ECE 451 LAB 3

Subway Signal Controller

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ECE 451 Lab 3: Subway Signal Controller

Objective:

- The objective of this lab is to design a control logic block using Cadence.

Lab Description and Specs:

- Function:
  - Design a subway signal controller for each subway station. Each section of tracks in a subway station will have a sensor to determine whether there is a train in that section and a signal with red, yellow, and green lights. You want the light in the track section to show red if there is a train in the track section in the very next station in the direction the train is traveling, yellow if there is no train in the track section in the very next station but the section after that is occupied, and green otherwise.

  - Tracks allow trains move both ways from left to right and vice versa. The input D indicates the direction allowed at the time. When it is 1, the left-to-right direction is allowed; when it is 0, the right-to-left direction is allowed. The outputs G, Y, and R should be 1 to light the green, yellow, and red signals, respectively. The input P is 1 if there is a train in this section (subway station). The signals Ai, Bi, Ao and Bo are signal used to communicate from/to the station to the right and from/to the station to the left. The signals Ai and Bi are received/sent from/to the section to the right of the station, and signals Ao and Bo are received/sent from/to the section to the left of the station. You may do with these what you like, but there are only two wires available, and you may not add more. Therefore, they must have proper tri-state control. Based on your decision, specify how you will use these two wires and what their functions are.

- Inputs:
  - Ai, Bi, Ao, Bo: Inputs from the neighboring subway stations.
  - P: Sensor input to indicate existence of a train on the track.
  - D: Track direction input.

- Outputs:
  - G, Y, R: Light control signals for green, yellow, and red lights, respectively.
  - Ai, Bi, Ao, Bo: Output signals for the neighboring stations.

Truth Table:

D	P	A0	B0		R	Y	G		Ai	B1
0	0	0	0		0	0	1		0	0
0	0	0	1		0	1	0		0	0
0	0	1	0		1	0	0		0	1
0	0	1	1		1	0	0		0	1
0	1	0	0		0	0	1		1	0
0	1	0	1		0	1	0		1	0
0	1	1	0		1	0	0		1	1
0	1	1	1		1	0	0		1	1

D	P	Ai	Bi		R	Y	G		A0	B0
1	0	0	0		0	0	1		0	0
1	0	0	1		0	1	0		0	0
1	0	1	0		1	0	0		0	1
1	0	1	1		1	0	0		0	1
1	1	0	0		0	0	1		1	0
1	1	0	1		0	1	0		1	0
1	1	1	0		1	0	0		1	1
1	1	1	1		1	0	0		1	1

Equations:

$$R = \overline{D}.A_0 + D.A_i$$

$$Y = \overline{D}.\overline{A_0}.B_0 + D.\overline{A_i}.B_i$$

$$G = \overline{D}.\overline{A_0}.\overline{B_0} + D.\overline{A_i}.\overline{B_i}$$

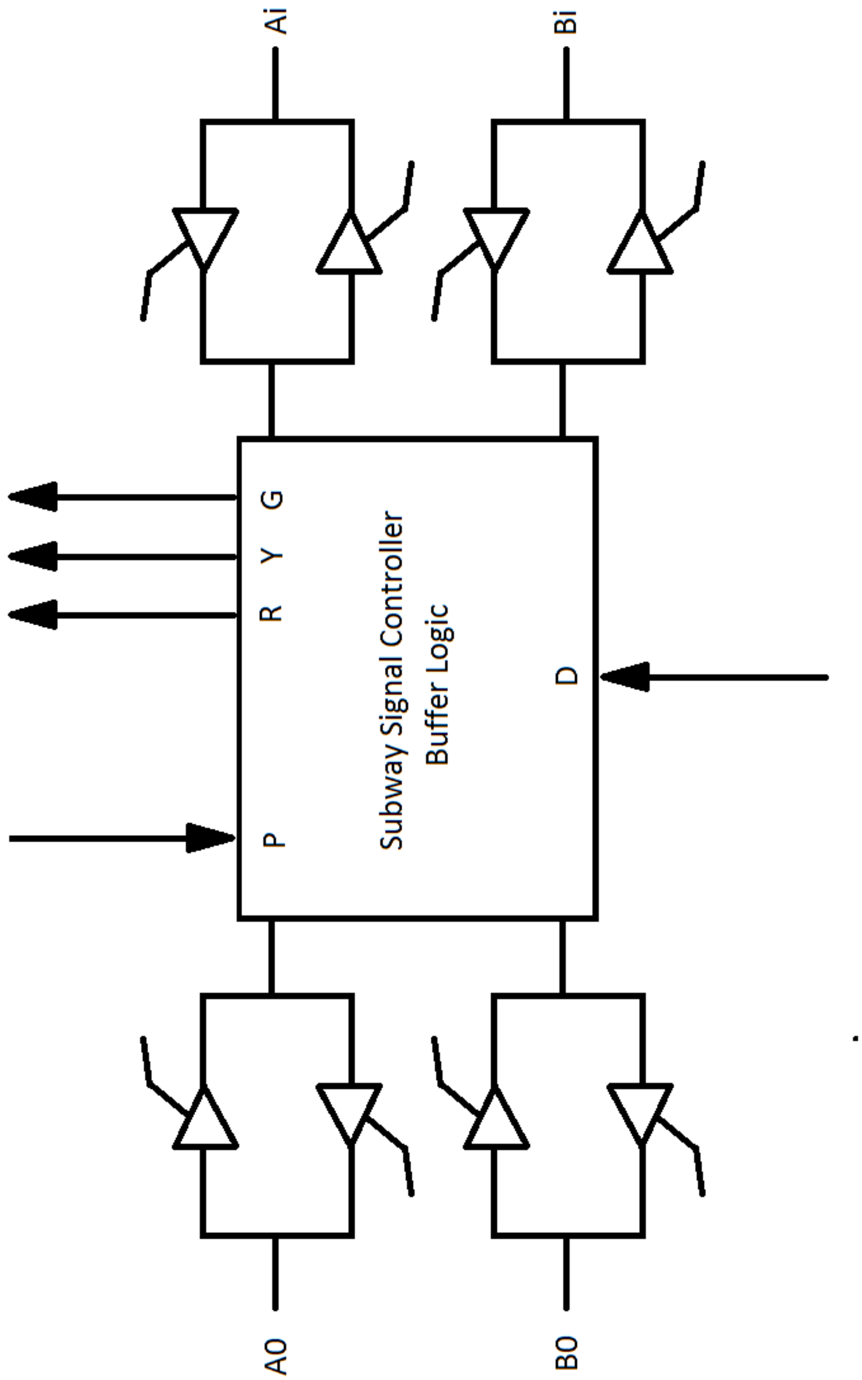
$$A_0 = D.P$$

$$B_0 = D.A_i$$

$$A_i = \overline{D}.P$$

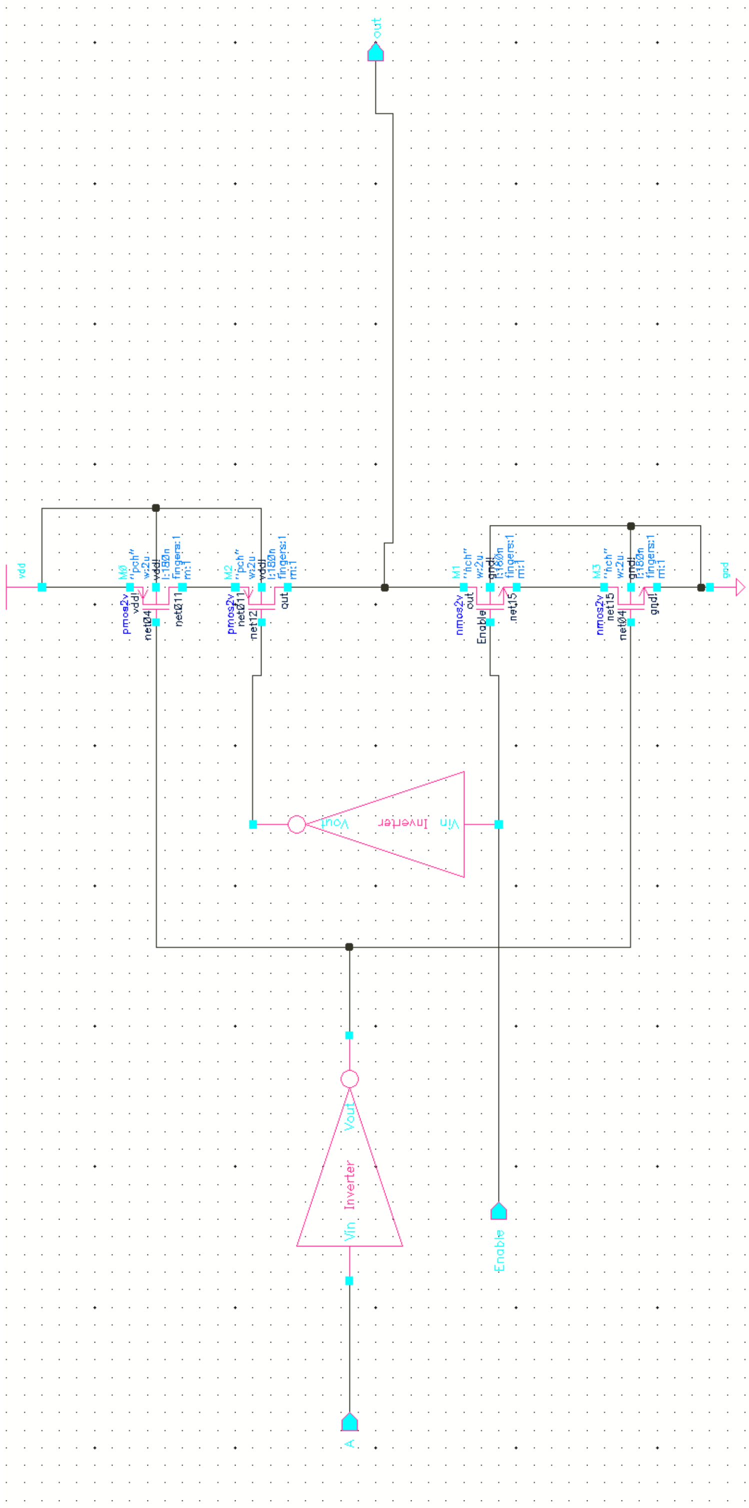
$$B_i = \overline{D}.A_0$$

<u>Subway Controller Buffer Logic</u>

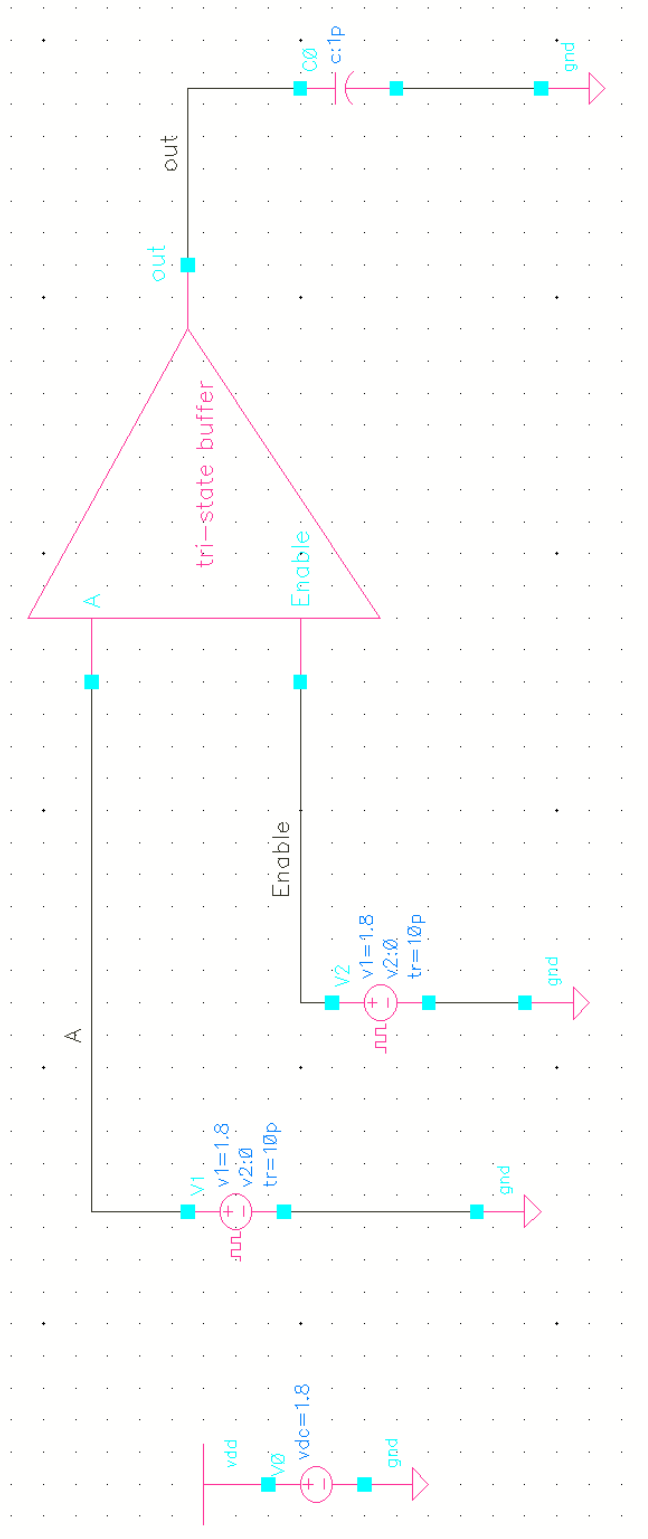


- **Tristate Buffer**

Schematic

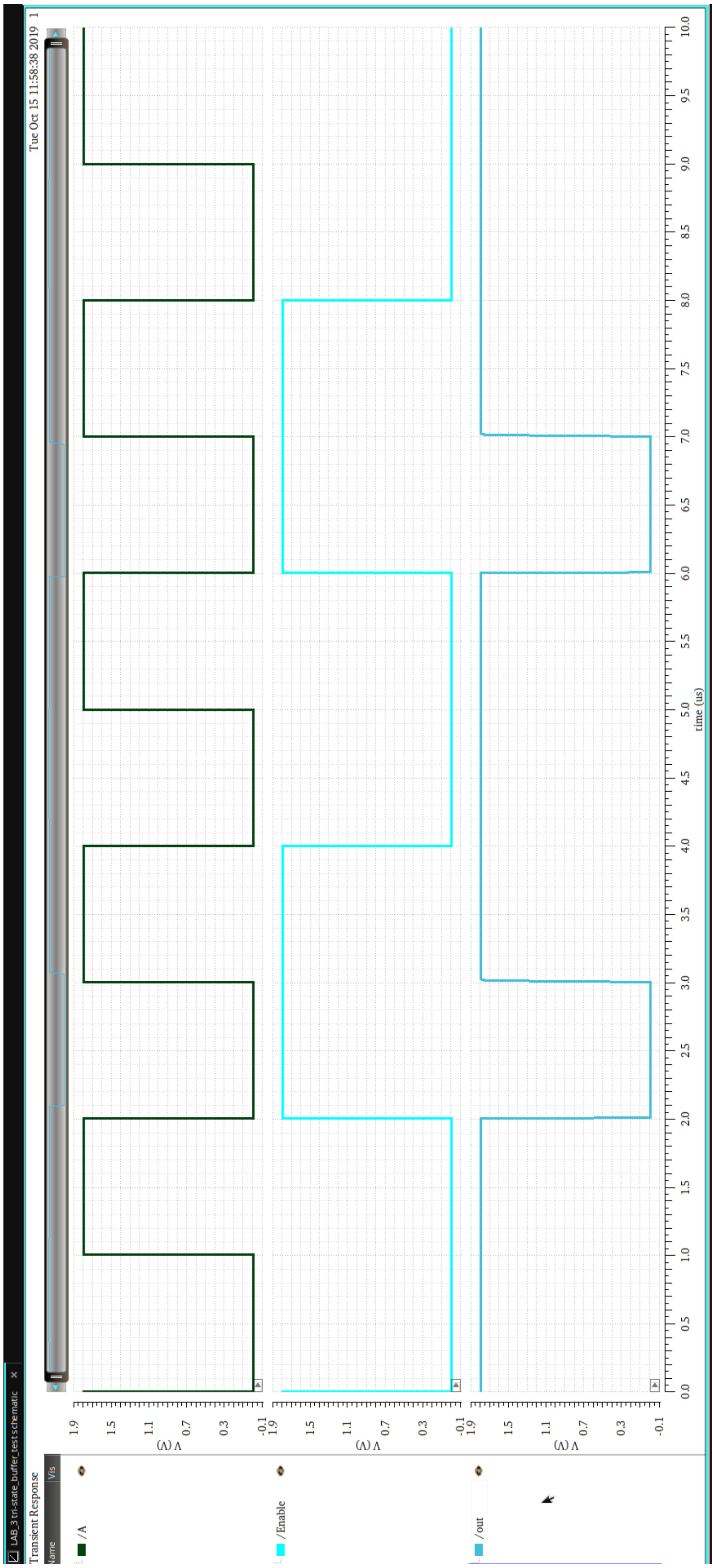


Test-bench

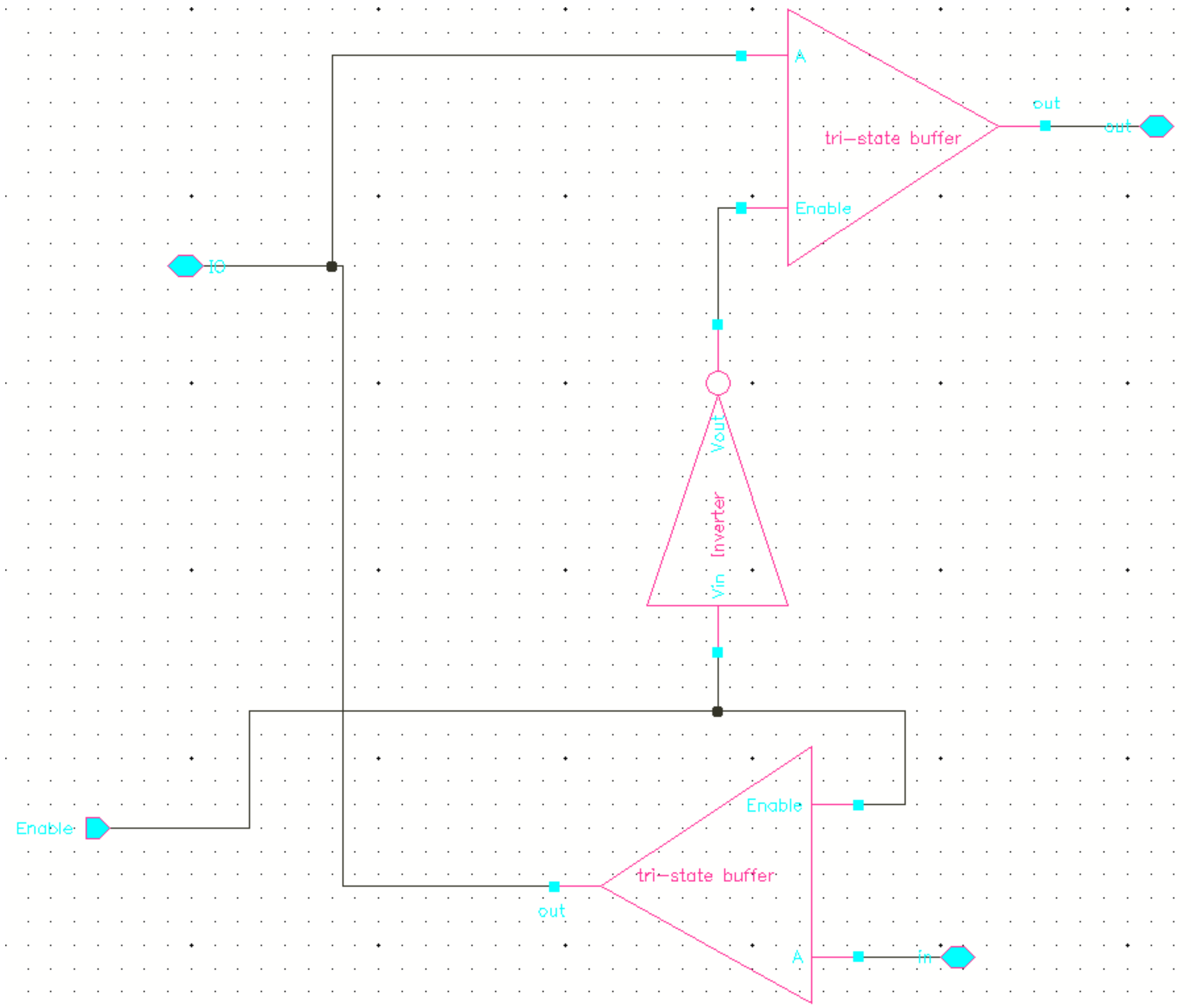


out
C0
c:1p
gnd
tri-state buffer
A
Enable
V2
v1=1.8
v2:0
tr=10p
V1
v1=1.8
v2:0
tr=10p
vdd
V0
vdc=1.8

Simulation Results

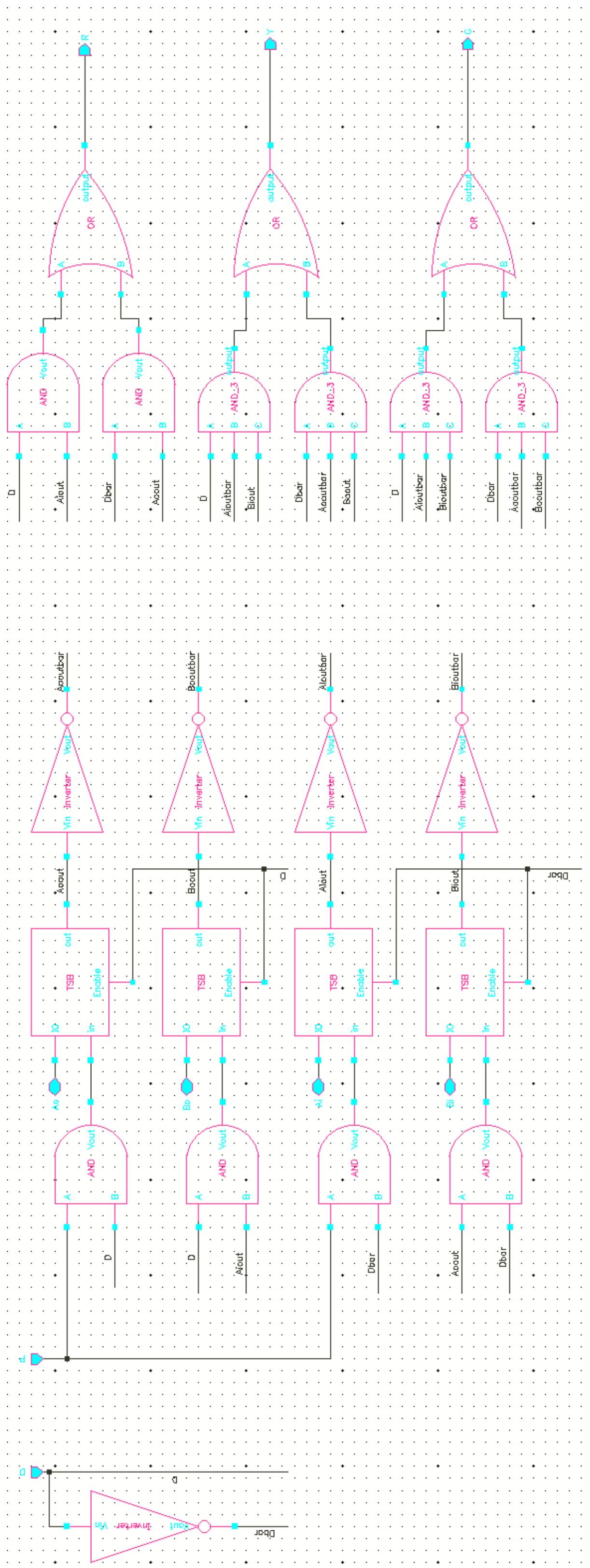


- **Bidirectional Bus Schematic**

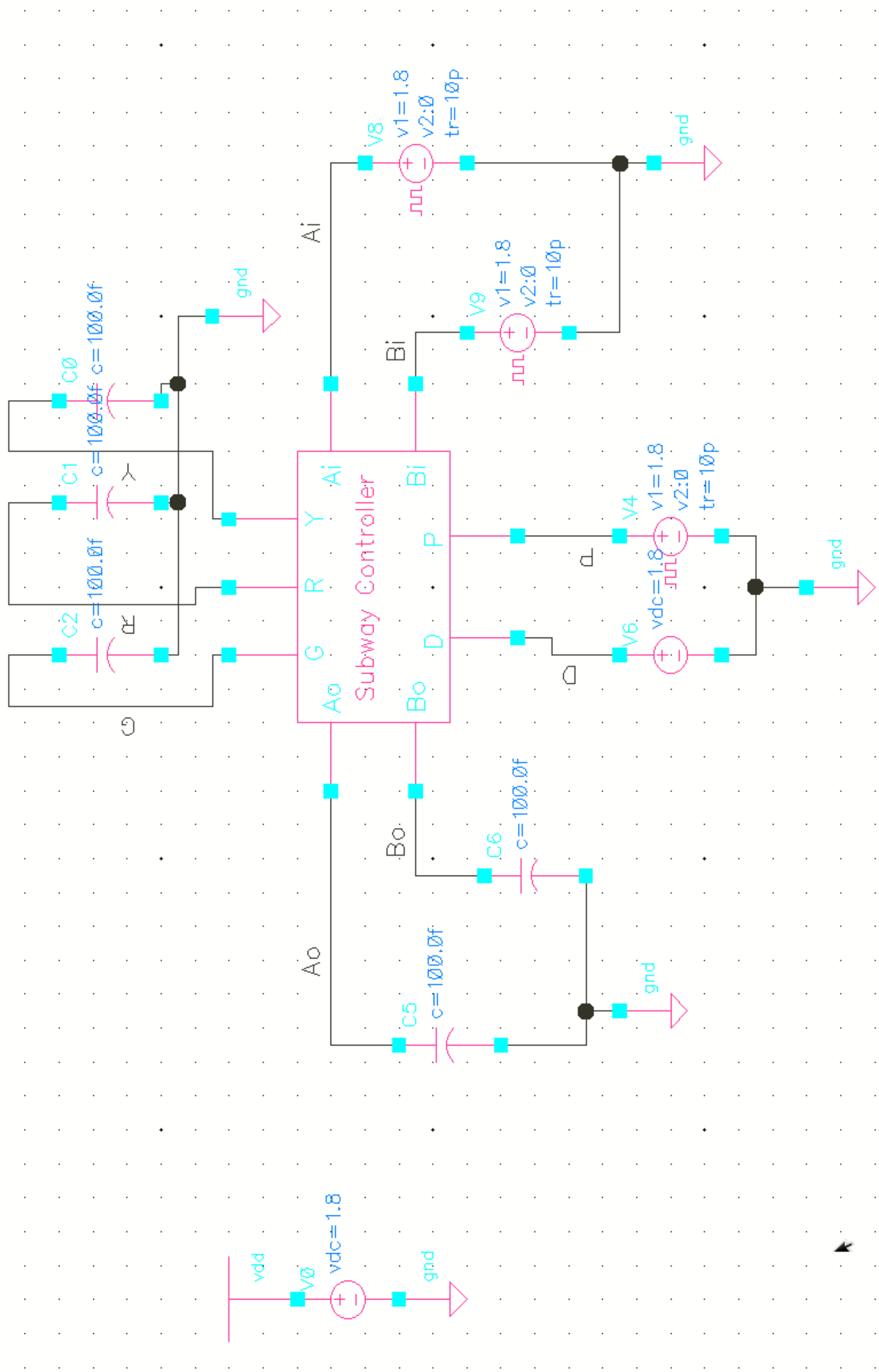


- **One Station Controller**

Schematic

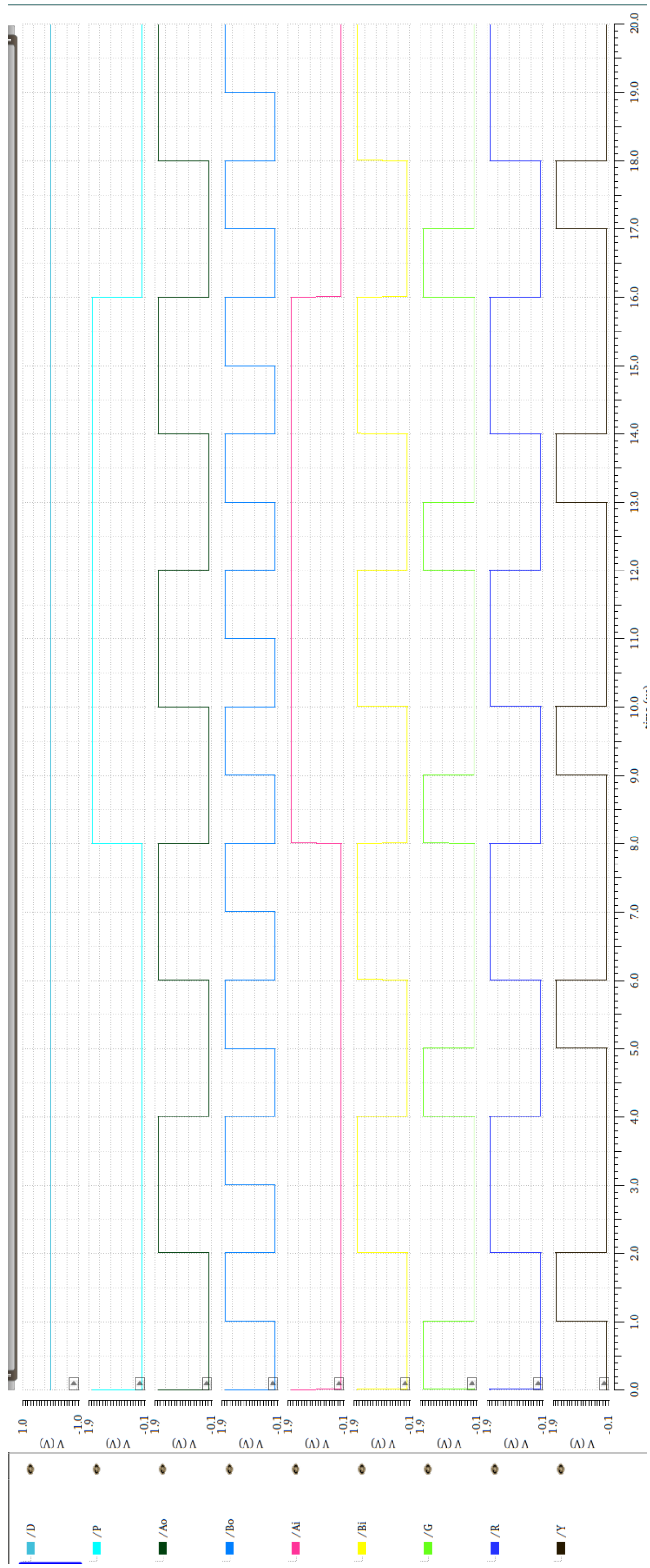


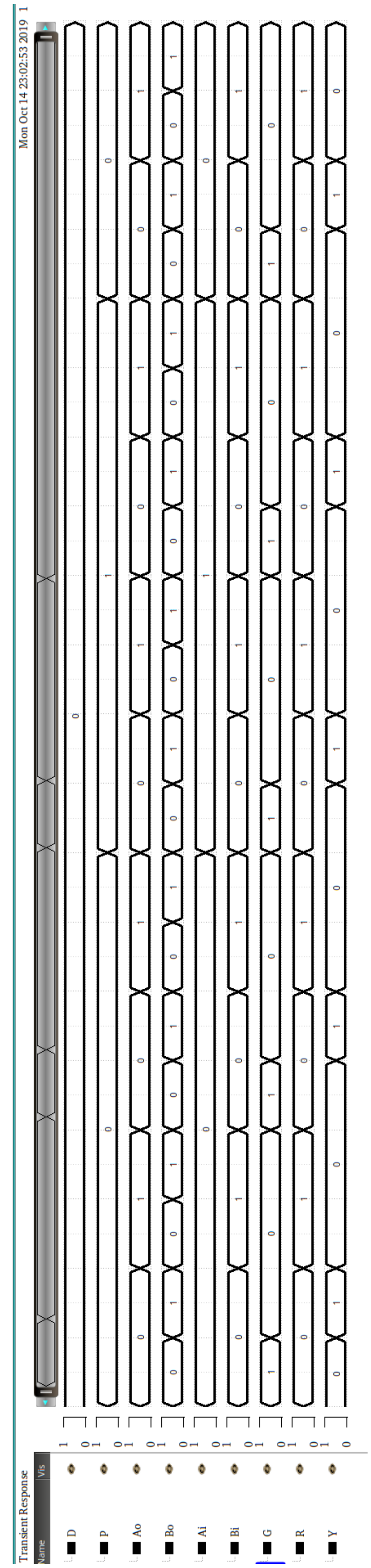
Test-bench


Subway Controller
Ai
Bi
Y
R
G
P
D
Ao
Bo
V8
v1=1.8
v2:0
tr=10p
V9
v1=1.8
v2:0
tr=10p
V4
v1=1.8
v2:0
tr=10p
V6
vdc=1.8
C0
c=100.0f
C1
c=100.0f
C2
c=100.0f
C5
c=100.0f
C6
c=100.0f
V0
vdc=1.8
vdd
gnd

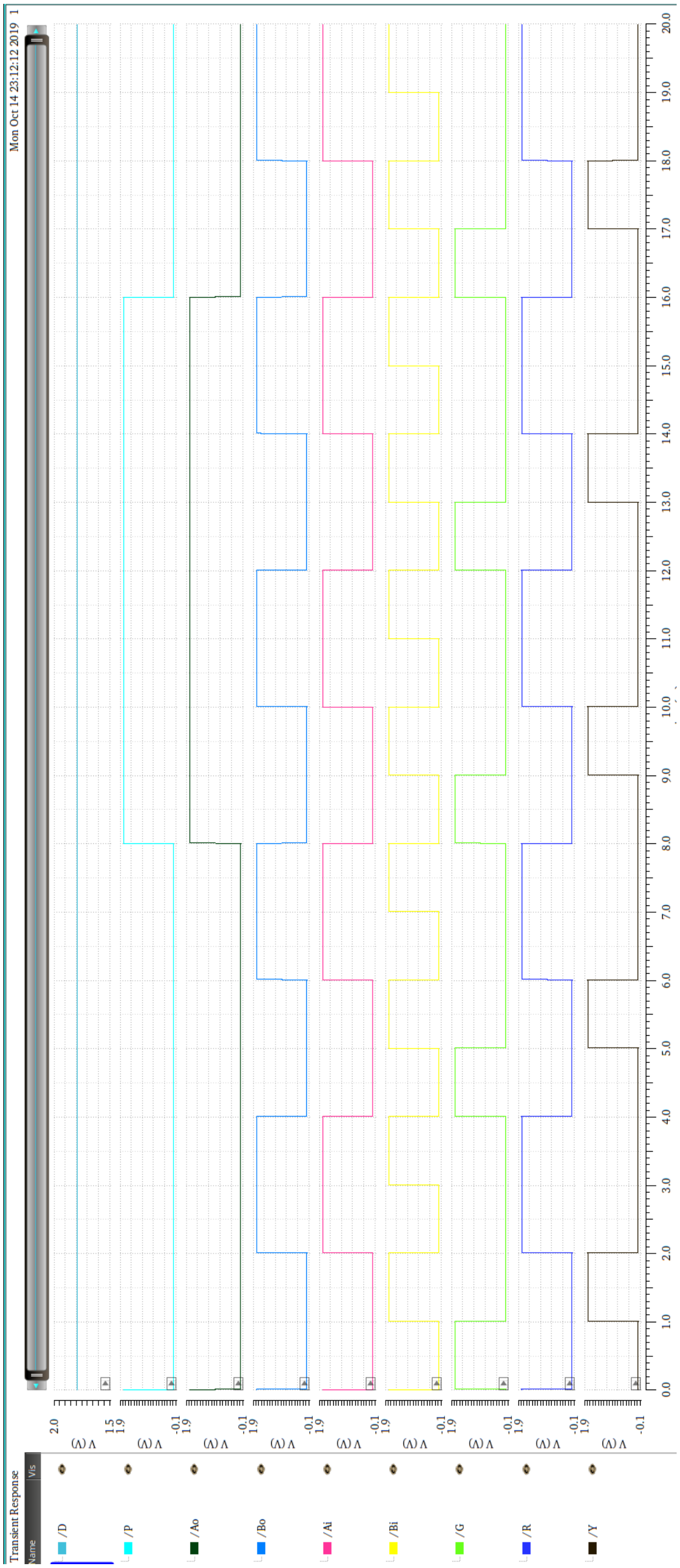
Simulation Results

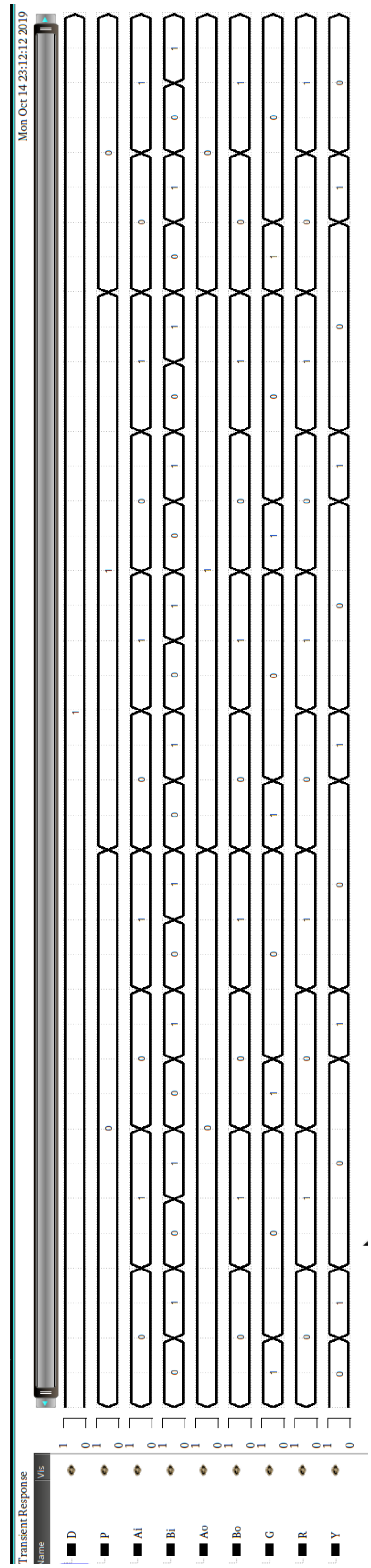
For D=0





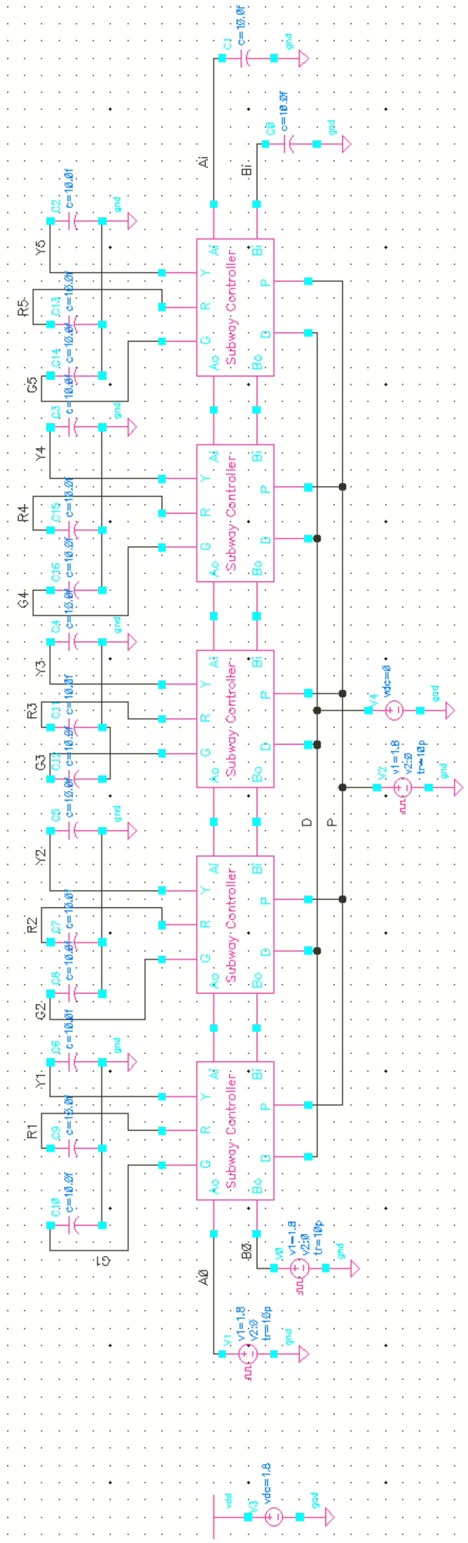
For D=1


Transient Response
Mon Oct 14 23:12:12 2019
/D
/P
/Ao
/Bo
/Ai
/Bi
/G
/R
/Y


Transient Response
Mon Oct 14 23:12:12 2019
D
P
Ai
Bi
Ao
Bo
G
R
Y

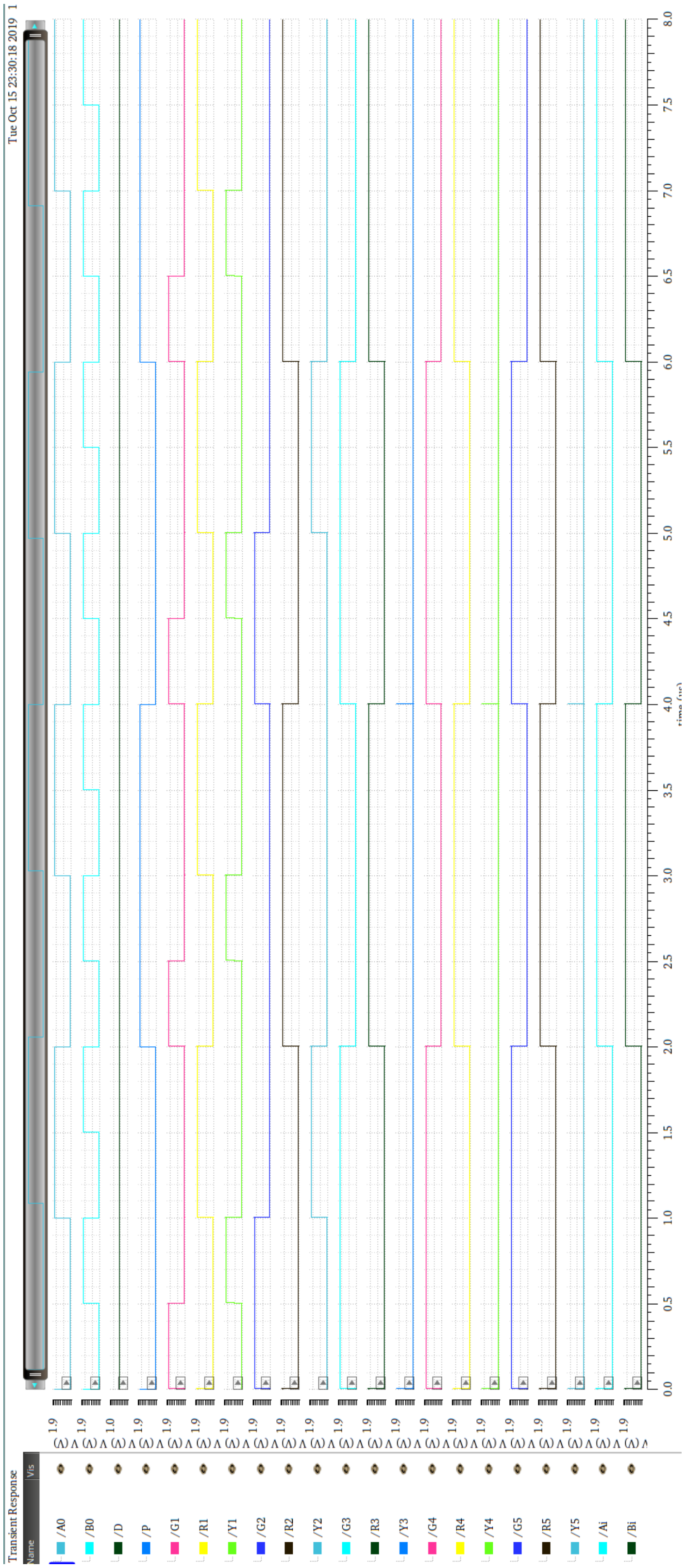
- **<u>Five Station Controller</u>**

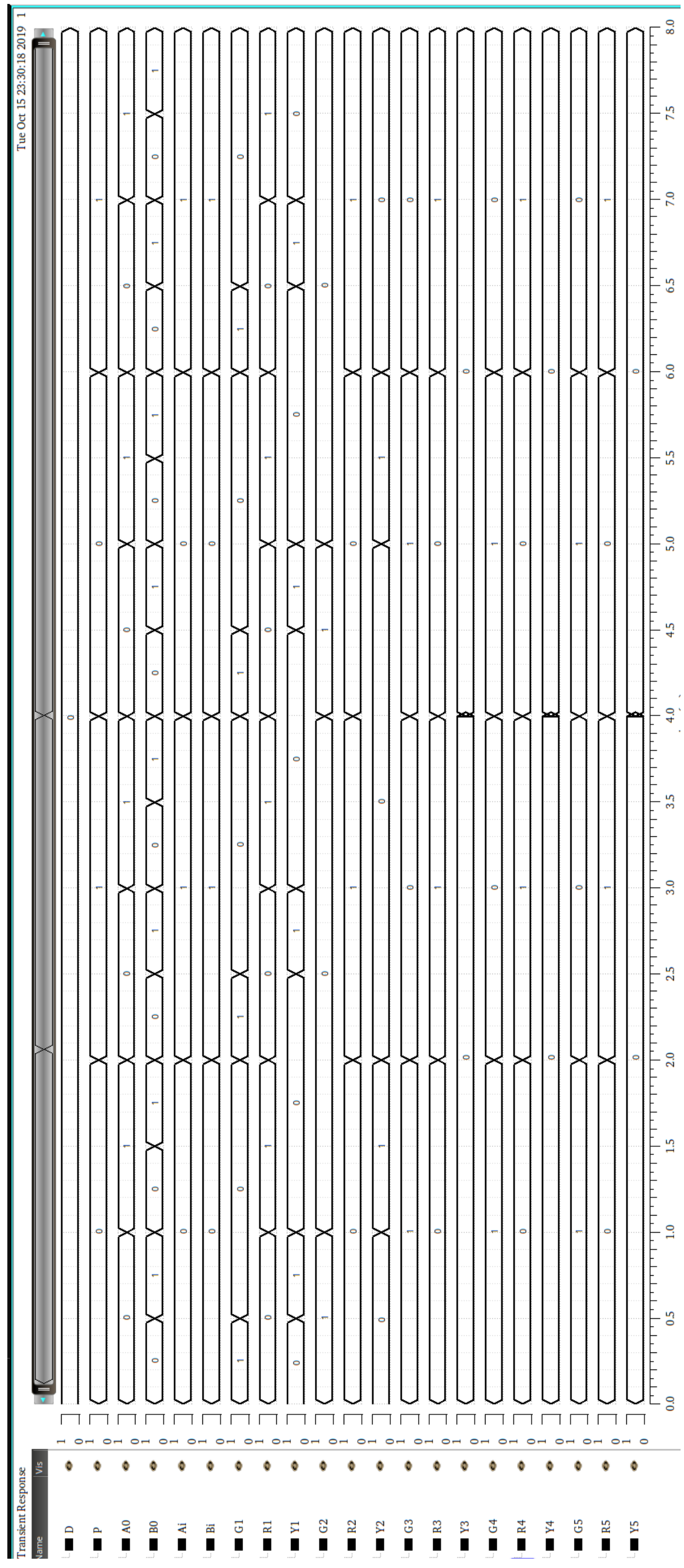
<u>Test-bench</u>



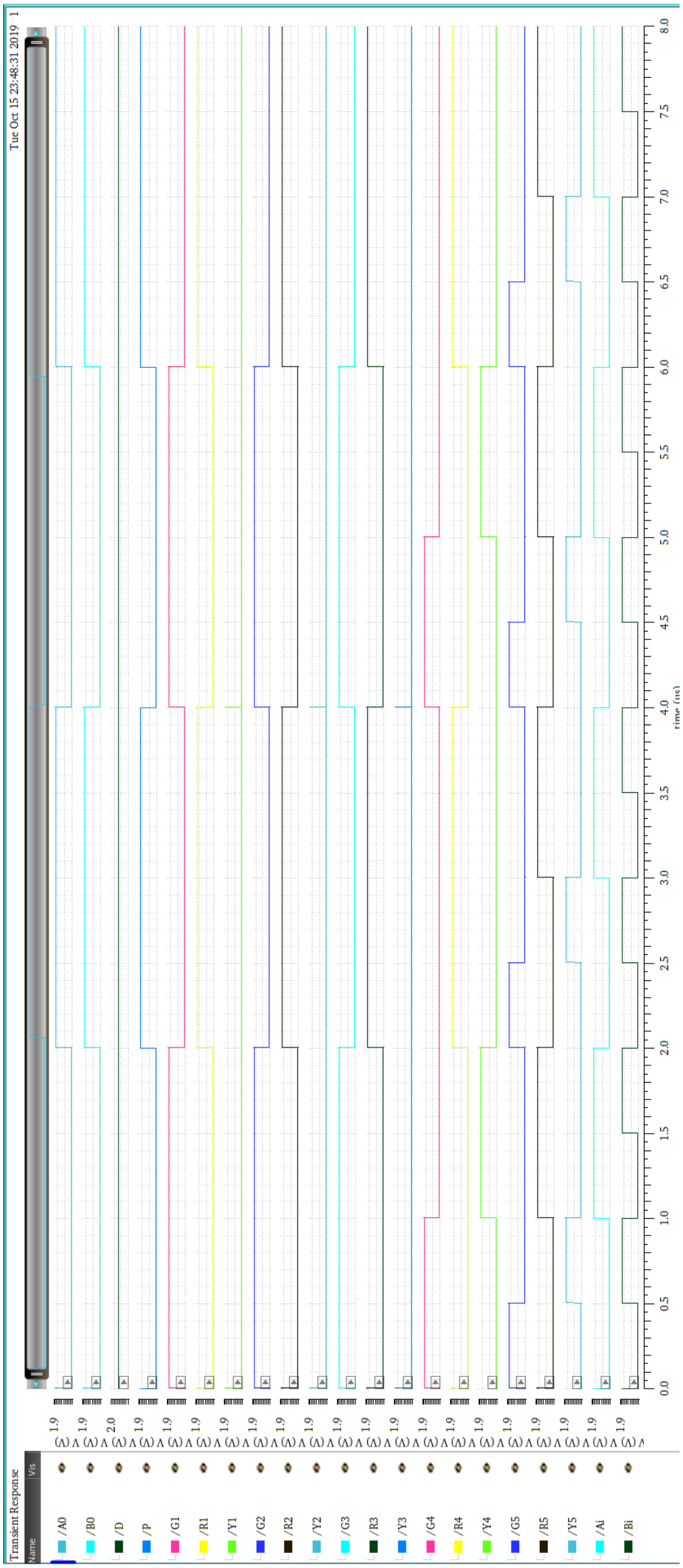
Simulation Results

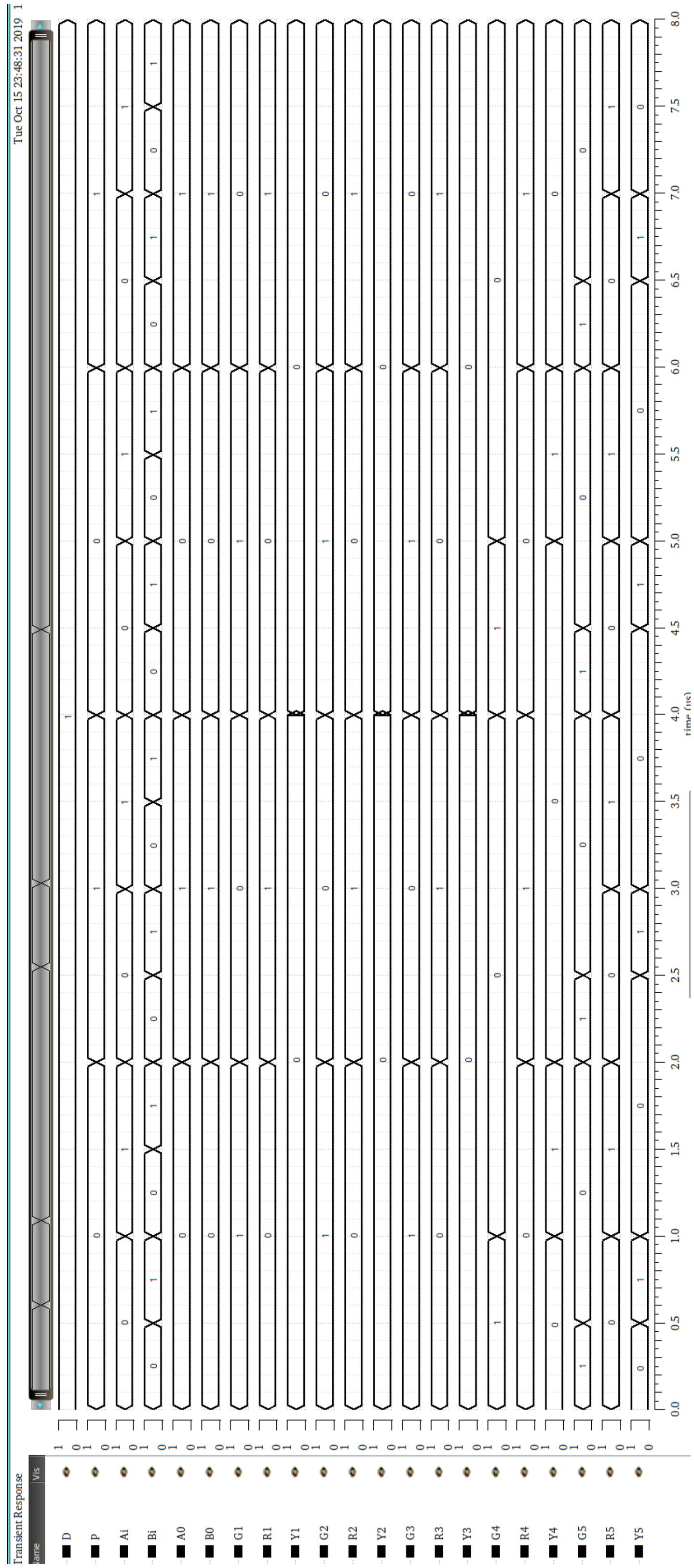
For D=0





For D=1


Transient Response
Tue Oct 15 23:48:31 2019 1
Name
Vis
/A0
/B0
/D
/P
/G1
/R1
/Y1
/G2
/R2
/Y2
/G3
/R3
/Y3
/G4
/R4
/Y4
/G5
/R5
/Y5
/Ai
/Bi
time (us)


Transient Response
Tue Oct 15 23:48:31 2019 1
Name
Vis
D
P
Ai
Bi
A0
B0
G1
R1
Y1
G2
R2
Y2
G3
R3
Y3
G4
R4
Y4
G5
R5
Y5
time (us)

Conclusion:

The subway station controller for N stations was successfully implemented on Cadence. The light in the track section is red if there was a train in the track section in the very next station in the direction the train is traveling, yellow if there was no train in the track section in the very next station but the section after that was occupied, and green otherwise.

Question:

- What is a static 1-hazard and a static 0-hazard.

Static-1 and static-0 hazard are hazards which occur during bit transitions i.e. For 1 to 0 or from 0 to 1. Suppose, from response to a single input change and for some combination of propagation delay, an output momentarily goes from 1 to 0 when it should remain at a constant value of 1, the circuit is said to have a **static 1-hazard**. Similarly, if the output momentarily goes to 1 when it should remain at a constant value of 0, the circuit is said to have a **static 0-hazard**.

- Discuss how you remove a static 1-hazard and a static 0-hazard

During implementation, if any two adjacent 1's are not covered by the same loop, then a 1-hazard occurs for the transition between those two ones. For any n variable K-map, this transition only occurs when one variable changes value and the other n -1 variables are held constant. If another loop is added including those two ones to the Karnaugh map and then add the corresponding redundant gate to the circuit the hazard can be eliminated.

During implementation, if any two adjacent 0's are not covered by the same loop, then a 0-hazard occurs for the transition between those two zeros. The 0-hazards can be eliminated by adding extra prime implicants that cover the 0's adjacent to one another, as long as they are not already covered by a common loop.