Assignment-2

Title Code converter

Problem Statement To Design and Implement the circuit for the following 4-bit code conversion.

1. Binary to Gray code
2. Gray to Binary code
3. BCD to Excess-3 code
4. Excess-3 to BCD code

Hardware and software requirements Digital Trainer Kit, IC 7404, IC 7432, IC 7408, IC 7486, Patch cord, +5V Power supply

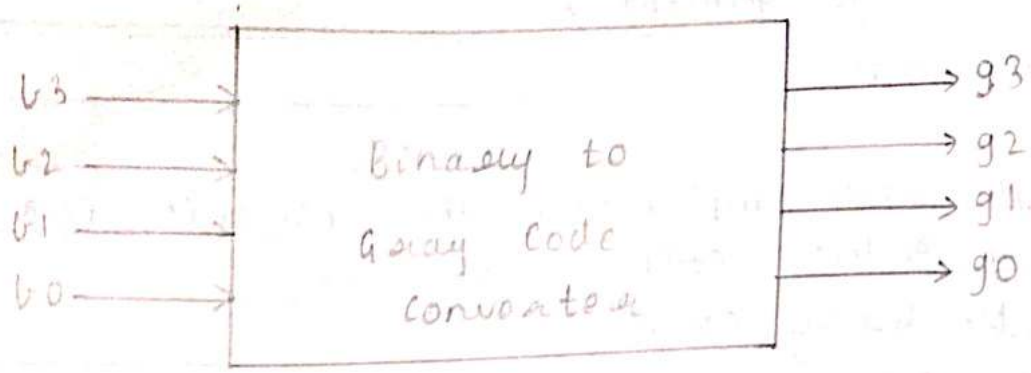
Theory: 1. Binary code:

- It is straight binary code. The binary number system (with base 2) represents value using two symbols, typically 0 and 1.
- Computers call these bits as either off (0) or on (1)
- The binary code are made up of only zeroes and ones, and used in computers to stand for letters and digits.
- It is used to represent numbers using natural or straight binary form.
- It is a weighted code since a weight is assigned to every position.
- Binary code is weighted and sequential code

2. Gray code

- It is a modified code in which a decimal number is represented in binary form in such a

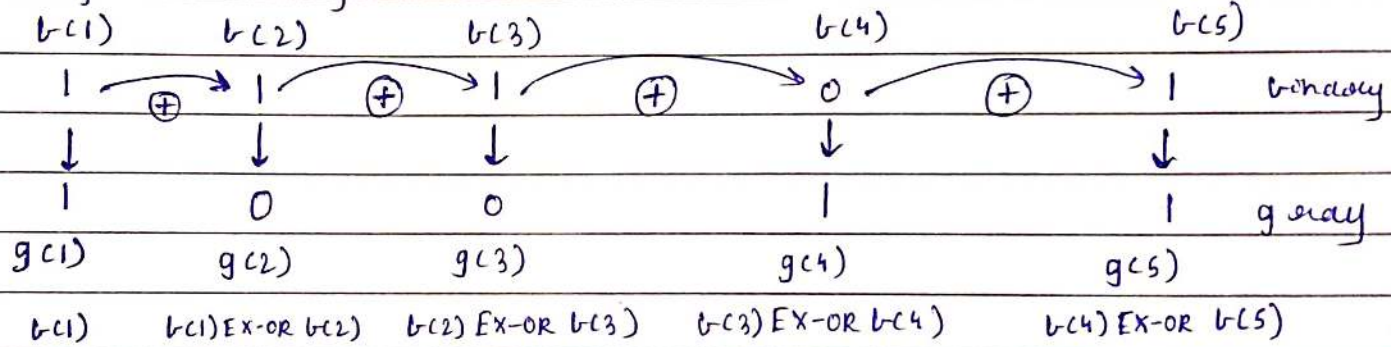
→ Binary to Gray code conversion



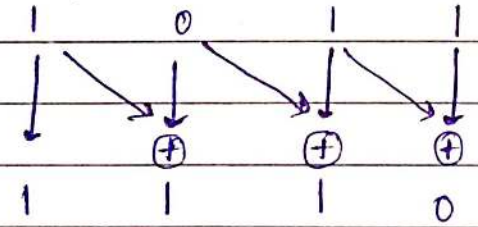
way that each Gray-Code number differs from the preceding and the succeeding number by a single bit.

- Eg: for decimal number 5 the equivalent Gray code is 0111 and for 6 it is 0101. These two codes differ by only one bit position i.e. third from the left.
- Whereas by using binary code there is a possibility of change of all bits if we move from one ~~no~~ number to other in sequence.
- eg: Binary code for 7 is 0111 and 8 it is 1000.

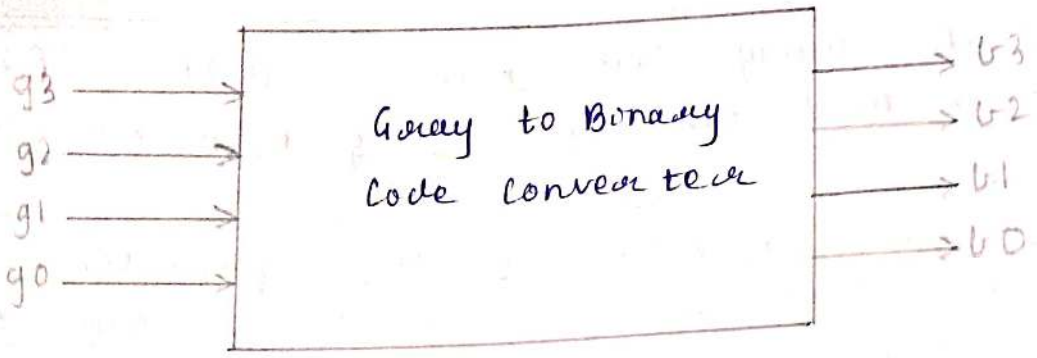
→ Binary to Gray Code Conversion



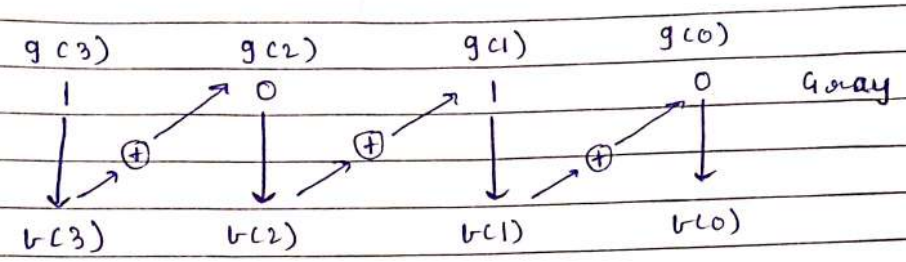
eg: Gray code of $(1011)_2$



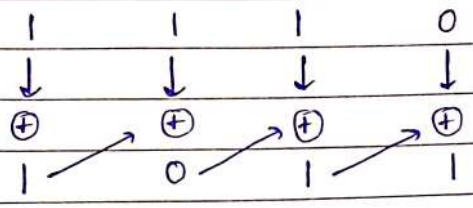
→ Gray to Binary code conversion



→ Gray to binary code Conversion



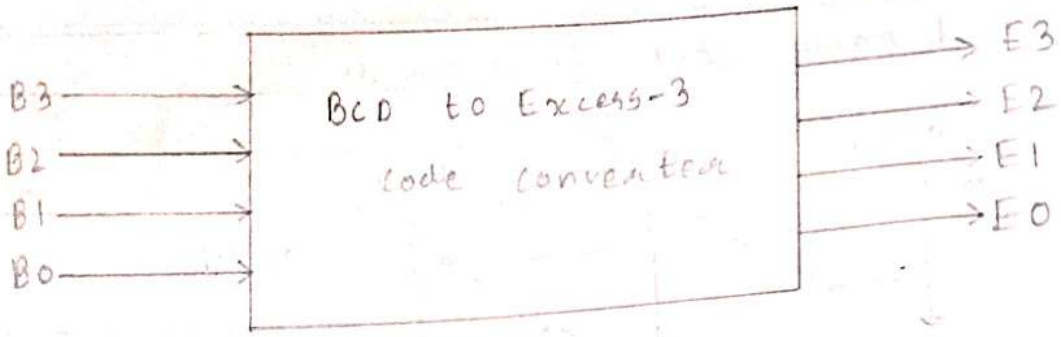
eg: (1110) gray code into binary



3. BCD code

- Binary coded Decimal (BCD) is used to represent each of decimal digits (0 to 9) with a 4-bit binary code.
- For example, $(23)_{10}$ is represented by 0010 0011 using BCD code rather than $(10111)_2$.
- This code is also known as 8-4-2-1 code as 8421 indicates the binary weights of four bits ($2^3, 2^2, 2^1, 2^0$).
- It is ~~the m~~ easy to convert BCD code numbers and the familiar decimal numbers. It is the main advantage of this code.
- With four bits, 16 numbers (0000 to 1111) can be presented, but in BCD code only 10 of these are used.

→ BCD to Ex-3 Code Conversion



4. Excess 3 code

- Excess-3, also called XS3, is a non-weighted code used to express decimal numbers.
- It can be used for the representation of multi-digit decimal numbers as can BCD.
- The code for each decimal number is obtained by adding decimal 3 and then converting it to a 4-bit binary number.
- For eg: decimal 2 is coded as 0010 + 0011 = 0101 in Excess-3 code.
- This is self complimenting code which means 1's complement of the coded number yields 9's complement of the number itself.

→ BCD to EX-3 Code conversion

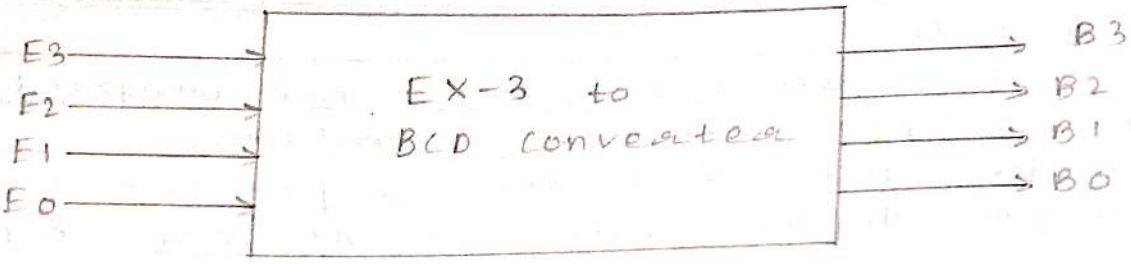
- Decimal number ⟶ 8421 BCD $\xrightarrow[0011]{\text{Add}}$ Excess-3

- Excess-3 for $(52)_{10}$ is,

5	2
0101	0010
+ 0011	+ 0011
1000	0101

∴ Excess-3 of $(52)_{10}$ = 1000 0101

→ EX-3 to BCD code conversion



→ EX-3 to BCD conversion

- Excess-3 $\xrightarrow{\text{subtract } 0011 \text{ or } 0011\ 0011}$ 8421 BCD
- eg: BCD for $(12)_{10}$ is,

1	2	
0100	0101	EX-3
−0011	−0011	
0001	0010	BCD

∴ BCD of $(12)_{10}$ is 0001 0010

~~Design:~~

1. ~~Binary to Gray code~~
2. ~~Truth table~~

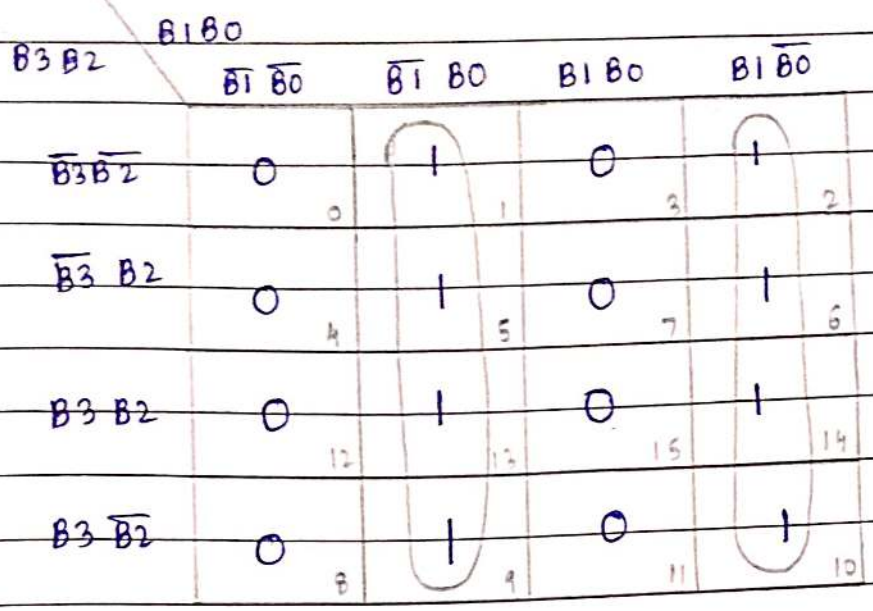
Design: 1. Binary to Gray code

- Truth Table

Binary				Gray code			
B3	B2	B1	B0	G3	G2	G1	G0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	0
0	1	0	1	0	1	1	1
0	1	1	0	0	1	0	1
0	1	1	1	0	1	0	0
1	0	0	0	1	1	0	0
1	0	0	1	1	1	0	1
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	1
1	1	1	1	1	0	0	0

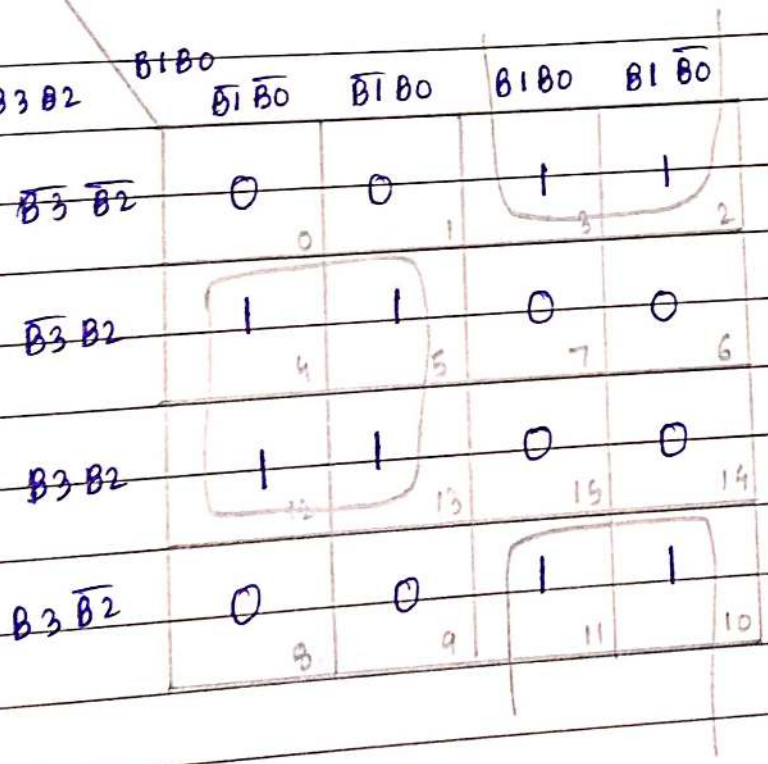
- K-map

1) G0



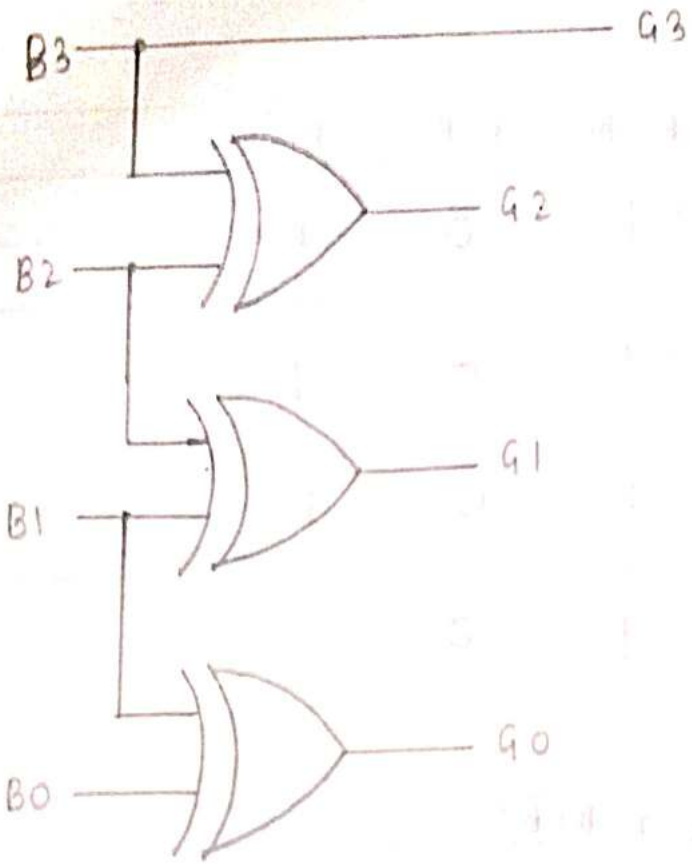
$$G0 = \overline{B1}\,B0 + B1\,\overline{B0}$$
$$= B1 \oplus B0$$

2) G1



$$G1 = B2\,\overline{B1} + \overline{B2}\,B1$$
$$= B1 \oplus B2$$

→ Circuit Diagram :-



3) G2

G2	$B_1\bar{B_0}$	$\bar{B_1}\bar{B_0}$	$\bar{B_1}B_0$	B_1B_0	$B_1\bar{B_0}$
$\bar{B_3}\bar{B_2}$	0 (0)	0 (1)	0 (3)	0 (2)
$\bar{B_3}B_2$	1 (4)	1 (5)	1 (7)	1 (6)
B_3B_2	0 (12)	0 (13)	0 (15)	0 (14)
$B_3\bar{B_2}$	1 (8)	1 (9)	1 (11)	1 (10)

$$G2 = \bar{B_3}B_2 + B_3\bar{B_2}$$
$$= B_2 \oplus B_3$$

4) G3

G3	$B_1\bar{B_0}$	$\bar{B_1}\bar{B_0}$	$\bar{B_1}B_0$	B_1B_0	$B_1\bar{B_0}$
$\bar{B_3}\bar{B_2}$	0 (0)	0 (1)	0 (3)	0 (2)
$\bar{B_3}B_2$	0 (4)	0 (5)	0 (7)	0 (6)
B_3B_2	1 (12)	1 (13)	1 (15)	1 (14)
$B_3\bar{B_2}$	1 (8)	1 (9)	1 (11)	1 (10)

$$G3 = B3$$

2. Gray to Binary

• Truth table

Gray Code				Binary			
G3	G2	G1	G0	B3	B2	B1	B0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	1
0	1	0	1	0	1	1	0
0	1	1	0	0	1	0	0
0	1	1	1	0	1	0	1
1	0	0	0	1	1	1	1
1	0	0	1	1	1	1	0
1	0	1	0	1	1	0	0
1	0	1	1	1	1	0	1
1	1	0	0	1	0	0	0
1	1	0	1	1	0	0	1
1	1	1	0	1	0	1	1
1	1	1	1	1	0	1	0

• K-map B0

1) B0

Q_3Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_3\bar{Q}_2$	0 (0)	1 (1)	0 (3)	1 (2)
$\bar{Q}_3Q_2$	1 (4)	0 (5)	1 (7)	0 (6)
Q_3Q_2	0 (12)	1 (13)	0 (15)	1 (14)
$Q_3\bar{Q}_2$	1 (8)	0 (9)	1 (11)	0 (10)

$B0 = \bar{Q}_3\bar{Q}_2\bar{Q}_1Q_0 + \bar{Q}_3\bar{Q}_2Q_1\bar{Q}_0 + \bar{Q}_3Q_2\bar{Q}_1\bar{Q}_0 + \bar{Q}_3Q_2Q_1Q_0 + Q_3Q_2\bar{Q}_1Q_0 + Q_3Q_2Q_1\bar{Q}_0 + Q_3\bar{Q}_2\bar{Q}_1\bar{Q}_0 + Q_3\bar{Q}_2Q_1Q_0$

$= \bar{Q}_3\bar{Q}_2(\bar{Q}_1Q_0 + Q_1\bar{Q}_0) + \bar{Q}_3Q_2(\bar{Q}_1\bar{Q}_0 + Q_1Q_0) + Q_3Q_2(\bar{Q}_1Q_0 + Q_1\bar{Q}_0) + Q_3\bar{Q}_2(\bar{Q}_1Q_0 + Q_1\bar{Q}_0)$

$B0 = (\bar{Q}_1Q_0 + Q_1\bar{Q}_0)(\bar{Q}_3\bar{Q}_2 + Q_3Q_2) + (\bar{Q}_1\bar{Q}_0 + Q_1Q_0)(\bar{Q}_3Q_2 + Q_3\bar{Q}_2)$

$= (Q_1 \oplus Q_0)(\overline{Q_3 \oplus Q_2}) + (\overline{Q_1 \oplus Q_0})(Q_3 \oplus Q_2)$

$B0 = Q_1 \oplus Q_0 \oplus Q_2 \oplus Q_3$

2) B1

B1

Q_3Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_3\bar{Q}_2$	0 (0)	0 (1)	1 (3)	1 (2)
$\bar{Q}_3Q_2$	1 (4)	1 (5)	0 (7)	0 (6)
Q_3Q_2	0 (12)	0 (13)	1 (15)	1 (14)
$Q_3\bar{Q}_2$	1 (8)	1 (9)	0 (11)	0 (10)

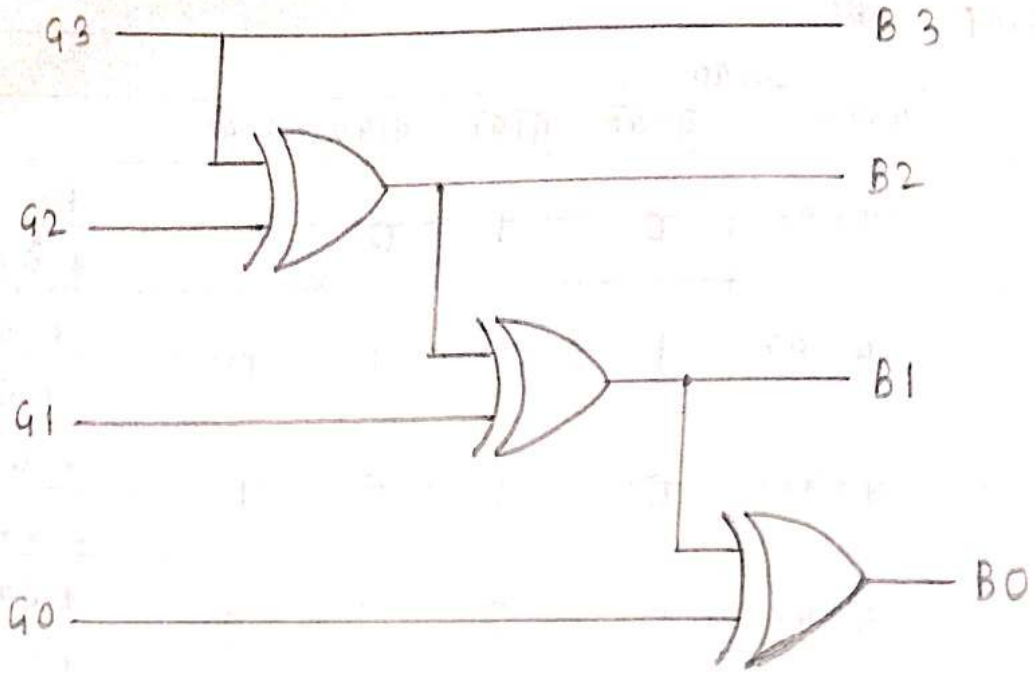
$B1 = \bar{Q}_3\bar{Q}_2Q_1 + \bar{Q}_3Q_2\bar{Q}_1 + Q_3Q_2Q_1 + Q_3\bar{Q}_2\bar{Q}_1$

$= Q_1(\bar{Q}_3\bar{Q}_2 + Q_3Q_2) + \bar{Q}_1(\bar{Q}_3Q_2 + Q_3\bar{Q}_2)$

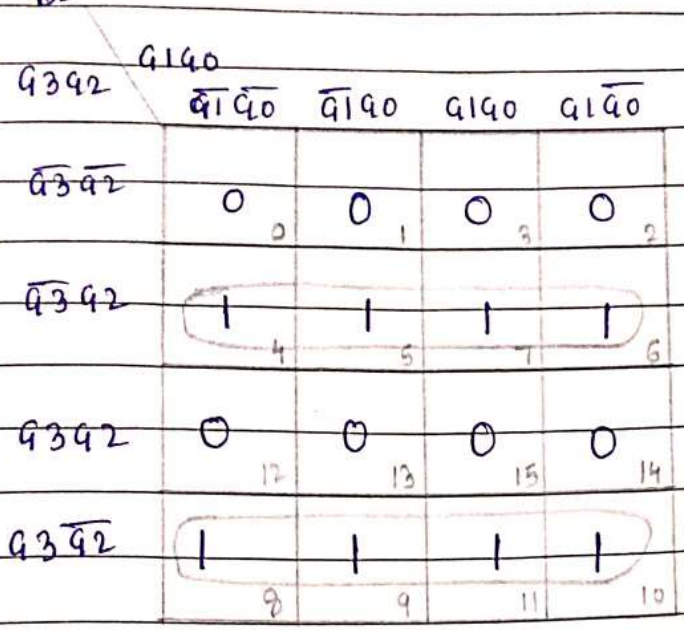
$= Q_1(\overline{Q_3 \oplus Q_2}) + \bar{Q}_1(Q_3 \oplus Q_2)$

$B1 = Q_1 \oplus Q_2 \oplus Q_3$

→ Circuit diagram



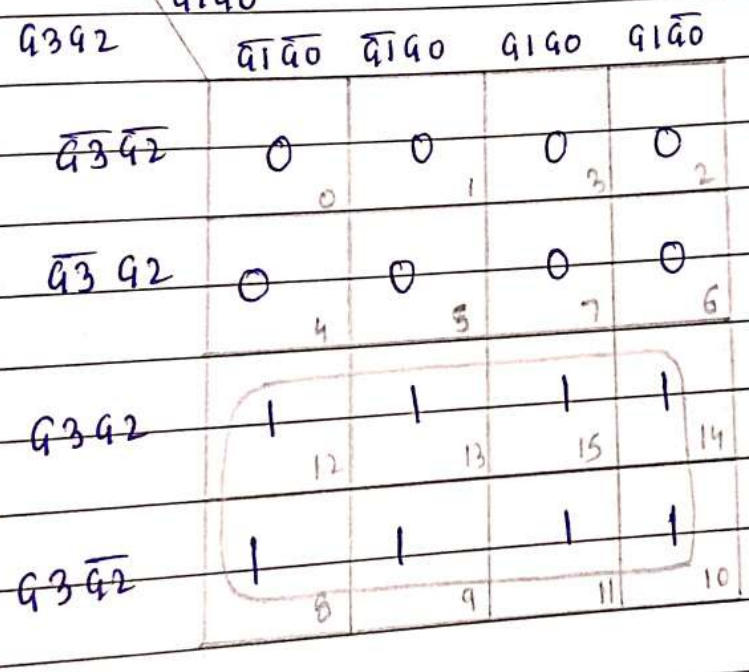
3) B2



$B2 = \bar{Q}_3Q_2 + Q_3\bar{Q}_2$

$B2 = Q_2 \oplus Q_3$

1) B3



$B3 = Q_3$

3. BCD to Excess-3

- Truth Table

BCD				Excess-3			
B3	B2	B1	B0	E3	E2	E1	E0
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0
1	0	1	0	X	X	X	X
1	0	1	1	X	X	X	X
1	1	0	0	X	X	X	X
1	1	0	1	X	X	X	X
1	1	1	0	X	X	X	X
1	1	1	1	X	X	X	X

K-map

1) E0

E0

B3B2 \ B1B0	$\overline{B1}\,\overline{B0}$	$\overline{B1}B0$	$B1B0$	$B1\overline{B0}$
$\overline{B3}\,\overline{B2}$	1 (0)	0 (1)	0 (3)	1 (2)
$\overline{B3}B2$	1 (4)	0 (5)	0 (7)	1 (6)
$B3B2$	X (12)	X (13)	X (15)	X (14)
$B3\overline{B2}$	1 (8)	0 (9)	X (11)	X (10)

$E0 = \overline{B1}\,\overline{B0} + B1\,\overline{B0}$

$= \overline{B0}\,(\overline{B1} + B1)$

$E0 = \overline{B0}$

2) E1

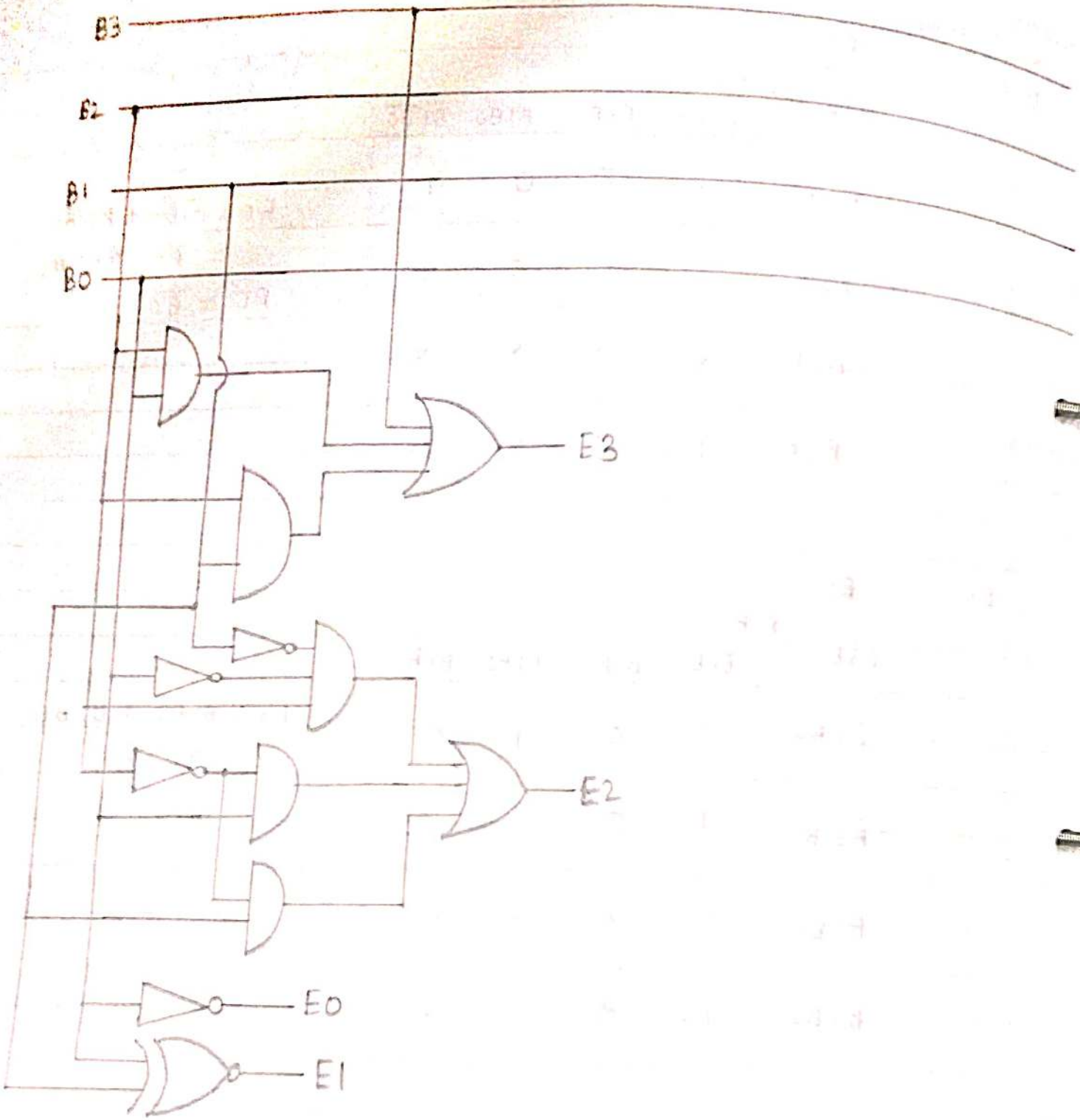
E1

B3B2 \ B1B0	$\overline{B1}\,\overline{B0}$	$\overline{B1}B0$	$B1B0$	$B1\overline{B0}$
$\overline{B3}\,\overline{B2}$	1 (0)	0 (1)	1 (3)	0 (2)
$\overline{B3}B2$	1 (4)	0 (5)	1 (7)	0 (6)
$B3B2$	X (12)	X (13)	X (15)	X (14)
$B3\overline{B2}$	1 (8)	0 (9)	X (11)	X (10)

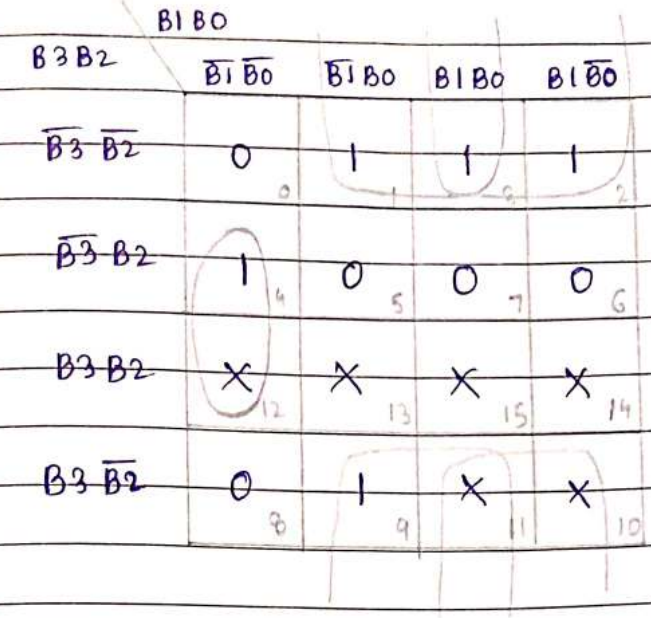
$E1 = \overline{B1}\,\overline{B0} + B1B0$

$= B1 \odot B0$

→ Circuit diagram

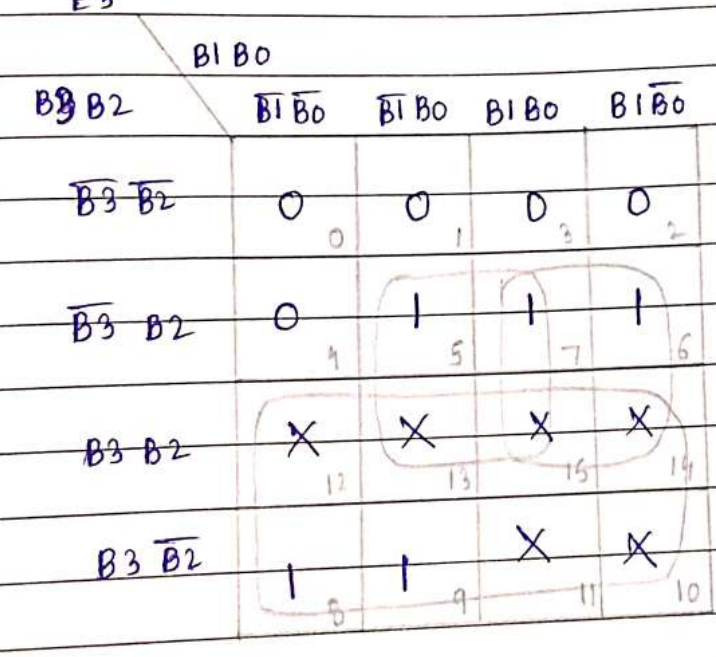


3) E2



$E2 = B2\bar{B1}\bar{B0} + \bar{B2}B0 + \bar{B2}B1$

4) E3



$E3 = B3 + B2B0 + B2B1$

4. Excess-3 to BCD Code

• Truth table

Excess-3				BCD			
E3	E2	E1	E0	B3	B2	B1	B0
0	0	0	0	X	X	X	X
0	0	0	1	X	X	X	X
0	0	1	0	X	X	X	X
0	0	1	1	0	0	0	0
0	1	0	0	0	0	0	1
0	1	0	1	0	0	1	0
0	1	1	0	0	0	1	1
0	1	1	1	0	1	0	0
1	0	0	0	0	1	0	1
1	0	0	1	0	1	1	0
1	0	1	0	0	1	1	1
1	0	1	1	1	0	0	0
1	1	0	0	1	0	0	1
1	1	0	1	X	X	X	X
1	1	1	0	X	X	X	X
1	1	1	1	X	X	X	X

- K-map

1) B0 B0

E3 E2 \ E1 E0	$\bar{E}_1\bar{E}_0$	$\bar{E}_1E_0$	E_1E_0	$E_1\bar{E}_0$
$\bar{E}_3\bar{E}_2$	X (0)	X (1)	0 (3)	X (2)
$\bar{E}_3E_2$	1 (4)	0 (5)	0 (7)	1 (6)
E_3E_2	1 (12)	X (13)	X (15)	X (14)
$E_3\bar{E}_2$	1 (8)	0 (9)	0 (11)	1 (10)

$B_0 = \bar{E}_0$

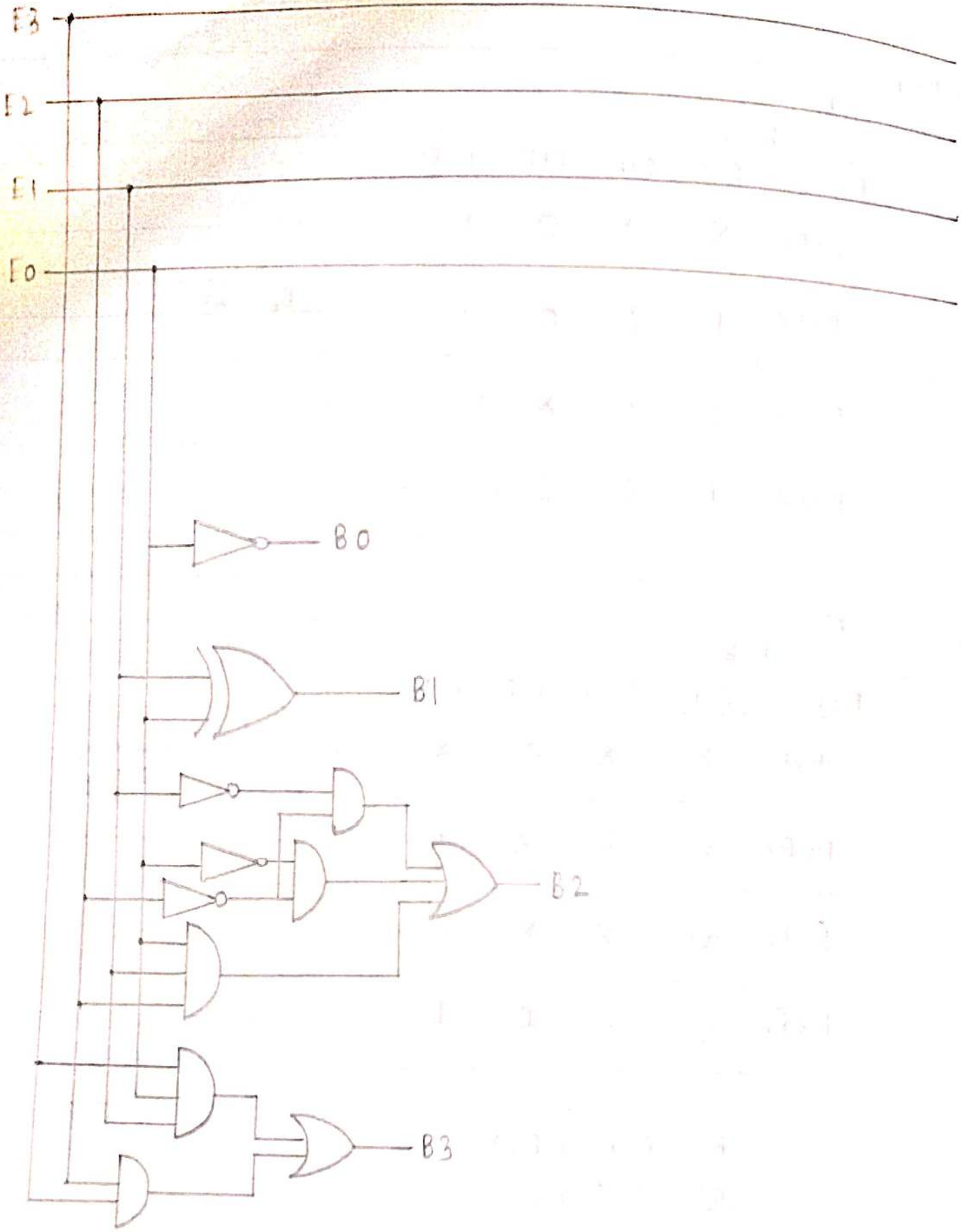
2) B1 B1

E3 E2 \ E1 E0	$\bar{E}_1\bar{E}_0$	$\bar{E}_1E_0$	E_1E_0	$E_1\bar{E}_0$
$\bar{E}_3\bar{E}_2$	X (0)	X (1)	0 (3)	X (2)
$\bar{E}_3E_2$	0 (4)	1 (5)	0 (7)	1 (6)
E_3E_2	0 (12)	X (13)	X (15)	X (14)
$E_3\bar{E}_2$	0 (8)	1 (9)	0 (11)	1 (10)

$B_1 = \bar{E}_1E_0 + E_1\bar{E}_0$

$B_1 = E_0 \oplus E_1$

→ Circuit Diagram :-



3) B2

B2

E_3E_2 \ E_1E_0	$\bar{E}_1\bar{E}_0$	$\bar{E}_1E_0$	E_1E_0	$E_1\bar{E}_0$
$\bar{E}_3\bar{E}_2$	X (0)	X (1)	0 (3)	X (2)
$\bar{E}_3E_2$	0 (4)	0 (5)	1 (7)	0 (6)
E_3E_2	0 (12)	X (13)	X (15)	X (14)
$E_3\bar{E}_2$	1 (8)	1 (9)	0 (11)	1 (10)

~~$B_2 = \bar{E}_2\bar{E}_0 + E_2E_1E_0$~~
~~$+ \bar{E}_2E_1E_0$~~
~~$= \bar{E}_2\bar{E}_0 + E_0$~~

$B_2 = \bar{E}_2\bar{E}_0 + \bar{E}_2\bar{E}_1 + E_2E_1E_0$

4) B3

B3

E_3E_2 \ E_1E_0	$\bar{E}_1\bar{E}_0$	$\bar{E}_1E_0$	E_1E_0	$E_1\bar{E}_0$
$\bar{E}_3\bar{E}_2$	X (0)	X (1)	0 (3)	X (2)
$\bar{E}_3E_2$	0 (4)	0 (5)	0 (7)	0 (6)
E_3E_2	1 (12)	X (13)	X (15)	X (14)
$E_3\bar{E}_2$	0 (8)	0 (9)	1 (11)	0 (10)

$B_3 = E_3E_2 + E_3E_1E_0$