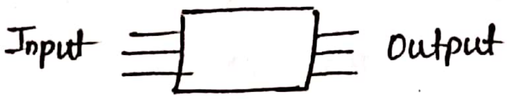
Combinational circuit and Sequential circuit

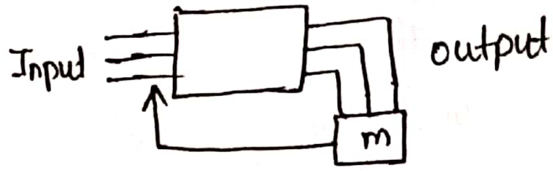
Digital electronics

- **Combinational circuit:** output is only depending on present input
- **Sequential circuit:** Output is depending on present input and past output



→ No feedback

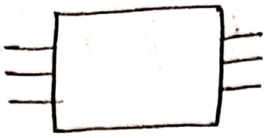
→ No memory



Example:
- Half Adder, Full Adder
- Half Subtractor, Full Subtractor
- Multiplexer and Demultiplexer
- Decoder, Encoder
- Code converter

Example:
- Counter
- Shift register
- Flip Flop

Designing of combinational circuits:

Inputs  Outputs

Step-1: Determine and define total inputs and outputs of the circuit.

Step-2: Make truth table that defines relationship in between inputs and outputs.

Step-3: Determine boolean equation using k-map.

Step-4: Based on boolean equation we can form circuit.

Question: 01

The minimal function that can detect "divisible by 2" with 8421 BCD [$D_8 D_4 D_2 D_1$] is given by _____

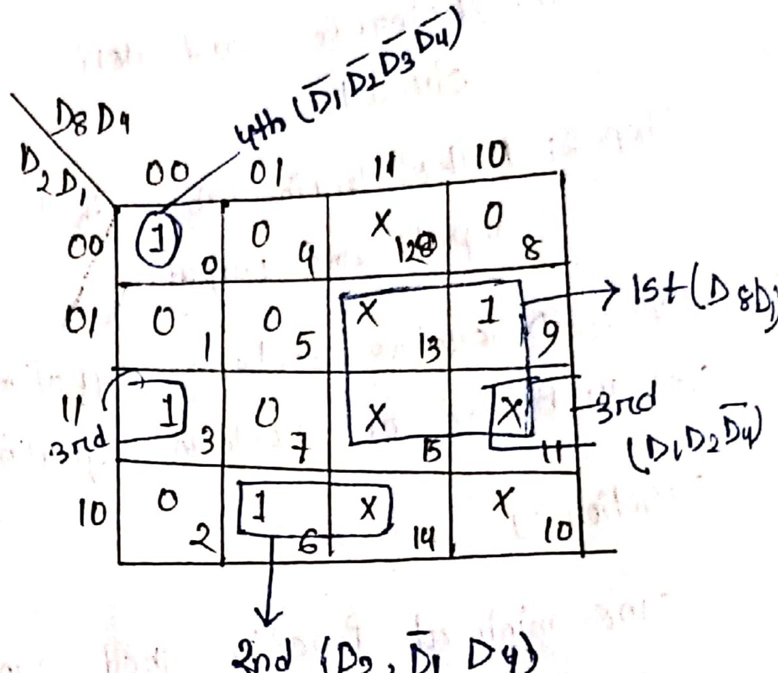
	D_8	D_4	D_2	D_1	Y
0	0	0	0	0	1
1	0	0	0	1	0
2	0	0	1	0	1
3	0	0	1	1	0
4	0	1	0	0	1
5	0	1	0	1	0
6	0	1	1	0	1
7	0	1	1	1	0
8	1	0	0	0	1
9	1	0	0	1	0
10	1	0	1	0	X
⋮	⋮	⋮	⋮	⋮	⋮
15	1	1	1	1	X

y: D_2D_1 \ D_8D_4	$\bar{D_8}\bar{D_4}$ 00	$\bar{D_8}D_4$ 01	D_8D_4 11	$D_8\bar{D_4}$ 10
$\bar{D_2}\bar{D_1}$ 00	1 (0)	1 (4)	X (12)	1 (8)
$\bar{D_2}D_1$ 01	0 (1)	0 (5)	X (13)	0 (9)
D_2D_1 11	0 (3)	0 (7)	X (15)	X (11)
$D_2\bar{D_1}$ 10	1 (2)	1 (6)	X (14)	X (10)

$$y = \bar{D_1}$$

Question-2 The minimal function that can detect "divisible by 3' with 8421 BCD [D_8 D_4 D_2 D_1] is given by ____

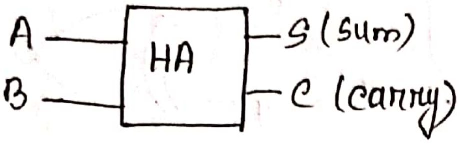
	D_8	D_4	D_2	D_1	y
0	0	0	0	0	1
1	0	0	0	1	0
2	0	0	1	0	0
3	0	0	1	1	1
4	0	1	0	0	0
5	0	1	0	1	0
6	0	1	1	0	1
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	1
10	1	0	1	0	X
⋮	⋮	⋮	⋮	⋮	⋮
15	1	1	1	1	X

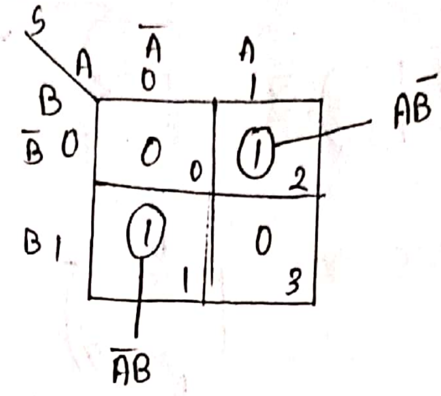


$$y = D_1 D_8 + \bar{D_1} D_2 D_4 + D_1 D_2 \bar{D_4} + \bar{D_1}\bar{D_2}\bar{D_3}\bar{D_4}$$

Half Adder

→ we perform two bit addition

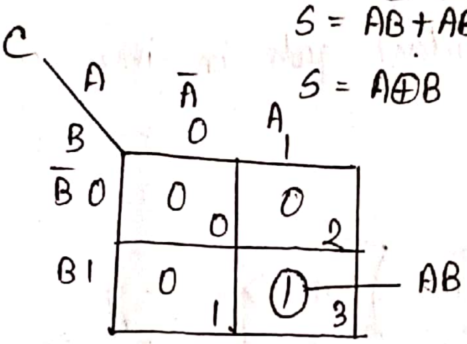




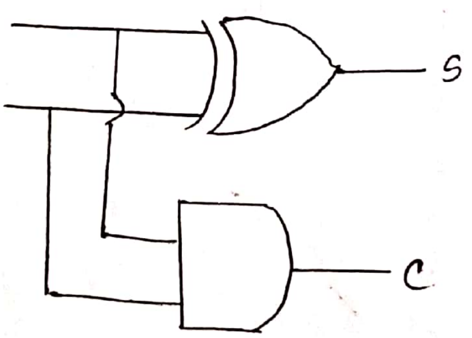
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

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

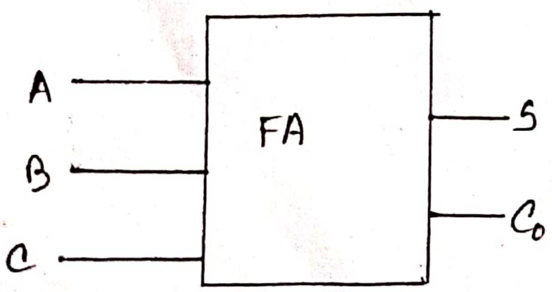
$S = A \oplus B$



$C = A \cdot B$



Full Adder: used to perform 3 bit addition



	A	B	C	S	C_o
0	0	0	0	0	0
1	0	0	1	1	0
2	0	1	0	1	0
3	0	1	1	0	1
4	1	0	0	1	0
5	1	0	1	0	1
6	1	1	0	0	1
7	1	1	1	1	1

S

C \ AB	$\bar{A}\bar{B}$ 00	$\bar{A}B$ 01	AB 11	$A\bar{B}$ 10
$\bar{C}$ 0	0 (0)	1 (2)	0 (6)	1 (4)
C 1	1 (1)	0 (9)	1 (7)	0 (5)

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

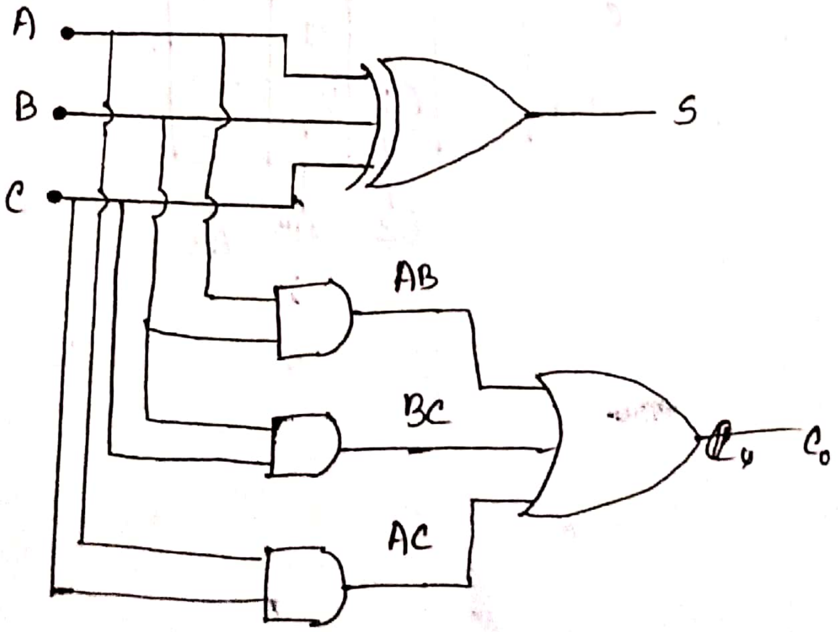
$$S = \bar{A}\bar{B}C + \bar{A}B\bar{C} + ABC + A\bar{B}\bar{C}$$
$$= \bar{A}(\bar{B}C + B\bar{C}) + A(BC + \bar{B}\bar{C})$$
$$= \bar{A}(B \oplus C) + A \cdot (B \odot C)$$
$$= \bar{A}(B \oplus C) + A\,\overline{(B \oplus C)}$$
$$= A \oplus B \oplus C$$

C_o

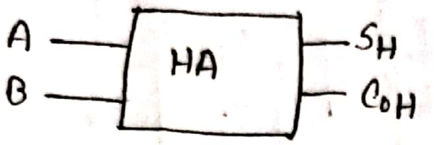
C \ AB	$\bar{A}\bar{B}$ 00	$\bar{A}B$ 01	AB 11	$A\bar{B}$ 10
$\bar{C}$ 0	0 (0)	0 (2)	1 (6)	0 (4)
C 1	0 (1)	1 (3)	1 (7)	1 (5)

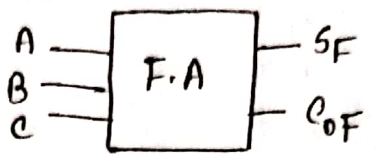
BC $\quad$ AB $\quad$ AC

$$C_o = AB + BC + AC$$



Full Adder circuit using half Adder



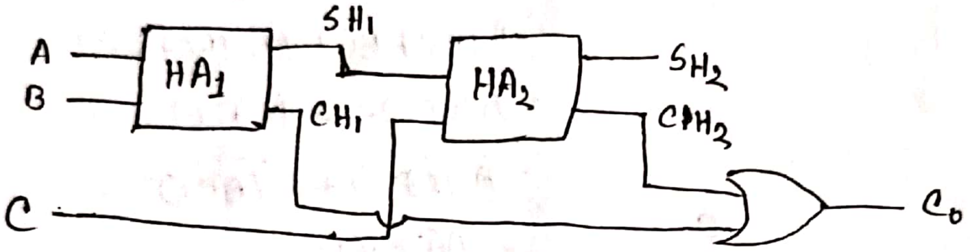


$S_H = A \oplus B$

$C_{oH} = A.B$

$S_F = A \oplus B \oplus C$

$S_{oF} = AB + BC + CA$



$SH_1 = A \oplus B$

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

$CH_1 = A.B$

$SH_2 = SH_1 + C = A \oplus B \oplus C$

$CH_2 = SH_1 . C$

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

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

$C_o = CH_1 + CH_2$

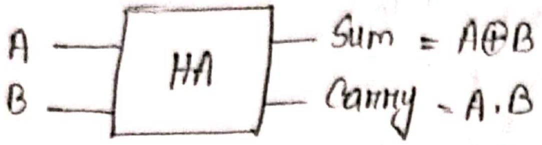
$= AB + A\bar{B}C + \bar{A}BC$

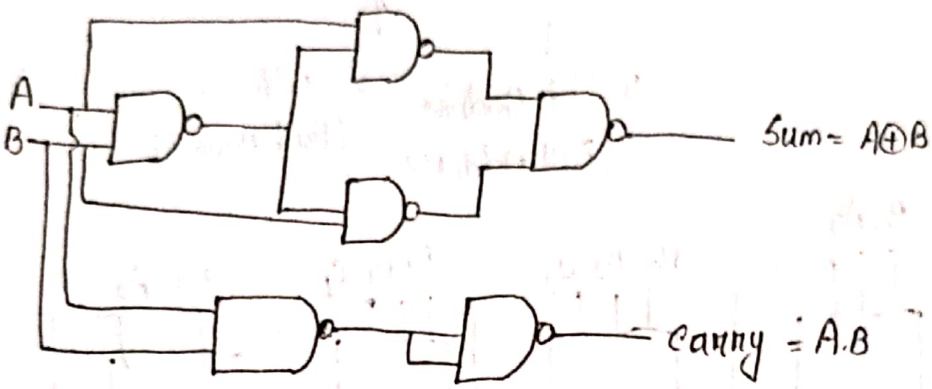
C_o

C \ AB	$\bar{A}\bar{B}$ 00	$\bar{A}B$ 01	AB 11	$A\bar{B}$ 10
$\bar{C}$ 0			1	
C 1		1	1	1

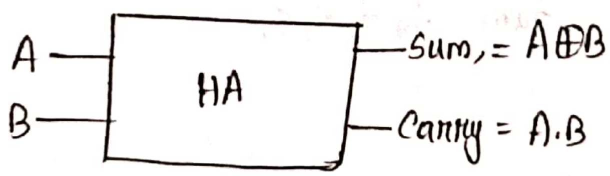
BC AB AC

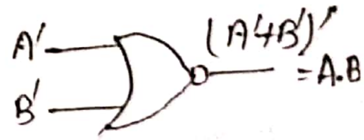
HALF ADDER BY NAND GATES

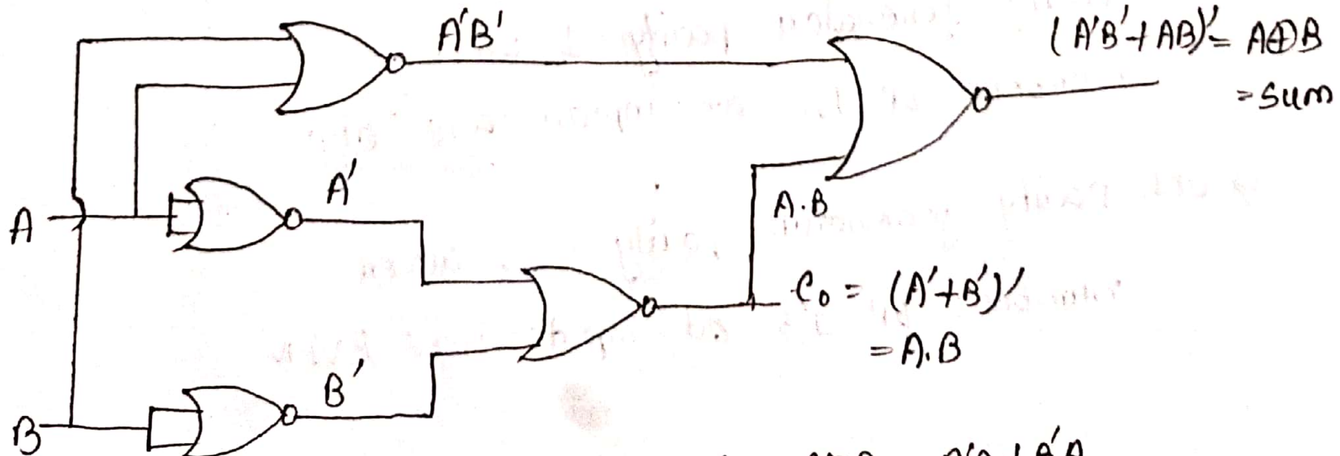




HALF ADDER BY NOR GATES





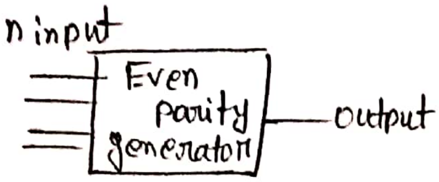


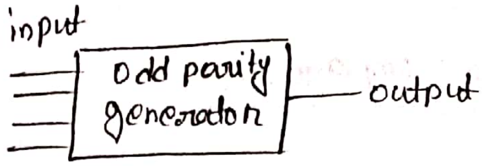
$$S = A \oplus B = A'B + B'A$$
$$= \overline{(A' \cdot B' + AB)}$$

Even parity Generator / odd parity Generator

→ Even parity generator parity = 1 when numbers of 1's at inputs are ODD

→ ODD parity generator parity = 1, when numbers of 1's at inputs are EVEN.





	b_3	b_2	b_1	b_0	O/P (Even parity) P	O/P (Odd parity) Q
(0)	0	0	0	0	0	1
(1)	0	0	0	1	1	0
(2)	0	0	1	0	1	0
(3)	0	0	1	1	0	1
(4)	0	1	0	0	1	0
(5)	0	1	0	1	0	1
(6)	0	1	1	0	0	1
(7)	0	1	1	1	1	0
(8)	1	0	0	0	1	0
(9)	1	0	0	1	0	1
(10)	1	0	1	0	1	0
(11)	1	0	1	1	1	0
(12)	1	1	0	0	0	1
(13)	1	1	0	1	1	0
(14)	1	1	1	0	1	0
(15)	1	1	1	1	0	1

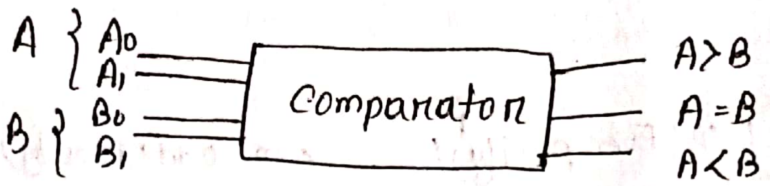
P

b_1b_0 \ b_3b_2	00	01	11	10
00	0_{0}	1_{4}	0_{12}	1_{8}
01	1_{1}	0_{5}	1_{13}	0_{9}
11	0_{3}	1_{7}	0_{15}	1_{11}
10	1_{2}	0_{6}	1_{14}	0_{10}

$$Q = \overline{b_3 \oplus b_1 \oplus b_2 \oplus b_3}$$

$$P(b_0\, b_1\, b_2\, b_3) = b_0 \oplus b_1 \oplus b_2 \oplus b_3$$

2 bits comparator



A_1	A_0	B_1	B_0	A>B	A=B	A<B	
0	0	0	0	0	1	0	0
0	0	0	1	0	0	1	1
0	0	1	0	0	0	1	2
0	0	1	1	0	0	1	3
0	1	0	0	1	0	0	4
0	1	0	1	0	1	0	5
0	1	1	0	0	0	1	6
0	1	1	1	0	0	1	7
1	0	0	0	1	0	0	8
1	0	0	1	1	0	0	9
1	0	1	0	0	1	0	10
1	0	1	1	0	0	1	11
1	1	0	0	1	0	0	12
1	1	0	1	1	0	0	13
1	1	1	0	1	0	0	14
1	1	1	1	0	1	0	15

(A>B)

B_1B_0 \ A_1A_0	$\bar{A}_1\bar{A}_0$ 00	$\bar{A}_1A_0$ 01	A_1A_0 11	$A_1\bar{A}_0$ 10
$\bar{B}_1\bar{B}_0$ 00	0 (0)	1 (4)	1 (12)	1 (8)
$\bar{B}_1B_0$ 01	0 (1)	0 (5)	1 (13)	1 (9)
B_1B_0 11	0 (3)	0 (7)	0 (15)	0 (11)
$B_1\bar{B}_0$ 10	0 (2)	0 (6)	1 (14)	0 (10)

3rd

$A_0\bar{B}_1\bar{B}_0$ (2nd group)

$A_1\bar{B}_1$ (1st group)

3rd group ($A_1A_0\bar{B}_0$)

$$(A>B) = A_1\bar{B}_1 + A_0\bar{B}_1\bar{B}_0 + A_1A_0\bar{B}_0$$

$$= A_1\bar{B}_1 + A_0\bar{B}_0(\bar{B}_1 + A_1)$$

A=B

B_1B_0 \ A_1A_0	$\bar{A}_1\bar{A}_0$ 00	$\bar{A}_1A_0$ 01	A_1A_0 11	$A_1\bar{A}_0$ 10
$\bar{B}_1\bar{B}_0$ 00	1 (0)	0 (4)	0 (12)	0 (8)
$\bar{B}_1B_0$ 01	0 (1)	1 (5)	0 (13)	0 (9)
B_1B_0 11	0 (3)	0 (7)	1 (15)	0 (11)
$B_1\bar{B}_0$ 10	0 (2)	0 (6)	0 (14)	1 (10)

1st group ($\bar{A}_1\bar{A}_0\bar{B}_1\bar{B}_0$)

2nd group ($\bar{A}_1A_0\bar{B}_1B_0$)

3rd group ($A_1A_0B_1B_0$)

4th group ($A_1\bar{A}_0B_1\bar{B}_0$)

$$(A=B) = \bar{A}_1\bar{A}_0\bar{B}_1\bar{B}_0 + \bar{A}_1A_0\bar{B}_1B_0 + A_1A_0B_1B_0 + A_1\bar{A}_0B_1\bar{B}_0$$

$$= \bar{A}_1\bar{B}_1(\bar{A}_0\bar{B}_0 + A_0B_0) + A_1B_1(B_1B_0 + \bar{A}_0\bar{B}_0)$$

(A<B)

B_1B_0 \ A_1A_0	$\bar{A}_1\bar{A}_0$ 00	$\bar{A}_1A_0$ 01	A_1A_0 11	$A_1\bar{A}_0$ 10
$\bar{B}_1\bar{B}_0$ 00	0 (0)	0 (4)	0 (12)	0 (8)
$\bar{B}_1B_0$ 01	1 (1)	0 (5)	0 (13)	0 (9)
B_1B_0 11	1 (3)	1 (7)	0 (15)	1 (11)
$B_1\bar{B}_0$ 10	1 (2)	1 (6)	0 (14)	0 (10)

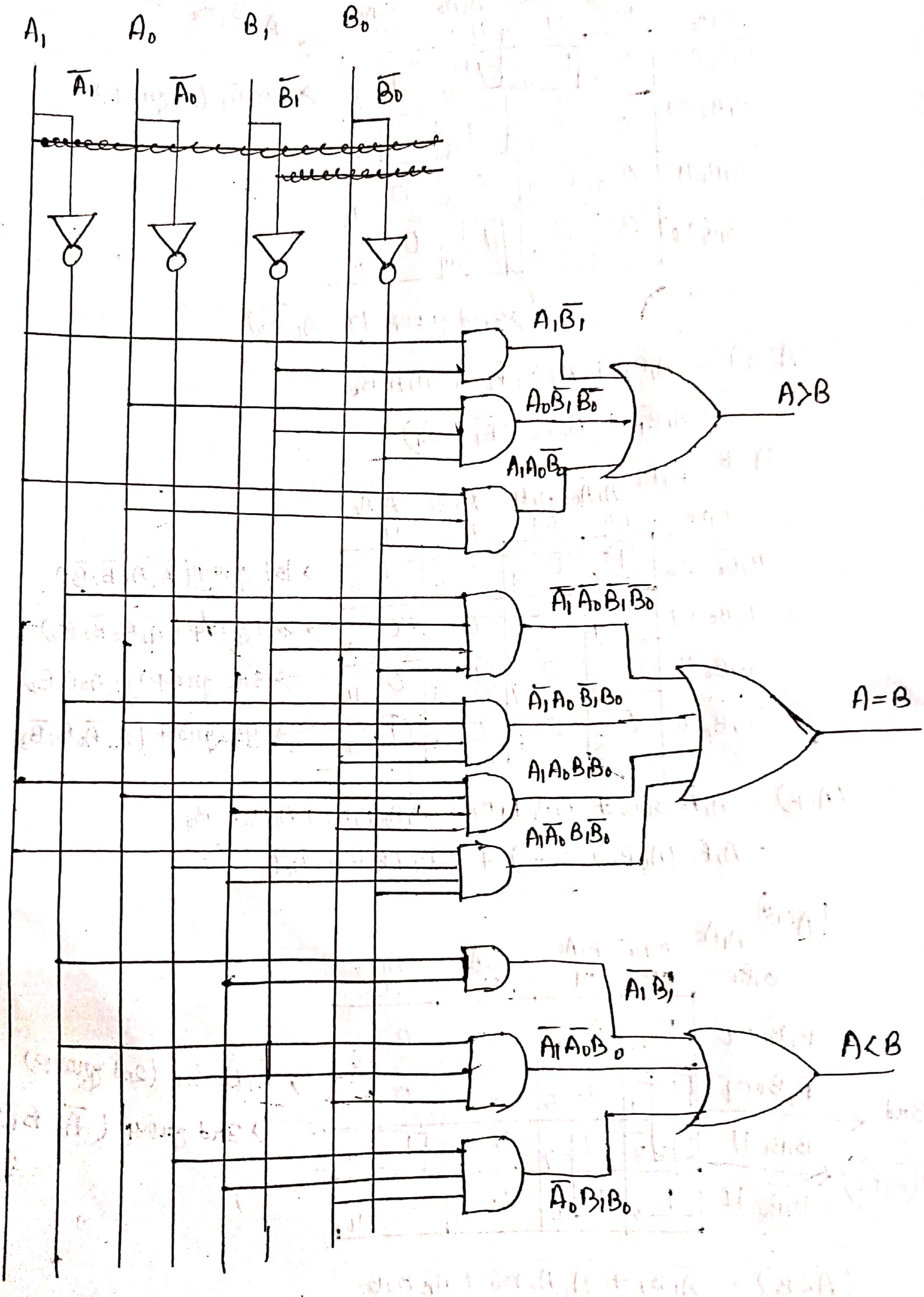
$\bar{A}_1\bar{A}_0B_0$ (2nd group)

3rd

3rd group ($\bar{A}_0B_1B_0$)

1stgrp($\bar{A}_1\bar{B}_1$)

$$(A<B) = \bar{A}_1B_1 + \bar{A}_1\bar{A}_0B_0 + \bar{A}_0B_1B_0$$



A_1
A_0
B_1
B_0
$\overline{A_1}$
$\overline{A_0}$
$\overline{B_1}$
$\overline{B_0}$
$A_1\overline{B_1}$
$A_0\overline{B_1}\,\overline{B_0}$
$A_1A_0\overline{B_0}$
$A>B$
$\overline{A_1}\,\overline{A_0}\,\overline{B_1}\,\overline{B_0}$
$\overline{A_1}A_0\overline{B_1}B_0$
$A_1A_0B_1B_0$
$A_1\overline{A_0}B_1\overline{B_0}$
$A=B$
$\overline{A_1}B_1$
$\overline{A_1}\,\overline{A_0}B_0$
$A<B$
$\overline{A_0}B_1B_0$