

## Homework#5 Solution CSE140

### Rubric:

1a 15 pts: 5 points for writing the equation, 5 pts for longest path, 5 pts for correct answer

1b 15pts: 5 points for writing the equation, 5 pts for shortest path, and 5 pts for correct answer

2a 5pts for attempt

2b 5pts for attempt

3a 5pts for attempt

3b 5pts for attempt

3c 5pts for attempt

4a 5pts for attempt

4b 5pts for attempt

4c 5pts for attempt

5a 10pts: 1.5 pts for each decoder, 2.5 for OR gate

For extra decoder deduct 1.5 pts and 0.5 points for any minor mistake

5b 15pts, 3 points for labeling the MUX select pin and input pin

3 points for each input of the last MUX

Deduct 2 point if not minimal

5c 5pts for attempt

### Problem 1

a). Critical path contains 3 XOR gates

$$t_{pcq} + t_{pd(max)} + t_{setup} \leq T$$

$$t_{pcq} + t_{pd(3-XOR)} + t_{setup} \leq T$$

$$70 + (60 + 60 + 60) + 60 \leq T$$

$$T \geq 310 \text{ ps}$$

$$\text{Max Frequency} = 1/T = 3.225 \text{ GHz}$$

b).  $t_{ccq} + t_{cd(min)} > t_{hold} + t_{skew}$

$$t_{cd(min)} = 0$$

$$t_{skew} < 50 - 20$$

$$t_{skew} < 30 \text{ ps}$$

## Problem 2

a).  $t_{pcq} + t_{pd(max)} + t_{setup} \leq T$

$$t_{pd(max)} = t_{pd(AorB \rightarrow Cout)} + 3 * t_{pd(Cin \rightarrow Cout)}$$

$$t_{pcq} + t_{pd(AorB \rightarrow Cout)} + 3 * t_{pd(Cin \rightarrow Cout)} + t_{setup} \leq T$$

$$35 + (25 + (20 + 20 + 20)) + 30 \leq T$$

$$T \geq 150 \text{ ps}$$

$$\text{Max Pfrequency} = 1/T = 6.67 \text{ GHz}$$

b).  $t_{pcq} + t_{pd(max)} + t_{setup} \leq T + \Delta$

$$t_{pd(max)} = t_{pd(AorB \rightarrow Cout)} + 3 * t_{pd(Cin \rightarrow Cout)}$$

$$t_{pcq} + t_{pd(AorB \rightarrow Cout)} + 3 * t_{pd(Cin \rightarrow Cout)} + t_{setup} \leq T + \Delta$$

$$35 + (25 + (20 + 20 + 20)) + 30 \leq T + \Delta$$

$$150 \leq T + \Delta$$

$$t_{ccq} + t_{cd(min)} > t_{hold} + \Delta$$

$$t_{cd(max)} = t_{cd(Cin \rightarrow Sum)}$$

$$t_{ccq} + t_{cd(Cin \rightarrow Sum)} > t_{hold} + \Delta$$

$$25 + 15 > 10 + \Delta$$

$$40 > 10 + \Delta$$

$$\Delta < 30$$

$$150 \leq T + \Delta$$

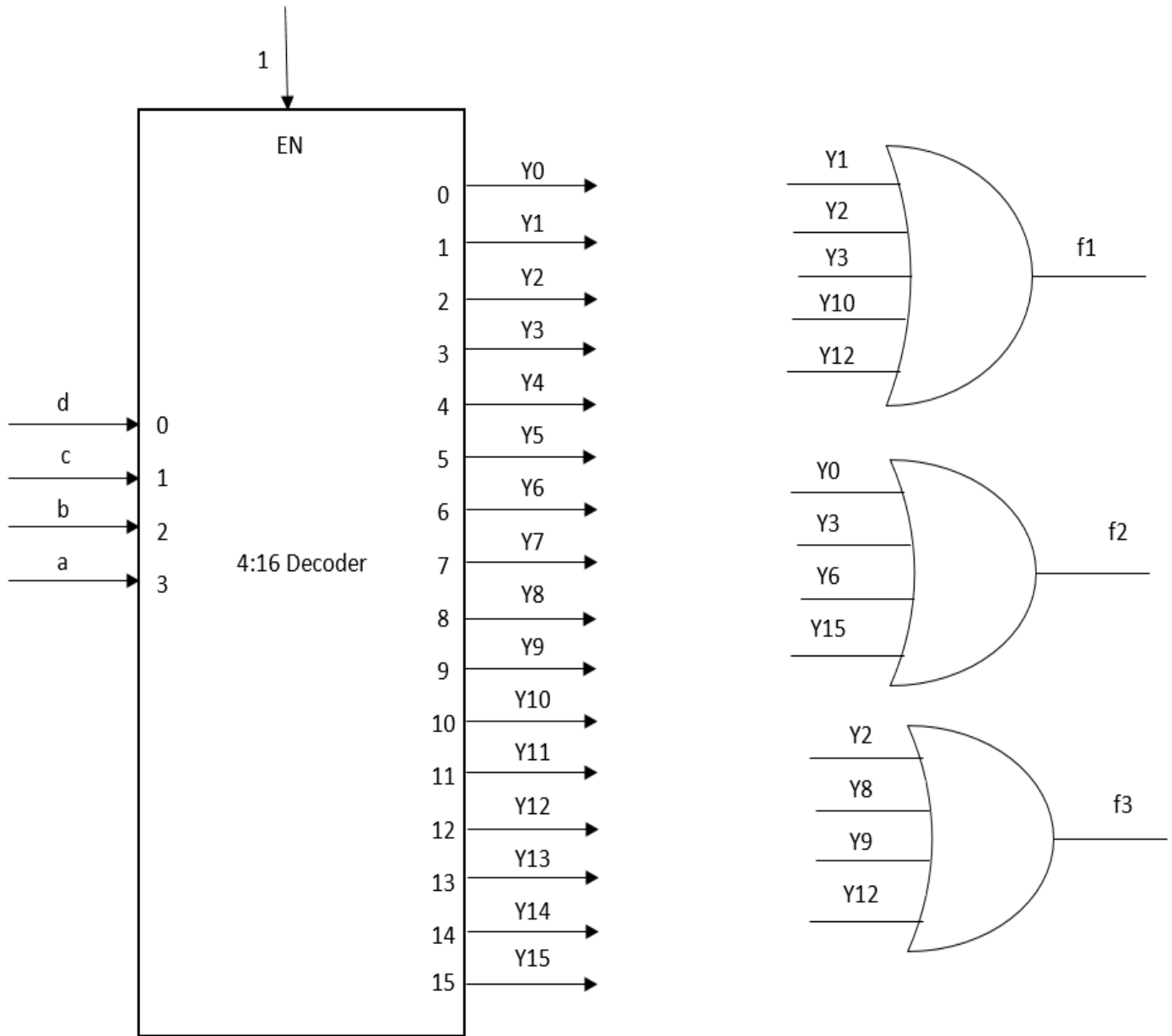
$$T \geq 150 - 30$$

$$T \geq 120$$

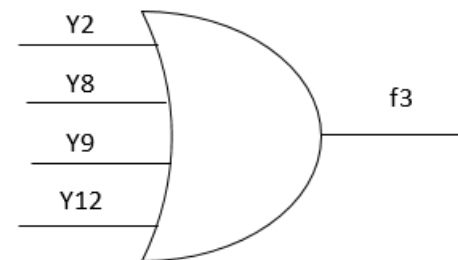
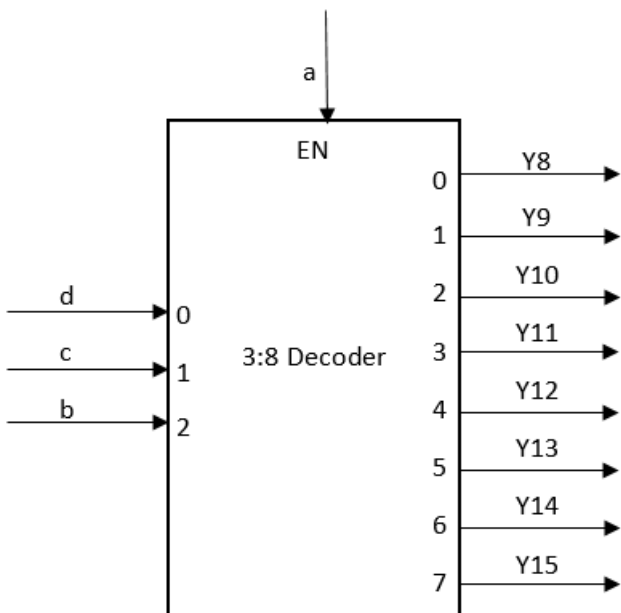
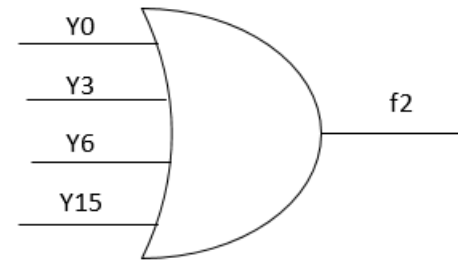
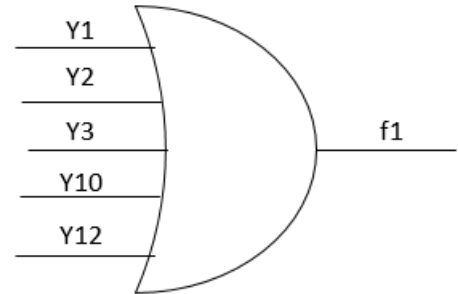
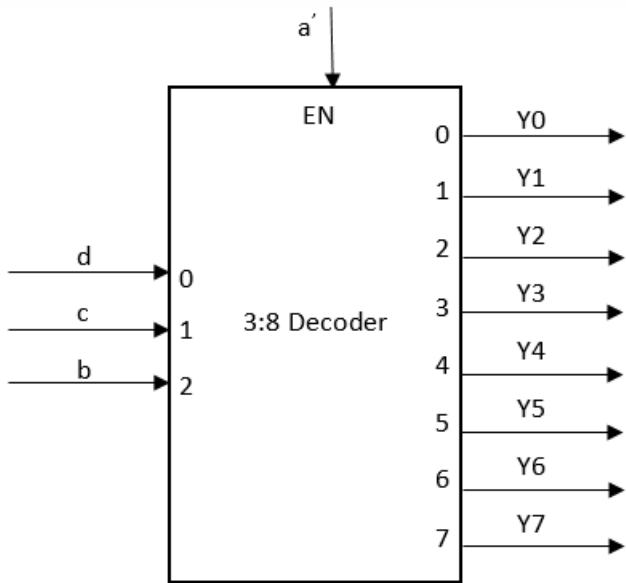
$$\text{Max Frequency} = 1/T = 8.33 \text{ GHz}$$

Problem 3:

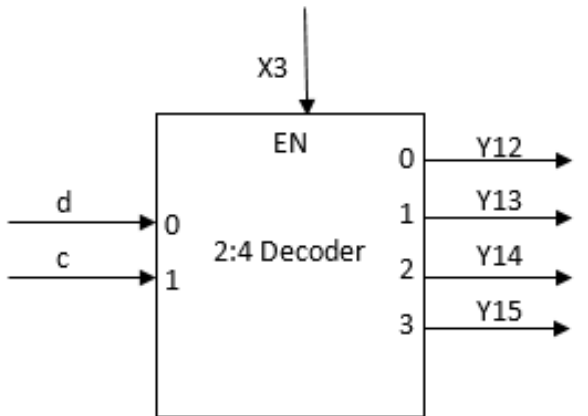
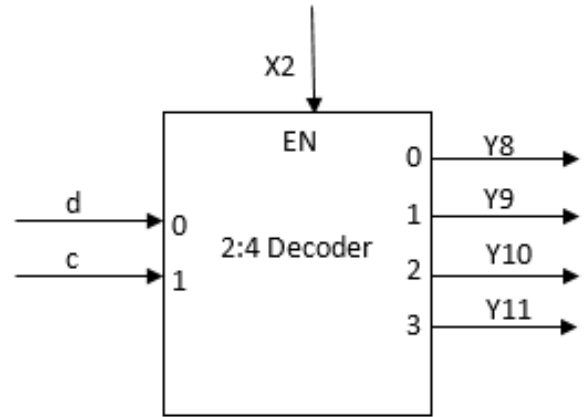
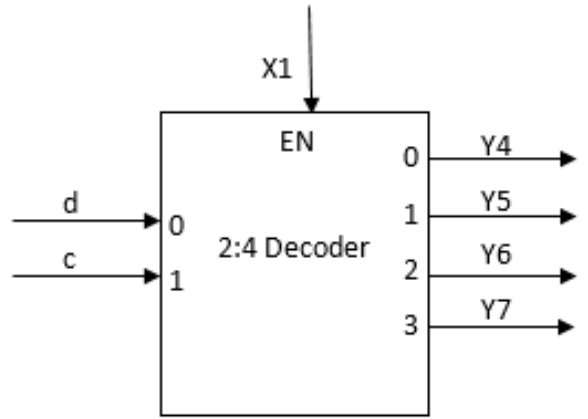
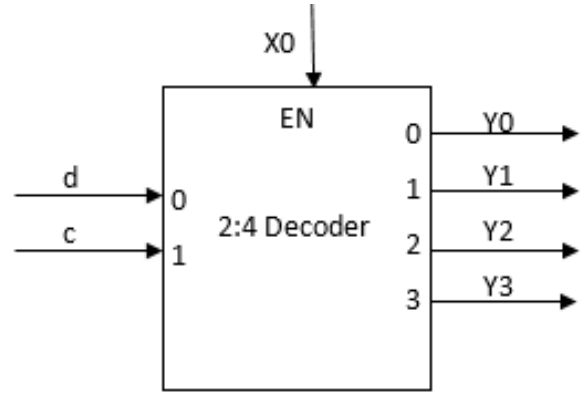
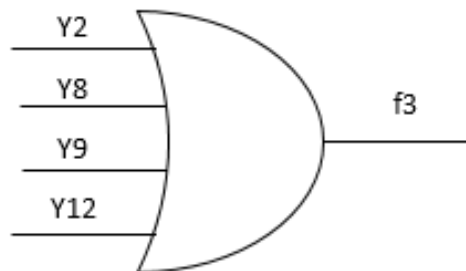
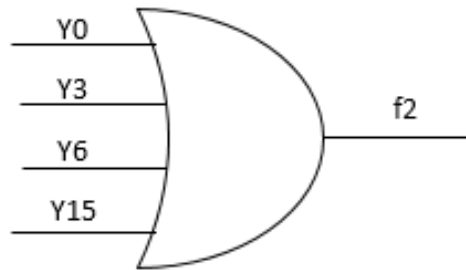
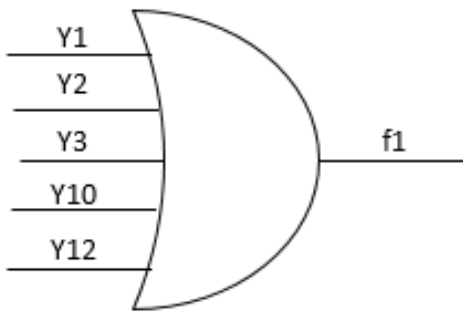
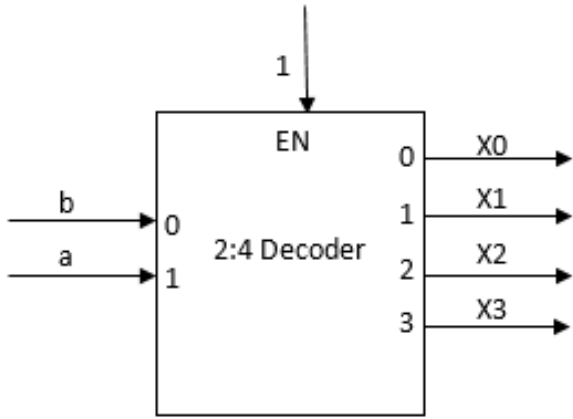
i).



ii).



iii).



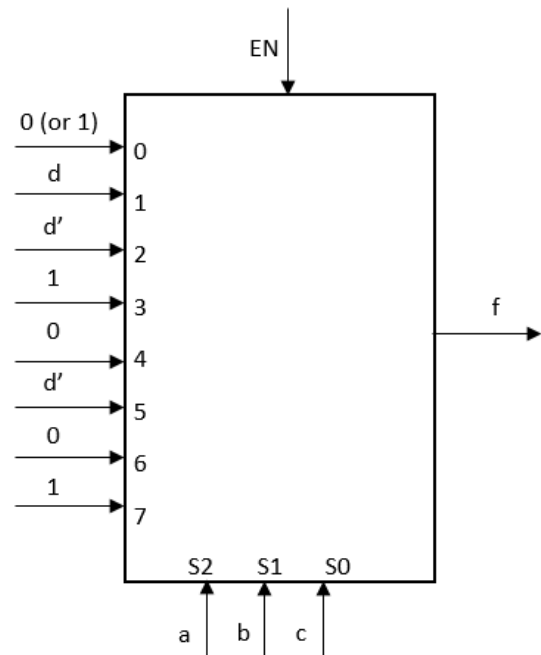
Problem 4:

$$f(a,b,c,d) = a'b'c'd' + a'b'c'd + a'b'cd + a'bc'd' + a'bcd' + a'bcd + ab'c'd' + ab'cd' + abc'd + abcd' + abcd$$

	a	b	c	d	f
0	0	0	0	0	x
1	0	0	0	1	x
2	0	0	1	0	0
3	0	0	1	1	1
4	0	1	0	0	1
5	0	1	0	1	0
6	0	1	1	0	x
7	0	1	1	1	1
8	1	0	0	0	x
9	1	0	0	1	0
10	1	0	1	0	1
11	1	0	1	1	0
12	1	1	0	0	0
13	1	1	0	1	x
14	1	1	1	0	1
15	1	1	1	1	1

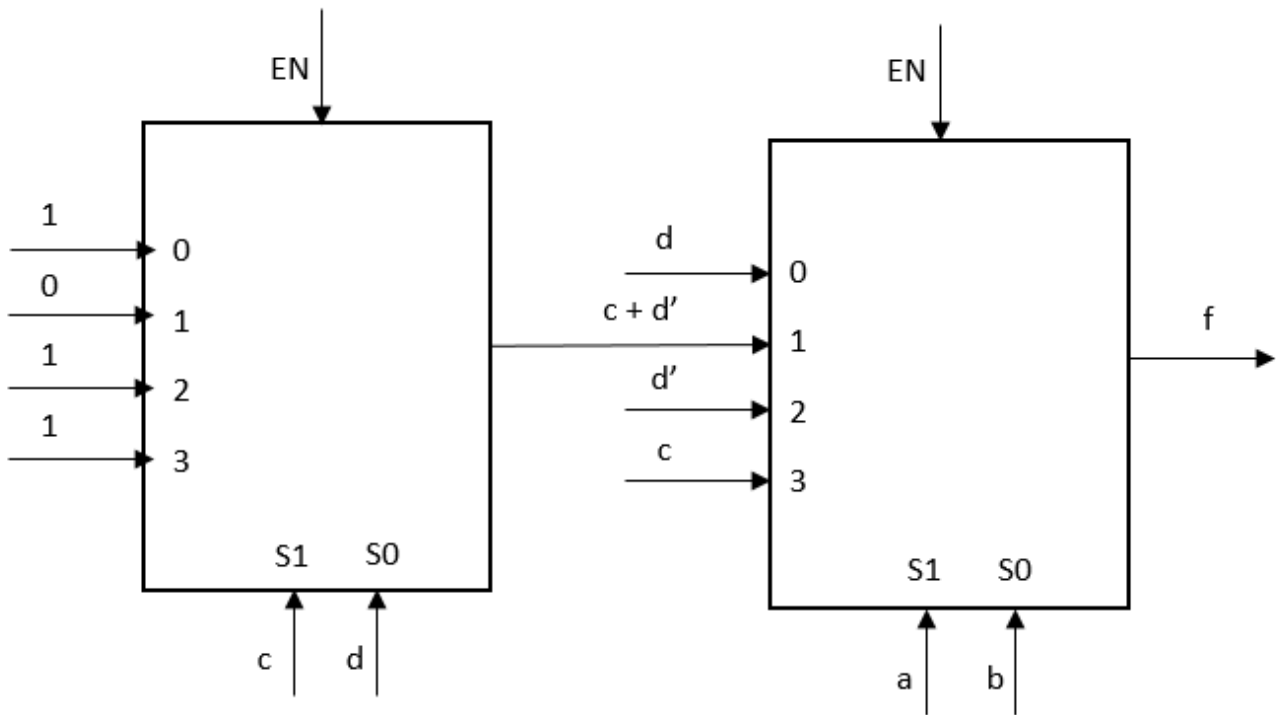
i).

a	B	c	f when d=0	f when d=1	<b>D(d)</b>
0	0	0	x	x	<b>x</b>
0	0	0	0	1	<b>d</b>
0	0	1	1	0	<b>d'</b>
0	0	1	x	1	<b>1</b>
0	1	0	x	0	<b>0</b>
0	1	0	1	0	<b>d'</b>
0	1	1	0	x	<b>0</b>
0	1	1	1	1	<b>1</b>



ii).

a	b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
0	0	x	x	0	1	D0= d
0	1	1	0	x	1	D1= c + d'
1	0	x	0	1	0	D2= d'
1	1	0	x	1	1	D3 = c



iii).

First Solution: (minimal but order is not followed)

a=0

d	f when b=0 c=0	f when b=0 c=1	f when b=1 c=0	f when b=1 c=1	D(b,c)
0	x	0	1	x	D0
1	x	1	0	1	D1

a=1

d	f when b=0 c=0	f when b=0 c=1	f when b=1 c=0	f when b=1 c=1	D(b,c)
0	X	1	0	1	D2
1	0	0	X	1	D3

D0

	c'	c
b'	X	0
b	1	X

= b

D1

	c'	c
b'	X	1
b	0	1

= c

D2

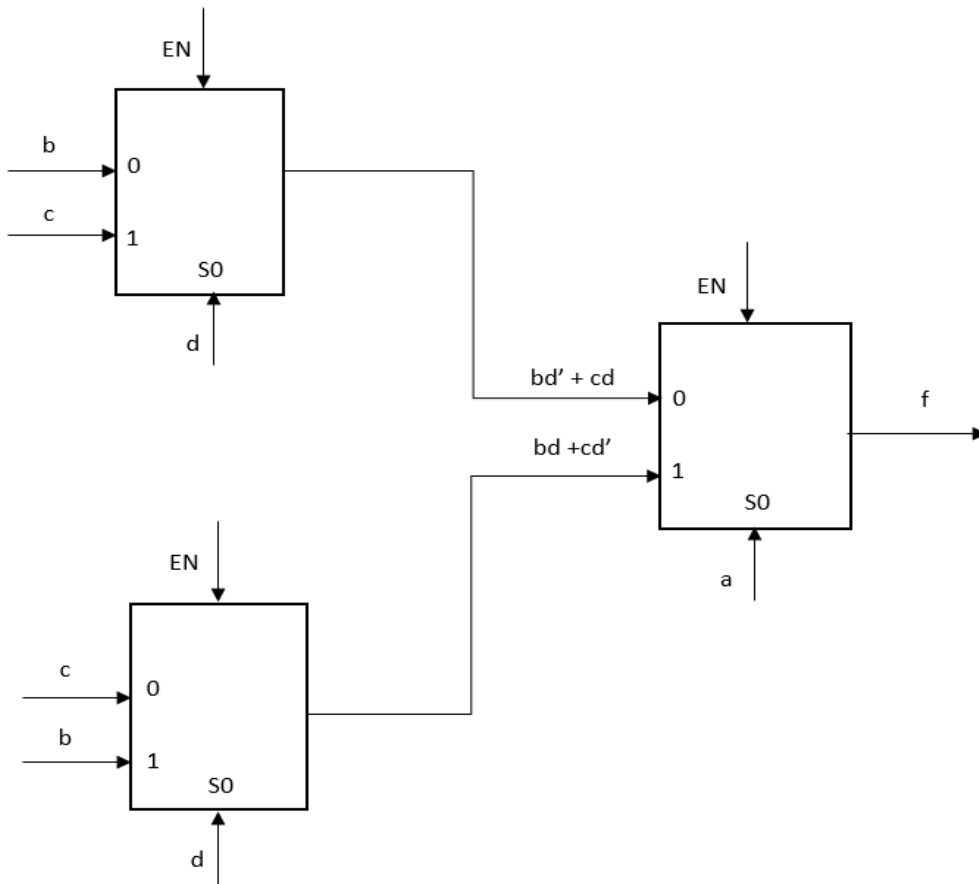
	c'	c
b'	X	1
b	0	1

= c

D3

	c'	c
b'	0	0
b	X	1

= b



Second Solution: (by following the order)

a=0



b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
0	x	x	0	1	D0
1	1	0	x	1	D1

a=1

b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
0	x	0	1	0	D2
1	0	x	1	1	D3

D0

	d'	d
c'	X	x
c	0	1

= d

D1

	d'	d	D(d)
c'	1	0	D4=d'
c	X	1	D5=1

= c + d'

D2

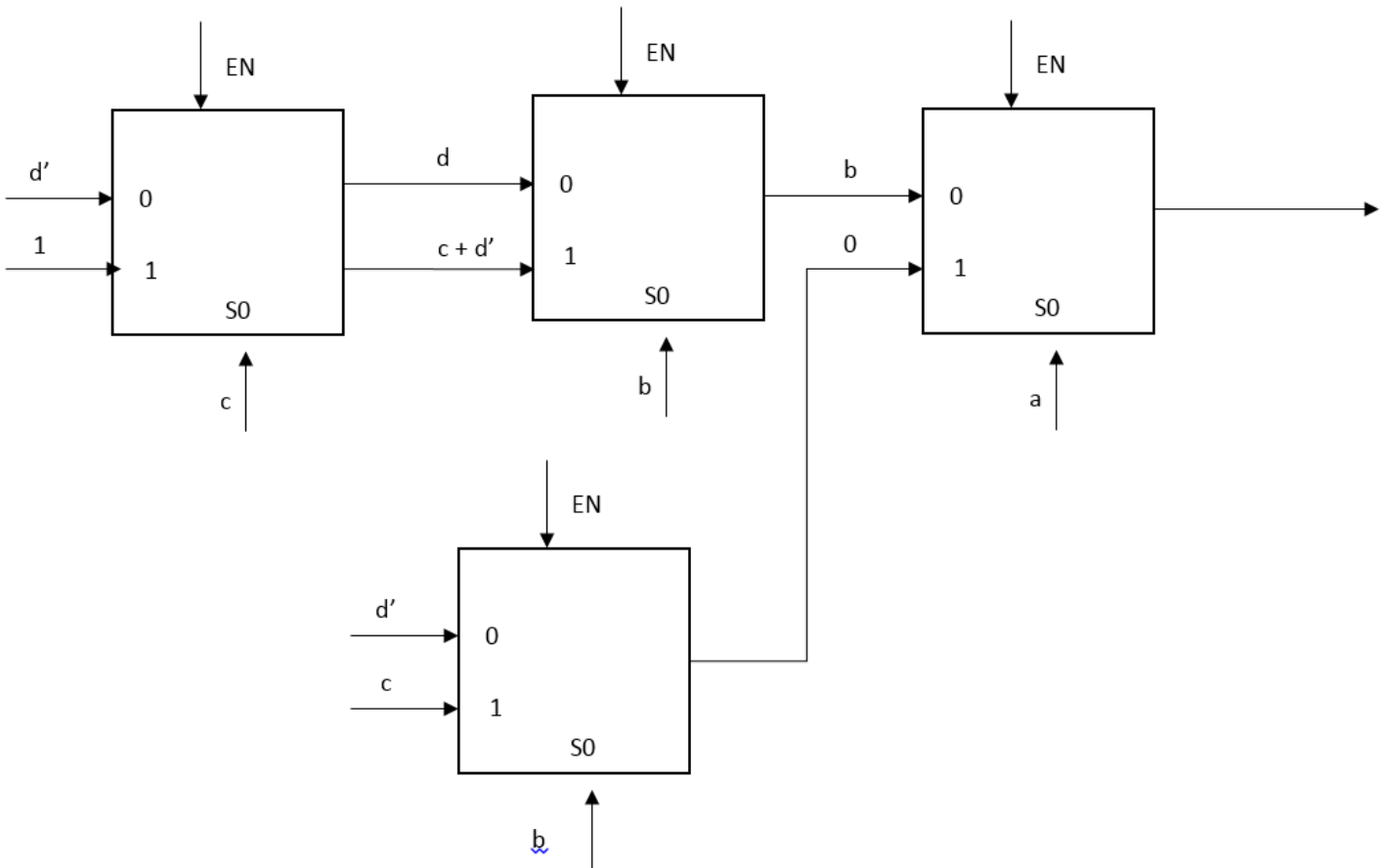
	d'	d
c'	X	0
c	1	0

= d'

D3

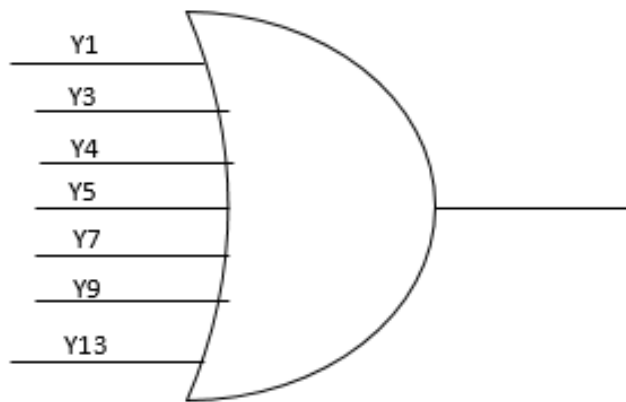
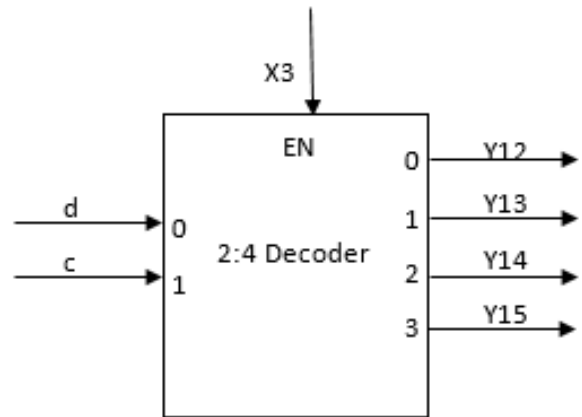
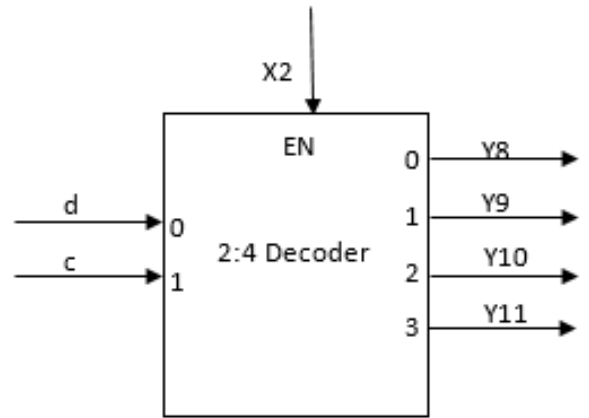
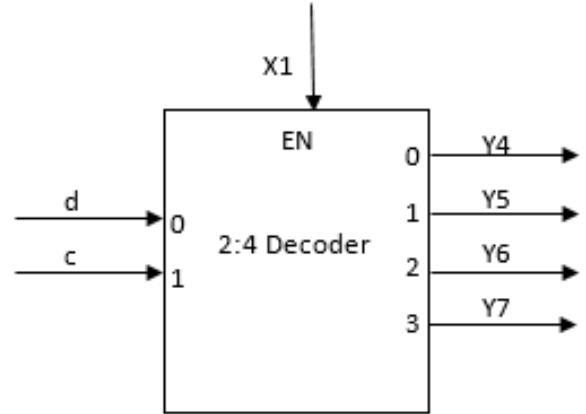
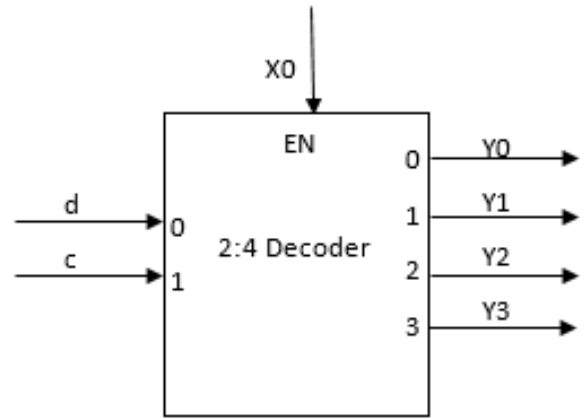
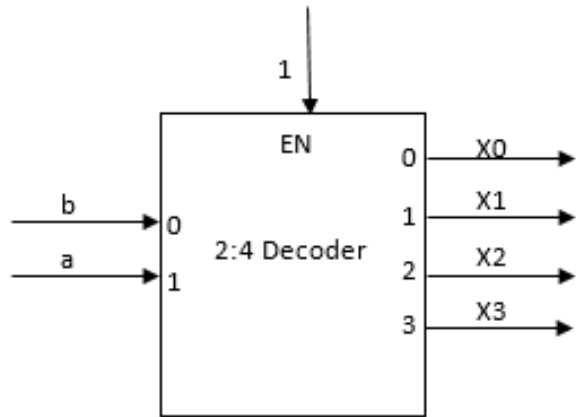
	d'	d
c'	0	X
c	1	1

= c



Problem 5:

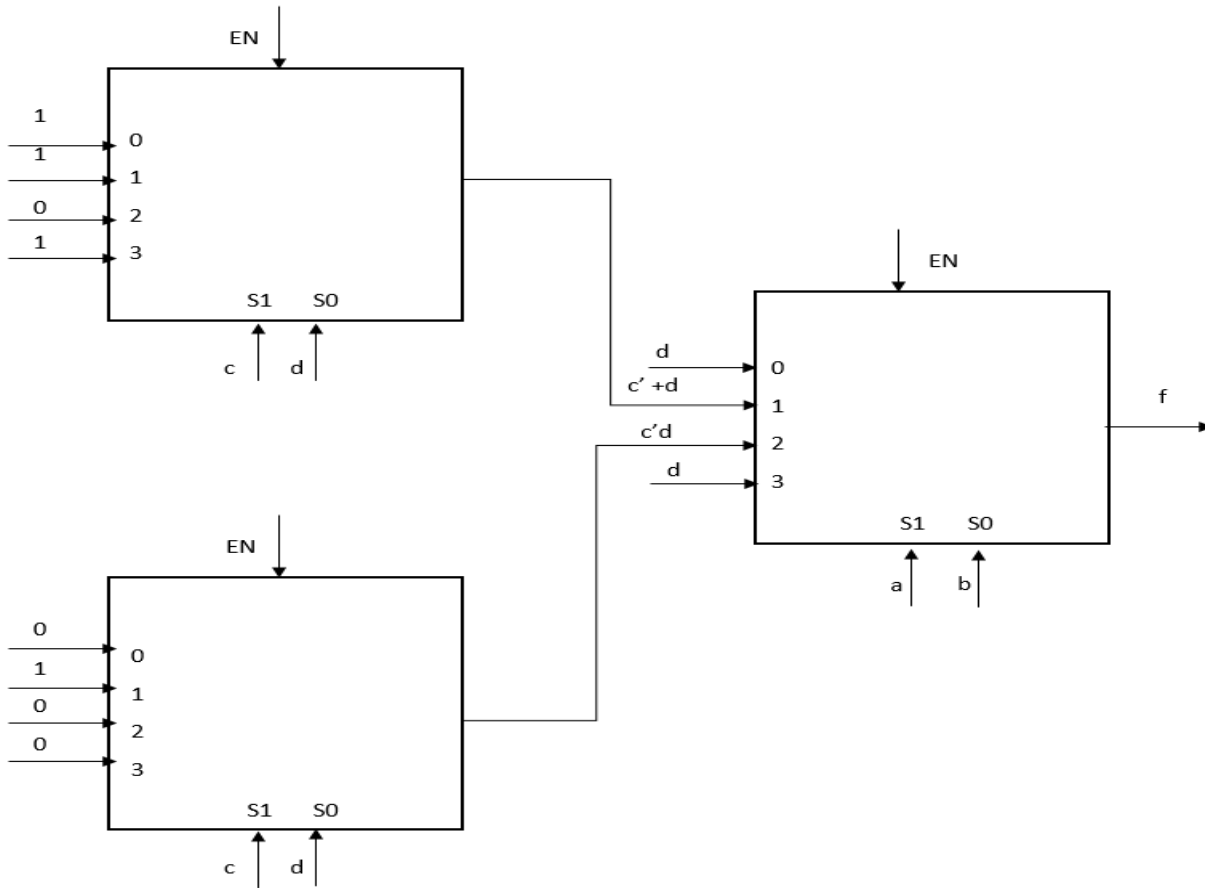
i).



ii)

	a	b	c	d	f
0	0	0	0	0	0
1	0	0	0	1	1
2	0	0	1	0	0
3	0	0	1	1	1
4	0	1	0	0	1
5	0	1	0	1	1
6	0	1	1	0	0
7	0	1	1	1	1
8	1	0	0	0	0
9	1	0	0	1	1
10	1	0	1	0	X
11	1	0	1	1	0
12	1	1	0	0	0
13	1	1	0	1	1
14	1	1	1	0	0
15	1	1	1	1	x

a	b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
0	0	0	1	0	1	d
0	1	1	1	0	1	c'+d
1	0	0	1	x	0	c'd
1	1	0	1	0	x	d



iii) It is advised to do the Shannon's expansion in order for  $f(abcd)$  first expand in terms of  $a$  and then  $b$  and so on

First Solution: (minimal but order is not followed)

a	b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
0	0	0	1	0	1	D0
0	1	1	1	0	1	D1

D0

	d'	d
c'	0	1
c	0	1

= d

D1

	d'	d	D(d)
c'	1	1	1
c	0	1	d

= c'+d

a	c	f when b=0 d=0	f when b=0 d=1	f when b=1 d=0	f when b=1 d=1	D(b,d)
1	0	0	1	0	1	D2
1	1	X	0	0	x	D3

D2

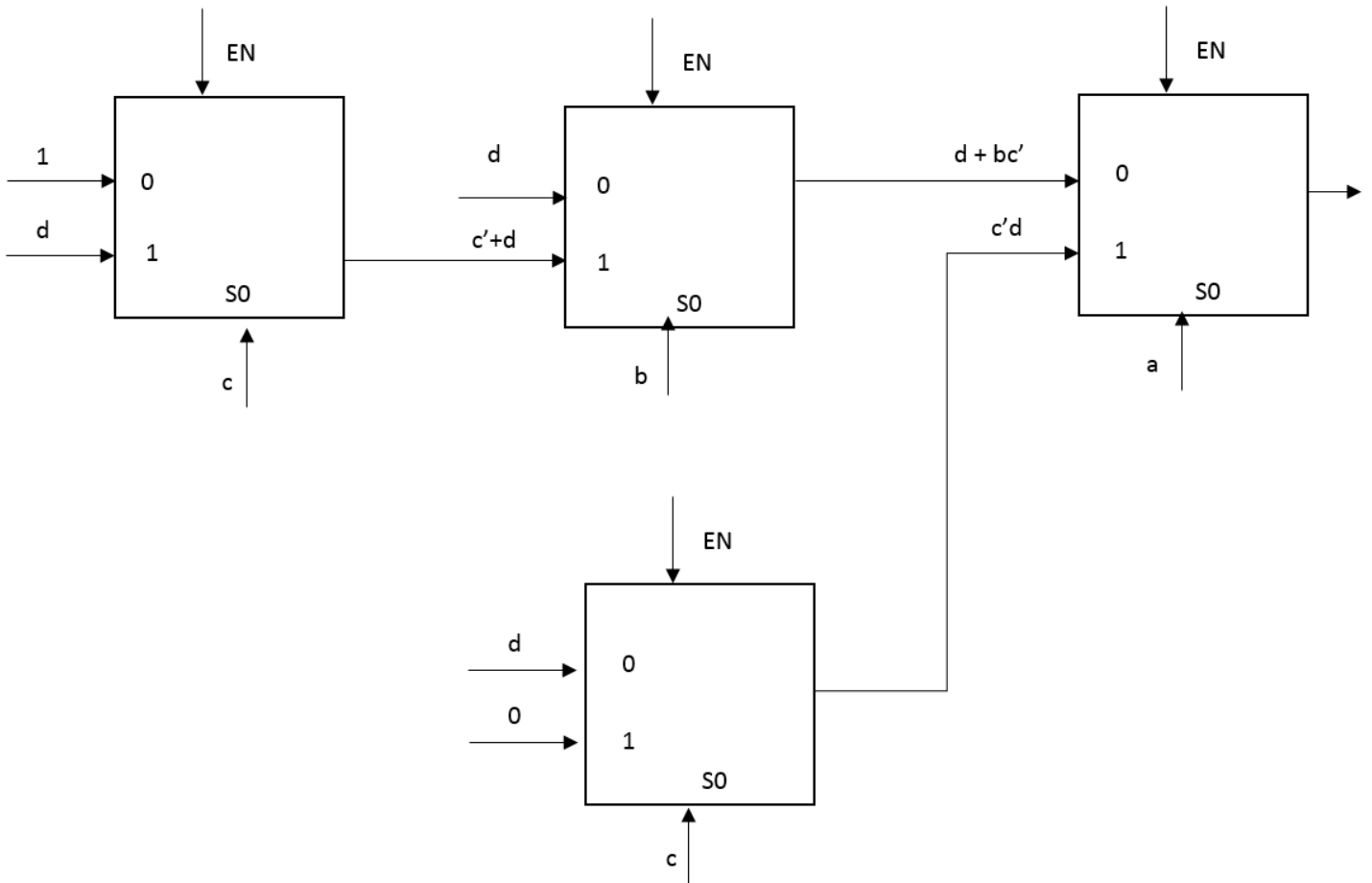
	d'	d
b'	0	1
b	0	1

= d

D3

	d'	d
b'	X	0
b	0	x

= 0



Second solution: (following the order)

a	b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
0	0	0	1	0	1	D0
0	1	1	1	0	1	D1

D0

	d'	d
c'	0	1
c	0	1

= d

D1

	d'	d	D(d)
c'	1	1	1
c	0	1	d

= c'+d

a	b	f when c=0 d=0	f when c=0 d=1	f when c=1 d=0	f when c=1 d=1	D(c,d)
1	0	0	1	x	0	D2
1	1	0	1	0	x	D3

D2

	d'	d	D(d)
c'	0	1	d
c	X	0	0

= c'd

D3

	d'	d
c'	0	1
c	0	x

= d

