ECSE 222 VHDL 2 Questions Report

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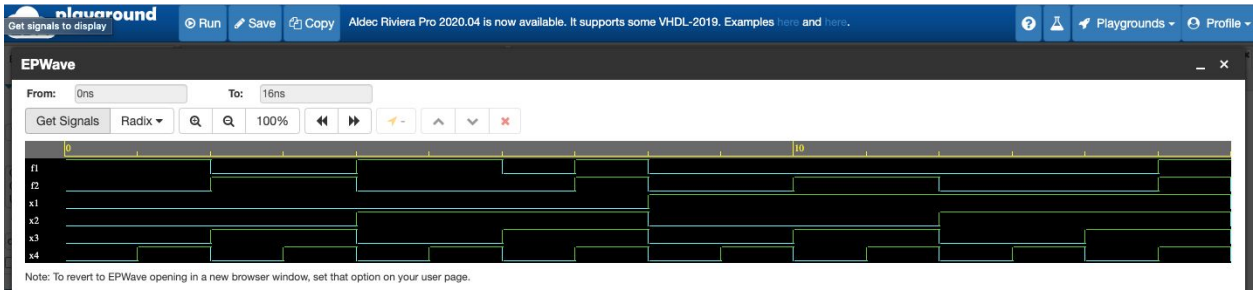
1. Explain your VHDL Code.
   Please see the comments in our code.

2. Report the costs and the number of logic modules used to fit your designs on the FPGA board.

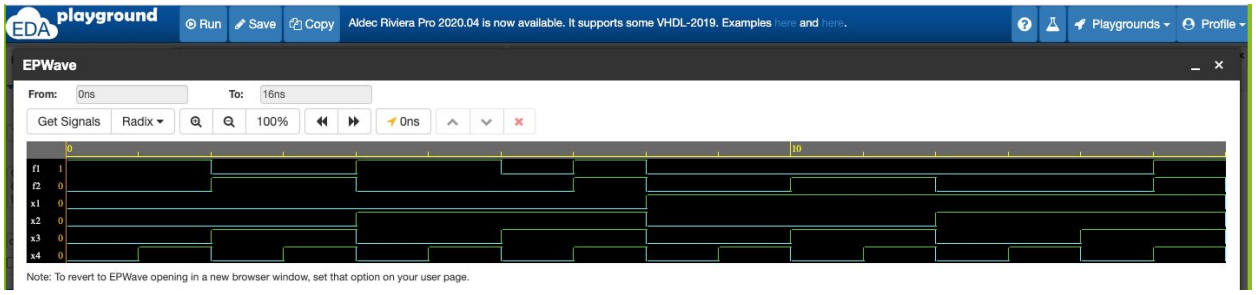
Task	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cost	72	100	25	25	N/A	N/A	22
Logic Utilization	2	2	2	2	4	4	2

3. Show representative simulation pilots of all tasks for all the possible input valves (exhaustive test results). Note that you can simply include snapshots from the waveform that you obtained from EPWave. In order to fully capture all signals from the waveform, you can adjust the display range using the magnifier icons. Make sure that all signal names and axes are properly visible.

Task 1: can_SOP



Task 2: can_POS



Task 3: sim_SOP

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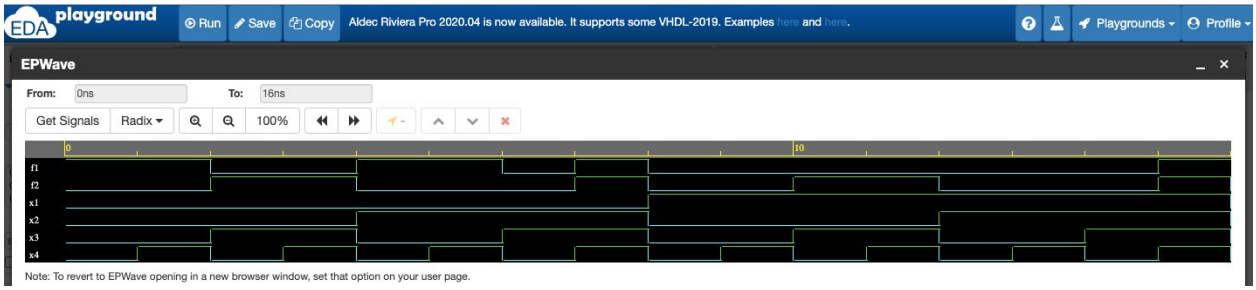
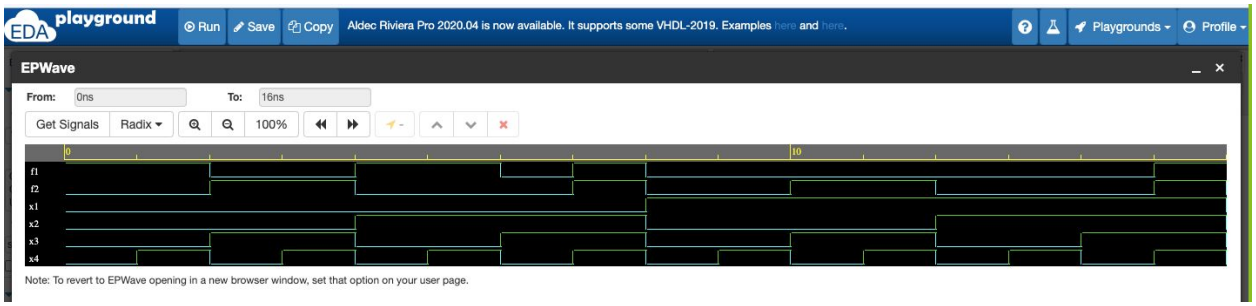
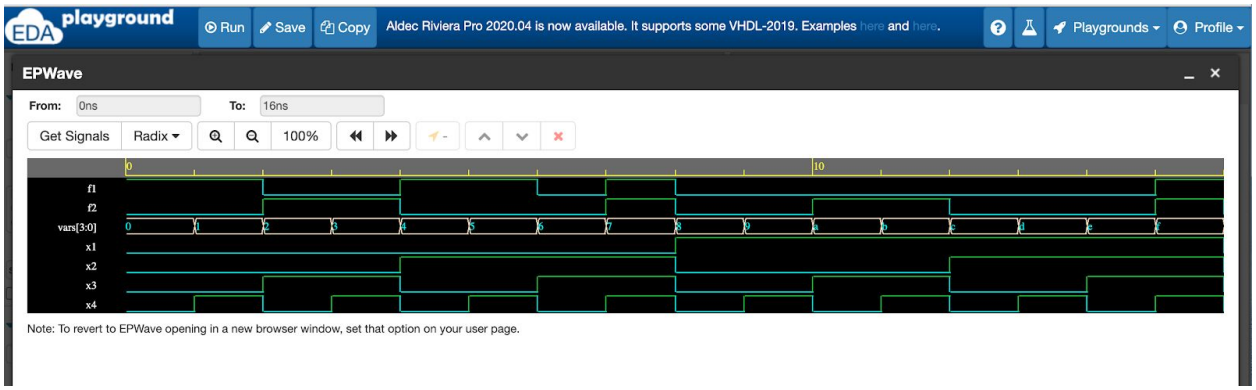


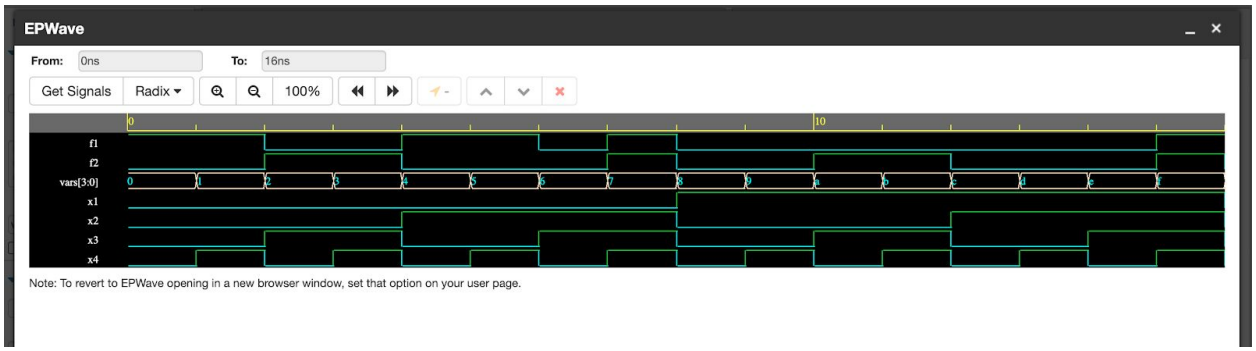
Task 4: sim_POS



Task 5: select_assignment



Task 6: when_assignment



Task 7: joint_SOP

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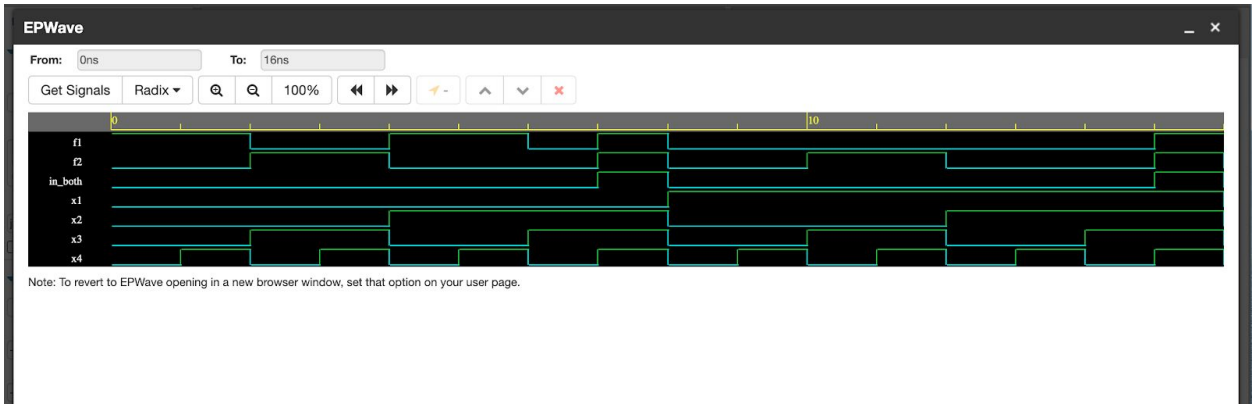


For Part 1: Finding the canonical SOP

x_1	x_2	x_3	x_4	f_1	f_2
0	0	0	0	1	0
0	0	0	1	1	0
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	1	0
0	1	0	1	1	0
0	1	1	0	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	0	1	0	0
1	0	1	0	0	1
1	0	1	1	0	1
1	1	0	0	0	0
1	1	0	1	0	0
1	1	1	0	0	0
1	1	1	1	1	1

$$f_1 = \bar{x}_1\bar{x}_2\bar{x}_3\bar{x}_4 + \bar{x}_1\bar{x}_2\bar{x}_3x_4 + \bar{x}_1x_2\bar{x}_3\bar{x}_4 + \bar{x}_1x_2\bar{x}_3x_4 + \bar{x}_1x_2x_3x_4 + x_1x_2x_3x_4$$

$$f_2 = \bar{x}_1\bar{x}_2x_3\bar{x}_4 + \bar{x}_1\bar{x}_2x_3x_4 + \bar{x}_1x_2x_3x_4 + x_1\bar{x}_2x_3\bar{x}_4 + x_1\bar{x}_2x_3x_4 + x_1x_2x_3x_4$$

As per the discussion board, we shall calculate cost as if f_1 and f_2 are in one circuit together but have two outputs.

$$\text{cost} = +8 + (10)(5) + 14 = 50 + 8 + 14 = 72$$

(+8: complements; 10: 10 distinct minterms; 14: 7 for f_1, 7 for f_2 to join together)

For Part 2: Finding the canonical POS

x_1	x_2	x_3	x_4	f_1	f_2
0	0	0	0	1	0
0	0	0	1	1	0
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	1	0
0	1	0	1	1	0
0	1	1	0	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	0	1	0	0
1	0	1	0	0	1
1	0	1	1	0	1
1	1	0	0	0	0
1	1	0	1	0	0
1	1	1	0	0	0
1	1	1	1	1	1

$$f_1 = (x_1+x_2+\bar{x}_3+x_4)(x_1+x_2+\bar{x}_3+\bar{x}_4)(x_1+\bar{x}_2+\bar{x}_3+x_4)(\bar{x}_1+x_2+x_3+x_4)$$
$$(\bar{x}_1+x_2+x_3+\bar{x}_4)(\bar{x}_1+x_2+\bar{x}_3+x_4)(\bar{x}_1+x_2+\bar{x}_3+\bar{x}_4)(\bar{x}_1+\bar{x}_2+x_3+x_4)$$
$$(\bar{x}_1+\bar{x}_2+x_3+\bar{x}_4)(\bar{x}_1+\bar{x}_2+\bar{x}_3+x_4)$$

x_1	x_2	x_3	x_4	f_1	f_2
0	0	0	0	1	0
0	0	0	1	1	0
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	1	0
0	1	0	1	1	0
0	1	1	0	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	0	1	0	0
1	0	1	0	0	1
1	0	1	1	0	1
1	1	0	0	0	0
1	1	0	1	0	0
1	1	1	0	0	0
1	1	1	1	1	1

$$f_2 = (x_1+x_2+x_3+x_4)(x_1+x_2+x_3+\bar{x}_4)(x_1+\bar{x}_2+x_3+x_4)$$
$$(x_1+\bar{x}_2+x_3+\bar{x}_4)(x_1+\bar{x}_2+\bar{x}_3+x_4)(\bar{x}_1+x_2+x_3+x_4)$$
$$(\bar{x}_1+x_2+x_3+\bar{x}_4)(\bar{x}_1+\bar{x}_2+x_3+x_4)(\bar{x}_1+\bar{x}_2+x_3+\bar{x}_4)$$
$$(\bar{x}_1+\bar{x}_2+\bar{x}_3+x_4)$$

$$\text{cost} = +8 + (14)(5) + 22 = 100$$

(+8: complements)

For Part 3: simplified/optimized SOP

x_3x_4 \ x_1x_2	00	01	11	10
00	1	1	0	0
01	1	1	0	0
11	0	1	1	0
10	0	0	0	0

$$f_1 = \bar{x}_1\bar{x}_3 + x_2x_3x_4$$

(3 + 4; 3 + 4 for complements = 14)

cost = 14

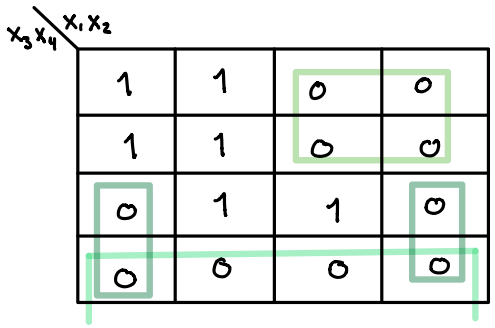
x_3x_4 \ x_1x_2	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	1	0	0	1

$$f_2 = x_3x_4 + \bar{x}_2x_3$$

(3 + 3; 3 for complements = 14)

Total Cost = 25

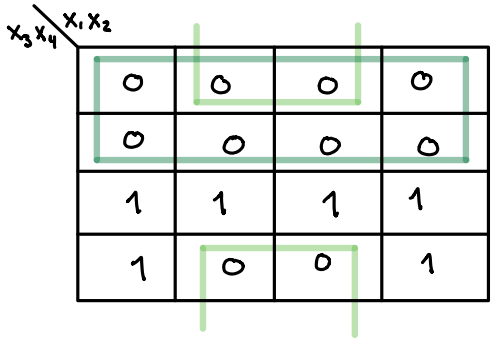
For Part 4: simplified / optimized POS



$$f_1 = (\bar{x}_1 + x_3)(x_2 + \bar{x}_3)(\bar{x}_3 + x_4)$$

cost = +4 + (3)(3) + 4 = 17

(+4: complements; (3)(3): maxterms; +4: overall joining)



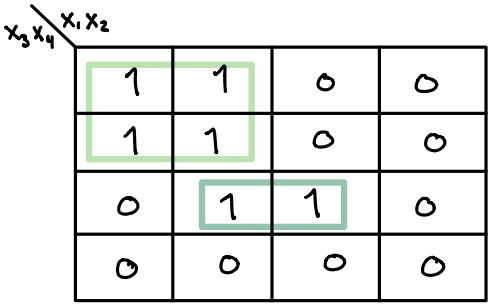
$$f_2 = (x_3)(\bar{x}_2 + x_4)$$

cost = +2 + 3 + 3 = 8

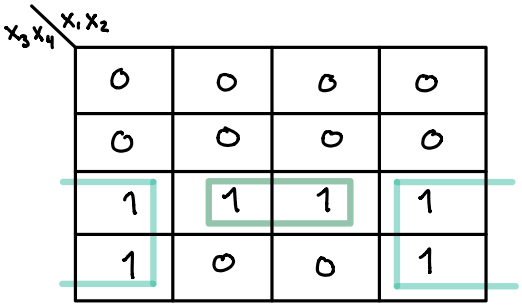
(+2: complements; 3: maxterms; +3: overall joining)

Total Cost = 17 + 8 = 25

For Part 7: most joint-optimized SOP



$$f_1 = \bar{x}_1\bar{x}_3 + x_2x_3x_4$$



$$f_2 = x_2x_3x_4 + \bar{x}_2x_3$$

Joint implementation:

$$f_1 = \bar{x}_1\bar{x}_3 + x_2x_3x_4$$

$$f_2 = x_2x_3x_4 + \bar{x}_2x_3$$

cost = +4 + 3 + 3 + 3 + 3 + 6 = 22

(+4: shared; 3: f_2; 3: f_1; +6: complements)

Cost = 22