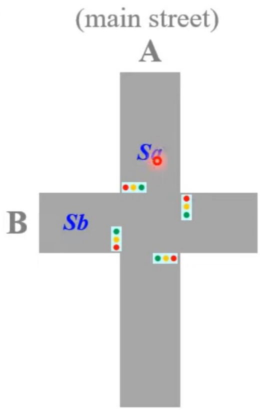
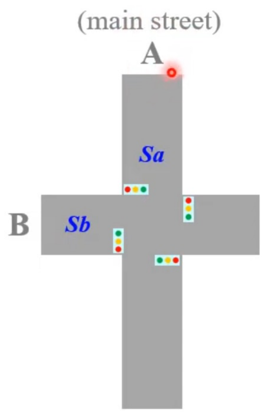
4.4 Traffic Light Controller

Traffic Light Controller

- Problem description: a ***seq ckt***
  - Design a traffic light controller for the intersection of street "A" and street "B".
  - Each street has traffic sensors, which detect the presence of vehicles approaching or stopped at the intersection.
    - ***Sa*** = 1: a vehicle is approaching on street "A"
    - ***Sb*** = 1: a vehicle is approaching on street "B"

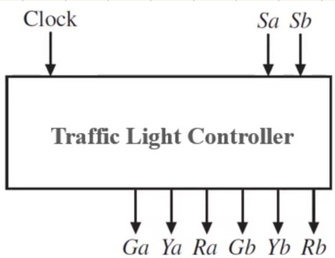


- Street "A" is a main street.
- When "A" is green, it remains green at least 60 seconds.
- If there is no car approaches on "B", the "A" cycle is extended for 10 additional seconds until a car approaches on "B".
- Then the lights change, and "B" has a green light.
- At the end of 50 seconds, the lights change back to "A" unless there is a car on street "B" and none on "A", in which case the "B" cycle is extended for 10 additional seconds.
- If cars continue to arrive on street "B" and no car appears on street "A", "B" continues to have a green light.
- The yellow light lasts for 10 seconds.



Implementation :

Block Diagram

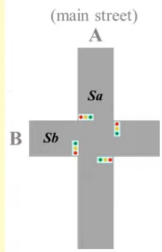


- Block diagram of traffic light controller:
  - Inputs:
    - ***Sa*** = 1 means a vehicle is approaching on street "A"
    - ***Sb*** = 1 means a vehicle is approaching on street "B"
  - Outputs:
    - ***Ga***, ***Ya***, ***Ra***: drive the green, yellow, and red lights on street "A"
    - ***Gb***, ***Yb***, ***Rb***: drive the corresponding lights on street "B"

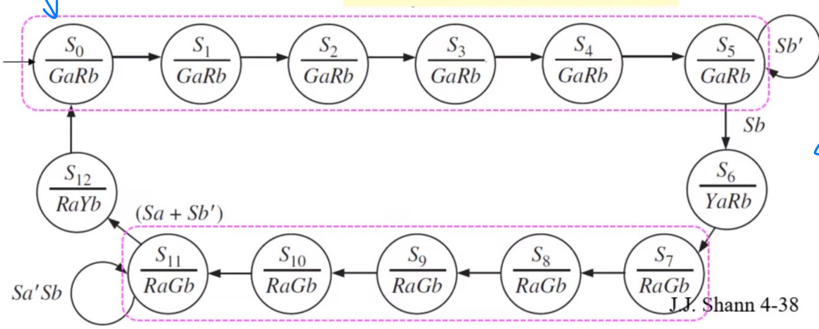
State Graph

- ***Moore*** State gra
  - For timing purp
    by a clock w/ a

- When "A" is green, it remains green at least 60 seconds.
- If there is no car approaches on "B", the "A" cycle is extended for 10 additional seconds until a car approaches on "B".
- Then the lights change, and "B" has a green light.
- At the end of 50 seconds, the lights change back to "A" unless there is a car on street "B" and none on "A", in which case the "B" cycle is extended for 10 additional seconds.
- The yellow light lasts for 10 seconds.



$\frac{S_{13\sim16}}{0}$



state diagram

* state table

present state	next state	(Ga, Ya, Ra, Gb, Yb, Rb)
S_i ($i=0\sim4$)	S_{i+1}	
S_5	$\begin{cases} S_b=0: & S_5 \\ S_b=1: & S_6 \end{cases}$	$G_a R_b$
S_6	S_7	$Y_a R_b$
S_i ($i=7\sim10$)	S_{i+1}	
S_{11}	$\begin{cases} S_a' S_b : & S_{11} \\ S_a + S_b' : & S_{12} \end{cases}$	$R_a G_b$
S_{12}	S_0	$R_a Y_b$
S_i ($i=13\sim15$)	S_0	0

* We don't do state reduction since the states here also serve as a counter.

* We use binary state assignment here.

$S_0 \sim S_{12} \Rightarrow Q_A\, Q_B\, Q_C\, Q_D$

msb lsb

✲ I'll deal with outputs first :

$$\begin{cases} G_a = \sum m(0 \sim 5) \\ Y_a = S_6 = Q_A' Q_B Q_C Q_D' \\ R_a = \sum m(7 \sim 12) \\ G_b = \sum m(7 \sim 11) \\ Y_b = S_{12} = Q_A Q_B Q_C' Q_D' \\ R_b = \sum m(0 \sim 6) \end{cases}$$

Q_AQ_B \ Q_CQ_D	00	01	11	10
00	1	1	1	1
01	0	1	0	0
11	0	0	0	0
10	0	0	0	0

$$G_A = Q_A'Q_B' + Q_A'Q_C'Q_D$$

$Q_AQ_B \backslash Q_CQ_D$	00	01	11	10
00	0	0	0	0
01	0	0	1	0
11	1	1	1	1
10	1	0	0	0

$$R_A = Q_A Q_B + Q_B Q_C Q_D + Q_A Q_C' Q_D'$$

$Q_AQ_B \backslash Q_CQ_D$	00	01	11	10
00	0	0	0	0
01	0	0	1	0
11	1	1	1	1
10	0	0	0	0

$$G_b = Q_A Q_B + Q_B Q_C Q_D$$

$Q_AQ_B \backslash Q_CQ_D$	00	01	11	10
00	1	1	1	1
01	1	1	0	1
11	0	0	0	0
10	0	0	0	0

$$R_b = Q_A' Q_B' + Q_A' Q_C' + Q_A' Q_D' S_b$$

✱ Next, I'll be dealing with next states Q^+ :

present state				next state			
Q_A	Q_B	Q_C	Q_D	Q_A^+	Q_B^+	Q_C^+	Q_D^+
0	0	0	0	0	0	0	1
0	0	0	1	0	0	1	0
0	0	1	0	0	0	1	1
0	0	1	1	0	1	0	0
0	1	0	0	0	1	0	1
0	1	0	1	S_b	1	S_b	S_b'

0	1	1	0	0	1	1	1
0	1	1	1	1	0	0	0
1	0	0	0	1	0	0	1
1	0	0	1	1	0	1	0
1	0	1	0	1	0	1	1
1	0	1	1	1	$(S_a'S_b)'$	$S_a'S_b$	$S_a'S_b$
1	1	0	0	0	0	0	0
1	1	0	1	0	0	0	0
1	1	1	0	0	0	0	0
1	1	1	1	0	0	0	0

Q_AQ_B \ Q_CQ_D	00	01	11	10
00	0	0	0	0
01	0	S_b	1	0
11	1	1	1	1
10	0	0	0	0

* S_b, $S_a'S_b$ are MEVs
* the result logic may not be the simplest as the MEVs are codependent

Solve for Q_A^+

→ setting all MEVs to 0

$$Q_A^+ = (Q_A Q_B + Q_B Q_C Q_D)$$

$$+ S_b (Q_A Q_B + Q_B Q_D)$$

$Q_A Q_B \backslash Q_C Q_D$	00	01	11	10
00	0	0	1	0
01	1	1	0	1
11	0	0	$(S_a' S_b)'$	0
10	0	0	0	0

Solve for Q_B^+

$$Q_B^+ = (Q_A' Q_B Q_C' + Q_A' Q_B' Q_C Q_D$$

$$+ Q_A' Q_B Q_C Q_D' + Q_A Q_B Q_C Q_D)$$

$$+ S_a' S_b (0)$$

$Q_AQ_B \backslash Q_CQ_D$	00	01	11	10
00	0	1	0	1
01	0	S_b	0	1
11	0	1	$S_a'S_b$	1
10	0	0	0	0

Solve for Q_C^+

$$Q_C^+ = (Q_A' Q_C' Q_D + Q_B Q_C' Q_D + Q_A' Q_C Q_D' + Q_B Q_C Q_D') + S_b (Q_B Q_C' Q_D) + S_a' S_b (Q_A Q_B Q_D)$$

$Q_AQ_B \backslash Q_CQ_D$	00	01	11	10
00	1	0	0	1
01	1	S_b'	0	1
11	1	0	$S_a'S_b$	1
10	0	0	0	0

Solve for Q_D^+

$$Q_D^{+} = (Q_A' Q_D' + Q_B Q_D' + Q_A' Q_B Q_C')$$

$$+ S_b (0)$$

$$+ S_a' S_b (Q_A' Q_B Q_D + Q_A Q_B Q_C)$$