Lecture Outline

Reminders to self:

- ❑ Turn on lecture recording to Cloud
- ❑ Turn on Zoom microphone

- Last Lecture
  - Started Analysis of clocked sequential circuits
    - Parity checker design example
    - Analysis by signal tracing and timing charts
    - Definitions of Moore and Mealy machines
    - Moore & Mealy machine analysis examples
- Today's Lecture
  - Continue Analysis of clocked sequential circuits
    - Analysis by Transition Tables & State Graphs

Handouts and Announcements

- Announcements
  - Homework Problem HW 13-1
    - Posted on Carmen this morning
    - Due 11:25am Wednesday 3/29
  - Homework Reminder
    - HW 12-4 Due: 11:59pm Tuesday 3/21
    - HW 12-5 Due: 11:25am Wednesday 3/22
  - Read for Wednesday: pages 453, 457-463
  - Mini-Exam 3 regrade finished Wednesday of last week

Basic Procedure to Find Output Sequence By Transition Tables and Graphs:

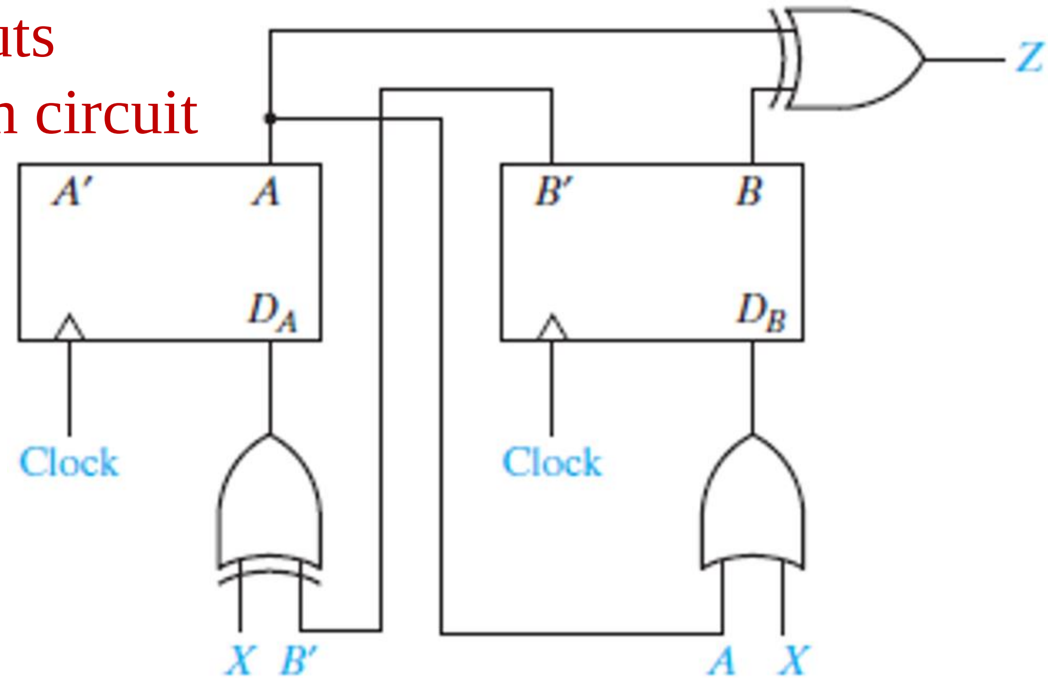
1. Determine equations for inputs to flip-flops and outputs from circuit
2. Derive next-state equations for each flip-flop from its input equations (using flip-flop next-state relations or truth tables)
   - D: $Q^+ = D$
   - D-CE: $Q^+ = D \cdot CE + Q \cdot CE'$
   - T: $Q^+ = TQ' + T'Q = T \oplus Q$
   - S-R: $Q^+ = S + R'Q$ (SR=0)
   - J-K: $Q^+ = JQ' + K'Q$
3. Plot a next-state map for each flip-flop (looks like k-map)
4. Combine these maps to form the transition table that gives the next state of the flip-flop as a function of current state and circuit inputs
5. Use the transition table to form the state table

   (names instead of next-states)
6. Use the state table to draw the state graph

Analysis by Transition Tables & Graphs

Repeat Moore example using these techniques:

1. Determine equations for inputs to flip-flops and outputs from circuit

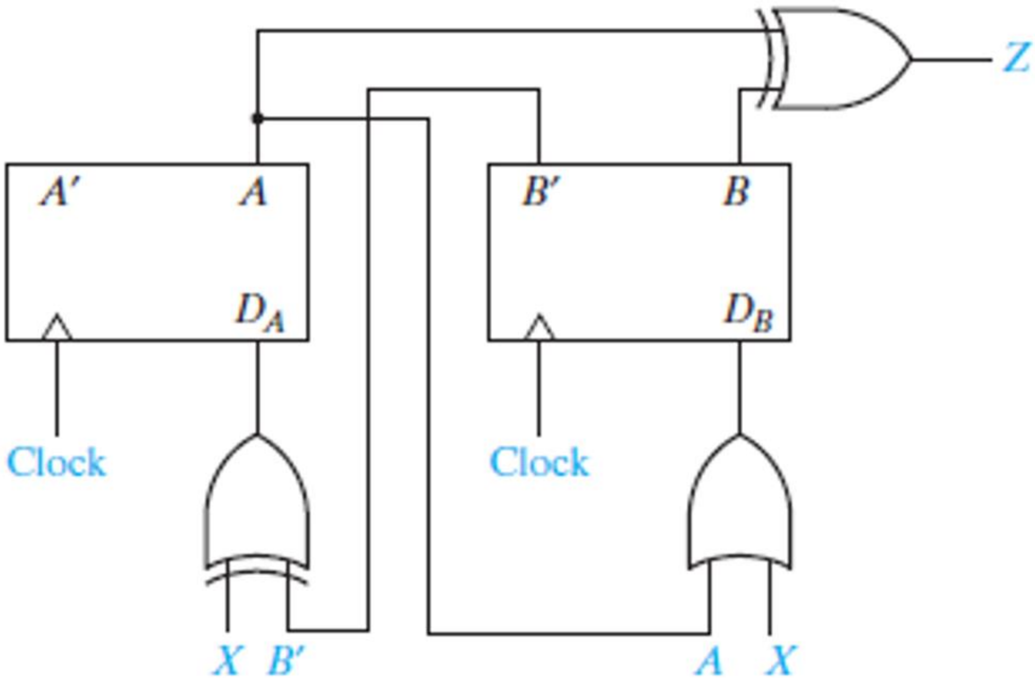


- $D_A = X \oplus B'$
- $D_B = X + A$
- $Z = A \oplus B$
- These are same as when worked before
- Except before we plugged in values of all variables for the initial state right away
- And then repeated as we stepped through each state

Analysis by Transition Tables & Graphs

Repeat Moore example using these techniques:

- $D_A = X \oplus B'$
- $D_B = X + A$
- $Z = A \oplus B$



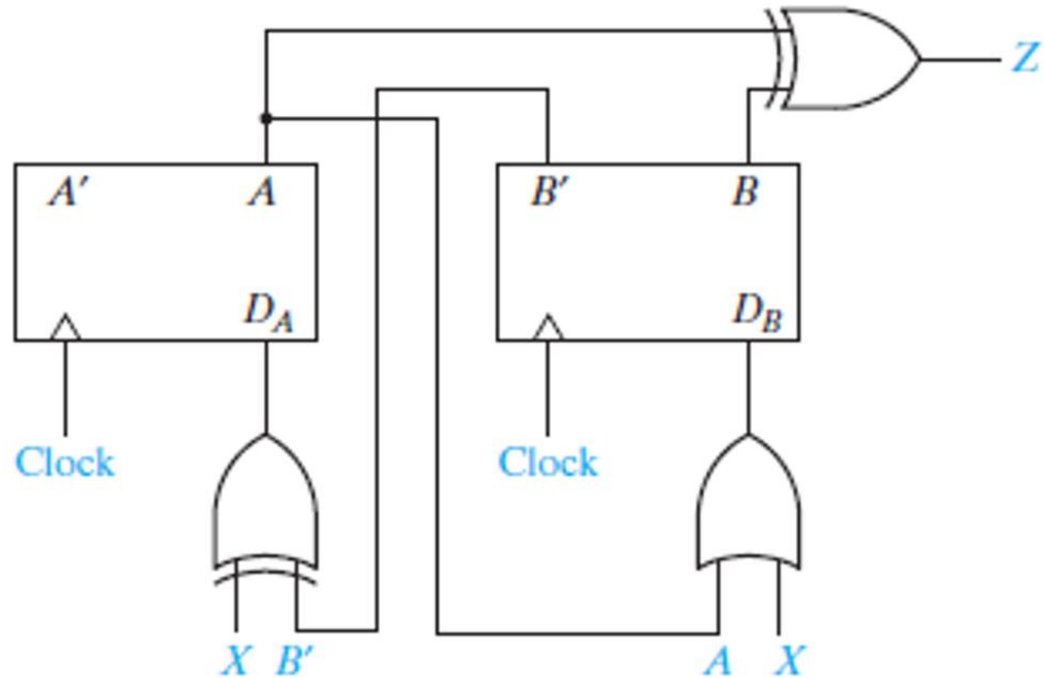
2. Derive next-state equations for each flip-flop from its input equations (using flip-flop next-state relations)
   - D: $Q^+ = D$

- $A^+ = X \oplus B'$
- $B^+ = X + A$

Analysis by Transition Tables & Graphs

Repeat Moore example using these techniques:

- $A^{+} = X \oplus B'$
- $B^{+} = X + A$
- $Z = A \oplus B$



3. Plot a next-state map for each flip-flop

A^{+}

AB \ X	0	1
00	1	0
01	0	1
11	0	1
10	1	0

B^{+}

AB \ X	0	1
00	0	1
01	0	1
11	1	1
10	1	1

Analysis by Transition Tables & Graphs

Repeat Moore example using these techniques:

- $Z = A \oplus B$

4. Combine these maps to form the transition table that gives the next state of the flip-flop as a function of current state and circuit inputs

A^+

$AB \backslash X$	0	1
00	1	0
01	0	1
11	0	1
10	1	0

B^+

$AB \backslash X$	0	1
00	0	1
01	0	1
11	1	1
10	1	1

	A^+B^+		
AB	$X = 0$	$X = 1$	$Z = A \oplus B$
00	10	01	0
01	00	11	1
11	01	11	0
10	11	01	1

Repeat Moore example using these techniques:

- $Z = A \oplus B$

State Name definitions for this example

$S_0(AB=00)$ $S_1(AB=01)$
$S_2(AB=11)$ $S_3(AB=10)$

4. Combine these maps to form the transition table that gives the next state of the flip-flop as a function of current state and circuit inputs

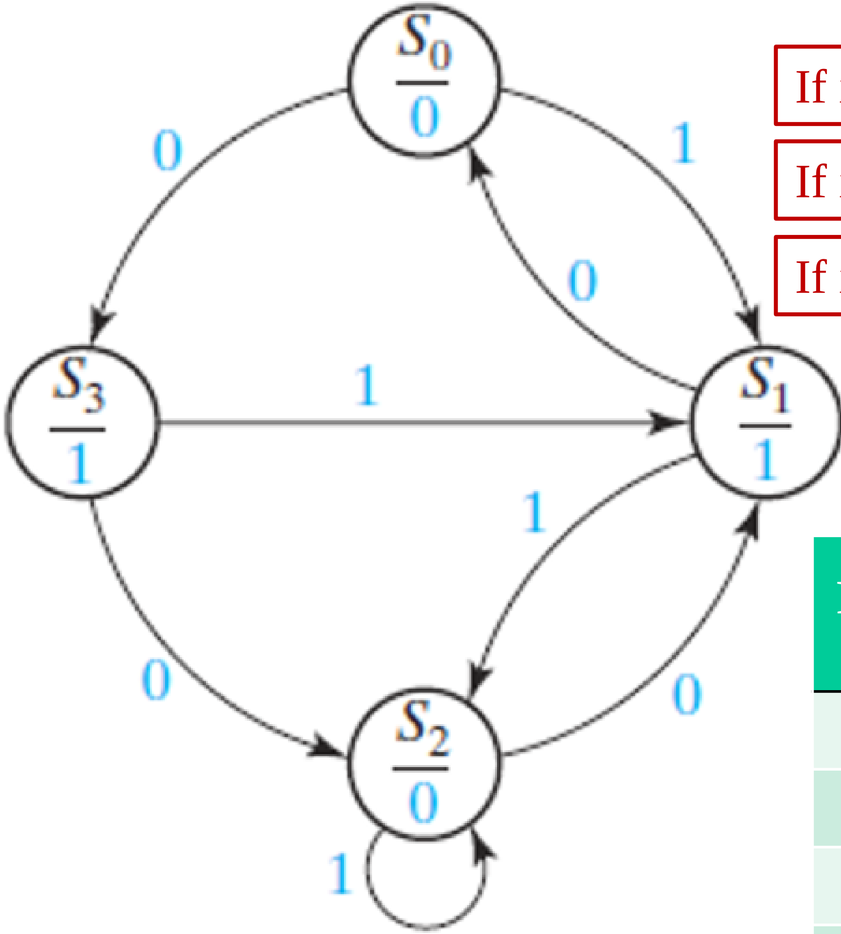
	A^+B^+		
AB	$X=0$	$X=1$	$Z = A \oplus B$
00	10	01	0
01	00	11	1
11	01	11	0
10	11	01	1

Symbols assigned to each state

Present State	Next State		Present Output
	$X=0$	$X=1$	$Z = A \oplus B$
S_0	S_3	S_1	0
S_1	S_0	S_2	1
S_2	S_1	S_2	0
S_3	S_2	S_1	1

Analysis by Transition Tables & Graphs

Repeat Moore example using these techniques:



If in S_0 and $X = 0$, go to S_3 at next active clock edge

If in S_0 and $X = 1$, go to S_1 at next active clock edge

If in S_1 and $X = 1$, go to S_2 at next active clock edge

If in S_2 and $X = 0$, go to S_1 at next active clock edge … etc.

Present State	Next State		Present Output
	$X = 0$	$X = 1$	$Z = A \oplus B$
S_0	S_3	S_1	0
S_1	S_0	S_2	1
S_2	S_1	S_2	0
S_3	S_2	S_1	1

Moore Machine Design Example

Traffic Signal – Left Turn Arrow (Moore Machine)

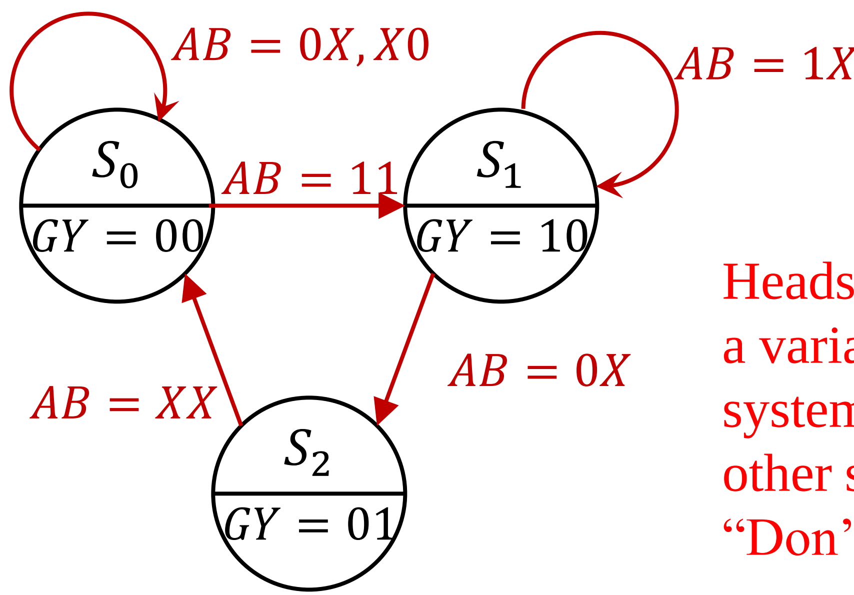
- Two outputs:
  - Green Arrow
  - Yellow Arrow
  - No Arrow

2 Flip Flops: Will use D

- Two control inputs:
  - $A =$ Time for the arrow to be on
  - $B =$ There is a car waiting to make a left turn

Heads Up: I labeled all outputs $GY = xy$. If only labeled with values, provide a key

Heads Up: I labeled all transitions $AB = xy$. If only labeled with values, provide a key

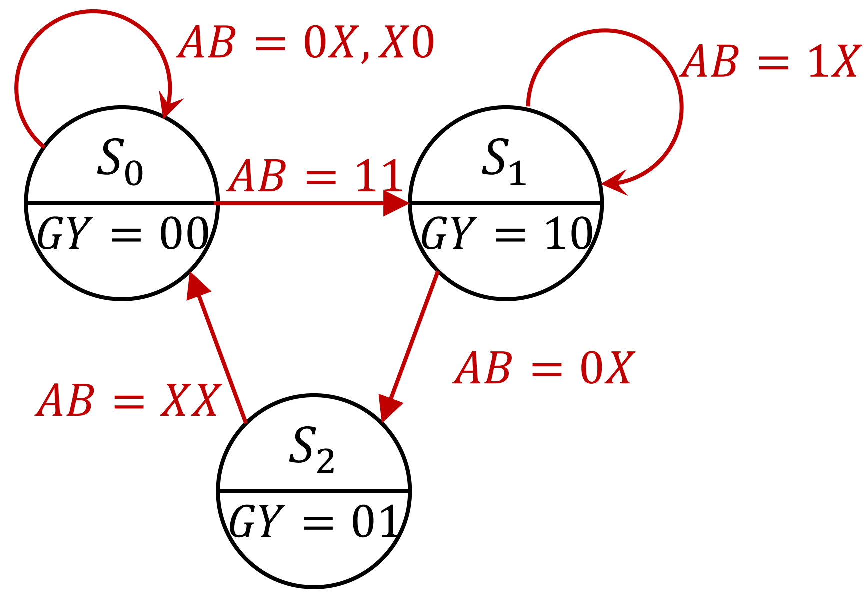


Heads Up: If X is a variable in a system, use some other symbol for “Don’t Care”!

Moore Machine Design Example

Traffic Signal – Left Turn Arrow (Moore Machine)

A = time for turn arrow to be on
B = car is waiting to make turn



Note:

- For complex systems one might need state graph → state table → transition table
- This problem is simple enough to skip directly to transition table

Present	Next G^+Y^+				Output
GY	$AB = 00$	$AB = 01$	$AB = 11$	$AB = 10$	GY
00	00	00	10	00	00
01	00	00	00	00	01
11	XX	XX	XX	XX	11
10	01	01	10	10	10

Moore Machine Design Example

Traffic Signal – Left Turn Arrow (Moore Machine)

Present	Next G^+Y^+				Output
GY	$AB = 00$	$AB = 01$	$AB = 11$	$AB = 10$	GY
00	00	00	10	00	00
01	00	00	00	00	01
11	XX	XX	XX	XX	11
10	01	01	10	10	10

G^+ $\quad G^+ = GA + ABY'$

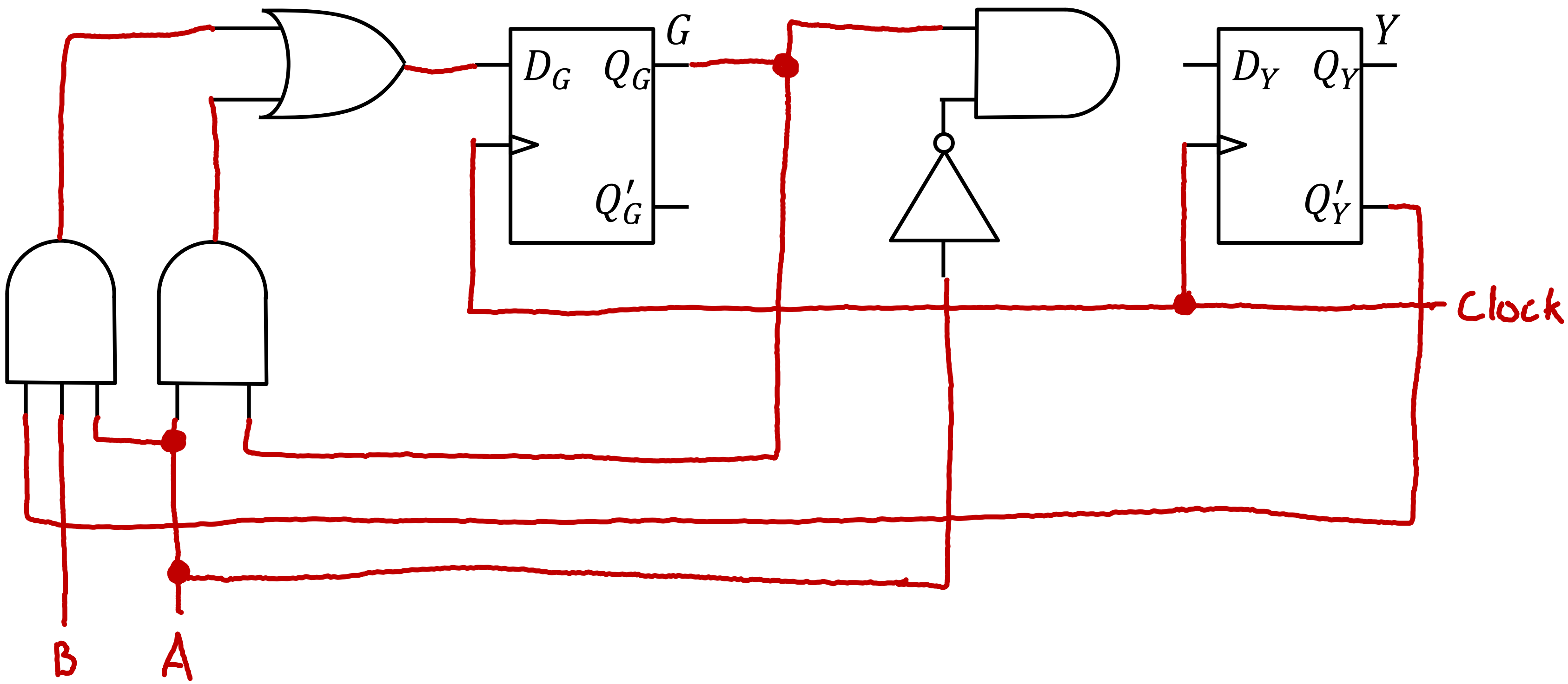
$GY \backslash AB$	00	01	11	10
00	0	0	1	0
01	0	0	0	0
11	X	X	X	X
10	0	0	1	1

Y^+ $\quad Y^+ = GA'$

$GY \backslash AB$	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	X	X	X	X
10	1	1	0	0

Traffic Signal – Left Turn Arrow (Moore Machine)

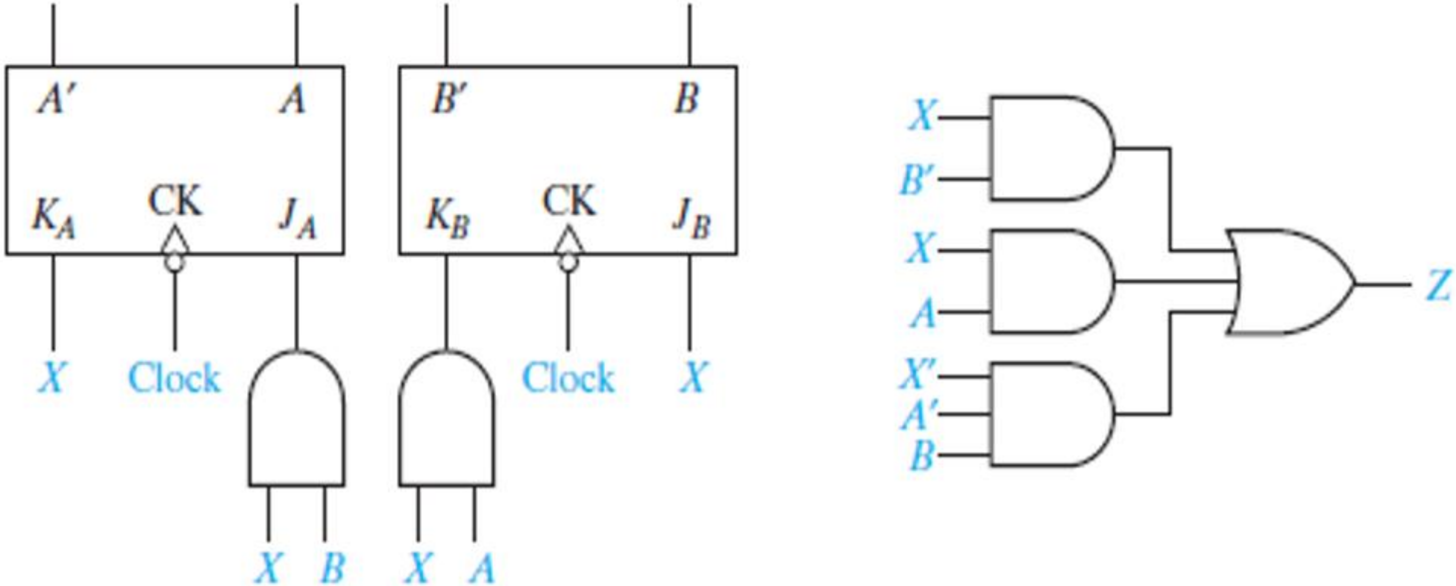
$G^+ = GA + ABY'$ $\qquad\qquad$ $Y^+ = GA'$



Analysis by Transition Tables & Graphs

Repeat Mealy example (last lecture) using these techniques:

1. Determine equations for inputs to flip-flops & outputs from circuit



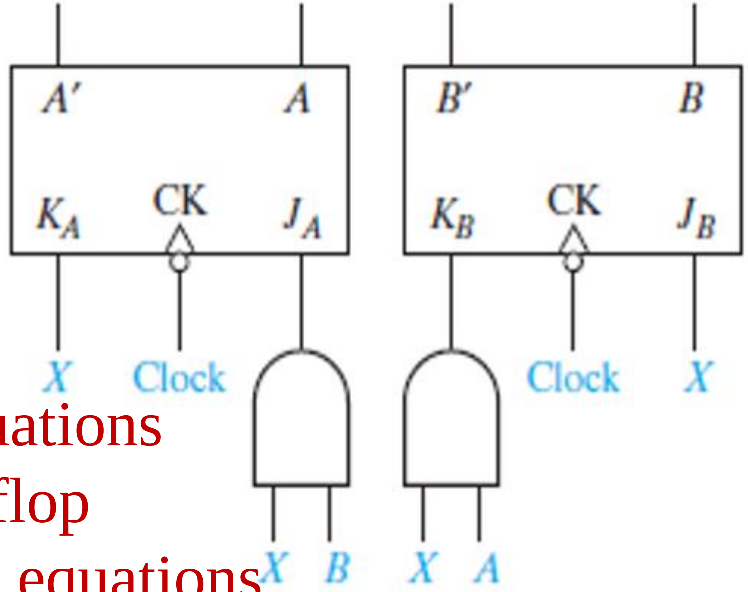
- $J_A = XB$
- $K_A = X$
- $J_B = X$
- $K_B = XA$
- $Z = XB' + XA + X'A'B$
- These are same as when worked last lecture, except last lecture we plugged in values of all variables for the initial state right away and then repeated as we stepped through each state

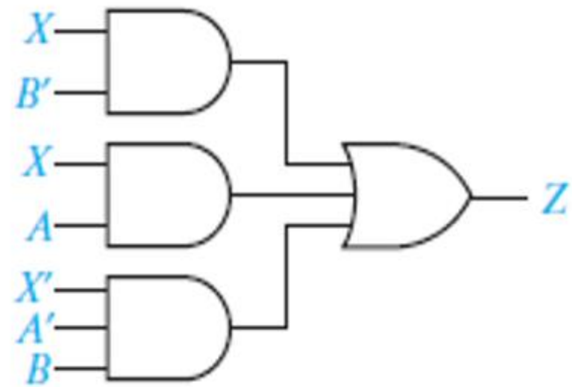
Analysis by Transition Tables & Graphs

Repeat Mealy example (last lecture) using these techniques:

- $J_A = XB$
- $K_A = X$
- $J_B = X$
- $K_B = XA$

2. Derive next-state equations for each flip-flop from its input equations (using flip-flop next-state relations)





$$Z = XB' + XA + X'A'B$$

J-K: $Q^+ = JQ' + K'Q$

- $A^+ = XBA' + X'A$
- $B^+ = XB' + (XA)'B = XB' + X'B + A'B$

Analysis by Transition Tables & Graphs

Repeat Mealy example (last lecture) using these techniques:

3. Plot a next-state map for each flip-flop

$$Z = XB' + XA + X'A'B$$

- $A^{+} = XBA' + X'A$
- $B^{+} = XB' + (XA)'B = XB' + X'B + A'B$

AB \ X	0	1
00	0	0
01	0	1
11	1	0
10	1	0

A^{+}

AB \ X	0	1
00	0	1
01	1	1
11	1	0
10	0	1

B^{+}

AB \ X	0	1
00	0	1
01	1	0
11	0	1
10	0	1

Z

Analysis by Transition Tables & Graphs

Repeat Mealy example (last lecture) using these techniques:

4. Combine these maps to form the transition table that gives the next state of the flip-flop as a function of current state and circuit inputs

A^+

AB \ X	0	1
00	0	0
01	0	1
11	1	0
10	1	0

B^+

AB \ X	0	1
00	0	1
01	1	1
11	1	0
10	0	1

Z

AB \ X	0	1
00	0	1
01	1	0
11	0	1
10	0	1

AB	A^+B^+ $X = 0$	1	Z $X = 0$	1
00	00	01	0	1
01	01	11	1	0
11	11	00	0	1
10	10	01	0	1

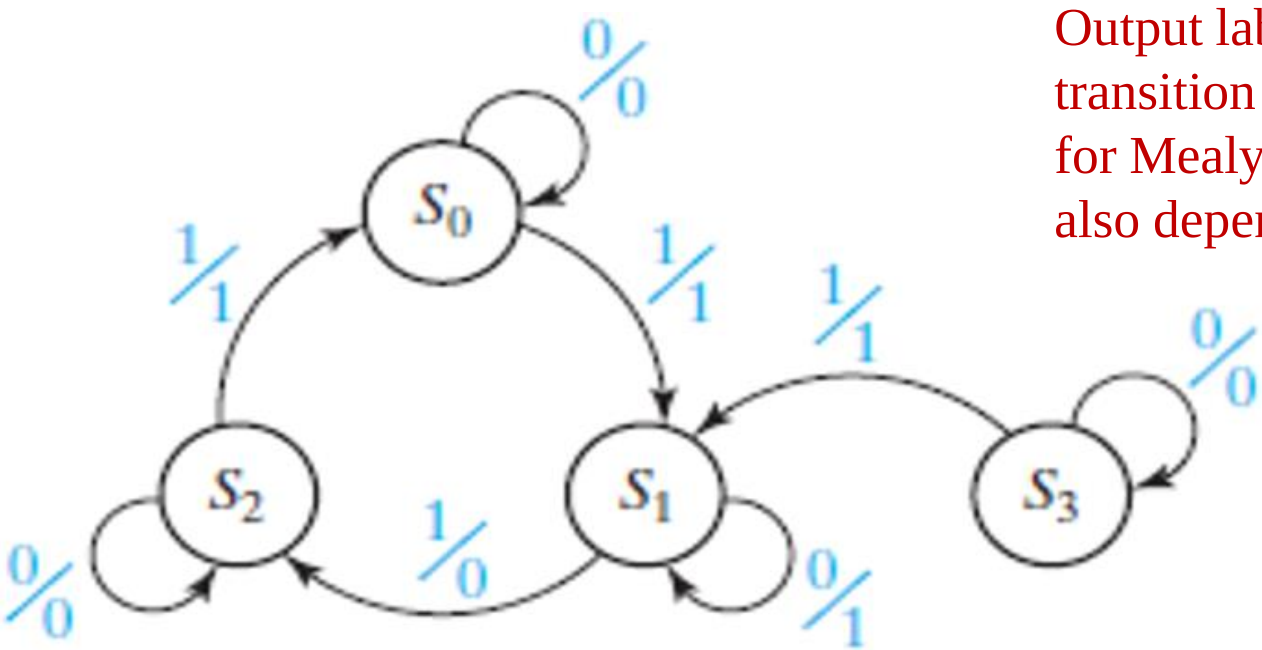
Present State	Next State $X = 0$	1	Present Output $X = 0$	1
S_0	S_0	S_1	0	1
S_1	S_1	S_2	1	0
S_2	S_2	S_0	0	1
S_3	S_3	S_1	0	1

Analysis by Transition Tables & Graphs

Repeat Mealy example (last lecture) using these techniques:

AB	A^+B^+ $X=0$	1	Z $X=0$	1
00	00	01	0	1
01	01	11	1	0
11	11	00	0	1
10	10	01	0	1

Present State	Next State $X=0$	1	Present Output $X=0$	1
S_0	S_0	S_1	0	1
S_1	S_1	S_2	1	0
S_2	S_2	S_0	0	1
S_3	S_3	S_1	0	1



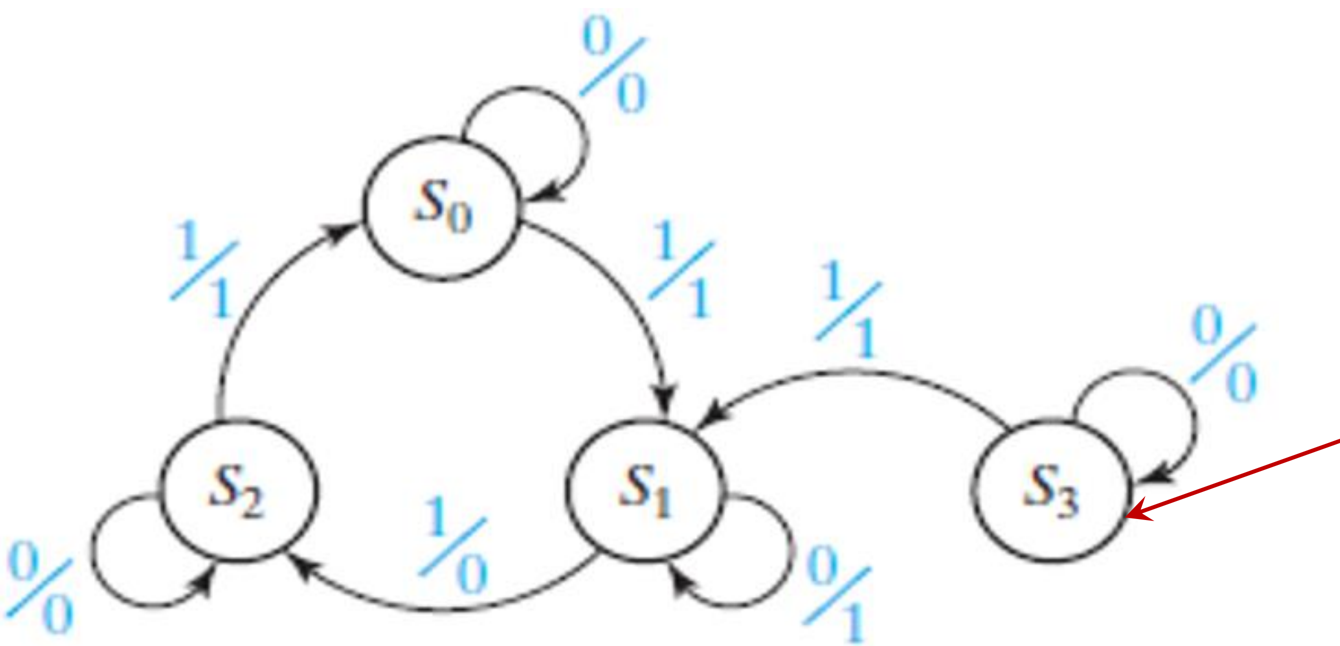
Output labeled on transition arrows since for Mealy machine output also depends on input

Analysis by Transition Tables & Graphs

Repeat Mealy example (last lecture) using these techniques:

AB	A^+B^+ $X=0$	1	Z $X=0$	1
00	00	01	0	1
01	01	11	1	0
11	11	00	0	1
10	10	01	0	1

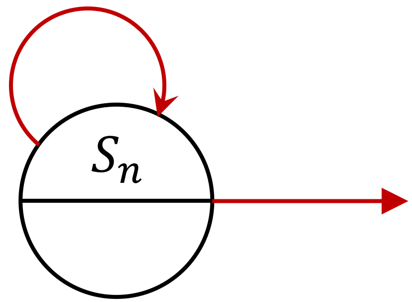
Present State	Next State $X=0$	1	Present Output $X=0$	1
S_0	S_0	S_1	0	1
S_1	S_1	S_2	1	0
S_2	S_2	S_0	0	1
S_3	S_3	S_1	0	1



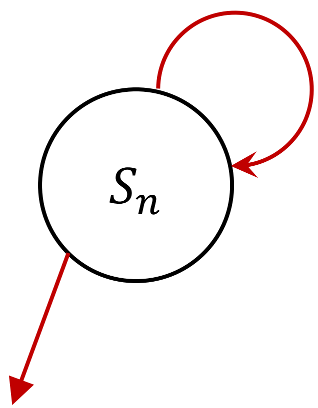
But look at S_3 out here without any transitions pointing into it

Comparison of Moore vs Mealy State Graphs

Moore:



Mealy:



- This labeling assumes that output is only on active clock edge
- Recall that doing so eliminates errors due to
- Thus no provision for extra input changes that produce false outputs included on state graphs