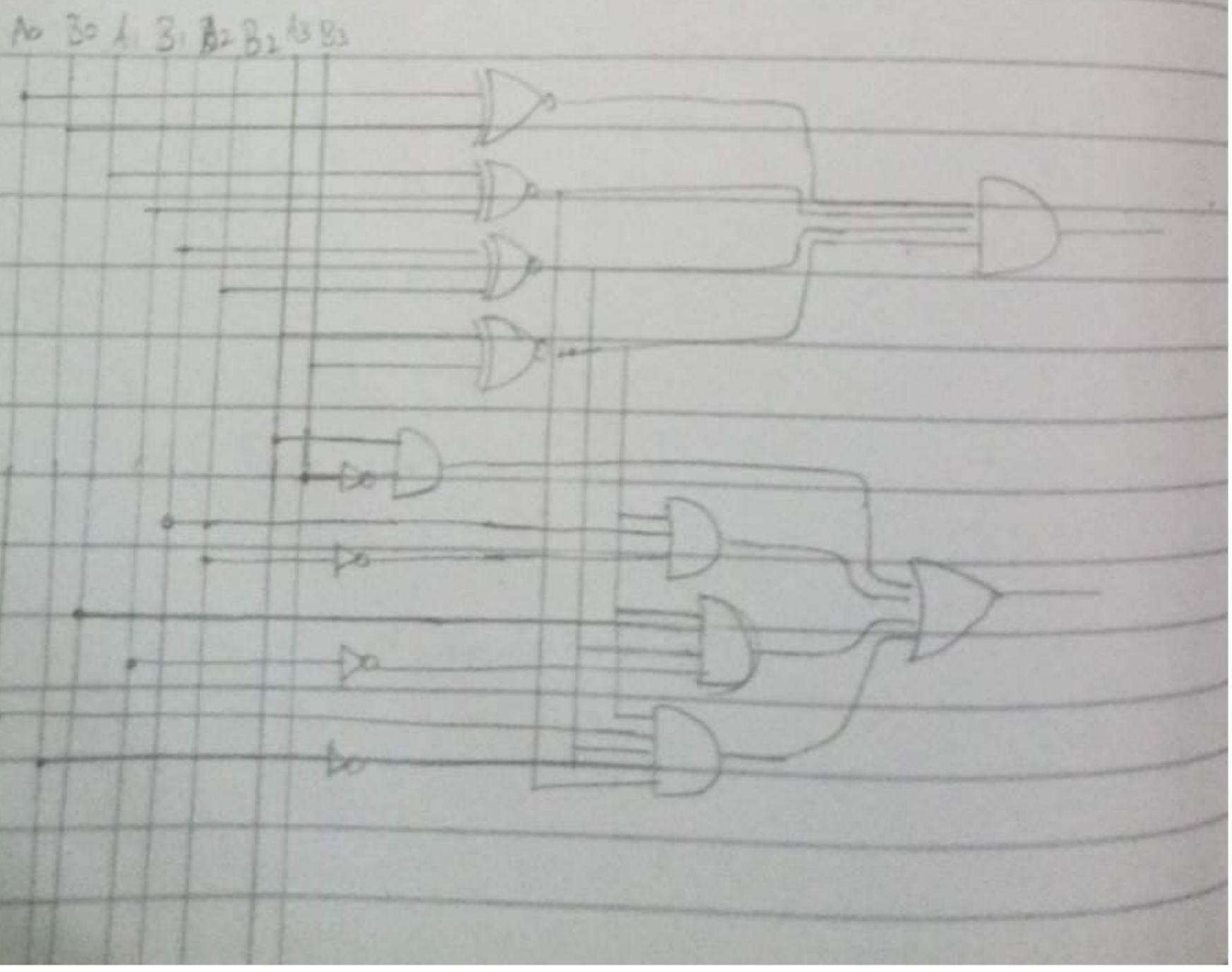
Greater than or less than

$$A>B = A_3\overline{B_3} + x_3 A_2\overline{B_2} + x_3x_2 A_1\overline{B_1} + x_3x_2x_1 A_0\overline{B_0}$$

$$A<B = \overline{A_3}B_3 + x_3\overline{A_2}B_2 + x_3x_2\overline{A_1}B_1 + x_3x_2x_1\overline{A_0}B_0$$





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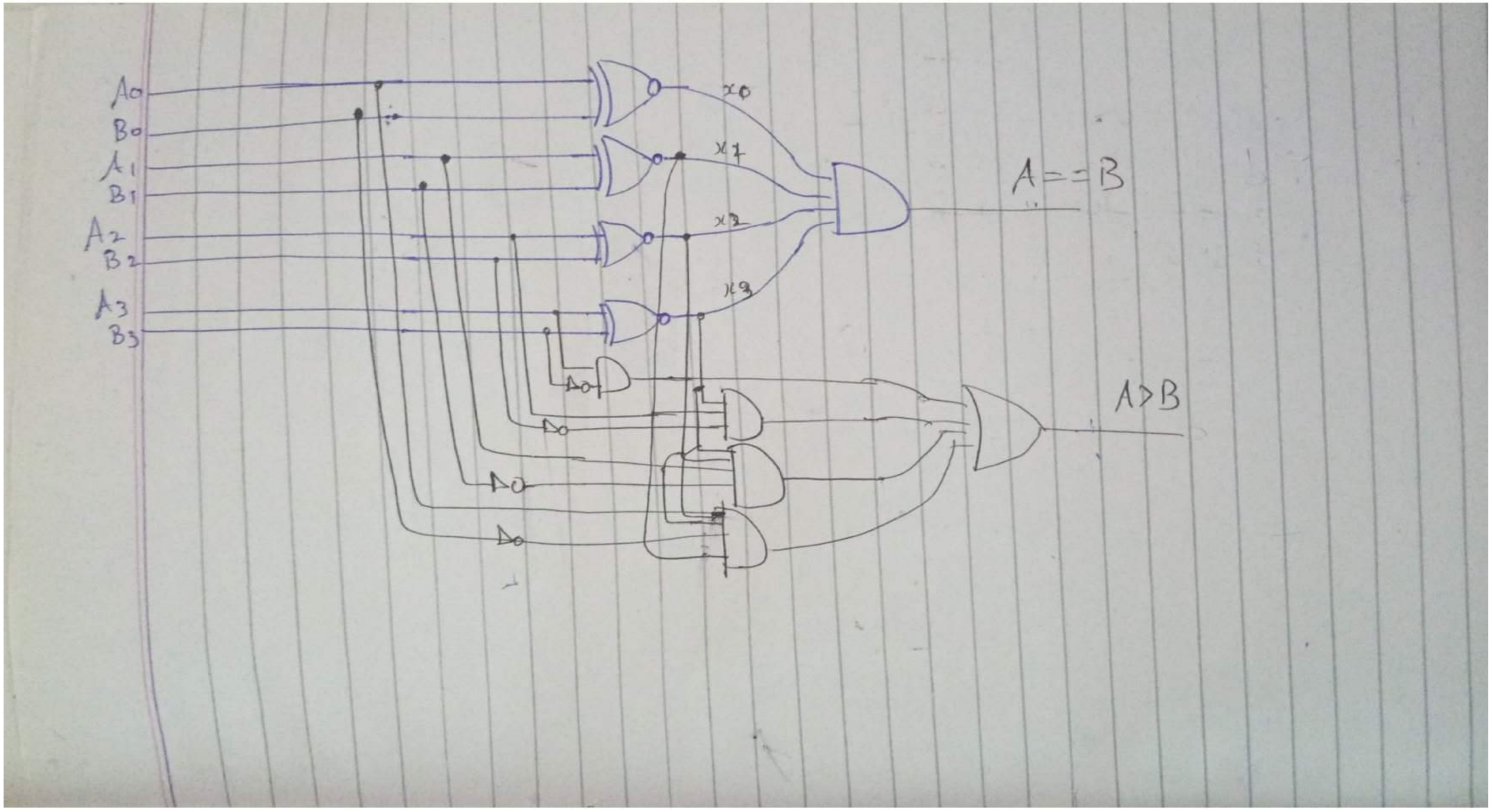

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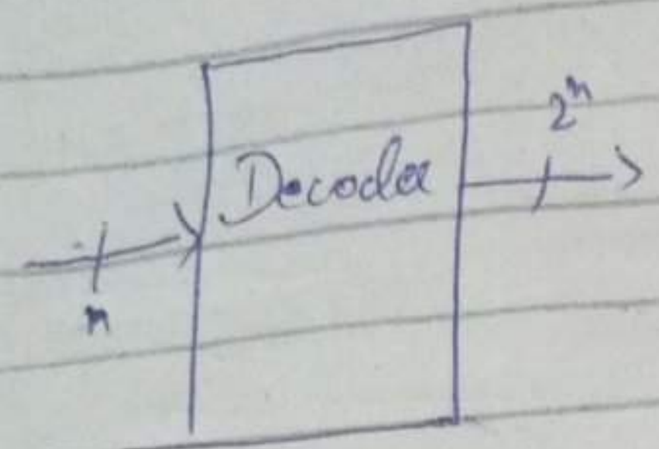
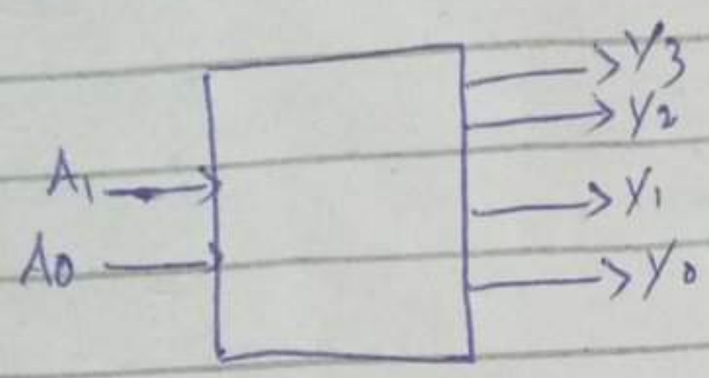
Scanned with CamScanner

Decoder :-



n to m line.

2 to 4
3 to 8



A_1	A_0	Y_3	Y_2	Y_1	Y_0	
0	0	0	0	0	1	Active High
0	1	0	0	1	0	
1	0	0	1	0	0	
1	1	1	0	0	0	

$Y_0 = \bar{A}_1 \bar{A}_0$ m0
$Y_1 = \bar{A}_1 A_0$ m1
$Y_2 = A_1 \bar{A}_0$ m2
$Y_3 = A_1 A_0$ m3

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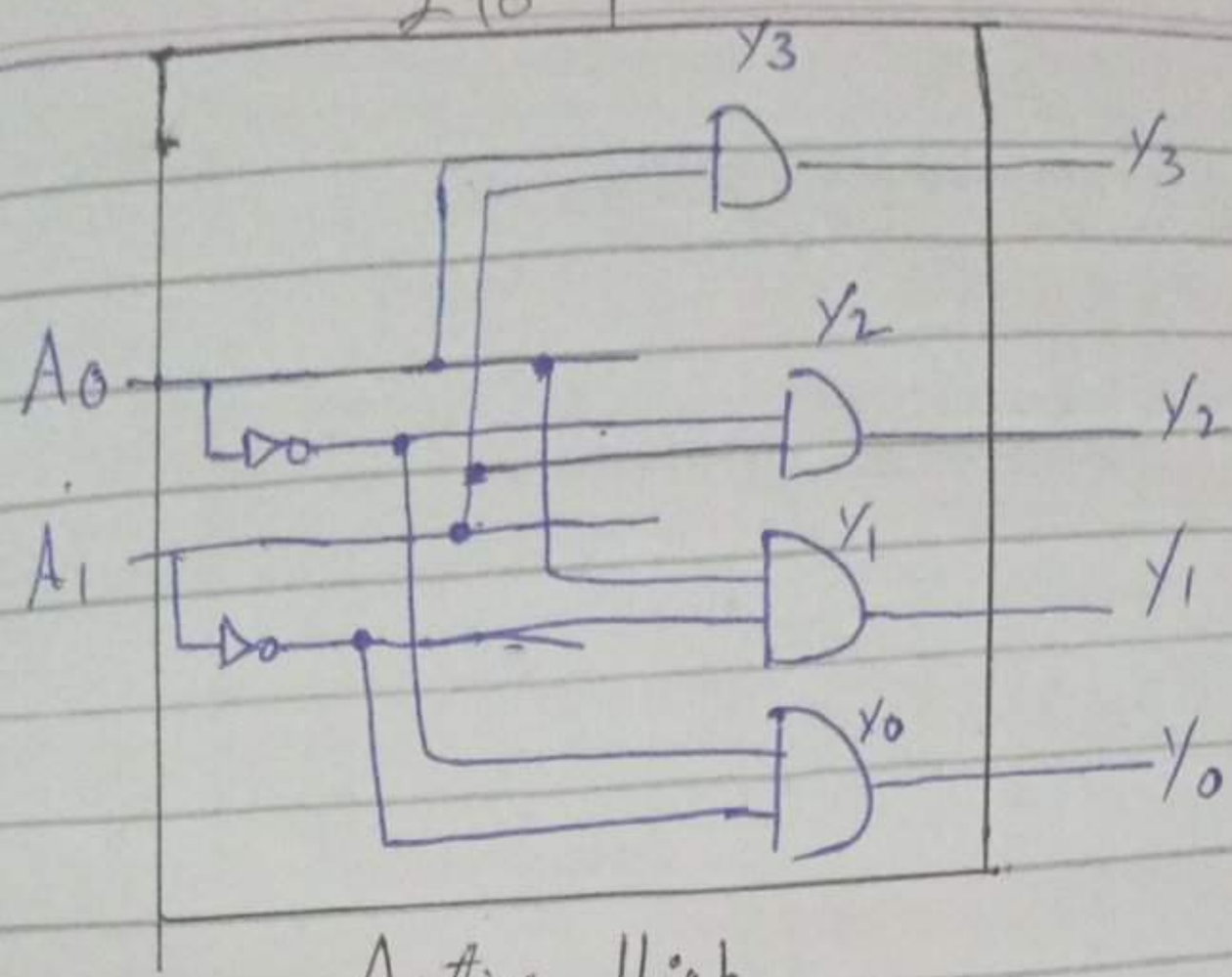
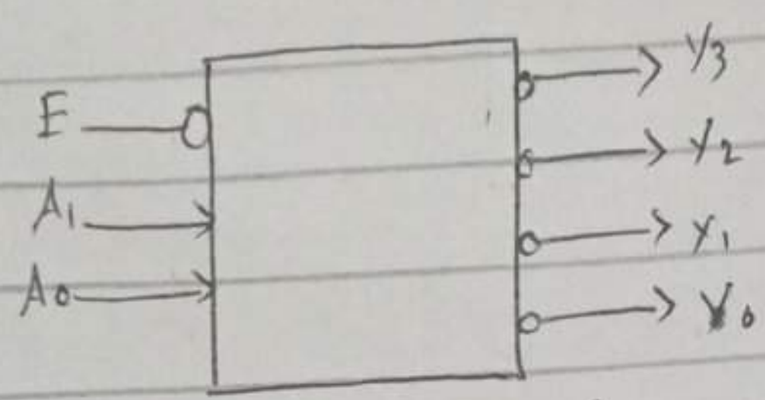
Scanned with CamScanner

2 to 4



Active High



Active low.

E	A_1	A_0	Y_3	Y_2	Y_1	Y_0
1	x	x	1	1	1	1
0	0	0	1	1	1	0
0	0	1	1	1	0	1
0	1	0	1	0	1	1
0	1	1	0	1	1	1

Active low

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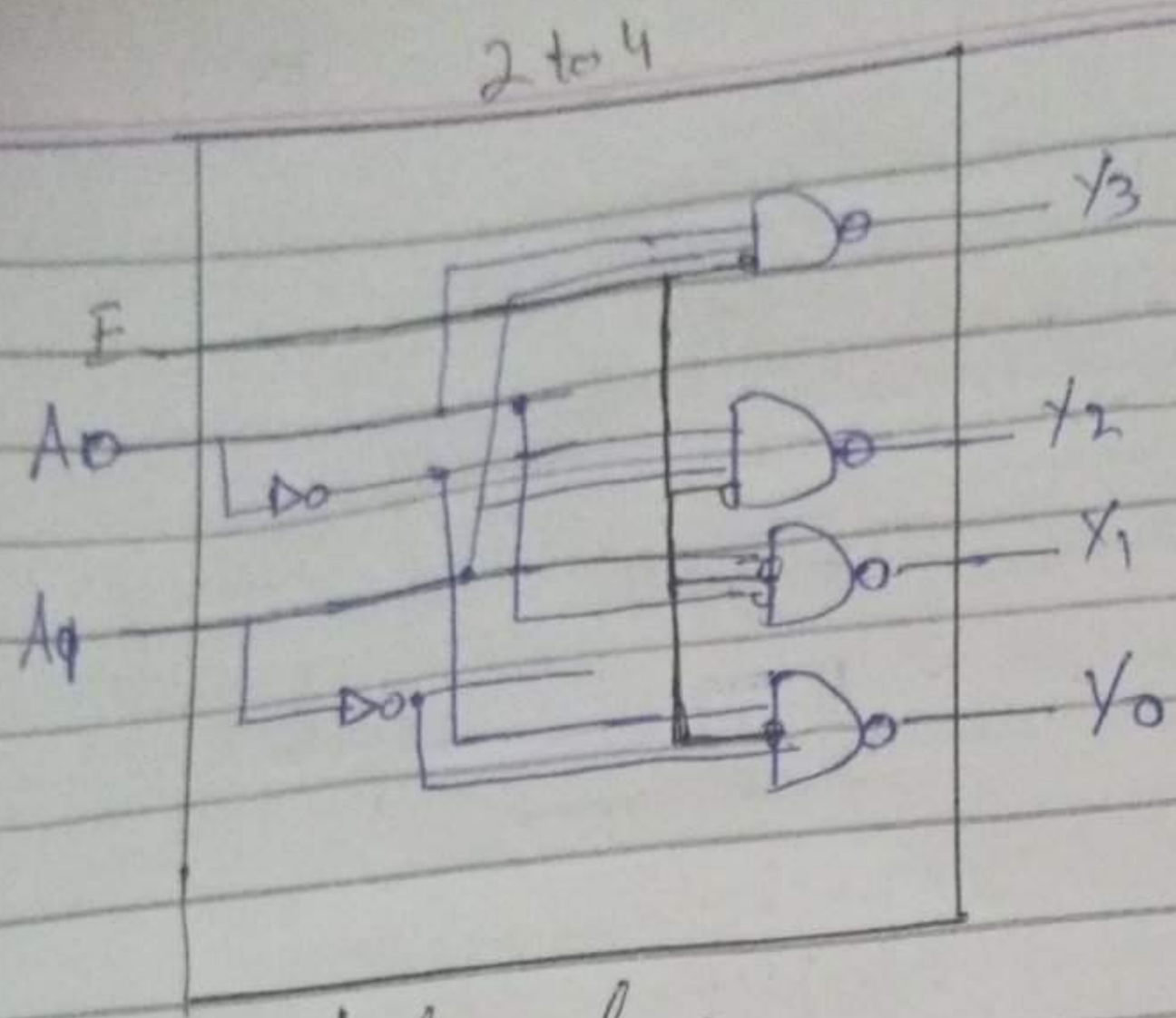
Scanned with CamScanner



Active low

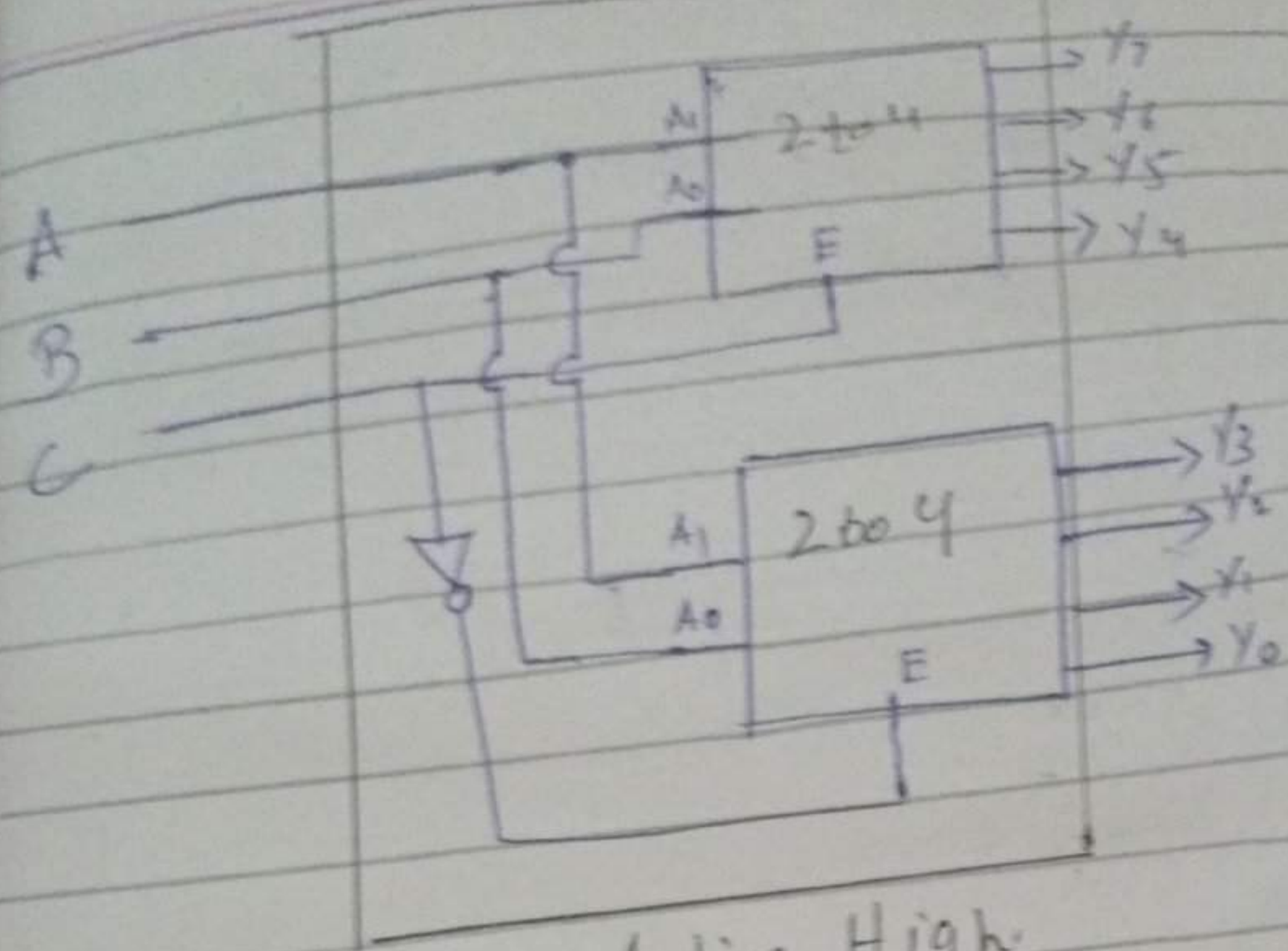
E	A_1	A_0	Y_3	Y_2	Y_1	Y_0
0	X	X	0	0	0	0
1	0	0	0	0	0	1
1	0	1	0	0	1	0
1	1	0	0	1	0	0
1	1	1	1	0	0	0

Active

Scanned with CamScanner

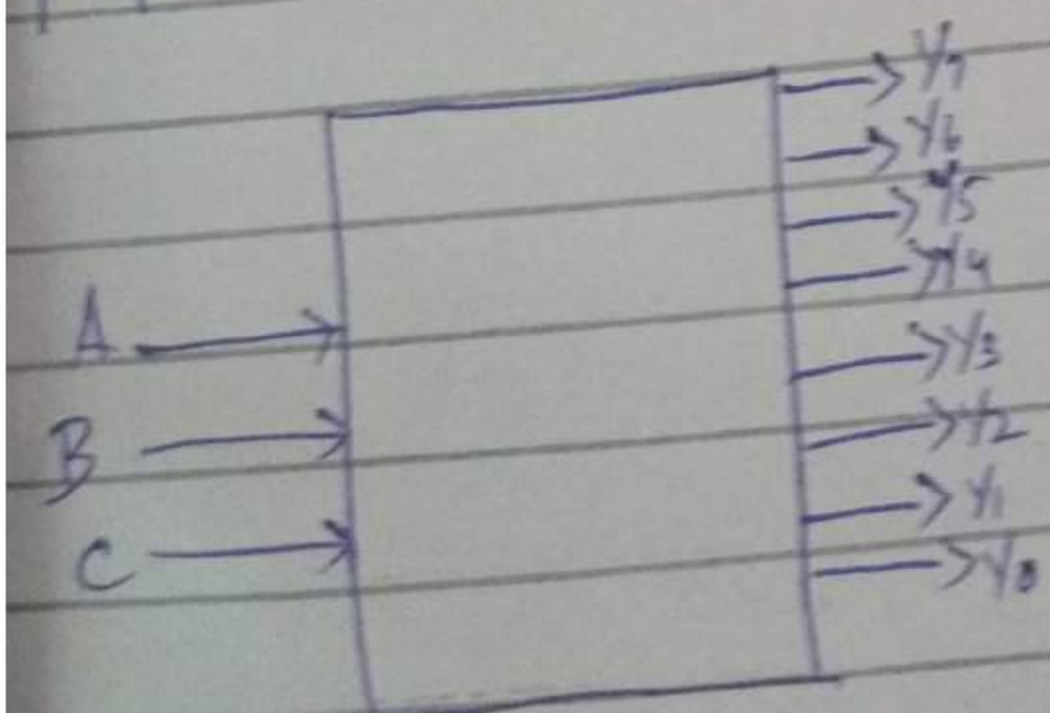
Scanned with CamScanner

3 to 8



Active High

C	B	A	Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	1	0	0
0	1	1	0	0	0	0	1	0	0	0
1	0	0	0	0	0	1	0	0	0	0
1	0	1	0	0	1	0	0	0	0	0
1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0



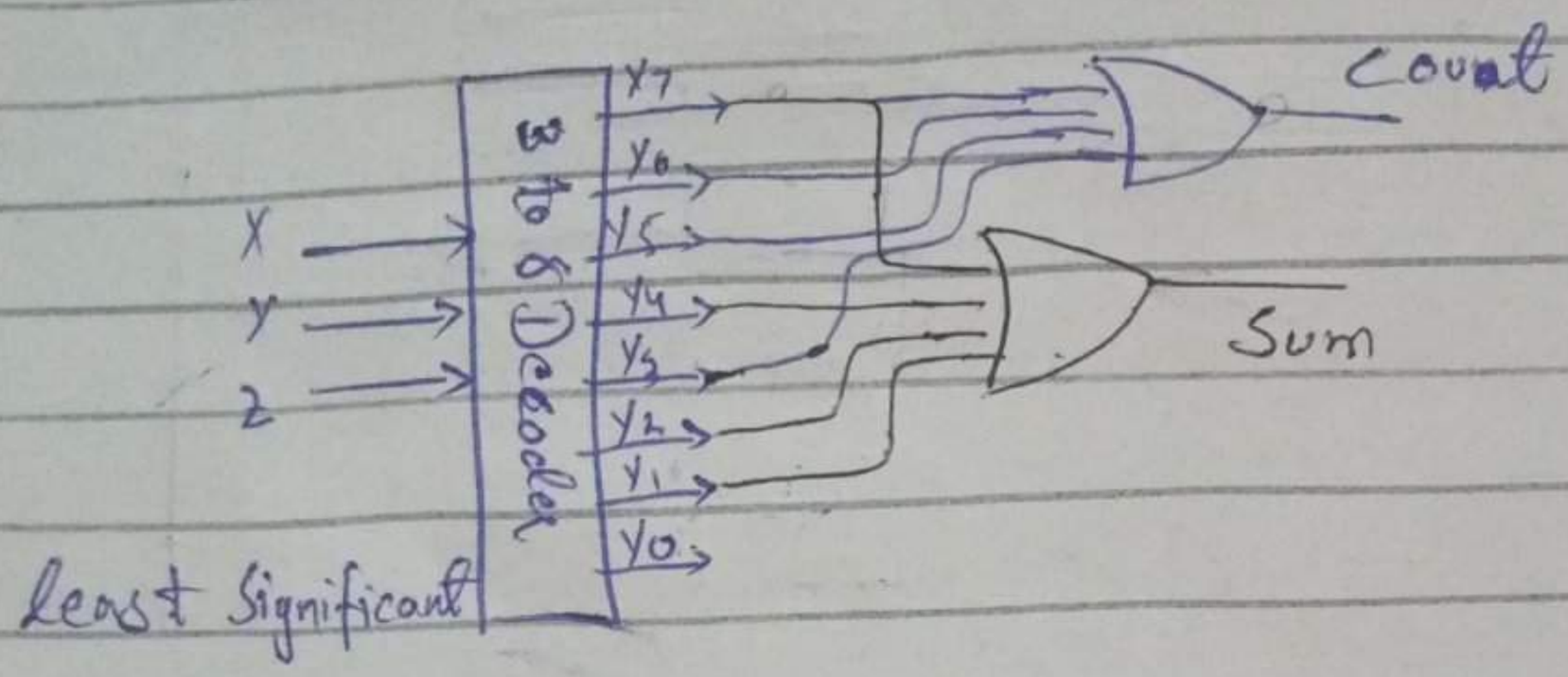
Scanned with CamScanner

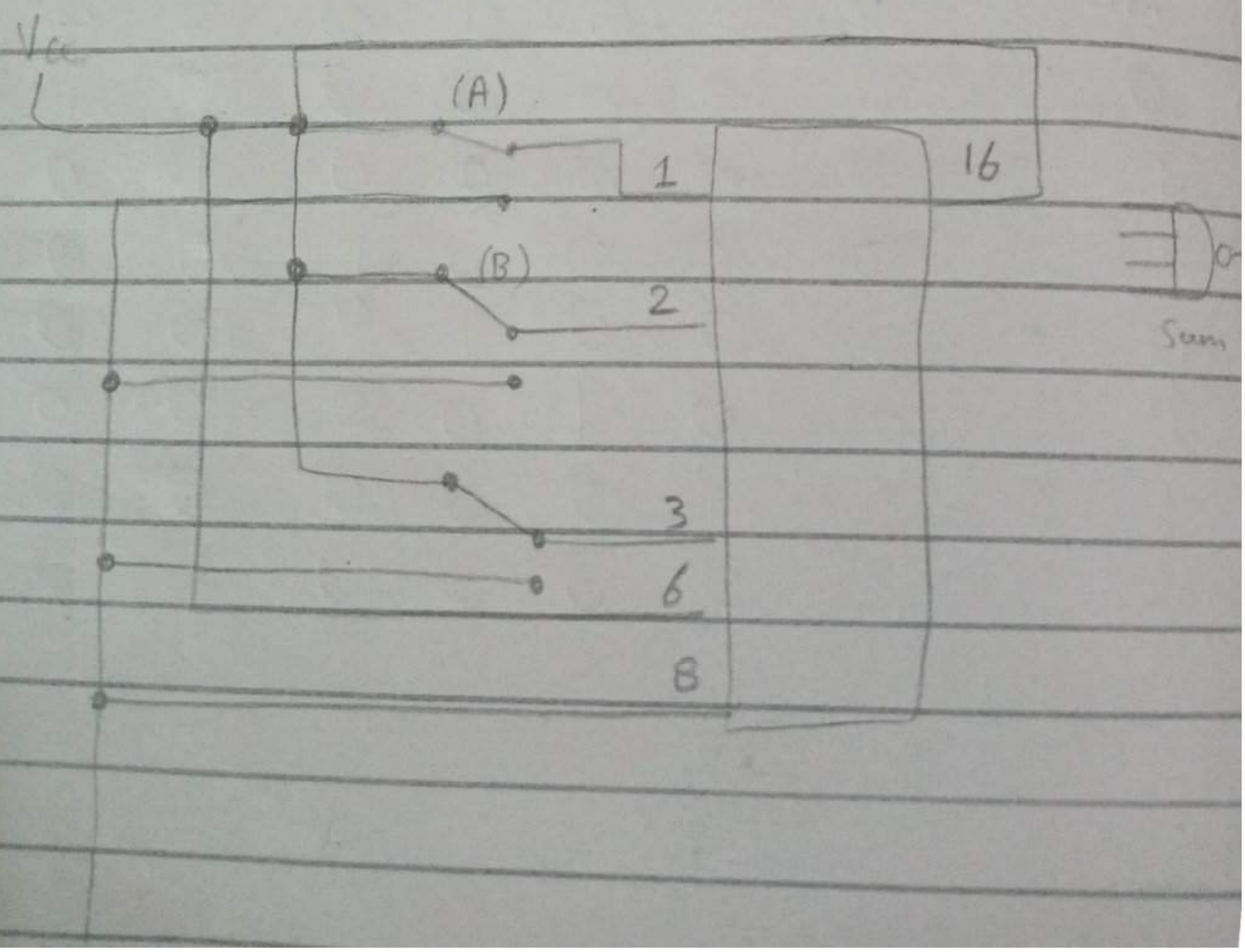
Scanned with CamScanner

Adder using Decoder.

$S(x, y, z) = \Sigma(1, 2, 4, 7)$

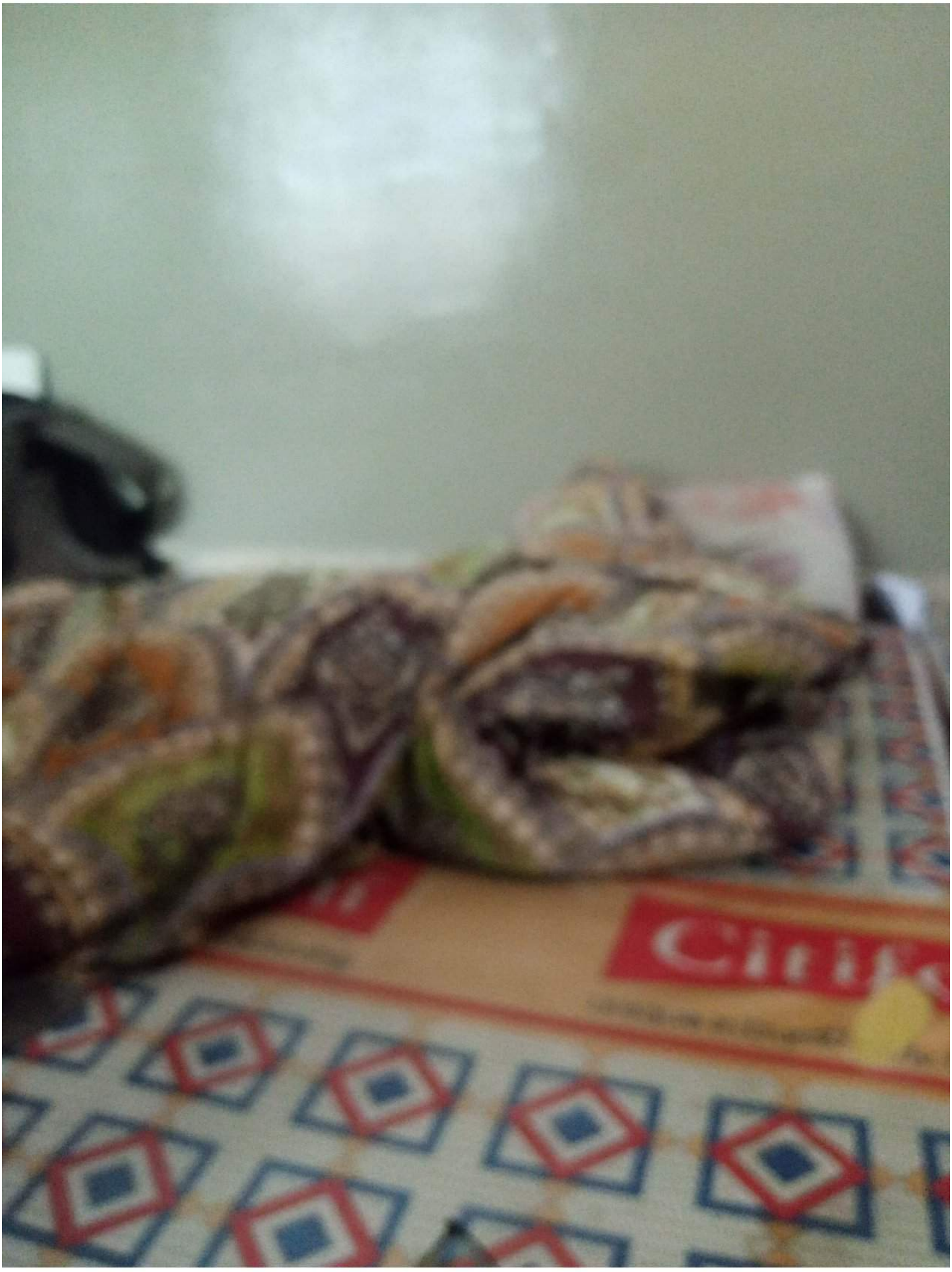
$C(x, y, z) = \Sigma(3, 5, 6, 7)$





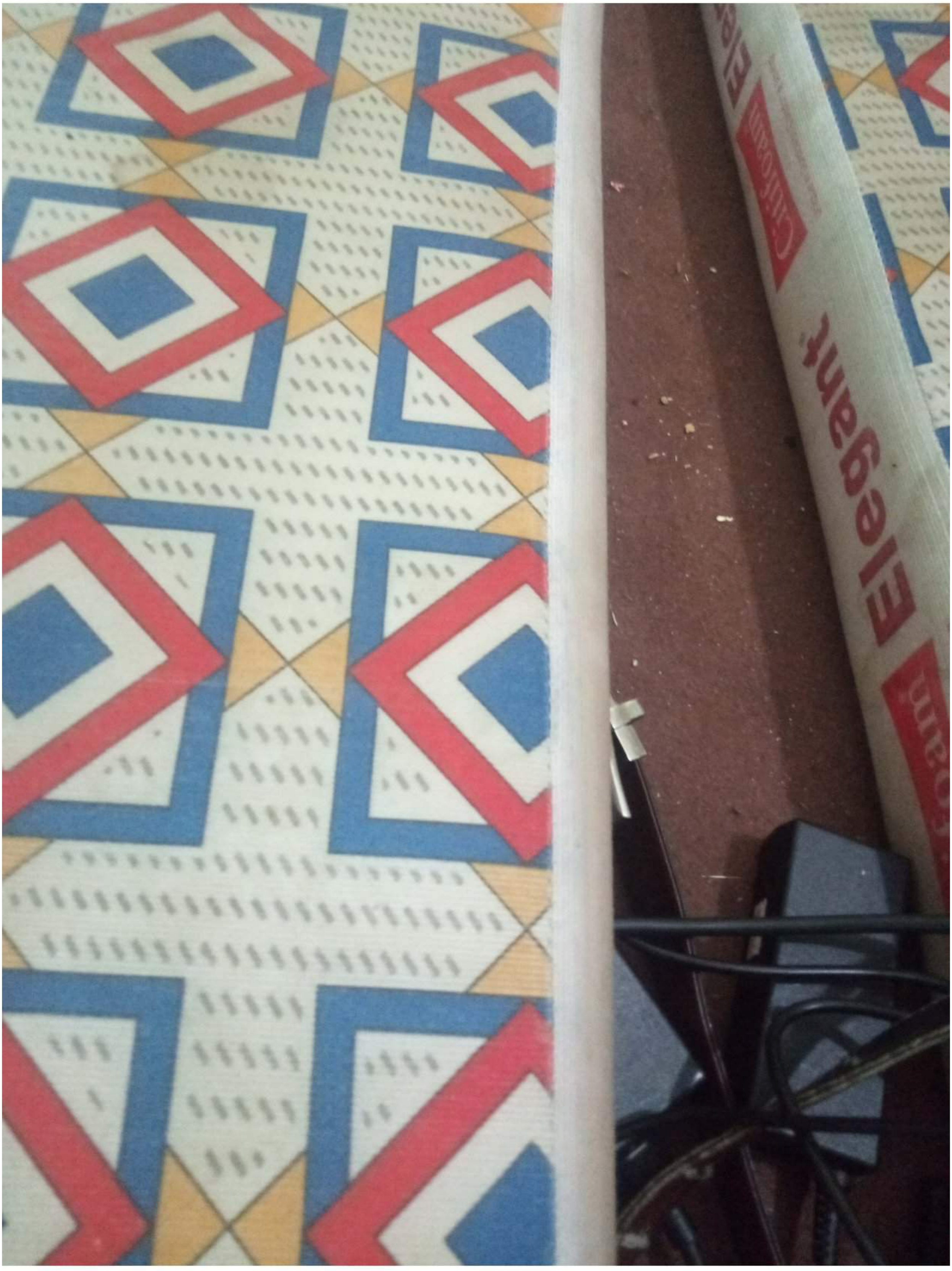
Scanned with CamScanner

Scanned with CamScanner



Scanned with CamScanner

Scanned with CamScanner

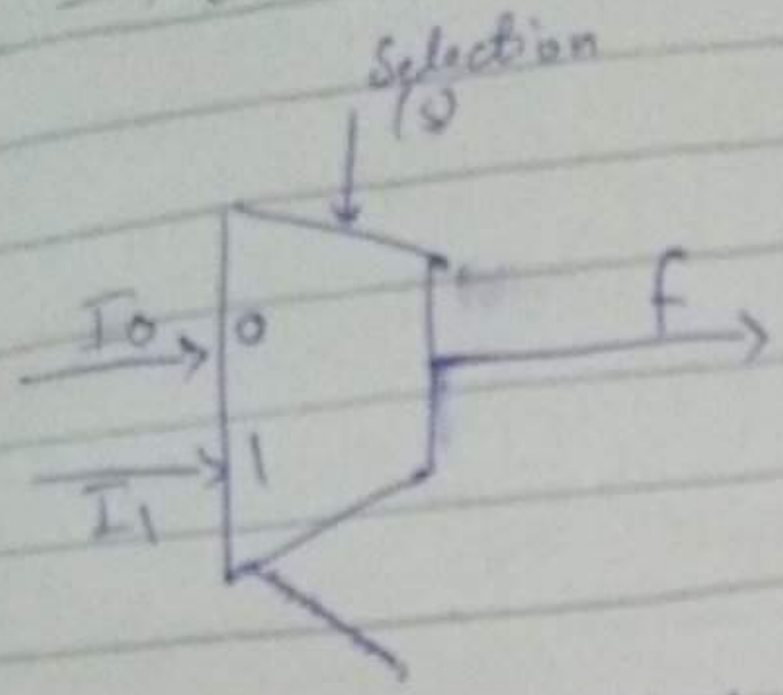


Scanned with CamScanner

Scanned with CamScanner

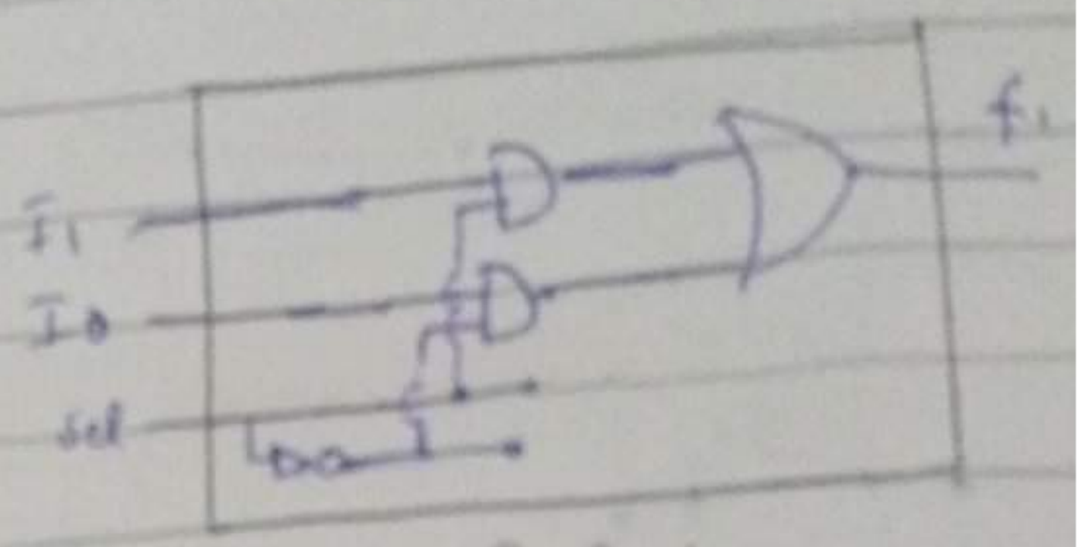
Multiplexer (many line to one)

→ one bit

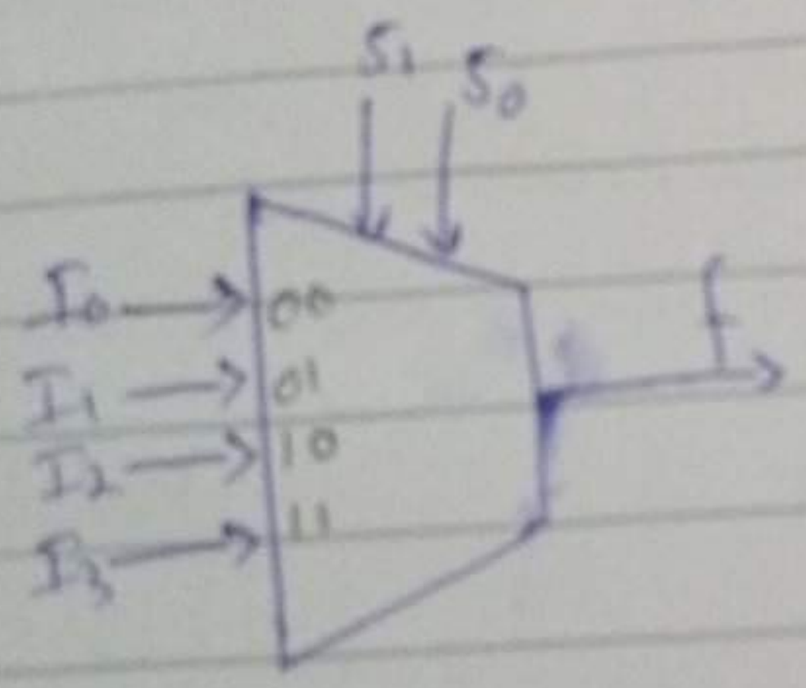


$f = \overline{Sel}\, I_0 + Sel\, I_1$

S	f
0	I_0
1	I_1



2 to 1

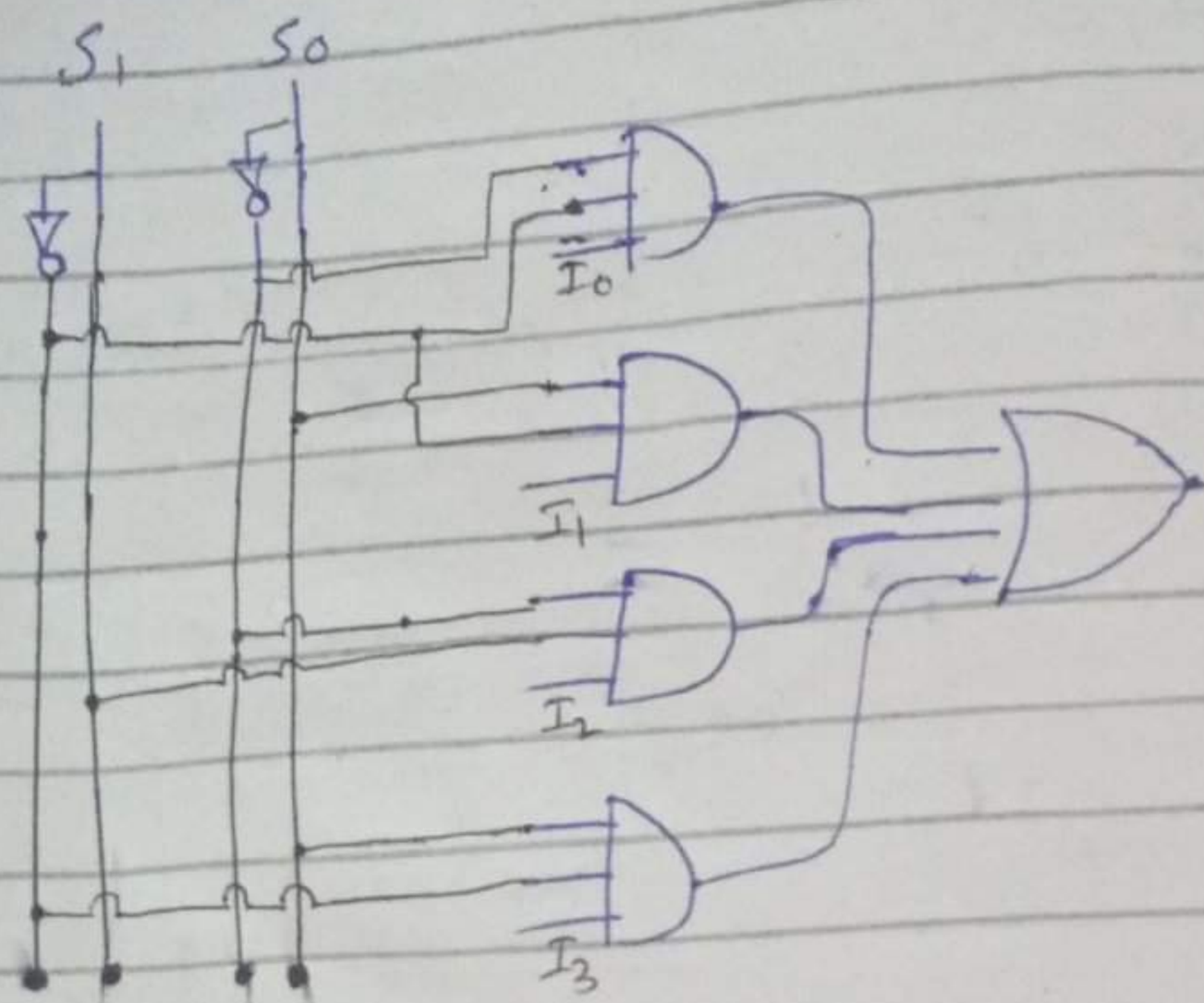


S_1	S_0	f
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

Scanned with CamScanner

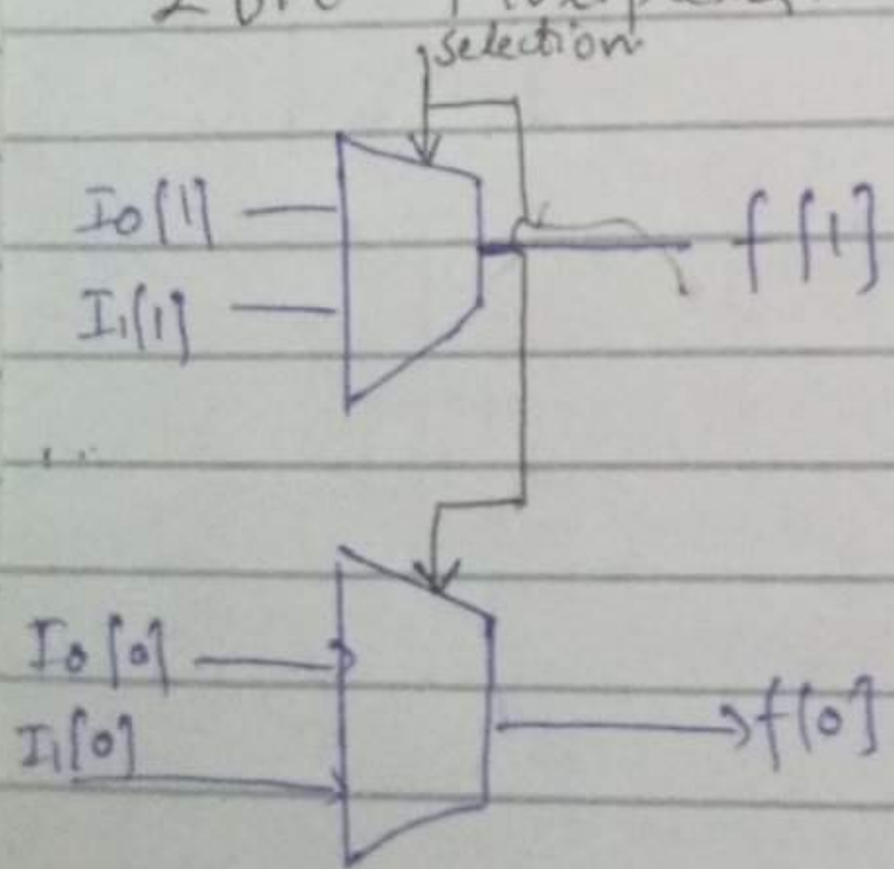
Scanned with CamScanner

$$f = \bar{S}_0 \bar{S}_1 I_0 + S_0 \bar{S}_1 I_1 + \bar{S}_0 S_1 I_2 + S_0 S_1 I_3$$



3 to 1

2 bit Muliplexer



$I_0 = \overbrace{\underbrace{\ }_{0,1}\ \underbrace{\ }_{0,1}}^{2\text{ bits}}$

$I_1 = \overbrace{\underbrace{\ }_{0,1}\ \underbrace{\ }_{0,1}}^{2\text{ bits}}$

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Scanned with CamScanner

Multiplication

```
A      1101          13
B    x 1010          10
     ---------       ---
     0000 0000       130
     1101 x
     0000 x x
     1101 x x x
     ----------
     10000010
```

Partial product generation

Encoder :-

- Inverse of ~~Decode~~ Decoder
- 2^n to n line

D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7	X	Y
1	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	1
0	0	0	1	0	0	0	0	0	1
0	0	0	0	1	0	0	0	1	0
0	0	0	0	0	1	0	0	1	0
0	0	0	0	0	0	1	0	1	1
0	0	0	0	0	0	0	1	1	1

$Z = D_1 + D_3 + D_5 + D_7 = Z$

$Y = D_2 + D_3 + D_6 + D_7 = Y$

$X = D_4 + D_5 + D_6 + D_7 = X$

Scanned with CamScanner

Scanned with CamScanner

Priority Encoder

D_0	D_1	D_2	D_3	X	Y	V
			→ M.S			
			0	x	x	0
0	0	0	0	0	0	1
1	0	0	0	0	1	1
x	1	0	0	1	0	1
x	x	1	0	1	1	1
x	x	x	1			

D_0D_1 \ D_2D_3	00	01	11	10
00		1	1	
01	1	1	1	
11	1	1	1	
10		1	1	

$$Y = D_3 + D_1\overline{D_2}$$

D_0D_1 \ D_2D_3	00	01	11	10
00		1	1	1
01		1	1	1
11		1	1	1
10		1	1	1

$$X = D_3 + D_2$$

Scanned with CamScanner

Scanned with CamScanner

Boolean Implementation using multiplexer

Example

$$f(x, y, z) = \Sigma(1, 2, 6, 7)$$

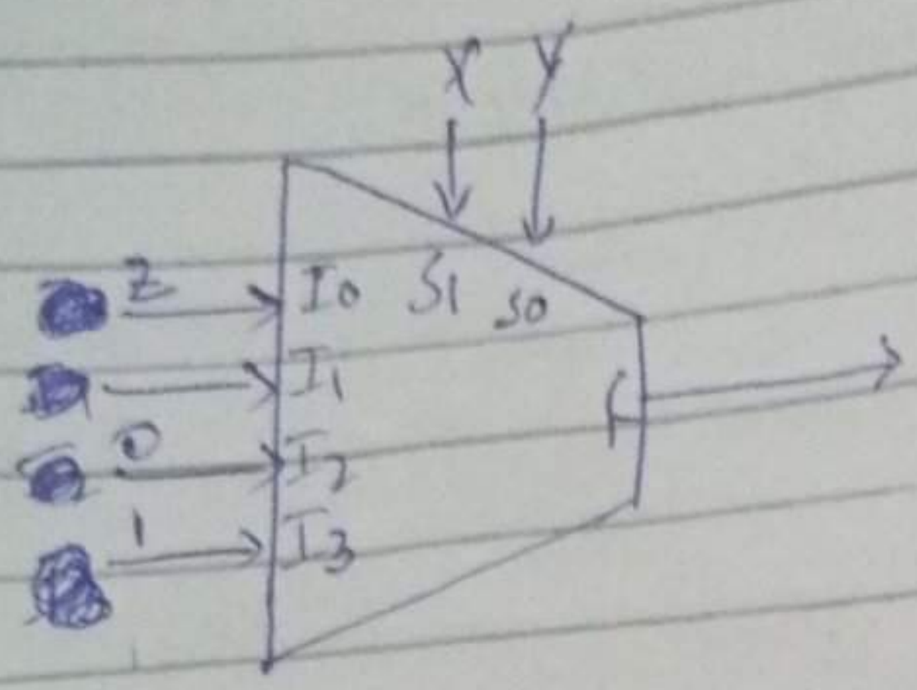
1- 1st n-1 variable selection i/ps of Mux.
2- remaining single variable is used for data inputs. if single variable is denoted by 'Z' each Data i/p of the Mux will be Z, Z, 1, 0

X, Y as select line

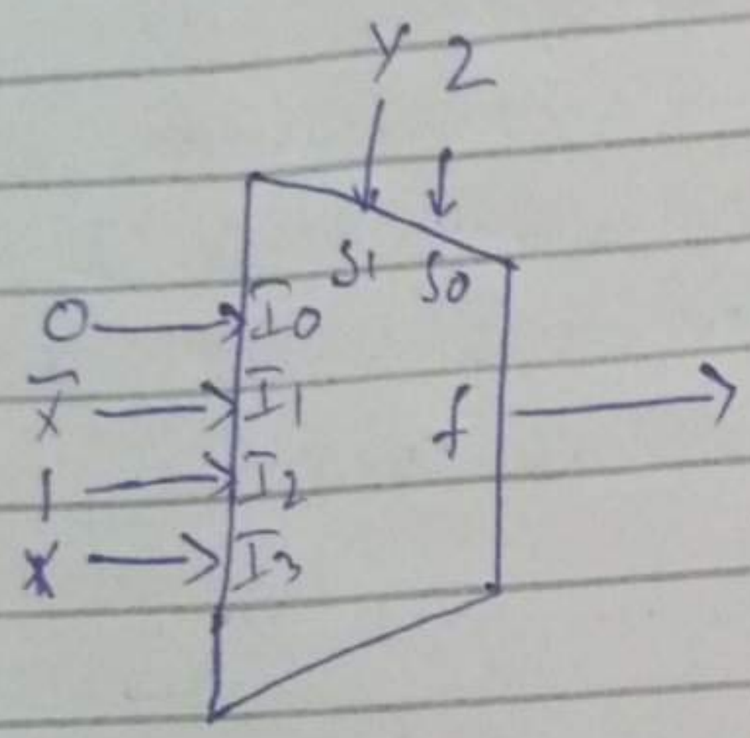
X	Y	Z	F	
0	0	0	0	$F = Z$
0	0	1	1	
0	1	0	1	$F = \bar{Z}$
0	1	1	0	
1	0	0	0	$F = 0$
1	0	1	0	
1	1	0	1	$F = 1$
1	1	1	1	

Scanned with CamScanner

Scanned with CamScanner



Y, Z as select line.



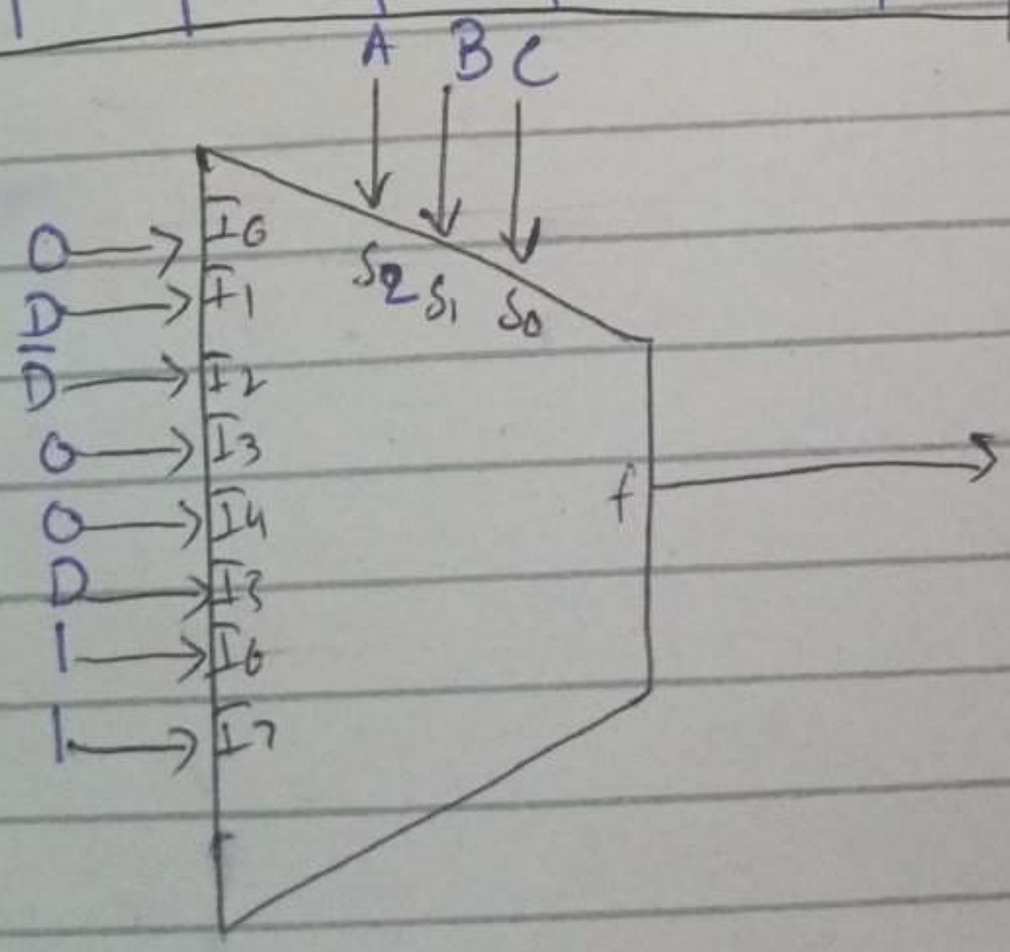
X	Y	Z	F	
0	0	0	0	1
0	0	1	1	2
0	1	0	1	3
0	1	1	0	4
1	0	0	0	1
1	0	1	0	2
1	1	0	1	3
1	1	1	1	4

Scanned with CamScanner

Scanned with CamScanner

$F(A, B, C, D) = \Sigma(3, 4, 11, 12, 13, 14, 15)$

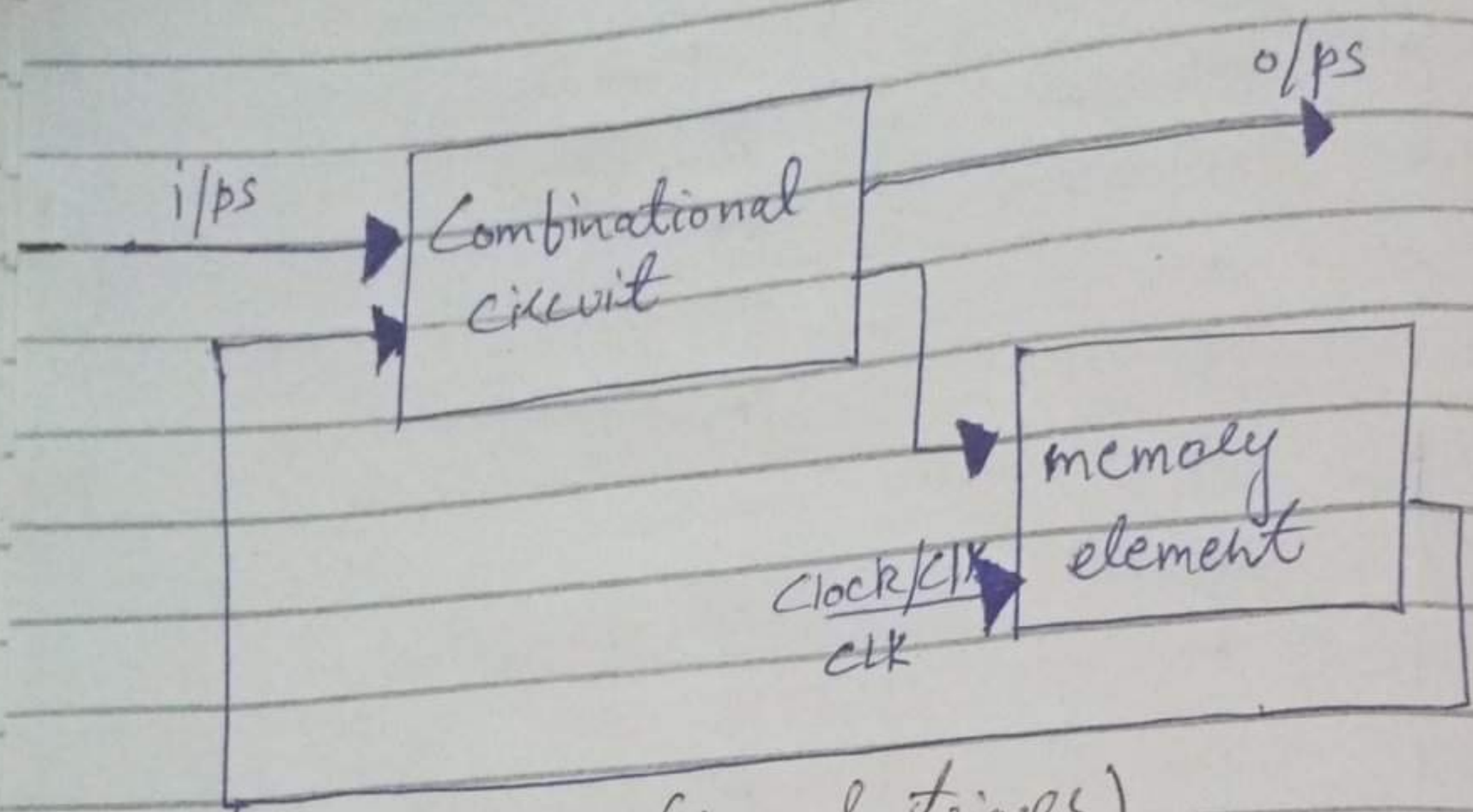
A	B	C	D	F	
0	0	0	0	0	I_0
0	0	0	1	0	
0	0	1	0	0	I_1
0	0	1	1	1	
0	1	0	0	1	
0	1	0	1	0	
0	1	1	0	0	
0	1	1	1	0	
1	0	0	0	0	
1	0	0	1	0	
1	0	1	0	0	
1	0	1	1	1	
1	1	0	0	1	
1	1	0	1	1	
1	1	1	0	1	
1	1	1	1	1	



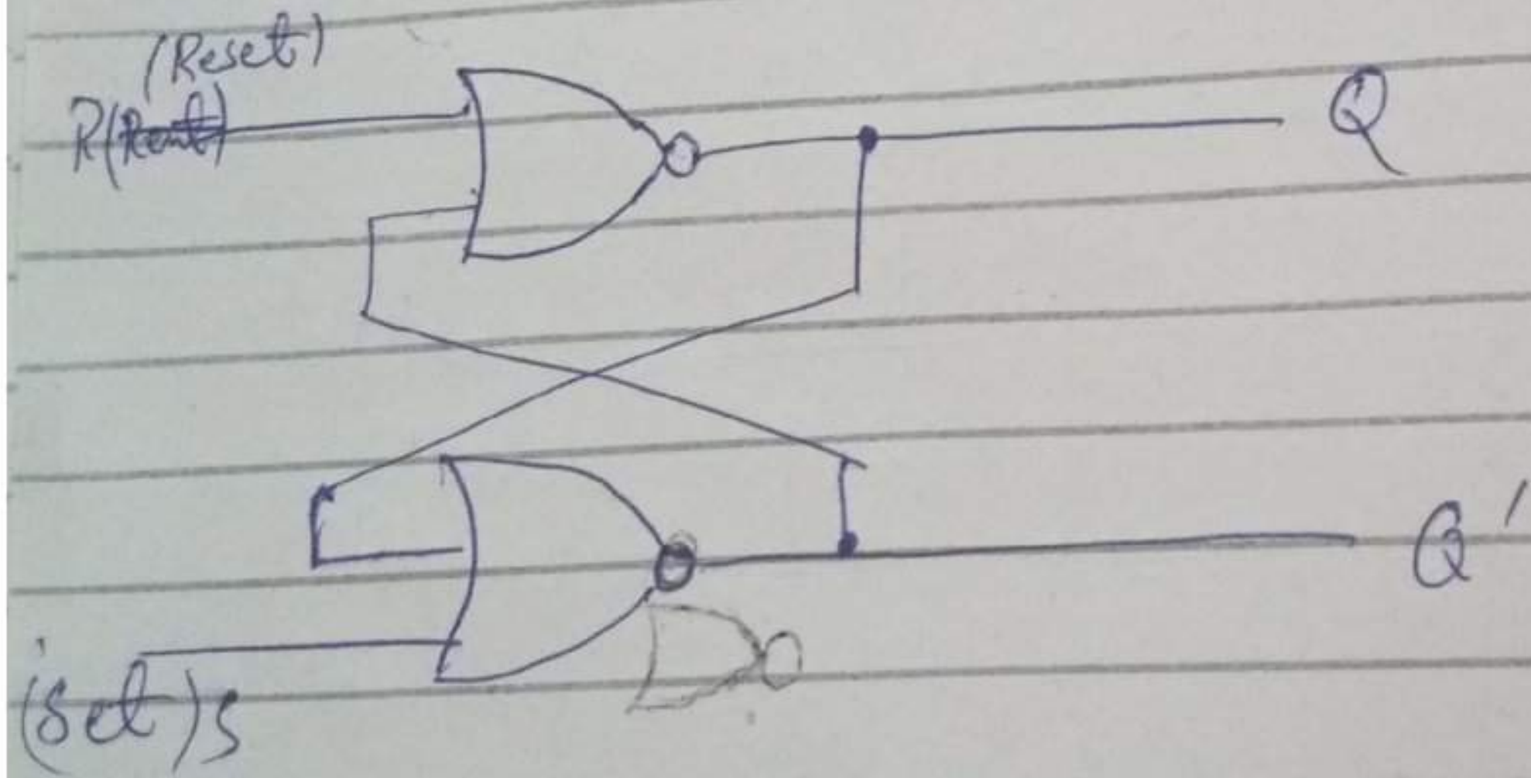
Scanned with CamScanner

Scanned with CamScanner

Sequential circuit:- (1



S-R latch:- (Level triggers)



A	B	NOR
0	0	1
0	1	0
1	0	0
1	1	0

Scanned with CamScanner

Scanned with CamScanner

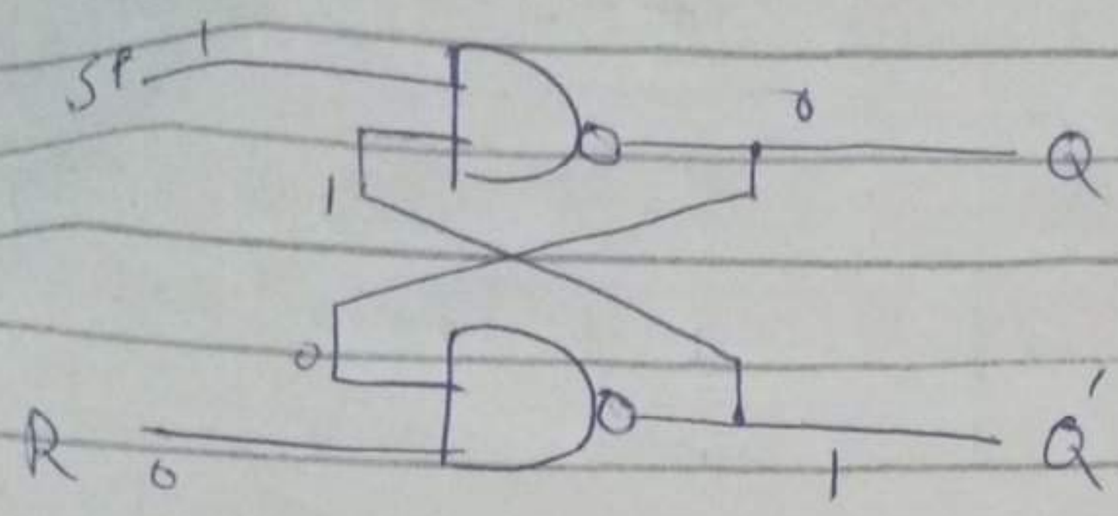
S	R	Q	Q'	
1	0	1	0	
0	0	1	0	(after S=1 & R=0)
0	1	0	1	
0	0	0	1	(after S=0 & R=1)
1	1	0	0	(folbiddlen) Latch

no change

Scanned with CamScanner

Scanned with CamScanner

S'R' latch (Active low)



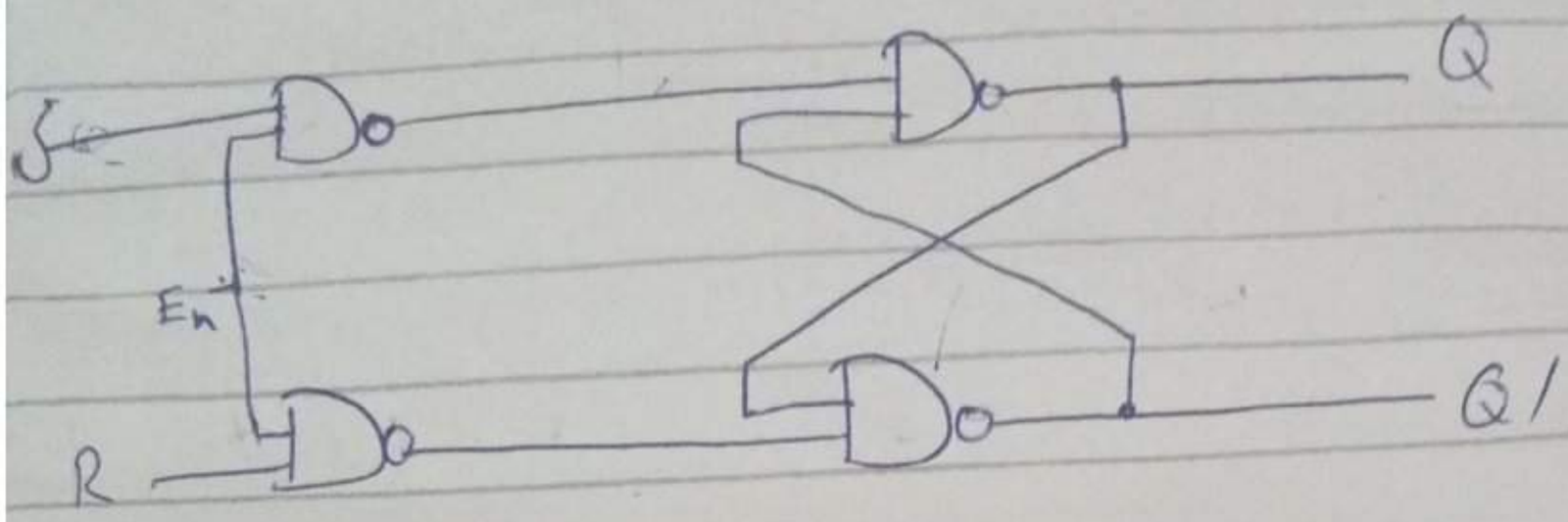
A	B	NAND
0	0	1
0	1	1
1	0	1
1	1	0

S	R	Q	Q'
1	0	0	1
1	1	0	1
0	1	1	0
1	1	1	0
0	0	1	1

0 1 10
1 1 10
1 0 01
1 1 01
0 0 10

forbidden

SR latch with control input:-



En	S	R	Q* (next State of Q)
0	X	X	No change
1	0	0	//
1	0	1	Q = 0 (Rest)
1	1	0	Q = 1 (Set)
1	1	1	Indeterminate

When En is 0 Q and Q' remain same state value, When we want to change value En is 1 then we change the state value in Q.

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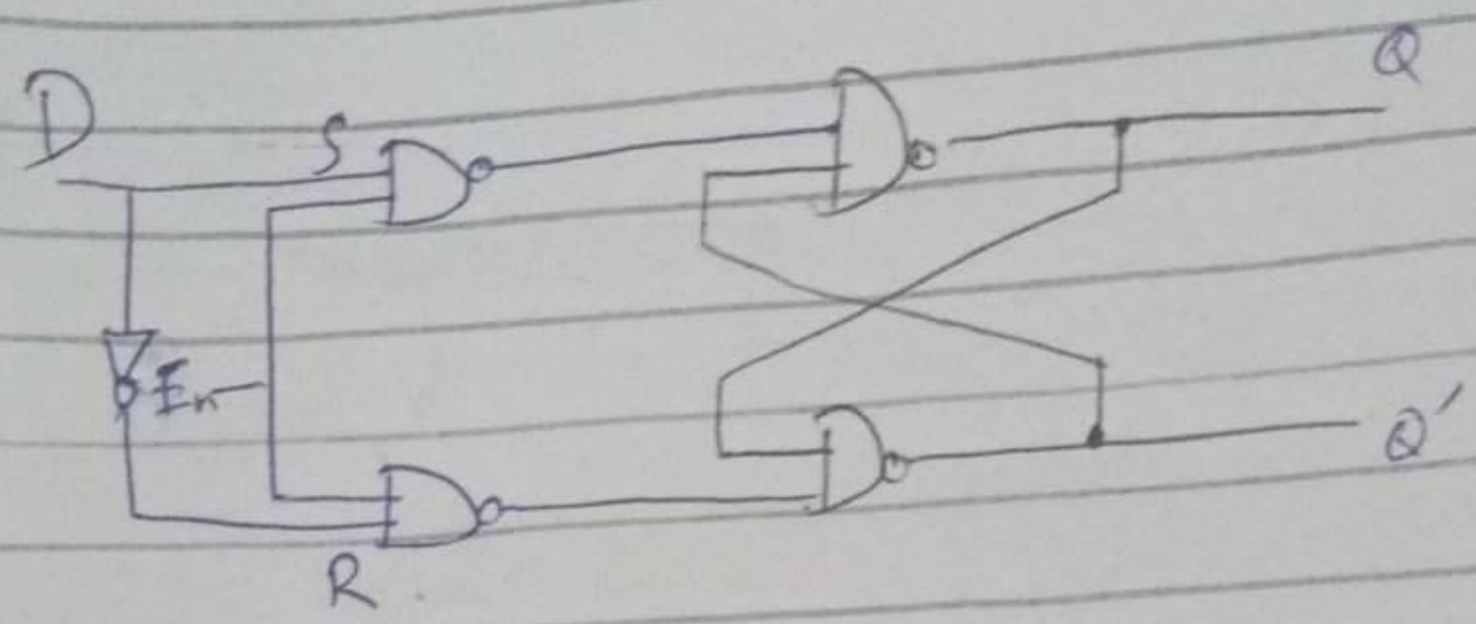
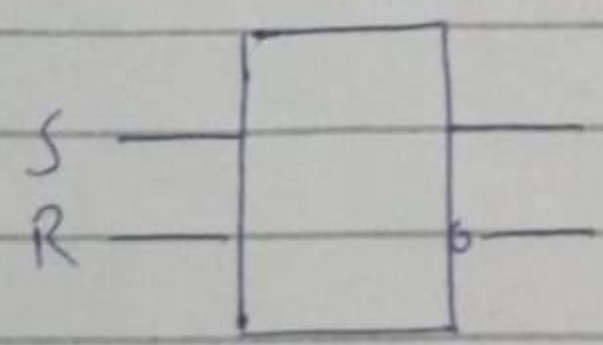
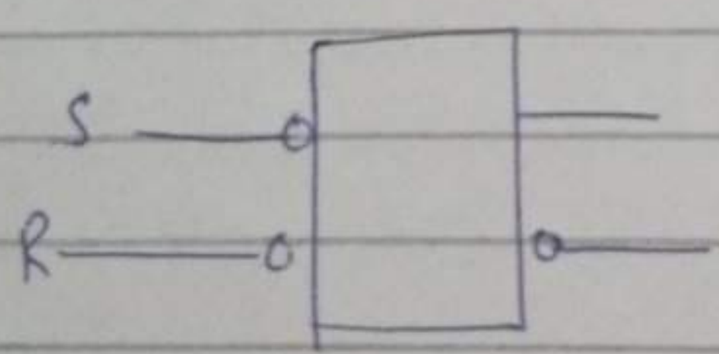
D-latch (transparent latch) (Level tiger)



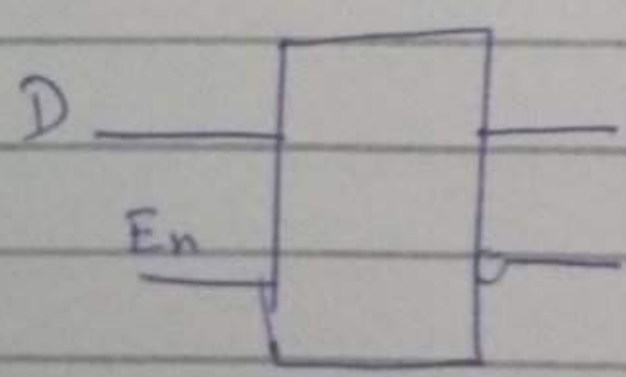
En	D	Q* (next State of Q).
0	X	No-change.
1	0	Q=0 (Reset)
1	1	Q=1 (Set)



SR latch



S'R' latch



D-latch

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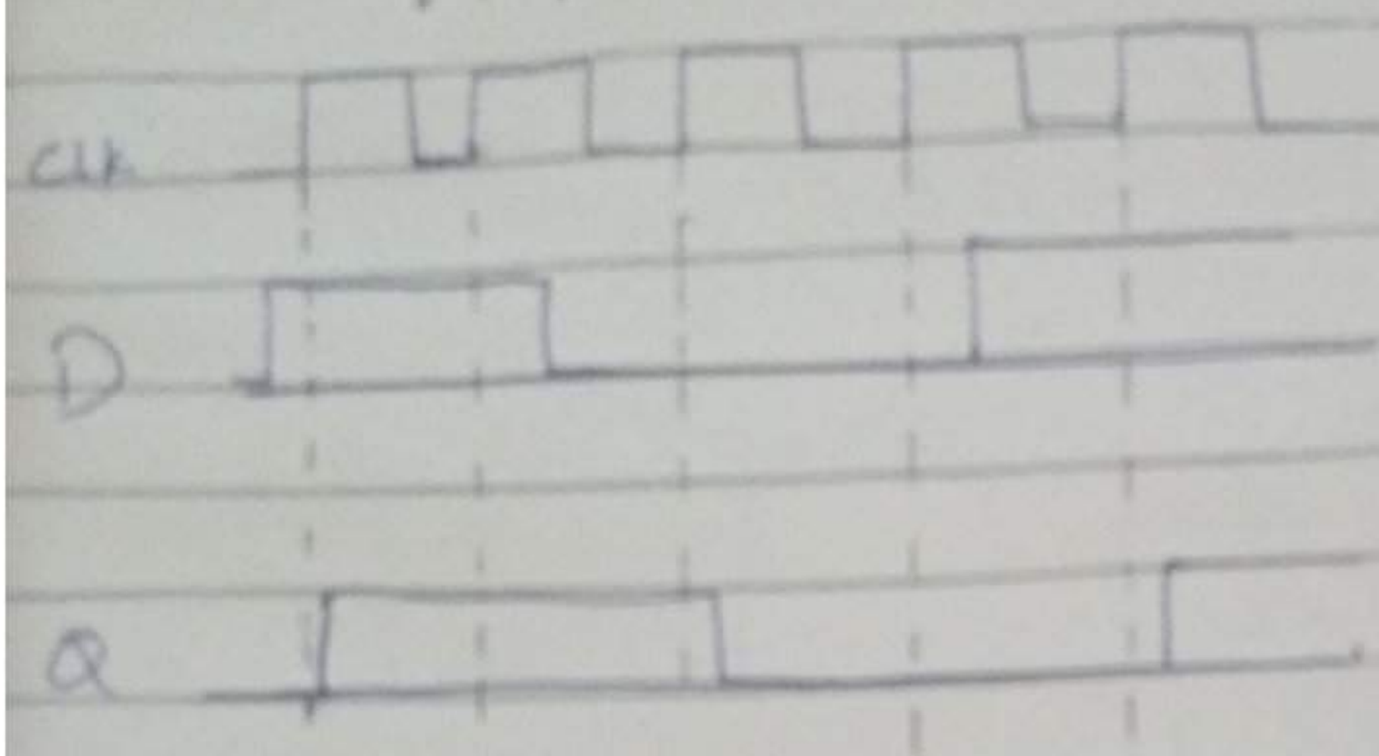
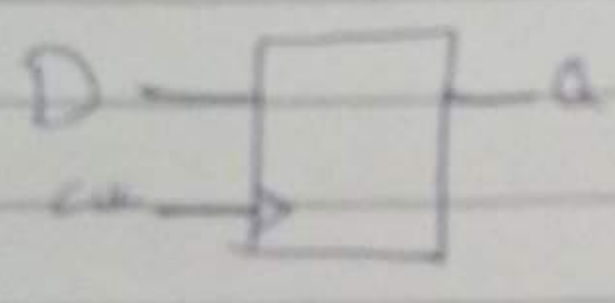
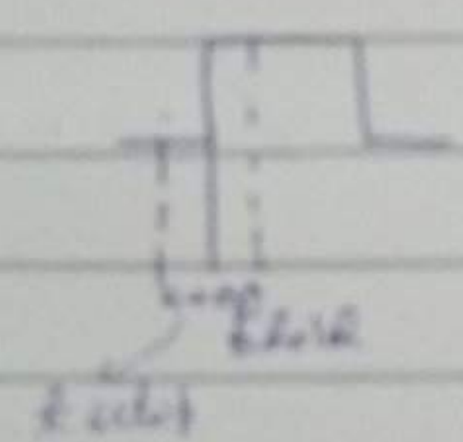
Flip-flop is base building block of register

D-Flipflop :-







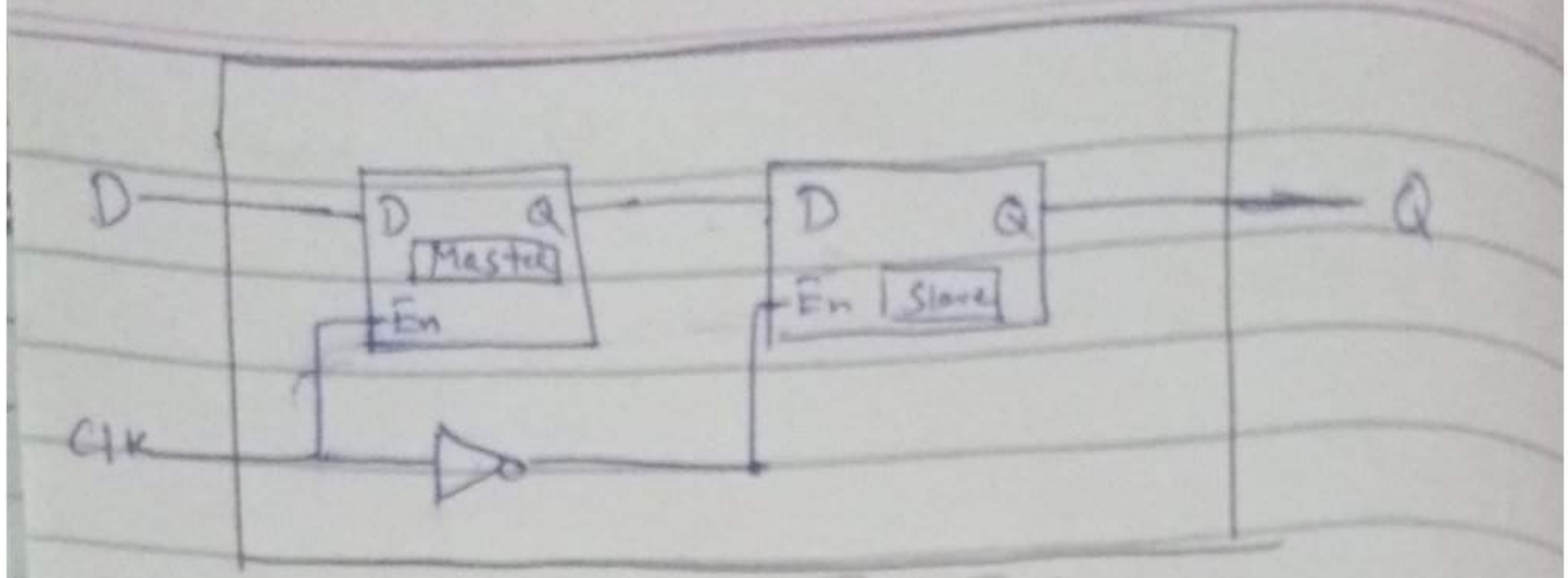
clk to Q delay

T_{cq}, T_{setup}, T_{hold}

$T_{combinational}$

$T_{cq} + T_{setup} + T_{comb} \leq (T_{period})$

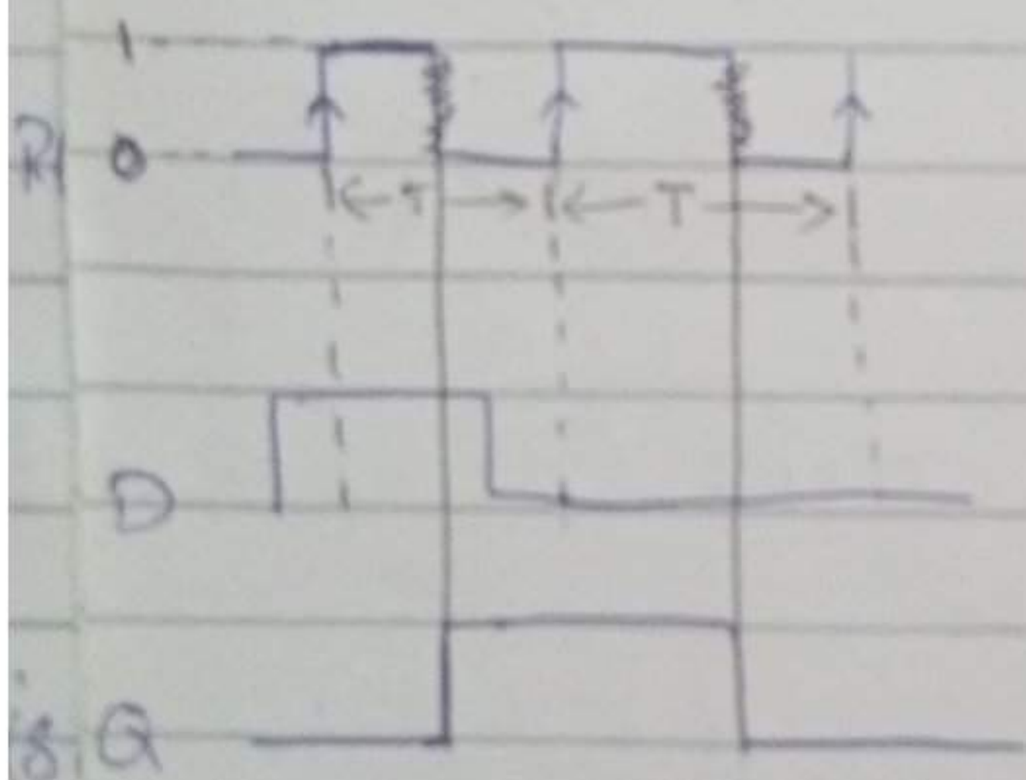
↳ minimum time period of your clock



Flip-Flop

En	D	Q
0	X	N.C
1	0	Q=0
1	1	Q=1

(work on falling Edge)



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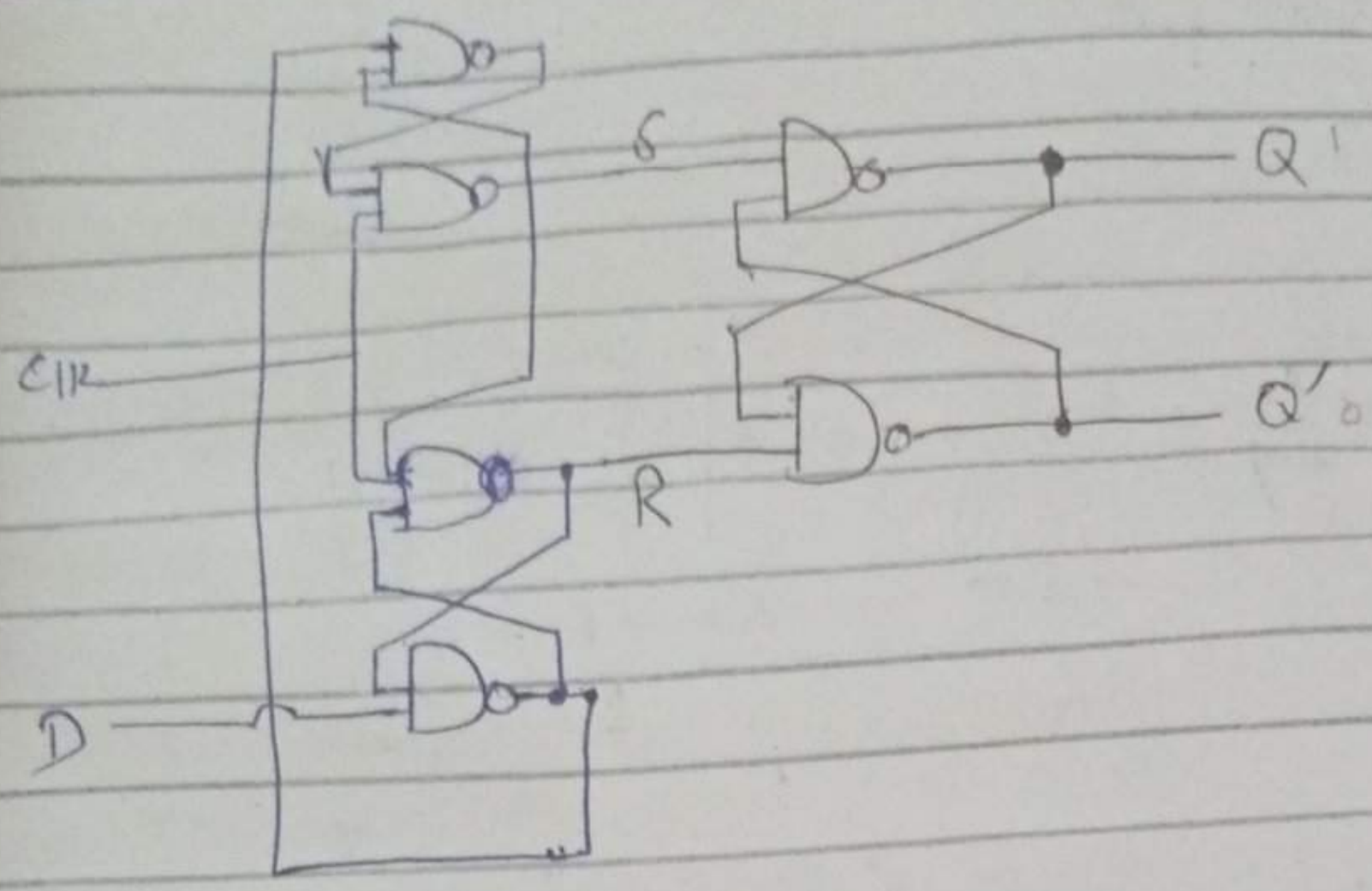

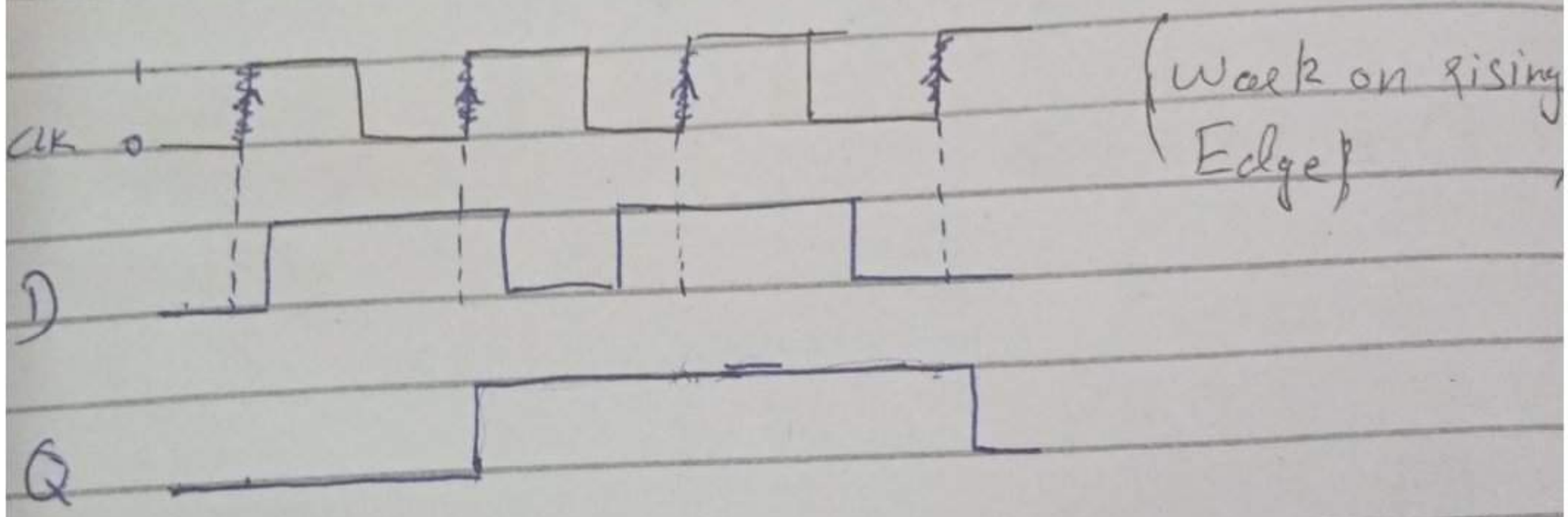

(Work on rising Edge)

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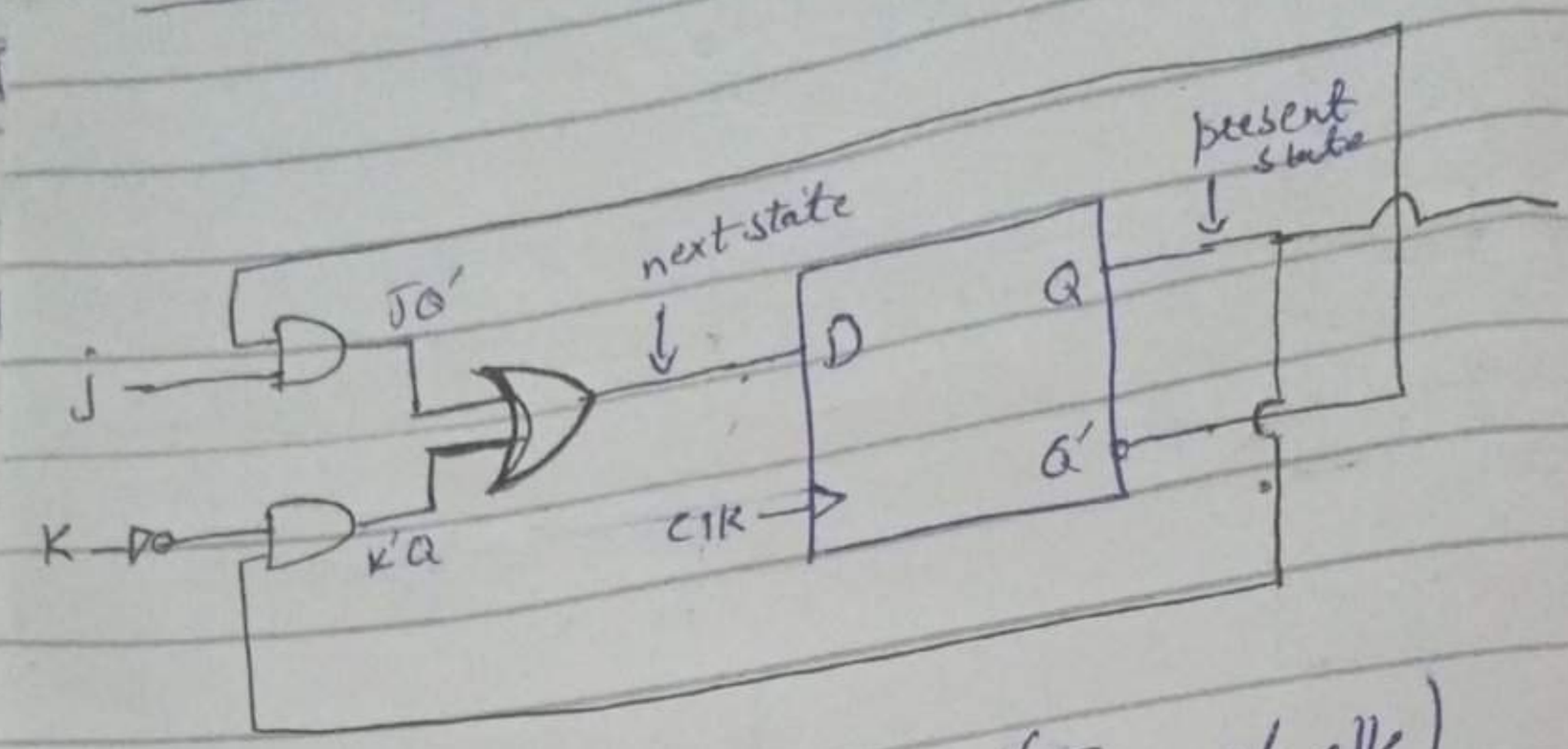
J-K Flip-Flop:-

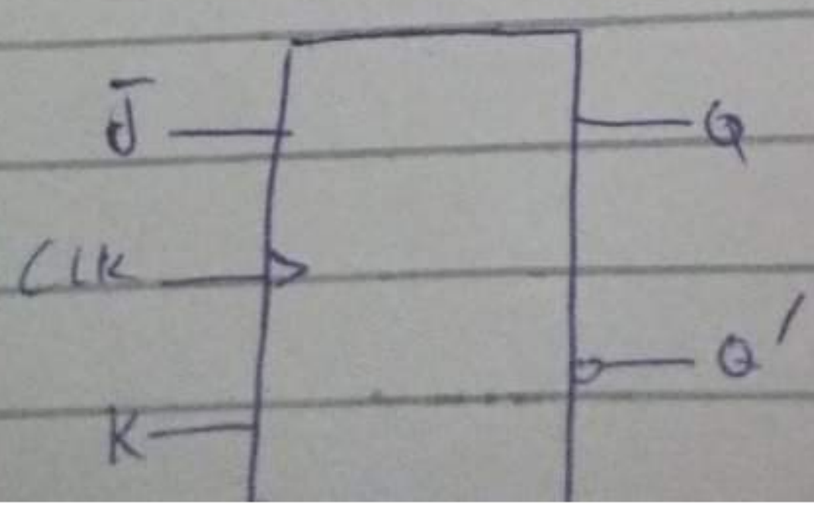


$t_{comb} + t_{setup} + t_{CQ} \leq$ (Time of clk)

$D = JQ' + K'Q$

Set J	Reset K	Q(t+1)
0	0	Q
0	1	0
1	0	1
1	1	Q'

Three operation
set, rest and complemint output



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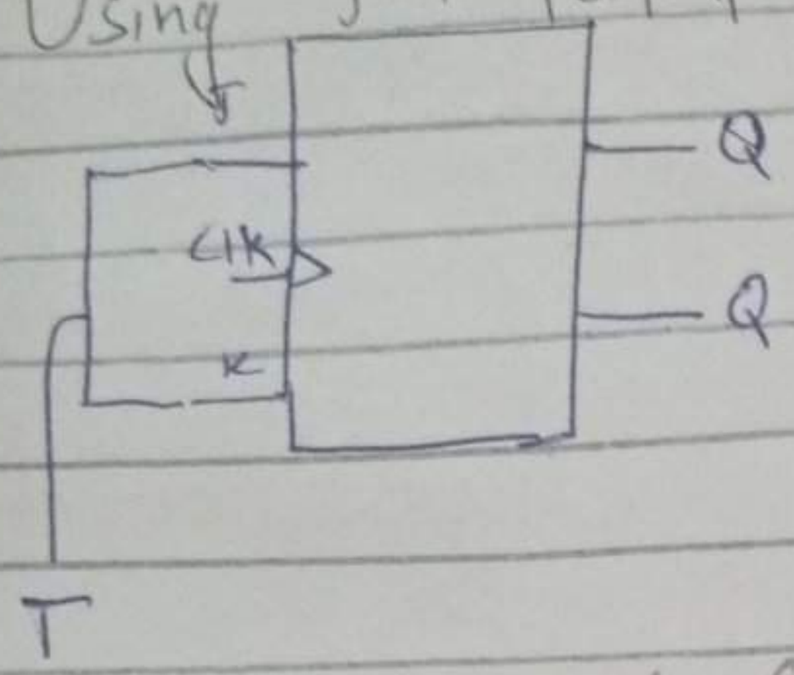
T-flip flop

(a) Using J-K flip flop



Q_t = present state Q_{t+1} = next state

T	J	K	$Q_{(t+1)}$
0	0	0	Q
1	1	1	Q'

$D = TQ' + T'Q$

$D = T \oplus Q$

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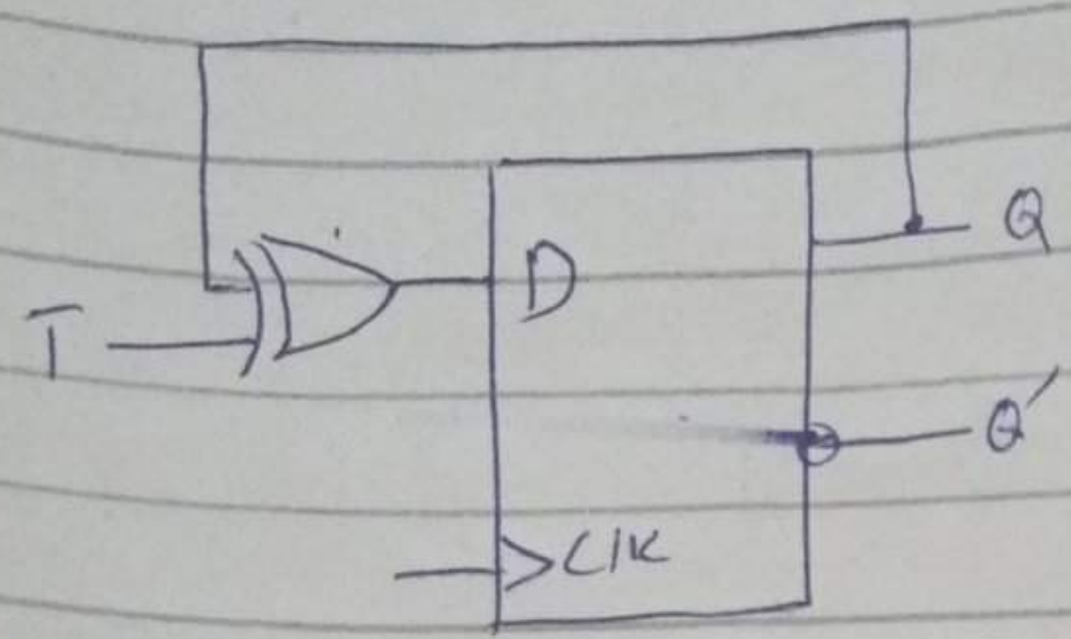
(b) Using Exclusive or Gate



A/Q	B/T	XOR
0	0	0
0	1	1
1	0	1
1	1	0

T	Q	D
0	0/1	Q
1	0/1	Q'

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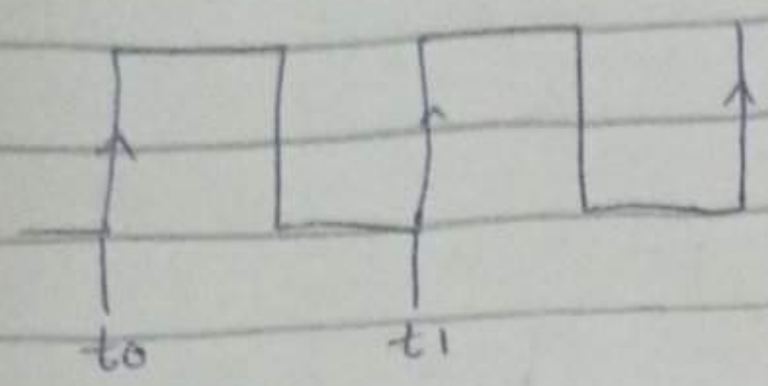
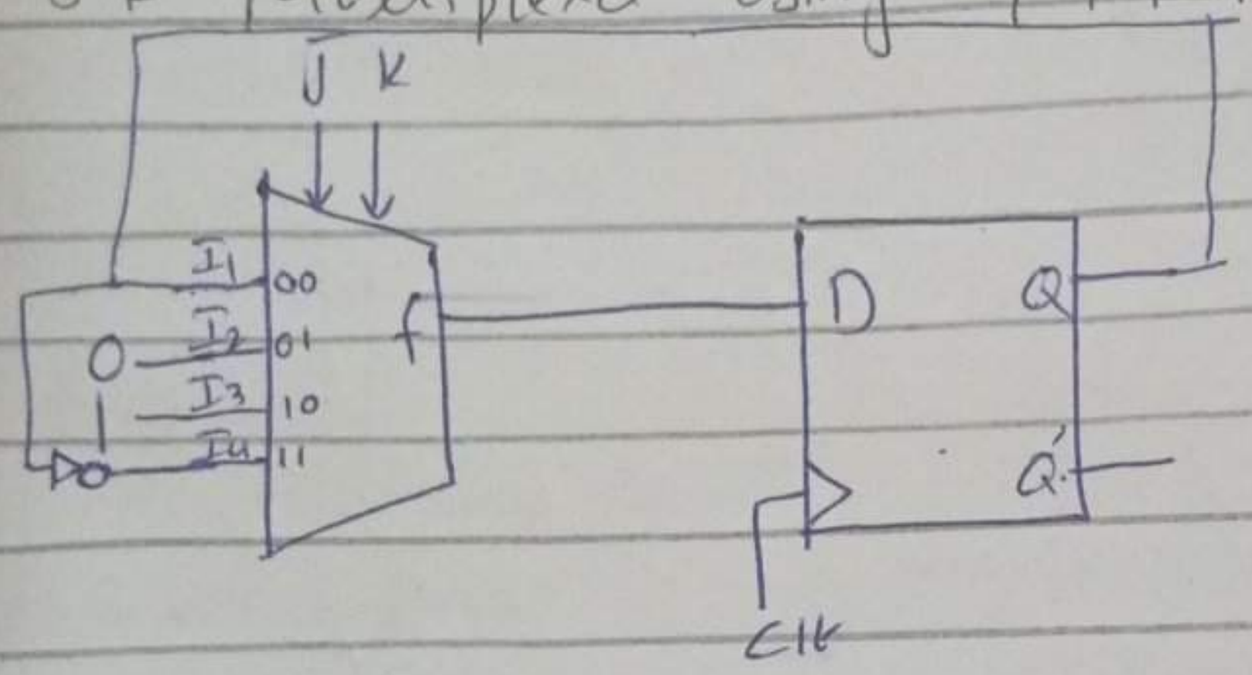


$T = t_1 - t_0$

$f = \frac{1}{T}$ (Hz)

JK Multiplexed using filp flop



Clock

→▷ (rising edge) ↑

→○▷ (falling edge) ↓

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Characteristic Equation

D flip flop : $D = Q(t+1)$

JK flip flop : $Q(t+1) = JQ' + K'Q$

T flip flop : $Q(t+1) = T \oplus Q$

$Q(t+1) = TQ' + T'Q$

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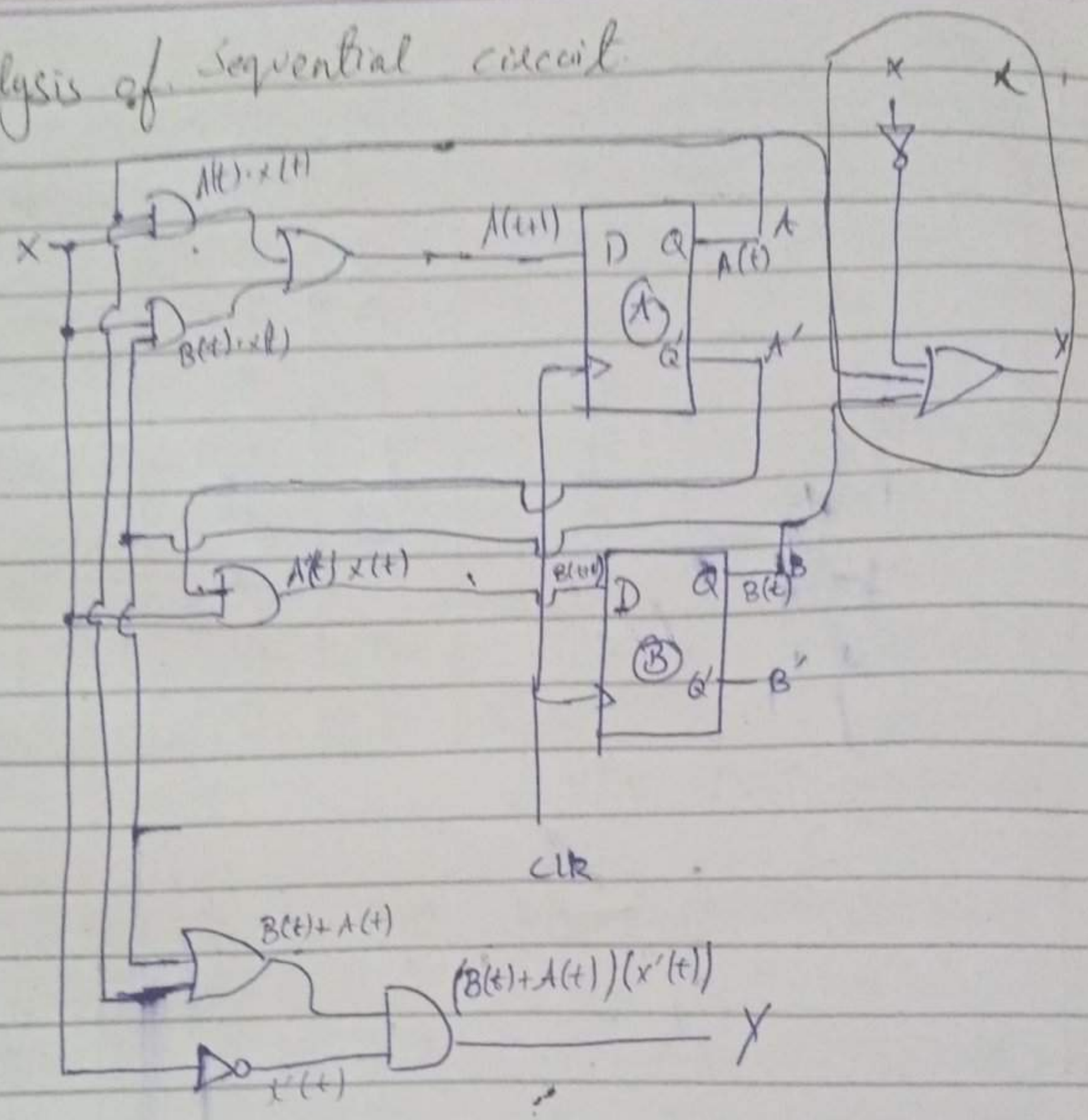
Analysis of sequential circuit



$$A(t+1) = A(t).x(t) + B(t).x(t)$$

$$B(t+1) = A'(t) \cdot x(t)$$

$$y(t) = (B(t) + A(t))(x(t))$$

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Scanned with CamScanner

State Table

Present State		Input	Next State		Output
A	B	x	A	B	Y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
0	1	0	0	0	1
1	0	1	1	0	0
1	0	0	0	0	1
1	1	0	1	0	0
1	1	1			

Simplify truth lable

present State		Next State				Output
		x0		x1		x0
A	B	A	B	A	B	Y
0	0	0	0	0	1	0
0	1	0	0	1	1	1
1	0	0	0	1	0	1
1	1	0	0	1	0	1

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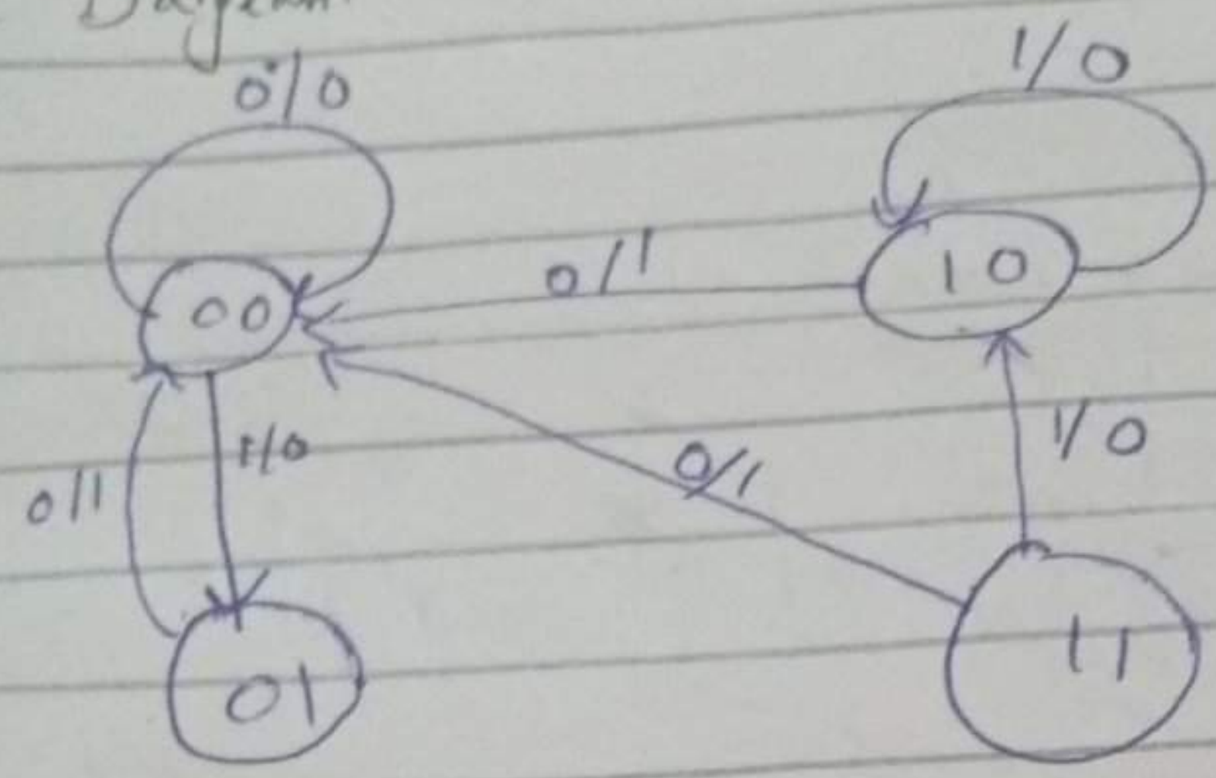
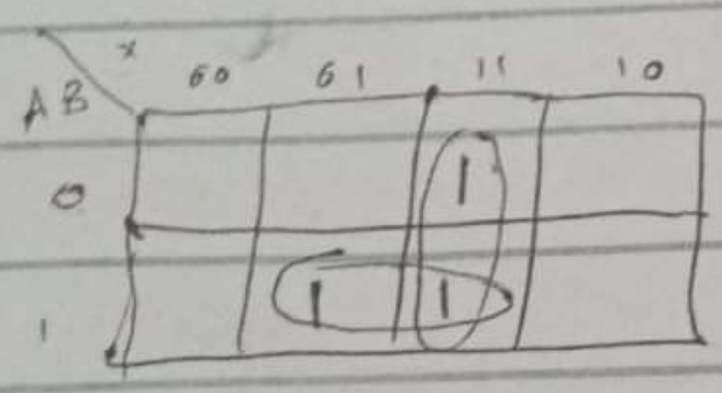
Graphical method to Define.

State Daigram



$A(t+1) = A'Bx + AB'x + ABx$



$A + Bx$

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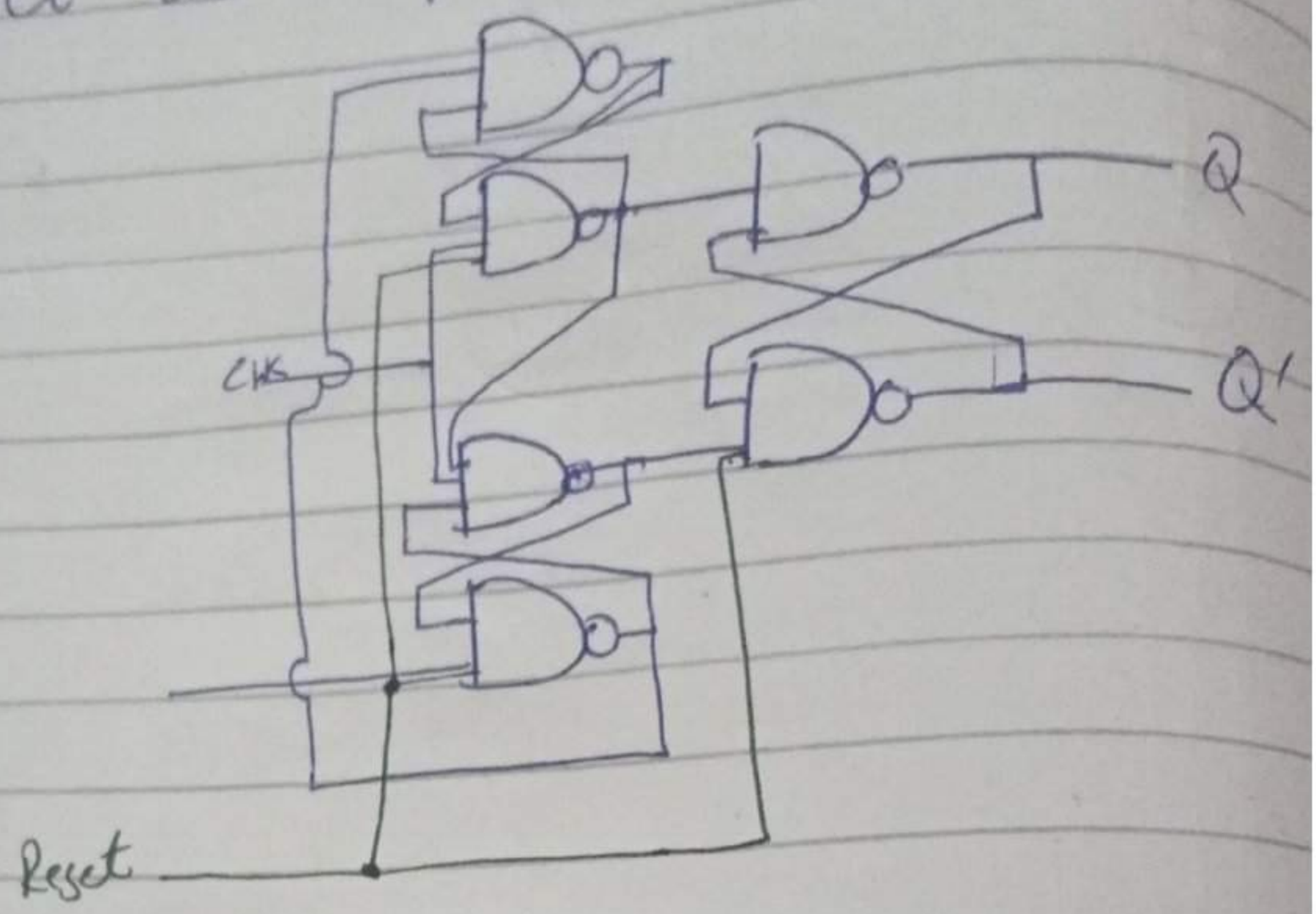
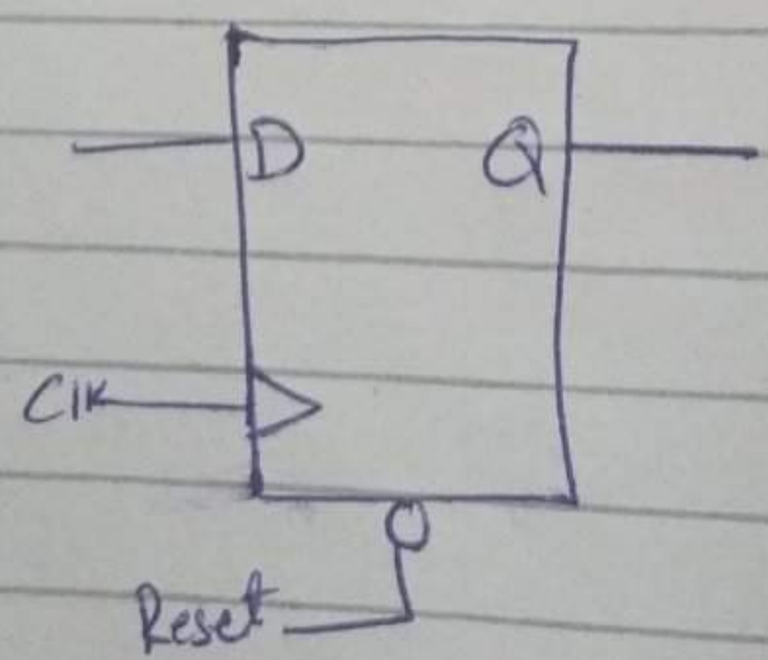
Reset the Flip Flop



R	CLK	D	Q
0	x	x	0
1	↑	0	0
1	↑	1	1



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