컴퓨터 공학 기초 실험2 보고서

실험제목: Traffic Light Controller with/without Left Turn Signals

실험일자: 2021년 10월 18일 (월)

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실습분반: 월요일 0, 1, 2

학 번: 2018202046

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1. 제목 및 목적

A. 제목

Traffic Light Controller with/without Left Turn Signals

B. 목적

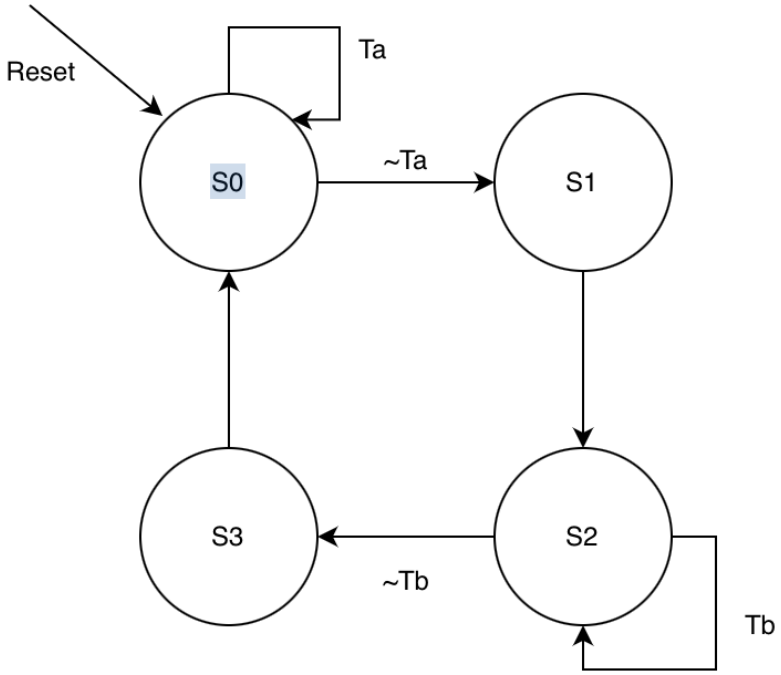
해당 수업을 통해 신호등을 제어하는 logic을 구현한다. 이를 통해 Final state machine에 따라 설계할 수 있다. 논리회로를 짜면서 카르노맵이나 퀸-매클러스키 알고리즘을 이용하여 논리식을 정리할 수 있다.

2. 원리(배경지식)

i. Traffic Light Controller 작동방식

- 신호등을 제어하는 Logic
- La(2bits)와 Lb(2bits)는 각각의 길의 신호등을 의미한다.
- Ta(1bits)와 Tb(1bits)는 각각의 길의 차량이 있는지 감지하는 센서다.
- 신호는 교통이 없을 때 초록에서 노랑을 거쳐 빨간색으로 변한다.

ii. Traffic Light Controller FSM State Transition Diagram



iii. Traffic Light Controller FSM Encoded State Transition Table

Current state		Input		Next state	
Q1	Q0	Ta	Tb	D1	D0
0	0	0	X	0	1
0	0	1	X	0	0
0	1	X	X	1	0
1	0	X	0	1	1
1	0	X	1	1	0
1	1	X	X	0	0

- D1 = Q1 & ~Q0 | ~Q1 & Q0 = Q1 ^ Q0
- D0 = ~Q1 & ~Q0 & ~Ta | Q1 & ~Q0 & ~Tb

iv. Traffic Light Controller FSM output table

Current state		Outputs			
Q1	Q0	La1	La0	Lb1	Lb0
0	0	0	0	1	0
0	1	0	1	1	0
1	0	1	0	0	0
1	1	1	0	0	1

- La1 = Q1
- La0 = ~Q1 & Q0
- Lb1 = ~Q1
- Lb0 = Q1 & Q0

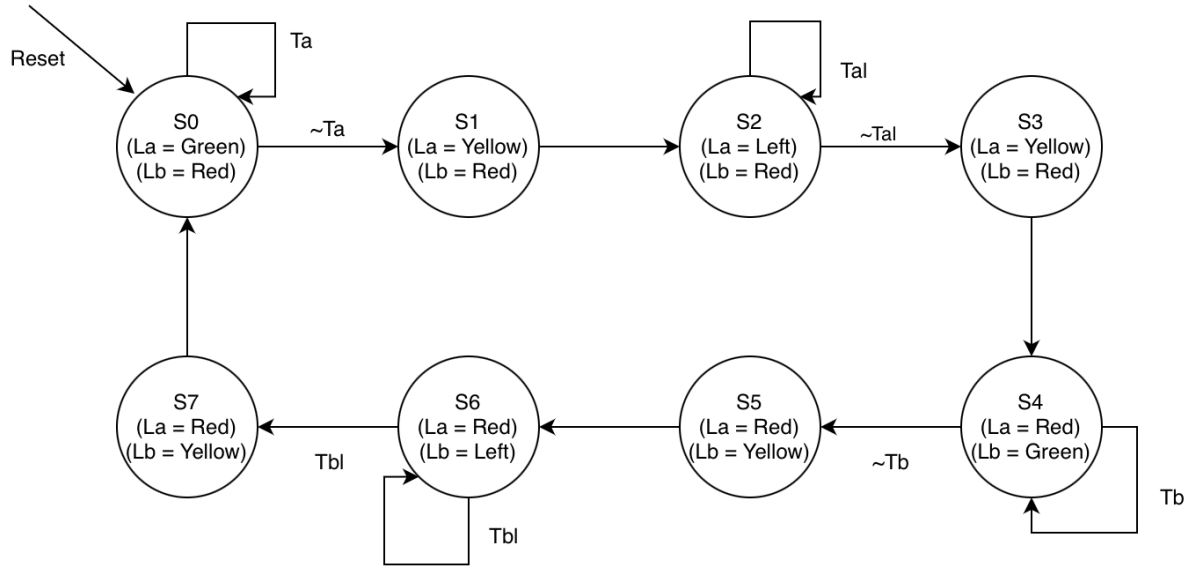
v. Traffic Light Controller FSM schematic

vi. Traffic Light Controller with Left Turn Signals 작동 방식

- 신호등을 제어하는 Logic
- 신호등 La(2bits)와 Lb(2bits)는 차량 통행을 제어하는 신호등
- 차량이 없을 경우 초록불에서 노란불로 바뀐 후 우회전 초록불로 바뀐다. 우회전 차량도 없을 경우 노란불로 바뀐 후 빨간불로 바뀐다

- Ta(1bit), Tal(1bit), Tb, Tbl는 각각의 길의 직진 또는 좌회전 신호를 기다리는 차량을 감지하는 센서다.

vii. Traffic Light Controller with Left Turn Signals FSM State Transition Diagram



viii. Traffic Light Controller with Left Turn Signals FSM State Transition Table

Current state	Input				Next state
	Ta	Tal	Tb	Tbl	
S0	0	X	X	X	S0
S0	1	X	X	X	S1
S1	X	X	X	X	S2
S2	X	1	X	X	S2
S2	X	0	X	X	S3
S3	X	X	X	X	S4
S4	X	X	1	X	S4
S4	X	X	0	X	S5
S5	X	X	X	X	S6
S6	X	X	X	1	S6
S6	X	X	X	0	S7
S7	X	X	X	X	S0

Q2	Q1	Q0	TA	TAL	TB	TBL	D2	D1	D0
0	0	0	0	X	X	X	0	0	1
0	0	0	1	X	X	X	0	0	0
0	0	1	X	X	X	X	0	1	0
0	1	0	X	0	X	X	0	1	1
0	1	0	X	1	X	X	0	1	0
0	1	1	X	X	X	X	1	0	0
1	0	0	X	X	0	X	1	0	1
1	0	0	X	X	1	X	1	0	0
1	0	1	X	X	X	X	1	1	0
1	1	0	X	X	X	0	1	1	1
1	1	0	X	X	X	1	1	1	0
1	1	1	X	X	X	X	0	0	0

ix. Quine-Mcclusky Algorithm of D0

0:	0	0	0	0	0	0	0	→
1:	0	0	0	0	0	0	1	→
2:	0	0	0	0	0	1	0	→
3:	0	0	0	0	0	1	1	→
4:	0	0	0	0	1	0	0	→
5:	0	0	0	0	1	0	1	→
6:	0	0	0	0	1	1	0	→
7:	0	0	0	0	1	1	1	→
32:	0	1	0	0	0	0	0	→
33:	0	1	0	0	0	0	1	→
34:	0	1	0	0	0	1	0	→
35:	0	1	0	0	0	1	1	→
40:	0	1	0	1	0	0	0	→
41:	0	1	0	1	0	0	1	→
42:	0	1	0	1	0	1	0	→
43:	0	1	0	1	0	1	1	→
64:	1	0	0	0	0	0	0	→
65:	1	0	0	0	0	0	1	→
68:	1	0	0	0	1	0	0	→
69:	1	0	0	0	1	0	1	→
72:	1	0	0	1	0	0	0	→
73:	1	0	0	1	0	0	1	→
76:	1	0	0	1	1	0	0	→
77:	1	0	0	1	1	0	1	→
96:	1	1	0	0	0	0	0	→
98:	1	1	0	0	0	1	0	→
100:	1	1	0	0	1	0	0	→
102:	1	1	0	0	1	1	0	→
104:	1	1	0	1	0	0	0	→
106:	1	1	0	1	0	1	0	→
108:	1	1	0	1	1	0	0	→
110:	1	1	0	1	1	1	0	→

0, 1:	0	0	0	0	0	0	-	→
0, 2:	0	0	0	0	0	-	0	→
0, 4:	0	0	0	0	-	0	0	→
0, 32:	0	-	0	0	0	0	0	→
0, 64:	-	0	0	0	0	0	0	→
1, 3:	0	0	0	0	0	-	1	→
1, 5:	0	0	0	0	-	0	1	→
1, 33:	0	-	0	0	0	0	1	→
1, 65:	-	0	0	0	0	0	1	→
2, 3:	0	0	0	0	0	1	-	→
2, 6:	0	0	0	0	-	1	0	→
2, 34:	0	-	0	0	0	1	0	→
3, 7:	0	0	0	0	-	1	1	→
3, 35:	0	-	0	0	0	1	1	→
4, 5:	0	0	0	0	1	0	-	→
4, 6:	0	0	0	0	1	-	0	→
4, 68:	-	0	0	0	1	0	0	→
5, 7:	0	0	0	0	1	-	1	→
5, 69:	-	0	0	0	1	0	1	→
6, 7:	0	0	0	0	1	1	-	→
32, 33:	0	1	0	0	0	0	-	→
32, 34:	0	1	0	0	0	-	0	→
32, 40:	0	1	0	-	0	0	0	→
32, 96:	-	1	0	0	0	0	0	→
33, 35:	0	1	0	0	0	-	1	→
33, 41:	0	1	0	-	0	0	1	→
34, 35:	0	1	0	0	0	1	-	→
34, 42:	0	1	0	-	0	1	0	→
34, 98:	-	1	0	0	0	1	0	→
35, 43:	0	1	0	-	0	1	1	→
40, 41:	0	1	0	1	0	0	-	→
40, 42:	0	1	0	1	0	-	0	→
40, 104:	-	1	0	1	0	0	0	→
41, 43:	0	1	0	1	0	-	1	→
42, 43:	0	1	0	1	0	1	-	→
42, 106:	-	1	0	1	0	1	0	→
64, 65:	1	0	0	0	0	0	-	→
64, 68:	1	0	0	0	-	0	0	→
64, 72:	1	0	0	-	0	0	0	→
64, 96:	1	-	0	0	0	0	0	→
65, 69:	1	0	0	0	-	0	1	→
65, 73:	1	0	0	-	0	0	1	→
68, 69:	1	0	0	0	1	0	-	→
68, 76:	1	0	0	-	1	0	0	→
68, 100:	1	-	0	0	1	0	0	→
69, 77:	1	0	0	-	1	0	1	→
72, 73:	1	0	0	1	0	0	-	→
72, 76:	1	0	0	1	-	0	0	→
72, 104:	1	-	0	1	0	0	0	→
73, 77:	1	0	0	1	-	0	1	→
76, 77:	1	0	0	1	1	0	-	→
76, 108:	1	-	0	1	1	0	0	→
96, 98:	1	1	0	0	0	-	0	→
96, 100:	1	1	0	0	-	0	0	→
96, 104:	1	1	0	-	0	0	0	→
98, 102:	1	1	0	0	-	1	0	→
98, 106:	1	1	0	-	0	1	0	→
100, 102:	1	1	0	0	1	-	0	→
100, 108:	1	1	0	-	1	0	0	→
102, 110:	1	1	0	-	1	1	0	→
104, 106:	1	1	0	1	0	-	0	→
104, 108:	1	1	0	1	-	0	0	→
106, 110:	1	1	0	1	-	1	0	→
108, 110:	1	1	0	1	1	-	0	→

0, 1, 2, 3:	0	0	0	0	0	-	-	→
0, 1, 4, 5:	0	0	0	0	-	0	-	→
0, 1, 32, 33:	0	-	0	0	0	0	-	→
0, 1, 64, 65:	-	0	0	0	0	0	-	→
0, 2, 4, 6:	0	0	0	0	-	-	0	→
0, 2, 32, 34:	0	-	0	0	0	-	0	→
0, 4, 64, 68:	-	0	0	0	-	0	0	→
0, 32, 64, 96:	-	-	0	0	0	0	0	✓
1, 3, 5, 7:	0	0	0	0	-	-	1	→
1, 3, 33, 35:	0	-	0	0	0	-	1	→
1, 5, 65, 69:	-	0	0	0	-	0	1	→
2, 3, 6, 7:	0	0	0	0	-	1	-	→
2, 3, 34, 35:	0	-	0	0	0	1	-	→
4, 5, 6, 7:	0	0	0	0	1	-	-	→
4, 5, 68, 69:	-	0	0	0	1	0	-	→
32, 33, 34, 35:	0	1	0	0	0	-	-	→
32, 33, 40, 41:	0	1	0	-	0	0	-	→
32, 34, 40, 42:	0	1	0	-	0	-	0	→
32, 34, 96, 98:	-	1	0	0	0	-	0	→
32, 40, 96, 104:	-	1	0	-	0	0	0	→
33, 35, 41, 43:	0	1	0	-	0	-	1	→
34, 35, 42, 43:	0	1	0	-	0	1	-	→
34, 42, 98, 106:	-	1	0	-	0	1	0	→
40, 41, 42, 43:	0	1	0	1	0	-	-	→
40, 42, 104, 106:	-	1	0	1	0	-	0	→
64, 65, 68, 69:	1	0	0	0	-	0	-	→
64, 65, 72, 73:	1	0	0	-	0	0	-	→
64, 68, 72, 76:	1	0	0	-	-	0	0	→
64, 68, 96, 100:	1	-	0	0	-	0	0	→
64, 72, 96, 104:	1	-	0	-	0	0	0	→
65, 69, 73, 77:	1	0	0	-	-	0	1	→
68, 69, 76, 77:	1	0	0	-	1	0	-	→
68, 76, 100, 108:	1	-	0	-	1	0	0	→
72, 73, 76, 77:	1	0	0	1	-	0	-	→
72, 76, 104, 108:	1	-	0	1	-	0	0	→
96, 98, 100, 102:	1	1	0	0	-	-	0	→
96, 98, 104, 106:	1	1	0	-	0	-	0	→
96, 100, 104, 108:	1	1	0	-	-	0	0	→
98, 102, 106, 110:	1	1	0	-	-	1	0	→
100, 102, 108, 110:	1	1	0	-	1	-	0	→
104, 106, 108, 110:	1	1	0	1	-	-	0	→

0, 1, 2, 3, 4, 5, 6, 7:	0	0	0	0	-	-	-	✓
0, 1, 2, 3, 32, 33, 34, 35:	0	-	0	0	0	-	-	✓
0, 1, 4, 5, 64, 65, 68, 69:	-	0	0	0	-	0	-	✓
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32, 34, 40, 42, 96, 98, 104, 106:	-	1	0	-	0	-	0	✓
64, 65, 68, 69, 72, 73, 76, 77:	1	0	0	-	-	0	-	✓
64, 68, 72, 76, 96, 100, 104, 108:	1	-	0	-	-	0	0	✓
96, 98, 100, 102, 104, 106, 108, 110:	1	1	0	-	-	-	0	✓

	0	1	2	3	4	5	6	7	32	33	34	35	40	41	42	43	64	65	68	69	72	73	76	77	96	98	100	102	104	106	108	110
0000—	O	O	O	O	O	O	O	O																								
0-000–	O	O	O	O					O	O	O	O																				
-000-0-	O	O			O	O											O	O	O	O												
010-0–									O	O	O	O	O	O	O	O																
-10-0-0									O		O		O		O										O	O			O	O		
100-0-0																	O	O	O	O	O	O	O	O								
1-0—00																	O		O		O		O		O		O		O		O	
1100—0																									O	O	O	O	O	O	O	O
—00000	O								O								O								O							

D0 = ~Q2 & ~Q1 & Q0′ & TA′ | ~Q2 & Q1 & ~Q0 & ~TAL | Q2 & ~Q1 & ~Q0′ & ~TB | Q2 & Q1 & ~Q0 & ~TBL

x. Quine Mcclusky Algorithm of D1

16:	0	0	1	0	0	0	0	→
17:	0	0	1	0	0	0	1	→
18:	0	0	1	0	0	1	0	→
19:	0	0	1	0	0	1	1	→
20:	0	0	1	0	1	0	0	→
21:	0	0	1	0	1	0	1	→
22:	0	0	1	0	1	1	0	→
23:	0	0	1	0	1	1	1	→
24:	0	0	1	1	0	0	0	→
25:	0	0	1	1	0	0	1	→
26:	0	0	1	1	0	1	0	→
27:	0	0	1	1	0	1	1	→
28:	0	0	1	1	1	0	0	→
29:	0	0	1	1	1	0	1	→
30:	0	0	1	1	1	1	0	→
31:	0	0	1	1	1	1	1	→
32:	0	1	0	0	0	0	0	→
33:	0	1	0	0	0	0	1	→
34:	0	1	0	0	0	1	0	→
35:	0	1	0	0	0	1	1	→
36:	0	1	0	0	1	0	0	→
37:	0	1	0	0	1	0	1	→
38:	0	1	0	0	1	1	0	→
39:	0	1	0	0	1	1	1	→
40:	0	1	0	1	0	0	0	→
41:	0	1	0	1	0	0	1	→
42:	0	1	0	1	0	1	0	→
43:	0	1	0	1	0	1	1	→
44:	0	1	0	1	1	0	0	→
45:	0	1	0	1	1	0	1	→
46:	0	1	0	1	1	1	0	→
47:	0	1	0	1	1	1	1	→
80:	1	0	1	0	0	0	0	→
81:	1	0	1	0	0	0	1	→
82:	1	0	1	0	0	1	0	→
83:	1	0	1	0	0	1	1	→
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85:	1	0	1	0	1	0	1	→
86:	1	0	1	0	1	1	0	→
87:	1	0	1	0	1	1	1	→
88:	1	0	1	1	0	0	0	→
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92:	1	0	1	1	1	0	0	→
93:	1	0	1	1	1	0	1	→
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97:	1	1	0	0	0	0	1	→
98:	1	1	0	0	0	1	0	→
99:	1	1	0	0	0	1	1	→
100:	1	1	0	0	1	0	0	→
101:	1	1	0	0	1	0	1	→
102:	1	1	0	0	1	1	0	→
103:	1	1	0	0	1	1	1	→
104:	1	1	0	1	0	0	0	→
105:	1	1	0	1	0	0	1	→
106:	1	1	0	1	0	1	0	→
107:	1	1	0	1	0	1	1	→
108:	1	1	0	1	1	0	0	→
109:	1	1	0	1	1	0	1	→
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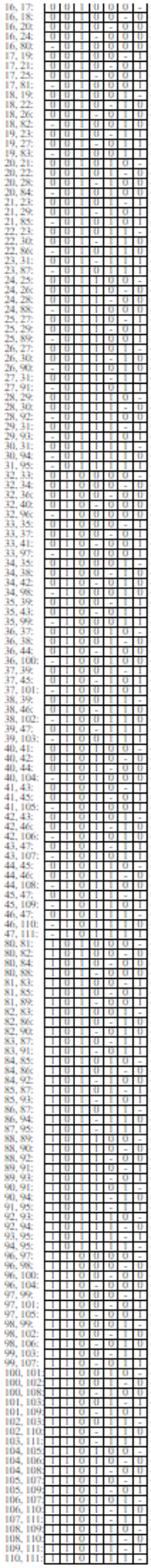
111:	1	1	0	1	1	1	1	→



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20, 22, 28, 30, 84, 86, 92, 94:	-	0	1	-	1	-	0	→
21, 23, 29, 31, 85, 87, 93, 95:	-	0	1	-	1	-	1	→
22, 23, 30, 31, 86, 87, 94, 95:	-	0	1	-	1	1	-	→
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24, 25, 28, 29, 88, 89, 92, 93:	-	0	1	1	-	0	-	→
24, 26, 28, 30, 88, 90, 92, 94:	-	0	1	1	-	-	0	→
25, 27, 29, 31, 89, 91, 93, 95:	-	0	1	1	-	-	1	→
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37, 39, 45, 47, 101, 103, 109, 111:	-	1	0	-	1	-	1	→
38, 39, 46, 47, 102, 103, 110, 111:	-	1	0	-	1	1	-	→
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100, 101, 102, 103, 108, 109, 110, 111:	1	1	0	-	1	-	-	→
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16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31:	0	0	1	-	-	-	→
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D1 = ~Q1 & Q0 | Q1 & ~Q0 = Q1 ^ Q0

xi. Quine-Mcclusky Algorithm of D2

48:	0	1	1	0	0	0	0	→
49:	0	1	1	0	0	0	1	→
50:	0	1	1	0	0	1	0	→
51:	0	1	1	0	0	1	1	→
52:	0	1	1	0	1	0	0	→
53:	0	1	1	0	1	0	1	→
54:	0	1	1	0	1	1	0	→
55:	0	1	1	0	1	1	1	→
56:	0	1	1	1	0	0	0	→
57:	0	1	1	1	0	0	1	→
58:	0	1	1	1	0	1	0	→
59:	0	1	1	1	0	1	1	→
60:	0	1	1	1	1	0	0	→
61:	0	1	1	1	1	0	1	→
62:	0	1	1	1	1	1	0	→
63:	0	1	1	1	1	1	1	→
64:	1	0	0	0	0	0	0	→
65:	1	0	0	0	0	0	1	→
66:	1	0	0	0	0	1	0	→
67:	1	0	0	0	0	1	1	→
68:	1	0	0	0	1	0	0	→
69:	1	0	0	0	1	0	1	→
70:	1	0	0	0	1	1	0	→
71:	1	0	0	0	1	1	1	→
72:	1	0	0	1	0	0	0	→
73:	1	0	0	1	0	0	1	→
74:	1	0	0	1	0	1	0	→
75:	1	0	0	1	0	1	1	→
76:	1	0	0	1	1	0	0	→
77:	1	0	0	1	1	0	1	→
78:	1	0	0	1	1	1	0	→
79:	1	0	0	1	1	1	1	→
80:	1	0	1	0	0	0	0	→
81:	1	0	1	0	0	0	1	→
82:	1	0	1	0	0	1	0	→
83:	1	0	1	0	0	1	1	→
84:	1	0	1	0	1	0	0	→
85:	1	0	1	0	1	0	1	→
86:	1	0	1	0	1	1	0	→
87:	1	0	1	0	1	1	1	→
88:	1	0	1	1	0	0	0	→
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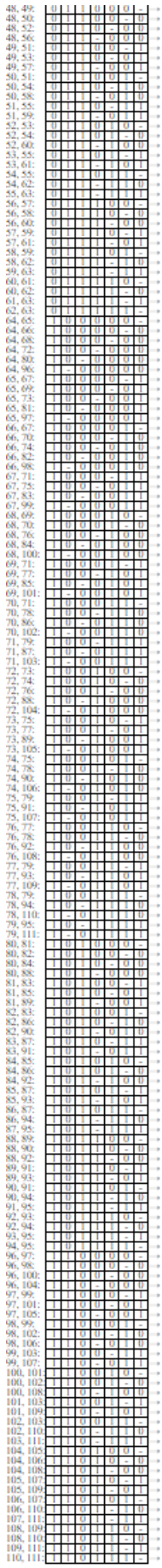
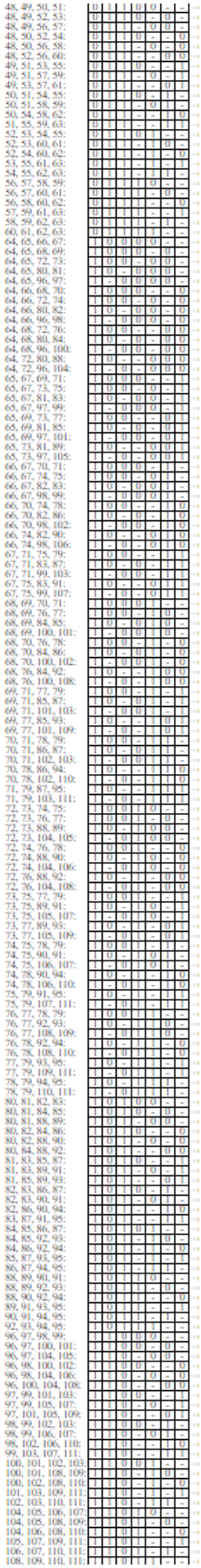
94:	1	0	1	1	1	1	0	→
95:	1	0	1	1	1	1	1	→
96:	1	1	0	0	0	0	0	→
97:	1	1	0	0	0	0	1	→
98:	1	1	0	0	0	1	0	→
99:	1	1	0	0	0	1	1	→
100:	1	1	0	0	1	0	0	→
101:	1	1	0	0	1	0	1	→
102:	1	1	0	0	1	1	0	→
103:	1	1	0	0	1	1	1	→
104:	1	1	0	1	0	0	0	→
105:	1	1	0	1	0	0	1	→
106:	1	1	0	1	0	1	0	→
107:	1	1	0	1	0	1	1	→
108:	1	1	0	1	1	0	0	→
109:	1	1	0	1	1	0	1	→
110:	1	1	0	1	1	1	0	→
111:	1	1	0	1	1	1	1	→

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64, 65, 68, 69, 80, 81, 84, 85:	1	0	-	0	-	0	-	→
64, 65, 68, 69, 96, 97, 100, 101:	1	-	0	0	-	0	-	→
64, 65, 72, 73, 80, 81, 88, 89:	1	0	-	-	0	0	-	→
64, 65, 72, 73, 96, 97, 104, 105:	1	-	0	-	0	0	-	→
64, 66, 68, 70, 72, 74, 76, 78:	1	0	0	-	-	-	0	→
64, 66, 68, 70, 80, 82, 84, 86:	1	0	-	0	-	-	0	→
64, 66, 68, 70, 96, 98, 100, 102:	1	-	0	0	-	-	0	→
64, 66, 72, 74, 80, 82, 88, 90:	1	0	-	-	0	-	0	→
64, 66, 72, 74, 96, 98, 104, 106:	1	-	0	-	0	-	0	→
64, 68, 72, 76, 80, 84, 88, 92:	1	0	-	-	-	0	0	→
64, 68, 72, 76, 96, 100, 104, 108:	1	-	0	-	-	0	0	→
65, 67, 69, 71, 73, 75, 77, 79:	1	0	0	-	-	-	1	→
65, 67, 69, 71, 81, 83, 85, 87:	1	0	-	0	-	-	1	→
65, 67, 69, 71, 97, 99, 101, 103:	1	-	0	0	-	-	1	→
65, 67, 73, 75, 81, 83, 89, 91:	1	0	-	-	0	-	1	→
65, 67, 73, 75, 97, 99, 105, 107:	1	-	0	-	0	-	1	→
65, 69, 73, 77, 81, 85, 89, 93:	1	0	-	-	-	0	1	→
65, 69, 73, 77, 97, 101, 105, 109:	1	-	0	-	-	0	1	→
66, 67, 70, 71, 74, 75, 78, 79:	1	0	0	-	-	1	-	→
66, 67, 70, 71, 82, 83, 86, 87:	1	0	-	0	-	1	-	→
66, 67, 70, 71, 98, 99, 102, 103:	1	-	0	0	-	1	-	→
66, 67, 74, 75, 82, 83, 90, 91:	1	0	-	-	0	1	-	→
66, 67, 74, 75, 98, 99, 106, 107:	1	-	0	-	0	1	-	→
66, 70, 74, 78, 82, 86, 90, 94:	1	0	-	-	-	1	0	→
66, 70, 74, 78, 98, 102, 106, 110:	1	-	0	-	-	1	0	→
67, 71, 75, 79, 83, 87, 91, 95:	1	0	-	-	-	1	1	→
67, 71, 75, 79, 99, 103, 107, 111:	1	-	0	-	-	1	1	→
68, 69, 70, 71, 76, 77, 78, 79:	1	0	0	-	1	-	-	→
68, 69, 70, 71, 84, 85, 86, 87:	1	0	-	0	1	-	-	→
68, 69, 70, 71, 100, 101, 102, 103:	1	-	0	0	1	-	-	→
68, 69, 76, 77, 84, 85, 92, 93:	1	0	-	-	1	0	-	→
68, 69, 76, 77, 100, 101, 108, 109:	1	-	0	-	1	0	-	→
68, 70, 76, 78, 84, 86, 92, 94:	1	0	-	-	1	-	0	→
68, 70, 76, 78, 100, 102, 108, 110:	1	-	0	-	1	-	0	→
69, 71, 77, 79, 85, 87, 93, 95:	1	0	-	-	1	-	1	→
69, 71, 77, 79, 101, 103, 109, 111:	1	-	0	-	1	-	1	→
70, 71, 78, 79, 86, 87, 94, 95:	1	0	-	-	1	1	-	→
70, 71, 78, 79, 102, 103, 110, 111:	1	-	0	-	1	1	-	→
72, 73, 74, 75, 76, 77, 78, 79:	1	0	0	1	-	-	-	→
72, 73, 74, 75, 88, 89, 90, 91:	1	0	-	1	0	-	-	→
72, 73, 74, 75, 104, 105, 106, 107:	1	-	0	1	0	-	-	→
72, 73, 76, 77, 88, 89, 92, 93:	1	0	-	1	-	0	-	→
72, 73, 76, 77, 104, 105, 108, 109:	1	-	0	1	-	0	-	→
72, 74, 76, 78, 88, 90, 92, 94:	1	0	-	1	-	-	0	→
72, 74, 76, 78, 104, 106, 108, 110:	1	-	0	1	-	-	0	→
73, 75, 77, 79, 89, 91, 93, 95:	1	0	-	1	-	-	1	→
73, 75, 77, 79, 105, 107, 109, 111:	1	-	0	1	-	-	1	→
74, 75, 78, 79, 90, 91, 94, 95:	1	0	-	1	-	1	-	→
74, 75, 78, 79, 106, 107, 110, 111:	1	-	0	1	-	1	-	→
76, 77, 78, 79, 92, 93, 94, 95:	1	0	-	1	1	-	-	→
76, 77, 78, 79, 108, 109, 110, 111:	1	-	0	1	1	-	-	→
80, 81, 82, 83, 84, 85, 86, 87:	1	0	1	0	-	-	-	→
80, 81, 82, 83, 88, 89, 90, 91:	1	0	1	-	0	-	-	→
80, 81, 84, 85, 88, 89, 92, 93:	1	0	1	-	-	0	-	→
80, 82, 84, 86, 88, 90, 92, 94:	1	0	1	-	-	-	0	→
81, 83, 85, 87, 89, 91, 93, 95:	1	0	1	-	-	-	1	→
82, 83, 86, 87, 90, 91, 94, 95:	1	0	1	-	-	1	-	→
84, 85, 86, 87, 92, 93, 94, 95:	1	0	1	-	1	-	-	→
88, 89, 90, 91, 92, 93, 94, 95:	1	0	1	1	-	-	-	→
96, 97, 98, 99, 100, 101, 102, 103:	1	1	0	0	-	-	-	→
96, 97, 98, 99, 104, 105, 106, 107:	1	1	0	-	0	-	-	→
96, 97, 100, 101, 104, 105, 108, 109:	1	1	0	-	-	0	-	→
96, 98, 100, 102, 104, 106, 108, 110:	1	1	0	-	-	-	0	→
97, 99, 101, 103, 105, 107, 109, 111:	1	1	0	-	-	-	1	→
98, 99, 102, 103, 106, 107, 110, 111:	1	1	0	-	-	1	-	→
100, 101, 102, 103, 108, 109, 110, 111:	1	1	0	-	1	-	-	→
104, 105, 106, 107, 108, 109, 110, 111:	1	1	0	1	-	-	-	→

48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63:	0	1	1	-	-	-	-	✓
64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79:	1	0	0	-	-	-	-	→
64, 65, 66, 67, 68, 69, 70, 71, 80, 81, 82, 83, 84, 85, 86, 87:	1	0	-	0	-	-	-	→
64, 65, 66, 67, 68, 69, 70, 71, 96, 97, 98, 99, 100, 101, 102, 103:	1	-	0	0	-	-	-	→
64, 65, 66, 67, 72, 73, 74, 75, 80, 81, 82, 83, 88, 89, 90, 91:	1	0	-	-	0	-	-	→
64, 65, 66, 67, 72, 73, 74, 75, 96, 97, 98, 99, 104, 105, 106, 107:	1	-	0	-	0	-	-	→
64, 65, 68, 69, 72, 73, 76, 77, 80, 81, 84, 85, 88, 89, 92, 93:	1	0	-	-	-	0	-	→
64, 65, 68, 69, 72, 73, 76, 77, 96, 97, 100, 101, 104, 105, 108, 109:	1	-	0	-	-	0	-	→
64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94:	1	0	-	-	-	-	0	→
64, 66, 68, 70, 72, 74, 76, 78, 96, 98, 100, 102, 104, 106, 108, 110:	1	-	0	-	-	-	0	→
65, 67, 69, 71, 73, 75, 77, 79, 81, 83, 85, 87, 89, 91, 93, 95:	1	0	-	-	-	-	1	→
65, 67, 69, 71, 73, 75, 77, 79, 97, 99, 101, 103, 105, 107, 109, 111:	1	-	0	-	-	-	1	→
66, 67, 70, 71, 74, 75, 78, 79, 82, 83, 86, 87, 90, 91, 94, 95:	1	0	-	-	-	1	-	→
66, 67, 70, 71, 74, 75, 78, 79, 98, 99, 102, 103, 106, 107, 110, 111:	1	-	0	-	-	1	-	→
68, 69, 70, 71, 76, 77, 78, 79, 84, 85, 86, 87, 92, 93, 94, 95:	1	0	-	-	1	-	-	→
68, 69, 70, 71, 76, 77, 78, 79, 100, 101, 102, 103, 108, 109, 110, 111:	1	-	0	-	1	-	-	→
72, 73, 74, 75, 76, 77, 78, 79, 88, 89, 90, 91, 92, 93, 94, 95:	1	0	-	1	-	-	-	→
72, 73, 74, 75, 76, 77, 78, 79, 104, 105, 106, 107, 108, 109, 110, 111:	1	-	0	1	-	-	-	→
80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95:	1	0	1	-	-	-	-	→
96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111:	1	1	0	-	-	-	-	→

64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95:	1	0	-	-	-	-	-	✓
64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111:	1	-	0	-	-	-	-	✓

D2 = ~Q2 & Q1 & Q0 | Q2 & ~Q1 | Q2 Q1 ~Q0

xii. Traffic Light Controller with Left Turn Signals FSM Output Encoded Table

Current state			Outputs			
Q2	Q1	Q0	La1	La0	Lb1	Lb0
0	0	0	0	0	1	1
0	0	1	0	1	1	1
0	1	0	1	0	1	1
0	1	1	0	1	1	1
1	0	0	1	1	0	0
1	0	1	1	1	0	1
1	1	0	1	1	1	0
1	1	1	1	1	0	1

La0					
q0	q2 q1	00	01	11	10
0		0	0	1	1
1		1	1	1	1

La0 = Q0 | Q2

La1					
q0	q2 q1	00	01	11	10
0		0	1	1	1
1		0	0	1	1

La1 = Q2 | ~Q0 & Q1

Lb0					
q0	q2 q1	00	01	11	10
0		1	1	0	0
1		1	1	1	1

Lb0 = ~Q2 | Q0

Lb1

q0	q2 q1	00	01	11	10
0		1	1	1	0
1		1	1	0	0

Lb1 = ~Q2 | ~Q0 & Q1

3. 설계 세부사항

i. _dff_r

해당 모듈은 r(reset_n)의 값에 의해 신호를 초기화 할 수 있는 Resettable D Flip-Flop이다. 해당 모듈은 저번시간에 만든 Async로 동작해야 하기 때문에 저번 시간에 만든 _dff_r_async를 수정하여 만들었다. clk의 posedge나 set_n 또는 reset_n이 negedge일 때 동작할 수 있도록 always 문을 걸어준다. 그 후 reset_n이 0일 경우 0을, set_n이 0일 경우 1을, 이외의 경우에는 d를 출력하도록 한다.

ii. _register2_async

해당 모듈은 2개의 Register가 Async 방식으로 동작하는 모듈이다. 해당 모듈은 _dff_r을 2개를 사용하여 각각의 입력과 출력에 연결함으로써 구성하였다.

iii. _register3_async

해당 모듈은 3개의 Register가 Async 방식으로 동작하는 모듈이다. 해당 모듈은 _dff_r을 3개를 사용하여 각각의 입력과 출력에 연결함으로써 구성하였다.

iv. ns_logic

해당 모듈은 2개가 제작되었다. 하나는 직진 신호만 존재하는 FSM, 다른 하나는 좌회전 신호가 존재하는 FSM을 위해 제작되었다. 각각의 모듈은 위에서 계산한 식을 바탕으로 gates.v 파일에 있는 모듈을 통해 다음 신호를 계산하는 모듈이다. 단 Not gate의 경우 너무 많은 양으로 인해 ~기호로 대체하여 사용하였다.

v. o_logic

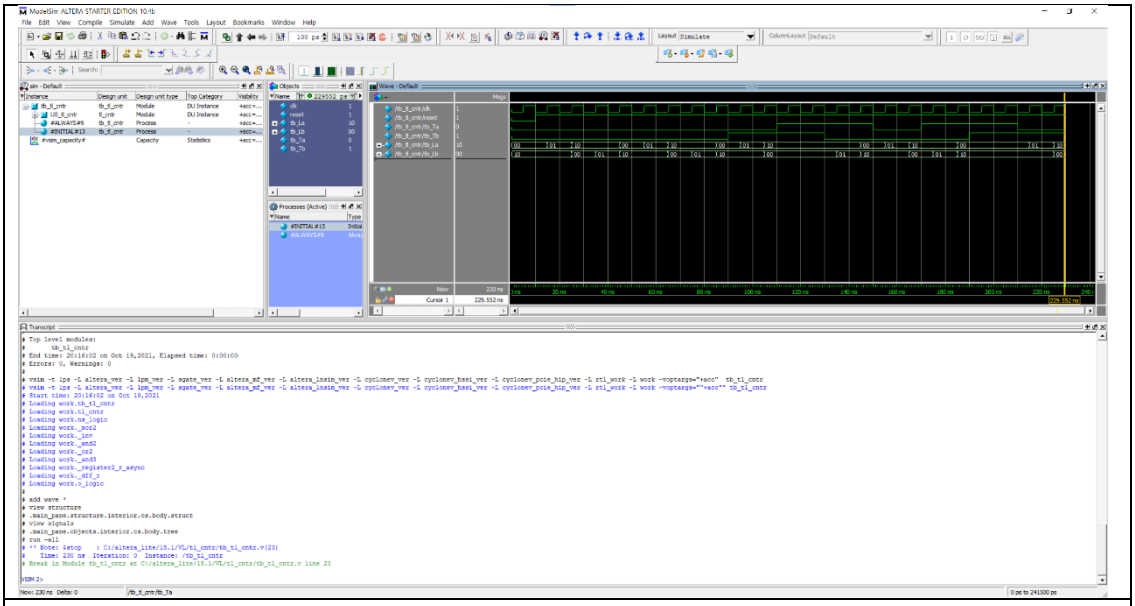
해당 모듈은 2개가 제작되었다. 하나는 직진 신호만 존재하는 FSM, 다른 하나는 좌회전 신호가 존재하는 FSM을 위해 제작되었다. 각각의 모듈은 위에서 계산한 식을 gates.v 파일에 있는 모듈을 통해 output 신호를 계산하는 모듈이다. 단 Not gate의 경우 너무 많은 양으로 인해 ~기호로 대체하여 사용하였다.

vi. tl_cntr / tl_cntr_w_left

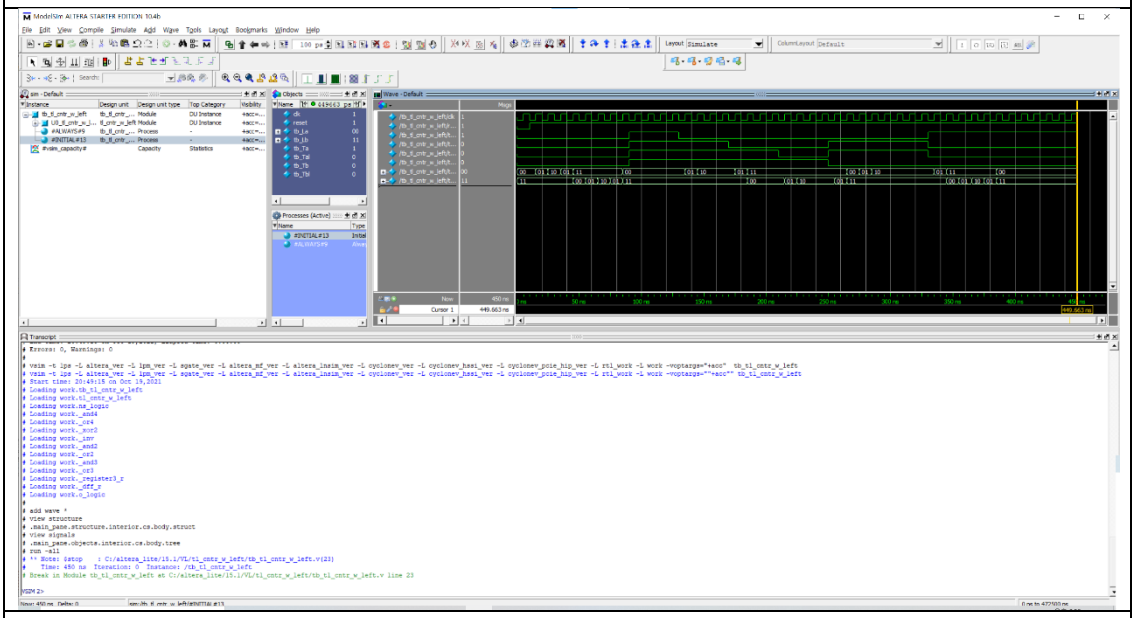
해당 모듈은 각각의 FSM을 최종적으로 완성하는 모듈이다. register의 입력은 wire q_n로, 출력은 q으로 한다. 그리고 ns_logic은 q, Ta, Tb를 입력으로 받아 Q_n으로 바꾼다. o_logic은 현재 상태인 q를 입력으로 받아 La, Lb를 바꾼다.

4. 설계 검증 및 실험 결과

A. 시뮬레이션 결과

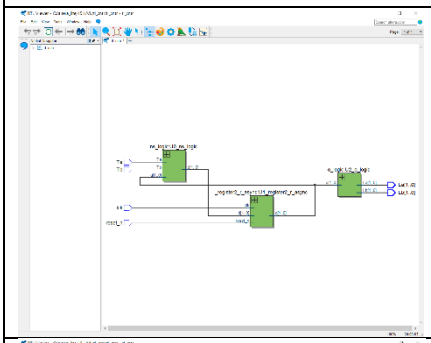
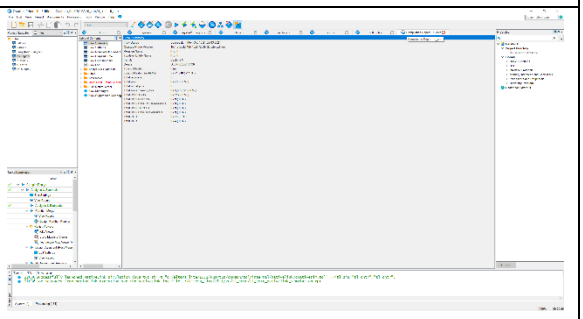
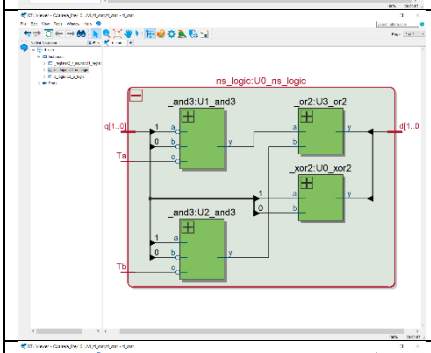
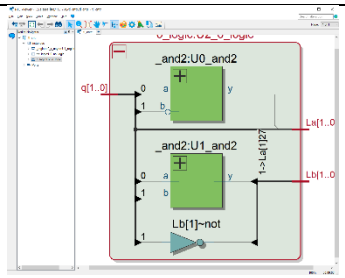
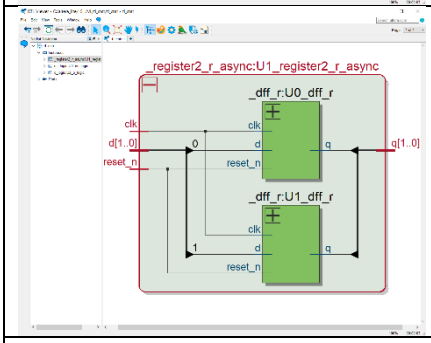
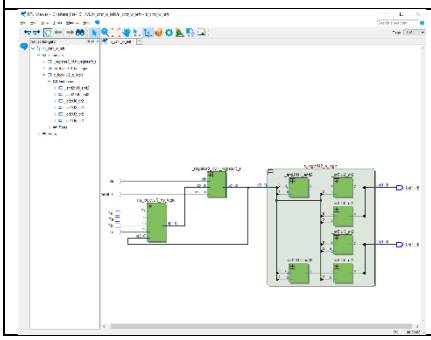
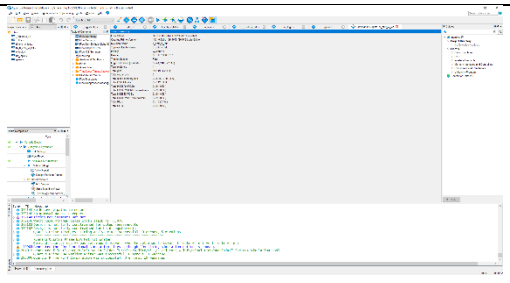


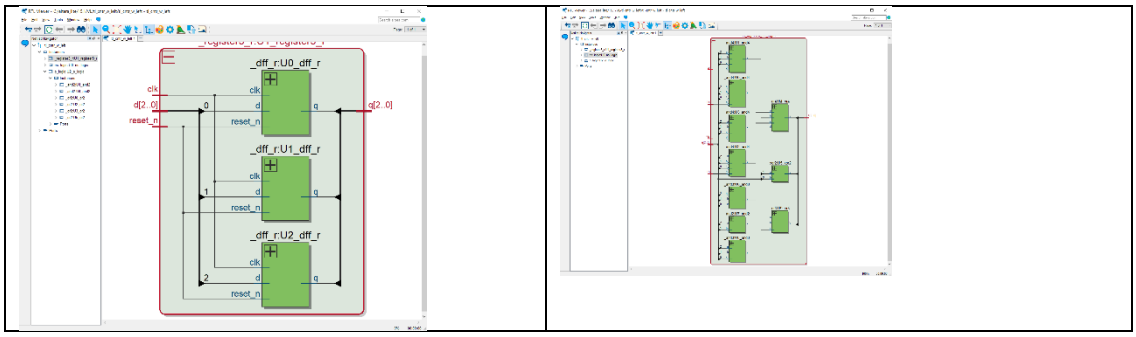
해당 testbench는 tl_cntr를 검증한다. 차량이 없을 경우 신호는 계속 순환한다. 그리고 차량이 있을 경우 차량이 없을 때까지 신호를 유지하다 바꾸는 모습을 볼 수 있다.



해당 testbench는 tl_cntr를 검증한다. 차량이 없을 경우 신호는 계속 순환한다. 그리고 차량이 있을 경우 차량이 없을 때까지 신호를 유지하다 바꾸는 모습을 볼 수 있다.

B. 합성(synthesis) 결과

<table>
<tr><td colspan="2">tl_cntr</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td> 
</td><td></td></tr>
<tr><td colspan="2">tl_cntr</td></tr>
<tr><td>  </td><td>  </td></tr>
</table>



해당 모듈의 설계를 확인하면 각각의 모듈이 정상적으로 설계되어 연결되었음을 알 수 있다.

C. FPGA board targeting 결과

5. 고찰 및 결론

A. 고찰

이번 주차의 과제는 제작 과정에서는 특별한 어려움은 없었다. 다만 보고서를 쓰는 과정에서 Quine_Mcclusky 알고리즘을 이용해서 결과를 도출하는 과정이 오래 걸렸다. 또한 과제가 여러 개 겹친 상황에 시험 기간이여서 시간 내에 진행하는 데에 어려움을 느꼈다.

B. 결론

해당 실험을 통해 FSM을 통해 직접 회로를 설계할 수 있다. 또한 Quine-Mcclusky 알고리즘을 활용하여 Boolen 식을 간소화할 수 있다. 그리고 register를 회로에 직접 사용할 수 있다.

6. 참고문헌

이준환 교수님/디지털논리회로1/광운대학교(컴퓨터정보공학부)/2021
이준환 교수님/디지털논리회로2/광운대학교(컴퓨터정보공학부)/2021