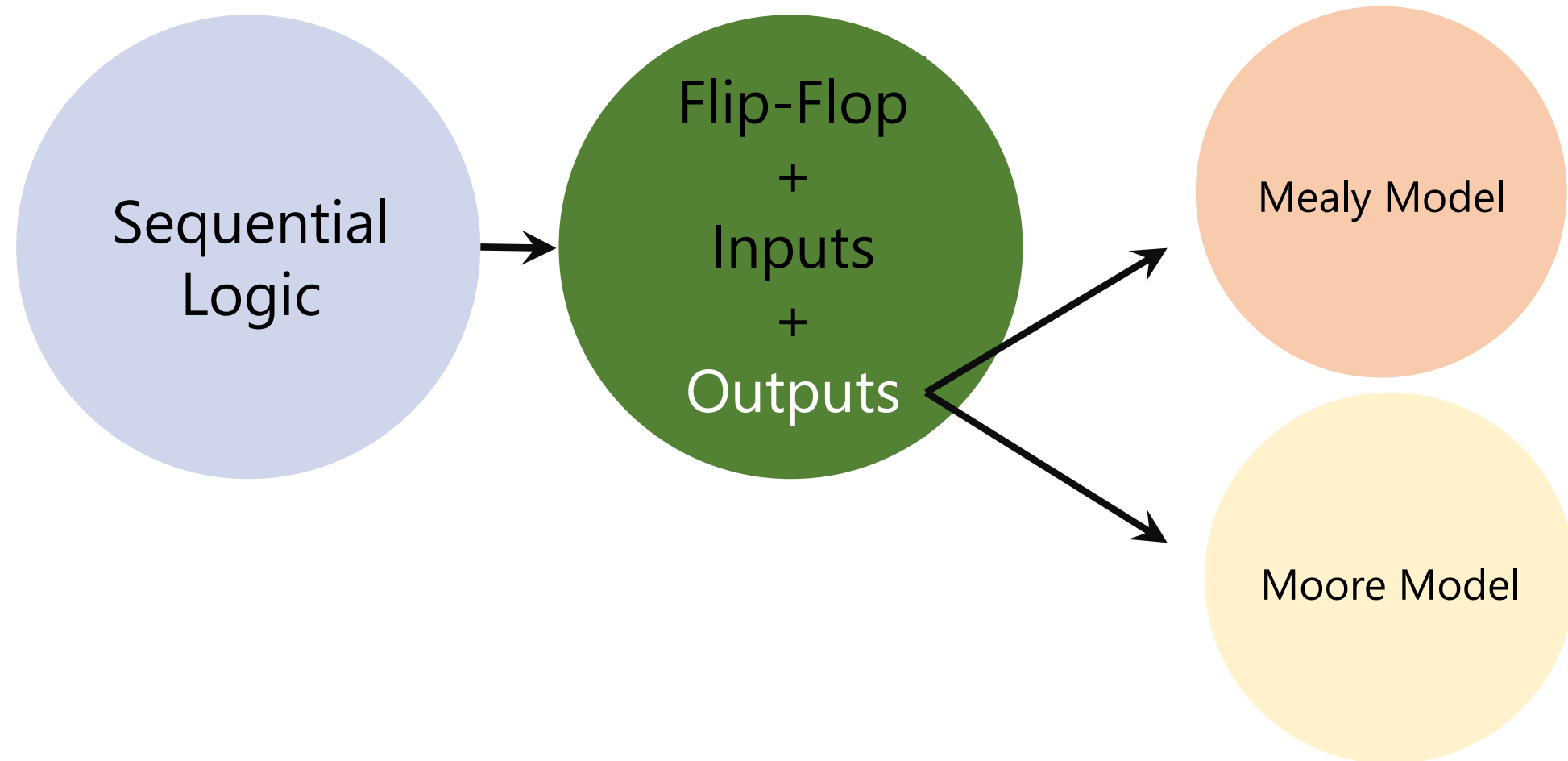


Analysis
vs.
Design

Analysis: Given a sequential circuit, show the behavior
vs.

Design: Given a behavior, build the sequential circuit





George H. Mealy

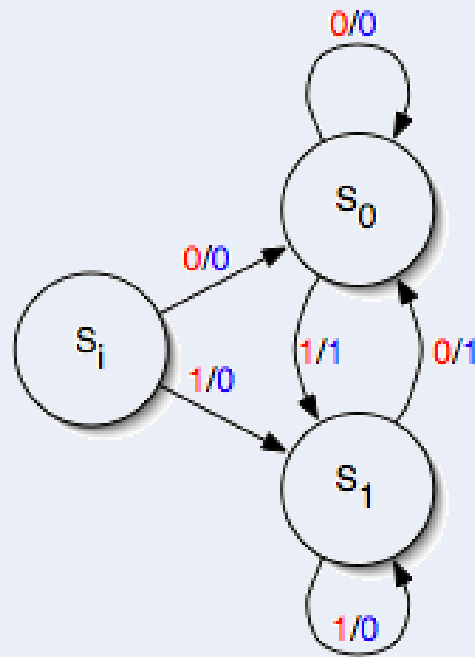
(1927 – 2010)

Mathematician and Computer Scientist

Invented Mealy Machine

Also a pioneer of modular programming

Outputs = Function(Current State, Inputs)



Edward Forrest Moore

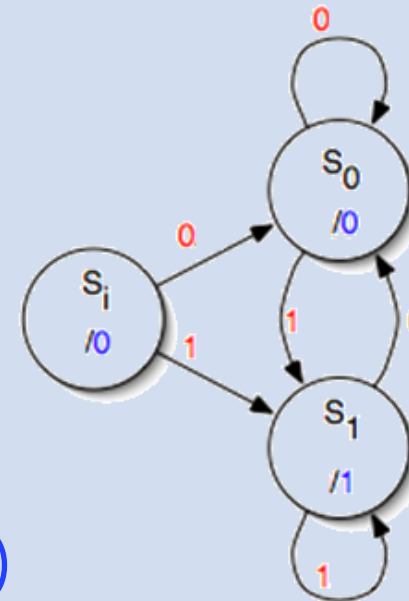
(1925 – 2003)

Mathematician and Computer Scientist

Inventor of the Moore Machine

Also an early pioneer of artificial life

Outputs = Function(Current State, Inputs)



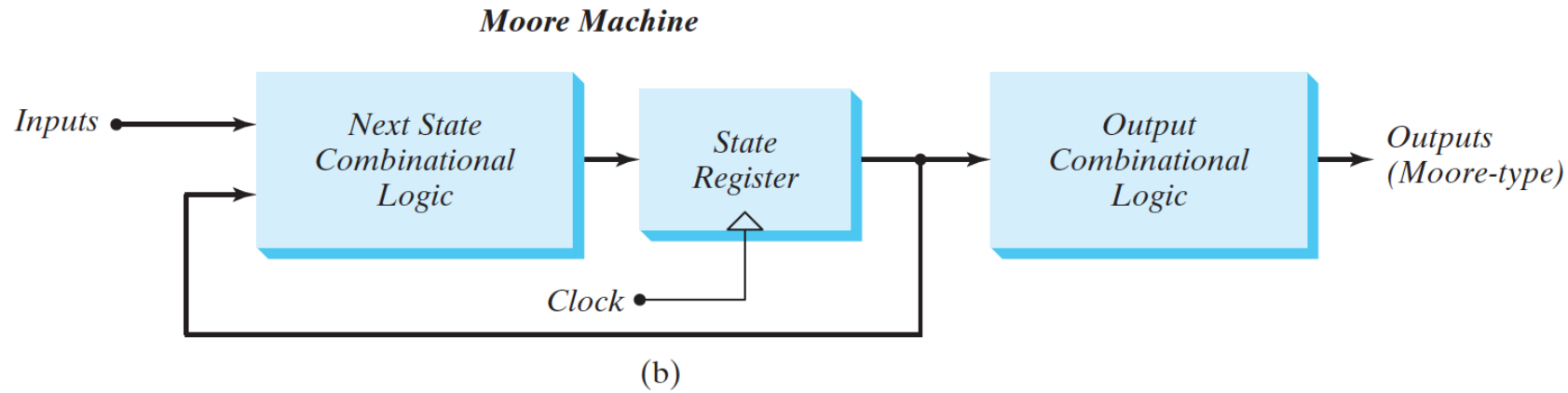
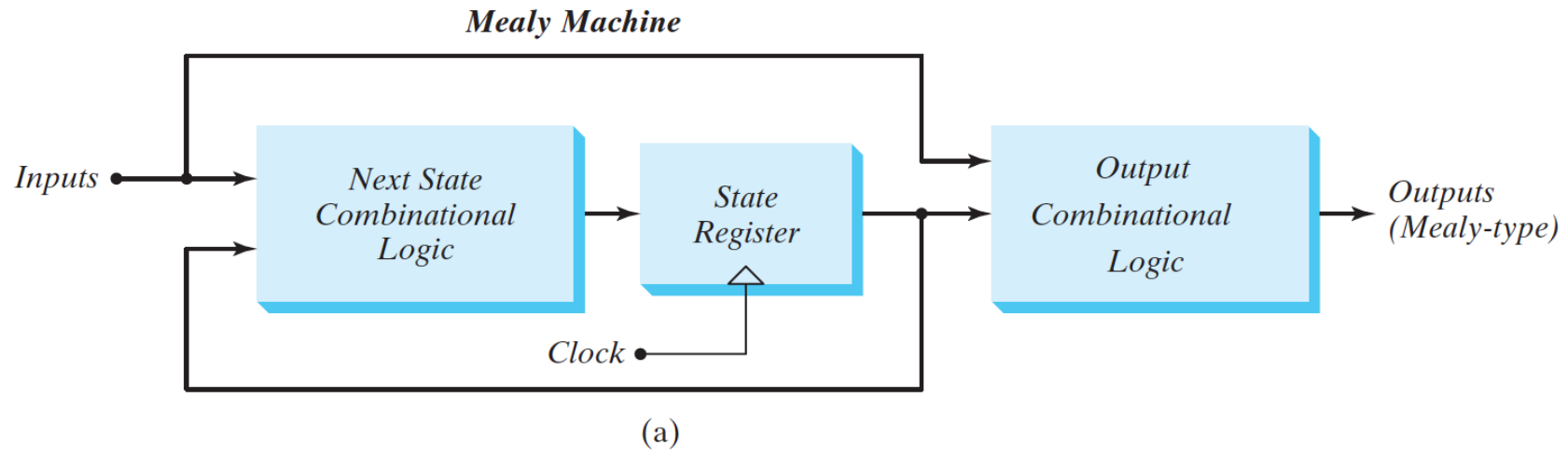


FIGURE 5.21
Block diagrams of Mealy and Moore state machines



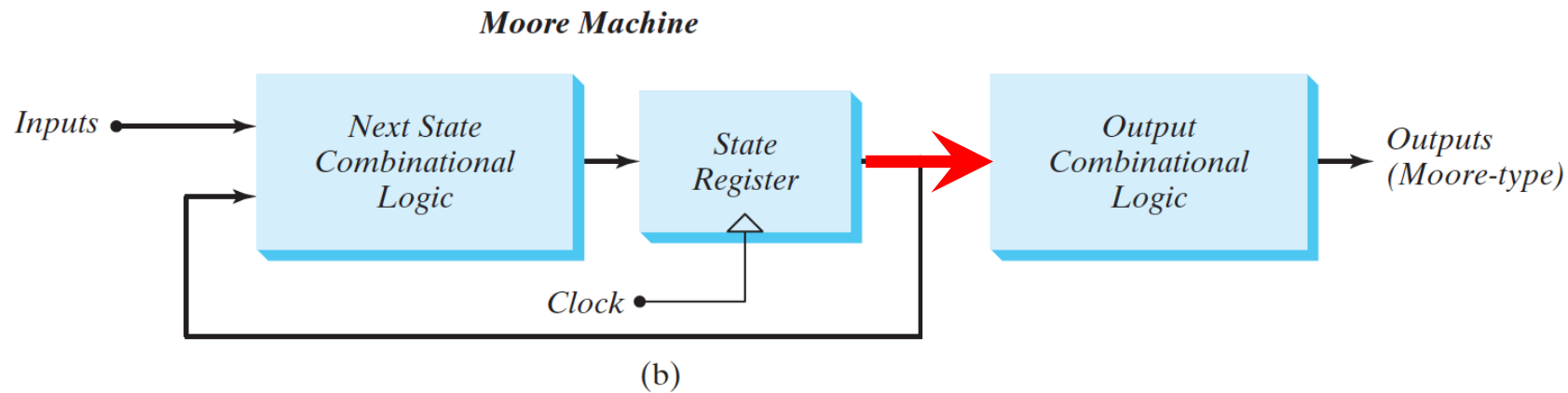
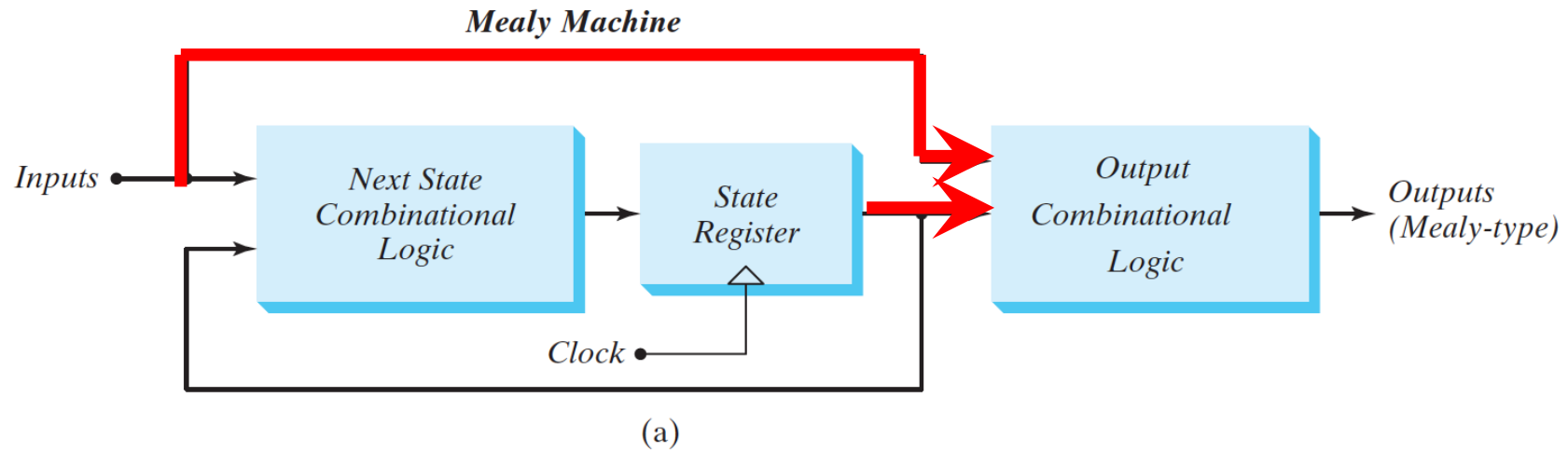


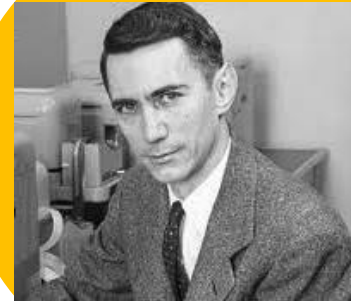
FIGURE 5.21
Block diagrams of Mealy and Moore state machines



Sequential
Logic

Flip-Flop
+
Inputs
+
Outputs

Mealy Model



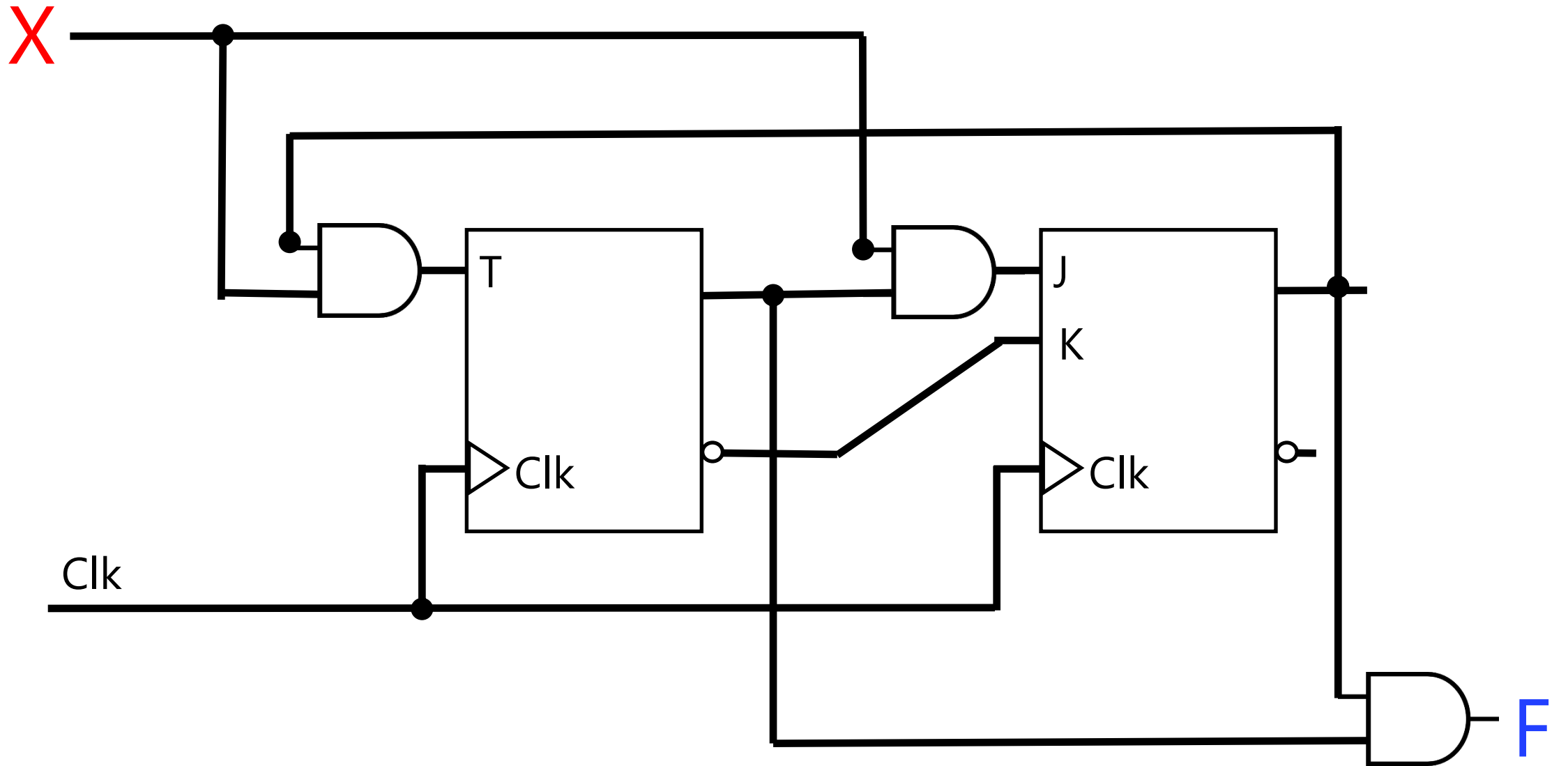
Analysis (Moore model in output) by an example

Analysis (Recap)

0. Is the circuit sequential or combinational? Any FF or feedback → Sequential
 1. What are the flip-flops? RS, D, T, JK, or mixed (e.g., 2 JK, 1 RS, ...)
 2. What are the state combinations? $2^{\#FF}$
 3. Form "State" table:
 - a) Columns: for each FF, two columns:
 - one for current state,
 - one for next state
 - b) Rows: for each state combination
 - In total: $2^{\#FF}$
 4. Fill the state table for next state columns based on:
 - a) the current state
 - b) the inputs to the FFs
 5. Form State Transition Diagram
 6. (Optional) Analyze paths and states in state transition diagram
-

Analysis (+ Input + Moore Model Output)

0. Is the circuit sequential or combinational? Any FF or feedback → Sequential
 1. What are the flip-flops? RS, D, T, JK, or mixed (e.g., 2 JK, 1 RS, ...)
 2. What are the state combinations? ~~$2^{\#FF}$~~
 3. Form "State" table:
 - a) Columns: for each FF, two columns:
 - one for current state,
 - one for next state
 - b) Rows: for each state combination
 - In total: ~~$2^{\#FF}$~~
 4. Fill the state table for next state columns based on:
 - a) the current state
 - b) the inputs to the FFs
 5. Form State Transition Diagram
 6. (Optional) Analyze paths and states in state transition diagram
-

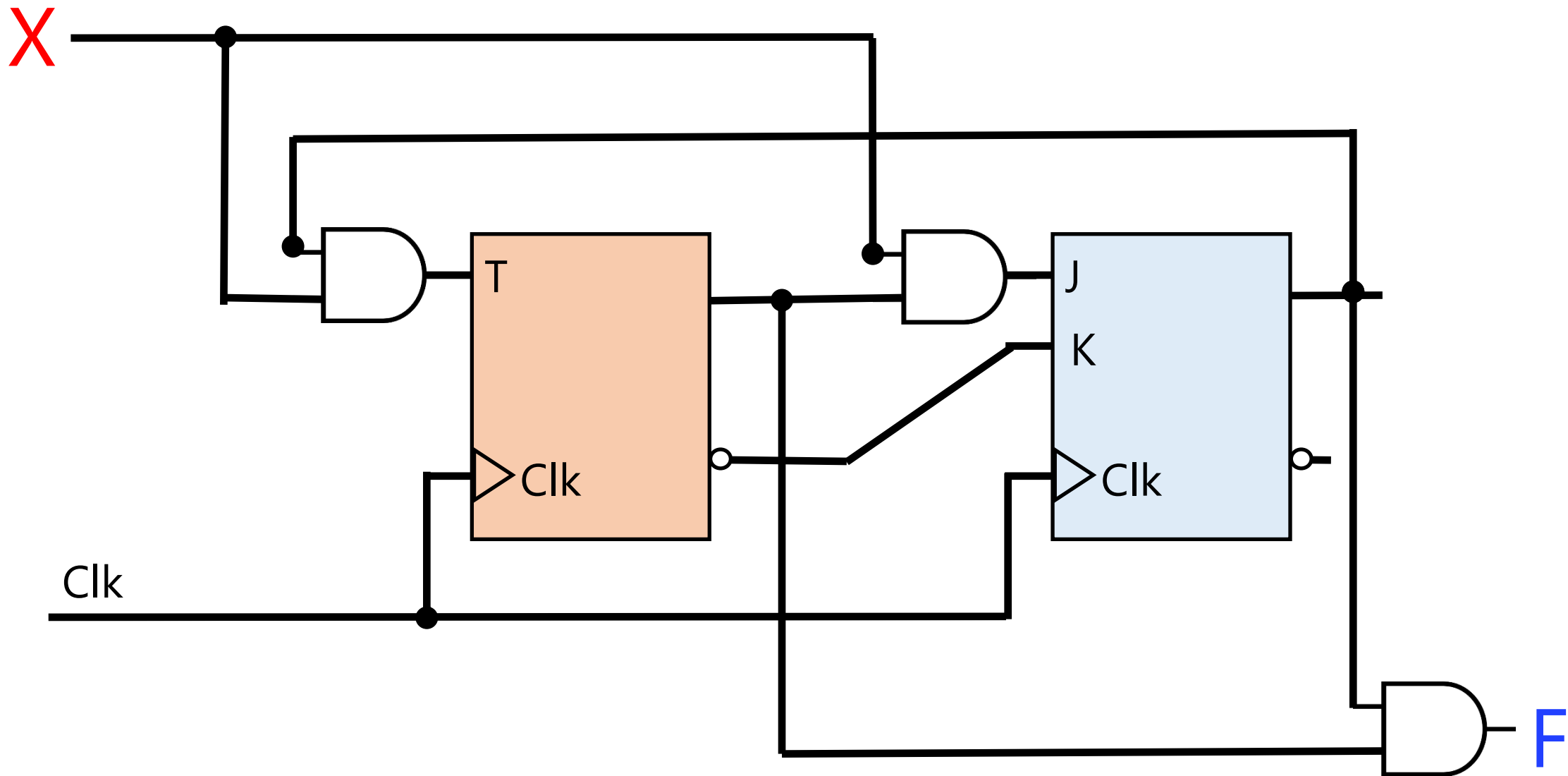


Analysis (Recap)

0. Is the circuit sequential or combinational? Any FF or feedback → Sequential

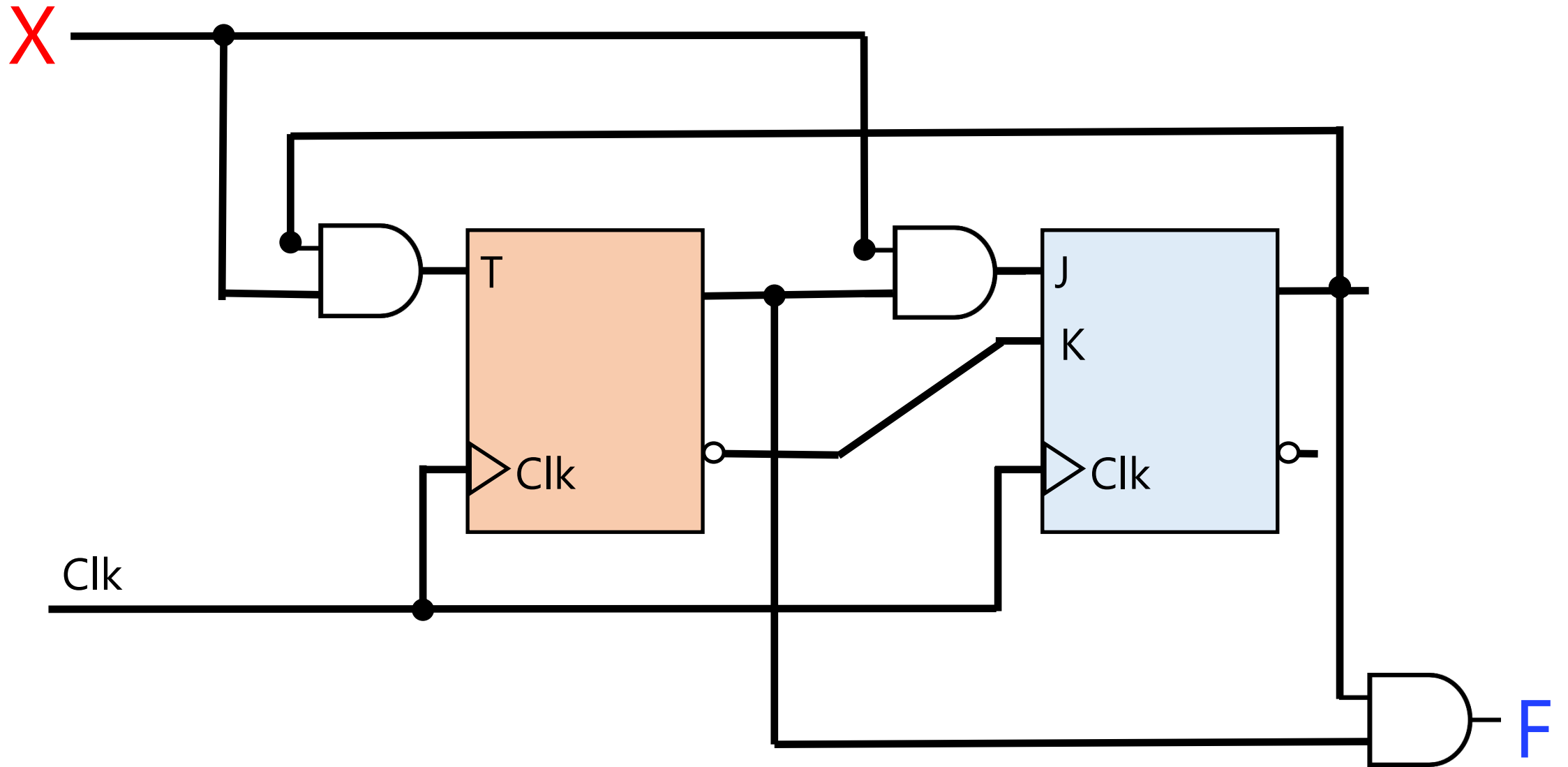
Analysis (Recap)

- 0. Is the circuit sequential or combinational? **Sequential**
- 1. What are the flip-flops?



Analysis (Recap)

0. Is the circuit sequential or combinational? Sequential
1. What are the flip-flops? T, JK
2. What are the state combinations?

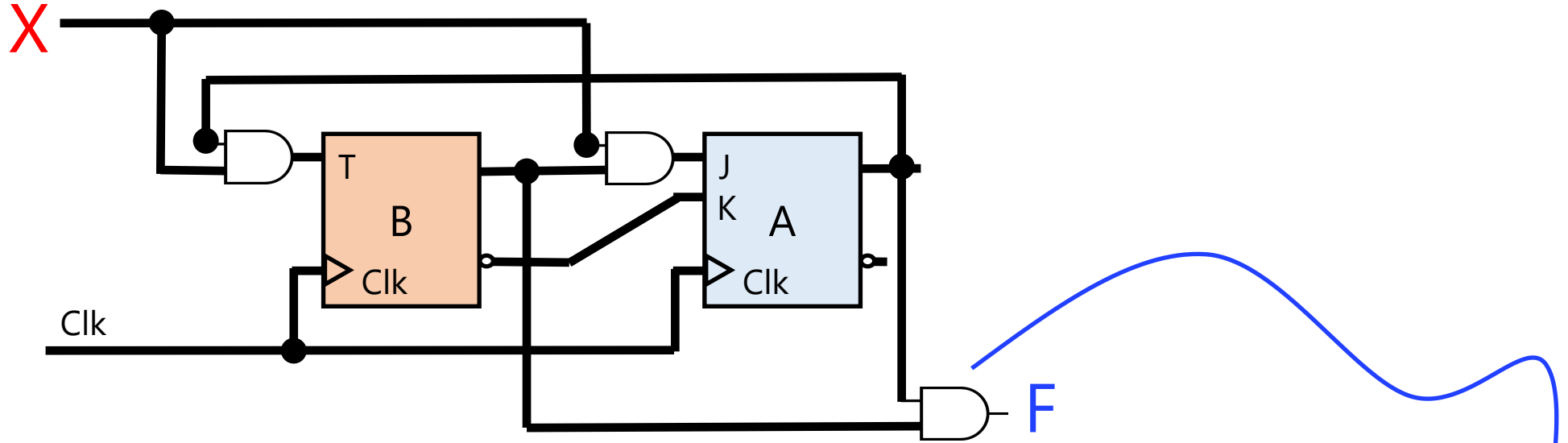


#FFs + #Inputs = 2+1 $\rightarrow 2^3 = 8$ combinations

Analysis (Recap)

0. Is the circuit sequential or combinational? Sequential
 1. What are the flip-flops? T, JK
 2. What are the state combinations? $2^{\#FF} \times 2^{\#inputs} = 2^{\#FF+\#inputs} = 2^3 = 8$
 3. Form "State" table:
 - a) Columns:
 - For each FF, two columns: one for current state, one for next state
 - For each input, one column
 - For each output, one column
 - b) Rows: See item 2
-

F

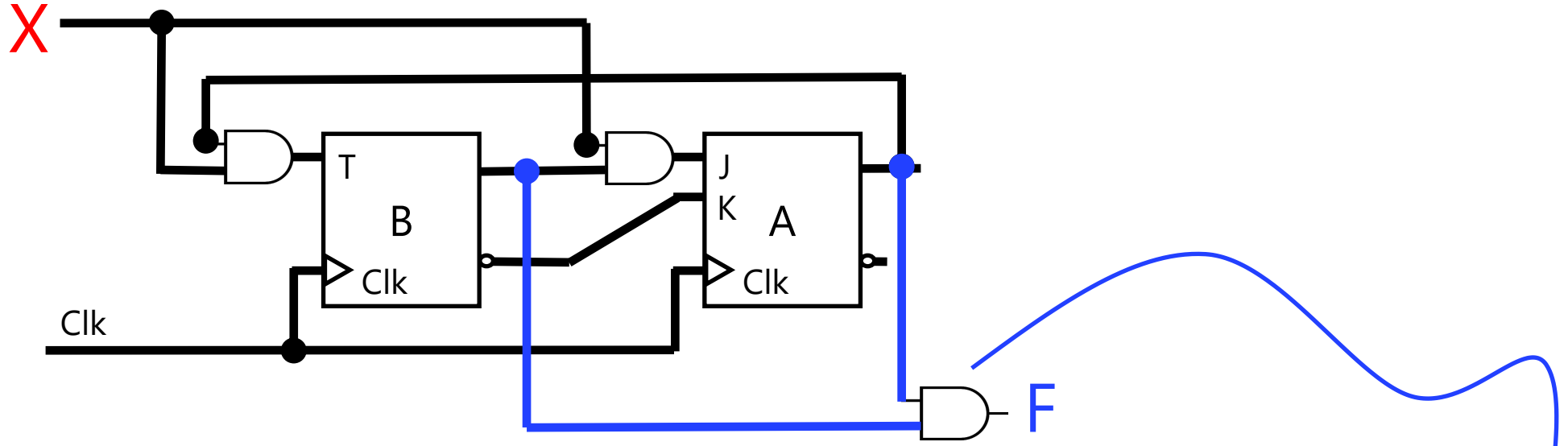


Q(T)		Q(T+1) when X=0		Q(T+1) when X=1		Outputs
B	A	B	A	B	A	F
						Moore model: does not depend on X

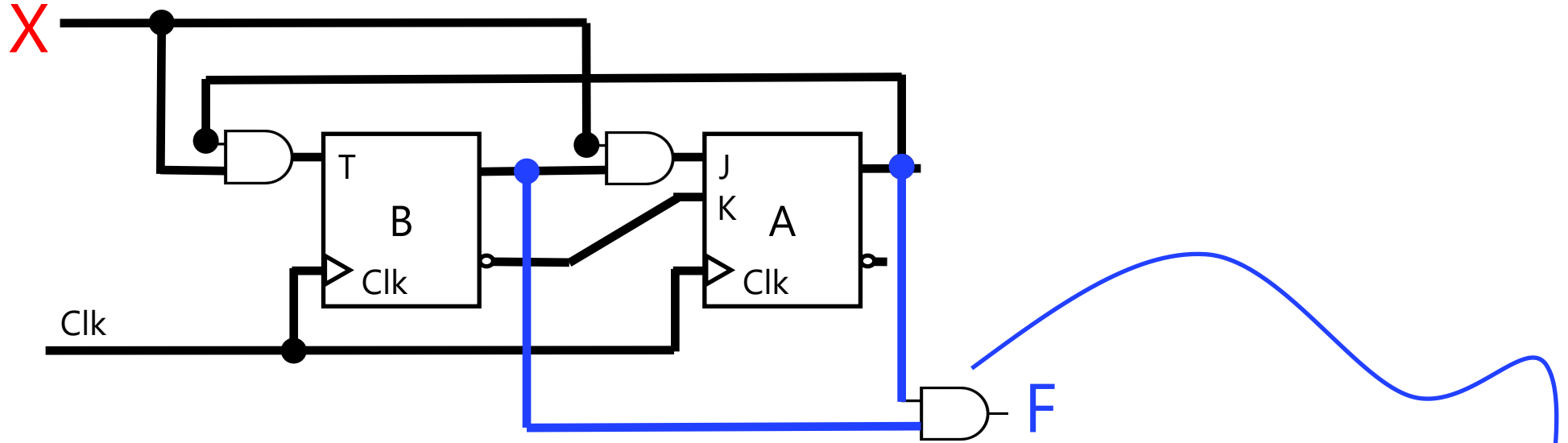
Alternative State Table

Analysis (Recap)

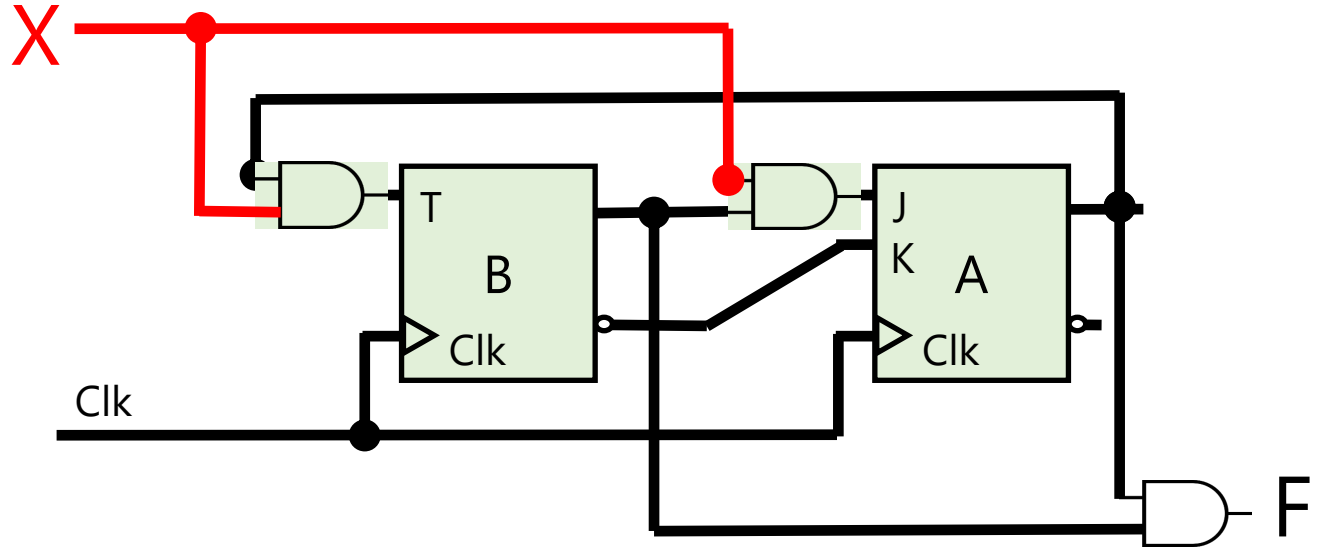
0. Is the circuit sequential or combinational? Sequential
 1. What are the flip-flops? T, JK
 2. What are the state combinations? $2^{\#FF} \times 2^{\#inputs} = 2^{\#FF+\#inputs} = 2^3 = 8$
 3. Form "State" table:
 - a) Columns:
 - For each FF, two columns: one for current state, one for next state
 - For each input, one column
 - For each output, one column
 - b) Rows: See item 2
 4. Fill the state table for
 - a) next state columns
 - b) the output value
-



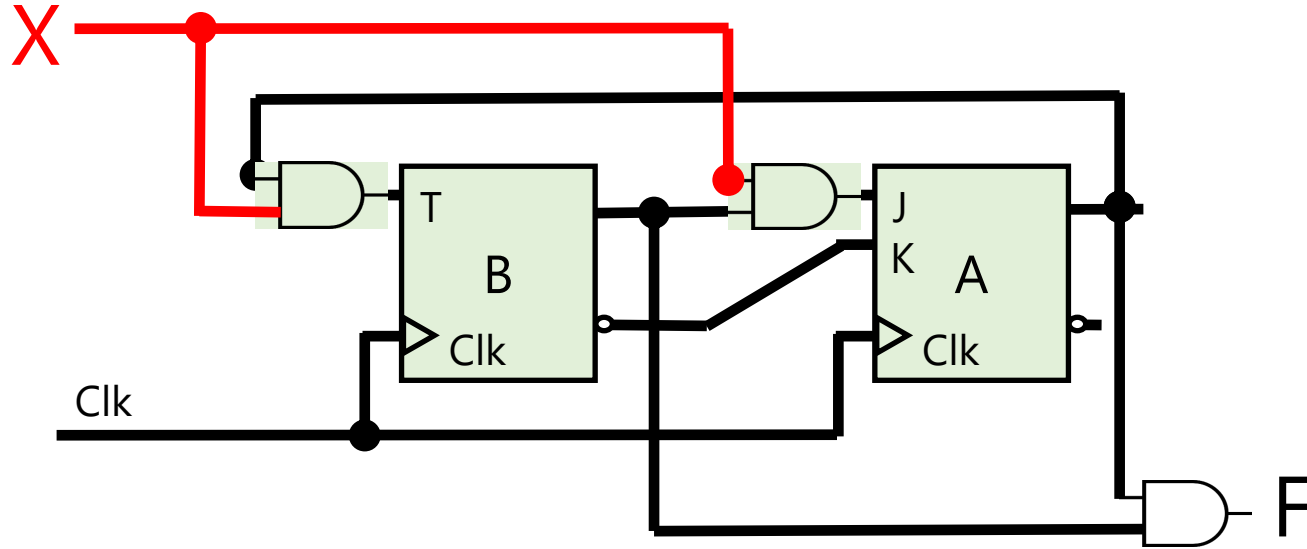
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			



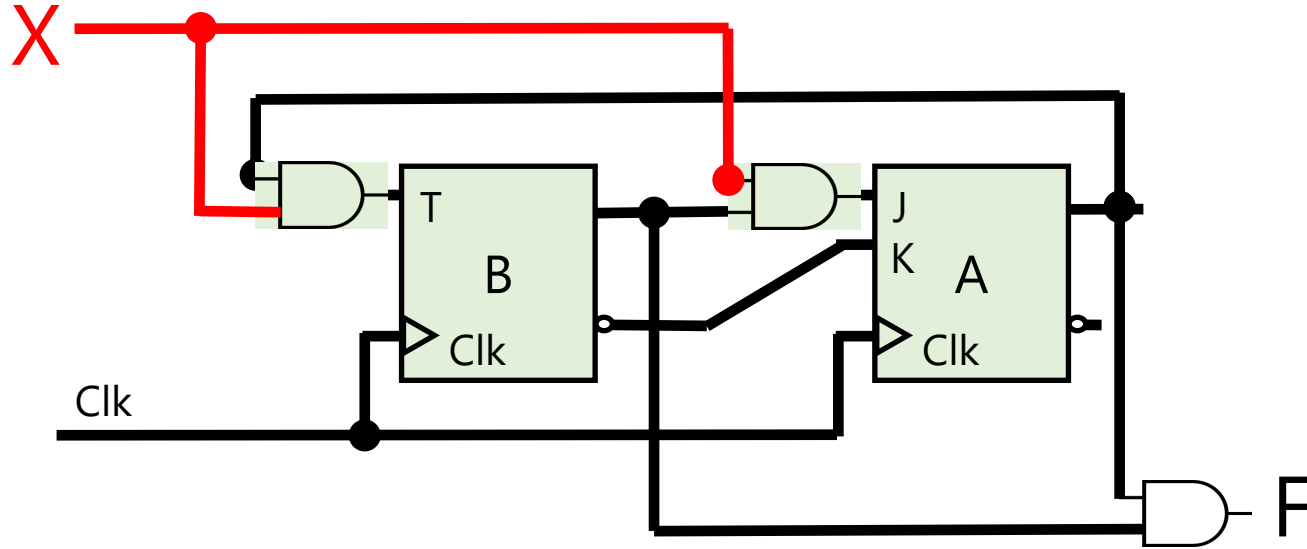
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0			0
0	0	1			0
0	1	0	Moore Model Only depends on current state X is not involved!		0
0	1	1			1
1	0	0			0
1	0	1			0
1	1	0			0
1	1	1			1



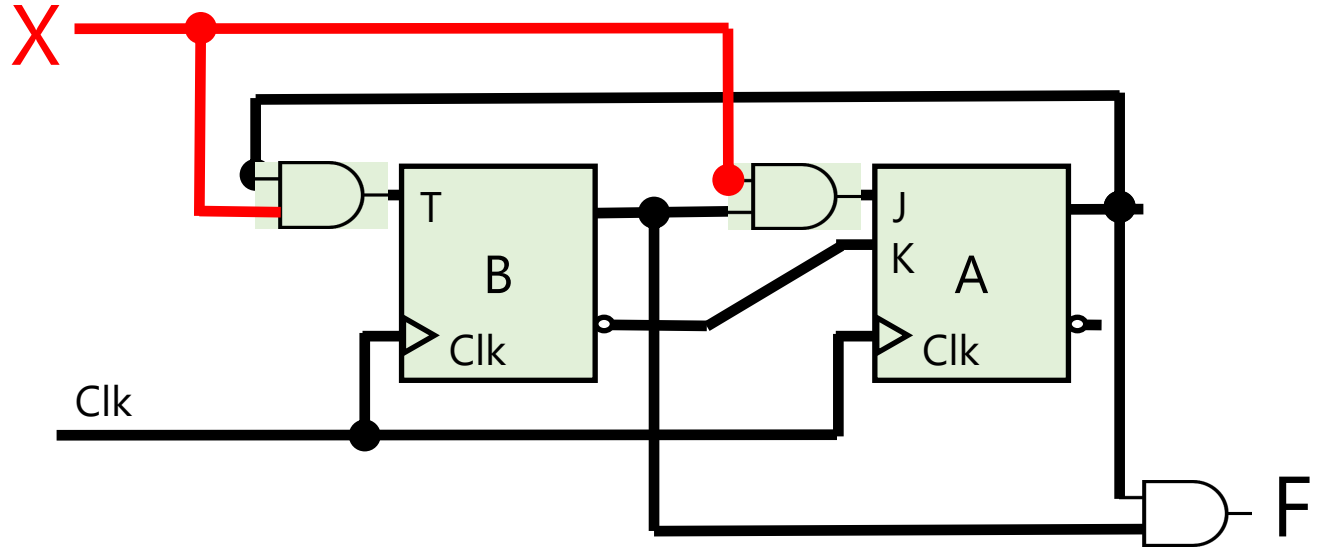
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	$F=BA$
0	0	0			0
0	0	1			0
0	1	0			0
0	1	1			1
1	0	0			0
1	0	1			0
1	1	0			0
1	1	1			1



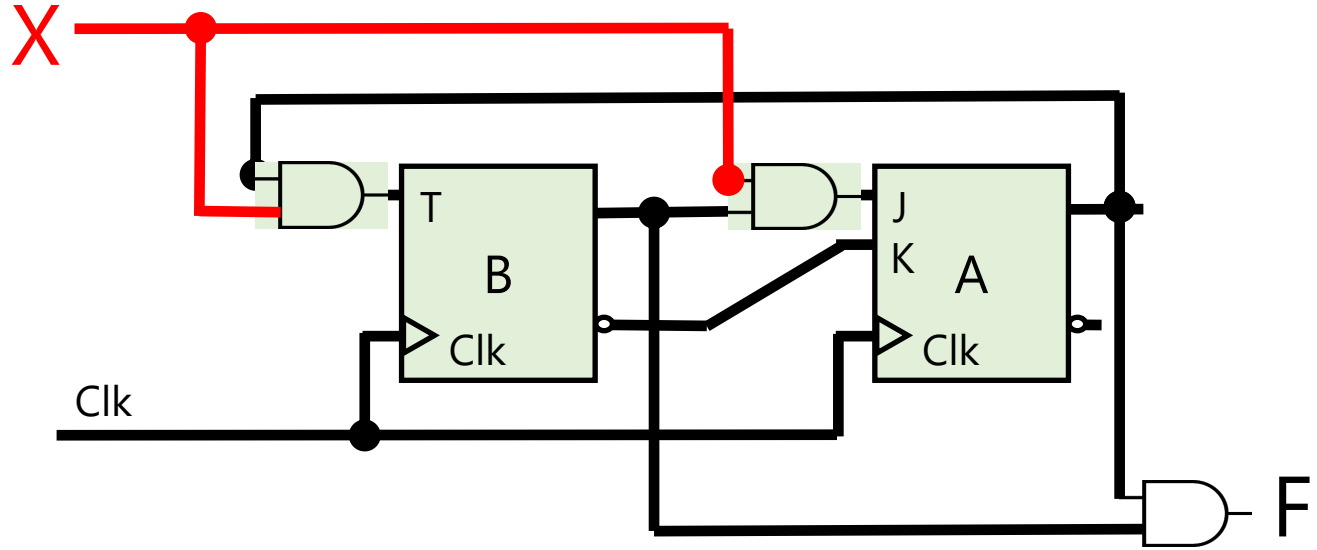
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0		A=0 $J_A = XB = 00 = 0$ $K_A = B' = 0' = 1$ ----- Reset $\rightarrow 0$	0
0	0	1			0
0	1	0			0
0	1	1			1
1	0	0			0



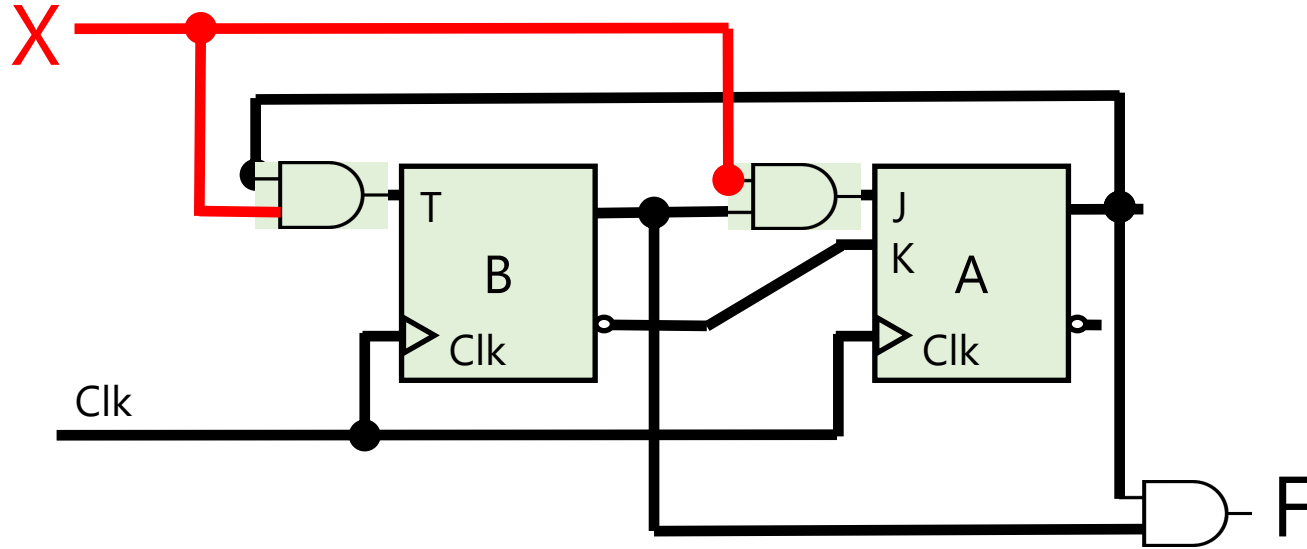
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0	B=0 $T_B = XA = 00 = 0$ ----- Store $\rightarrow 0$	0	0
0	0	1			0
0	1	0			0
0	1	1			1
1	0	0			0
1	0	1			0



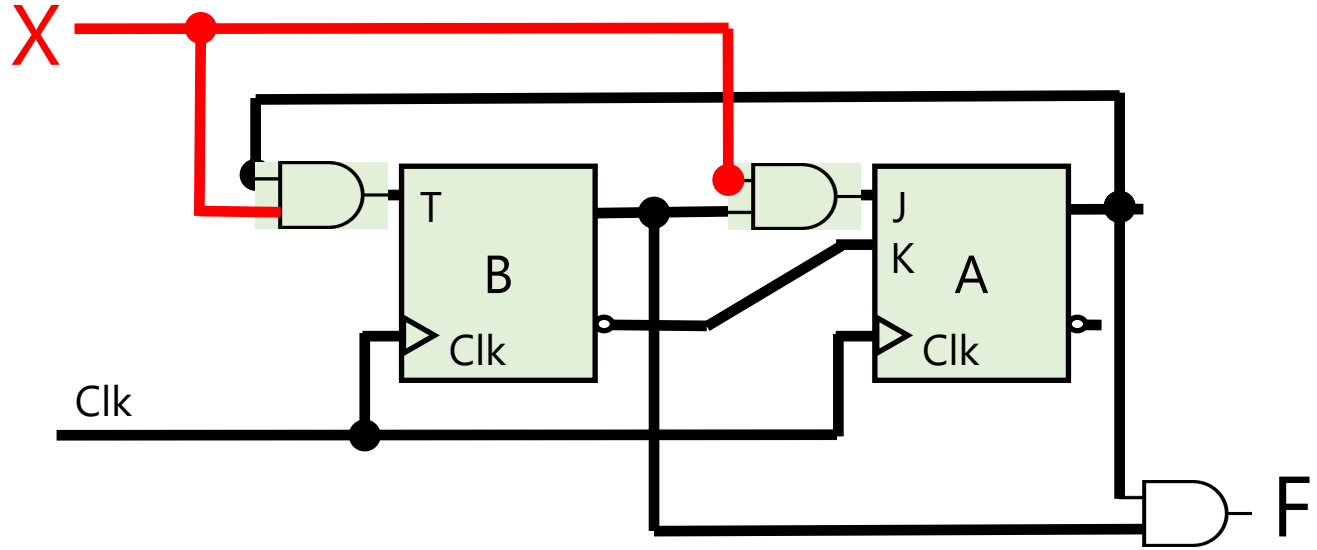
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0	0	0	0
0	0	1			0
0	1	0			0
0	1	1			1
1	0	0			0
1	0	1			0
1	1	0			0
1	1	1			1



Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	1	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	?	0	0
1	1	0	1	1	0
1	1	1	0	1	1



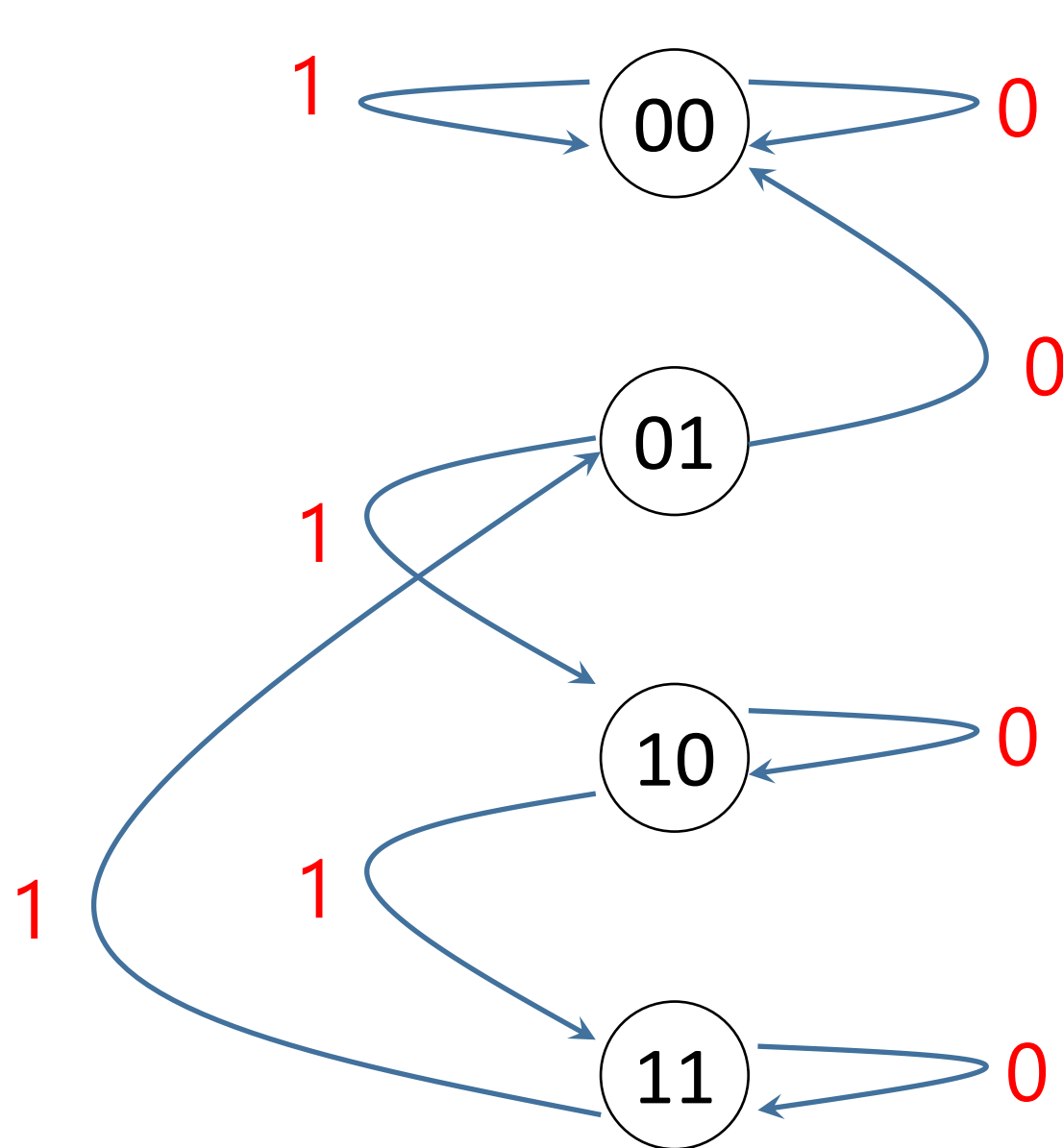
Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	$F=BA$
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	1	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	B=0 TB=XA=11=1 ----- Comp. \rightarrow 1		0



Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	F=BA
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	1	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	0	1	1	0	0
1	1	0	1	1	0
1	1	1	0	1	1

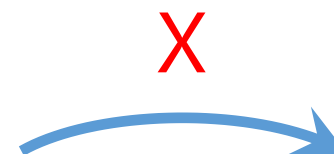
Analysis (Recap)

0. Is the circuit sequential or combinational? Sequential
 1. What are the flip-flops? T, JK
 2. What are the state combinations? $2^{\#FF} \times 2^{\#inputs} = 2^{\#FF+\#inputs} = 2^3 = 8$
 3. Form "State" table:
 - a) Columns:
 - For each FF, two columns: one for current state, one for next state
 - For each input, one column
 - For each output, one column
 - b) Rows: See item 2
 4. Fill the state table for
 - a) next state columns
 - b) the output value
 5. Form state (transition) diagram
 - a) nodes for states, directed edges for transitions between states
 - b) labels for edges by the value of input
 - c) labels for nodes by the value of output
-

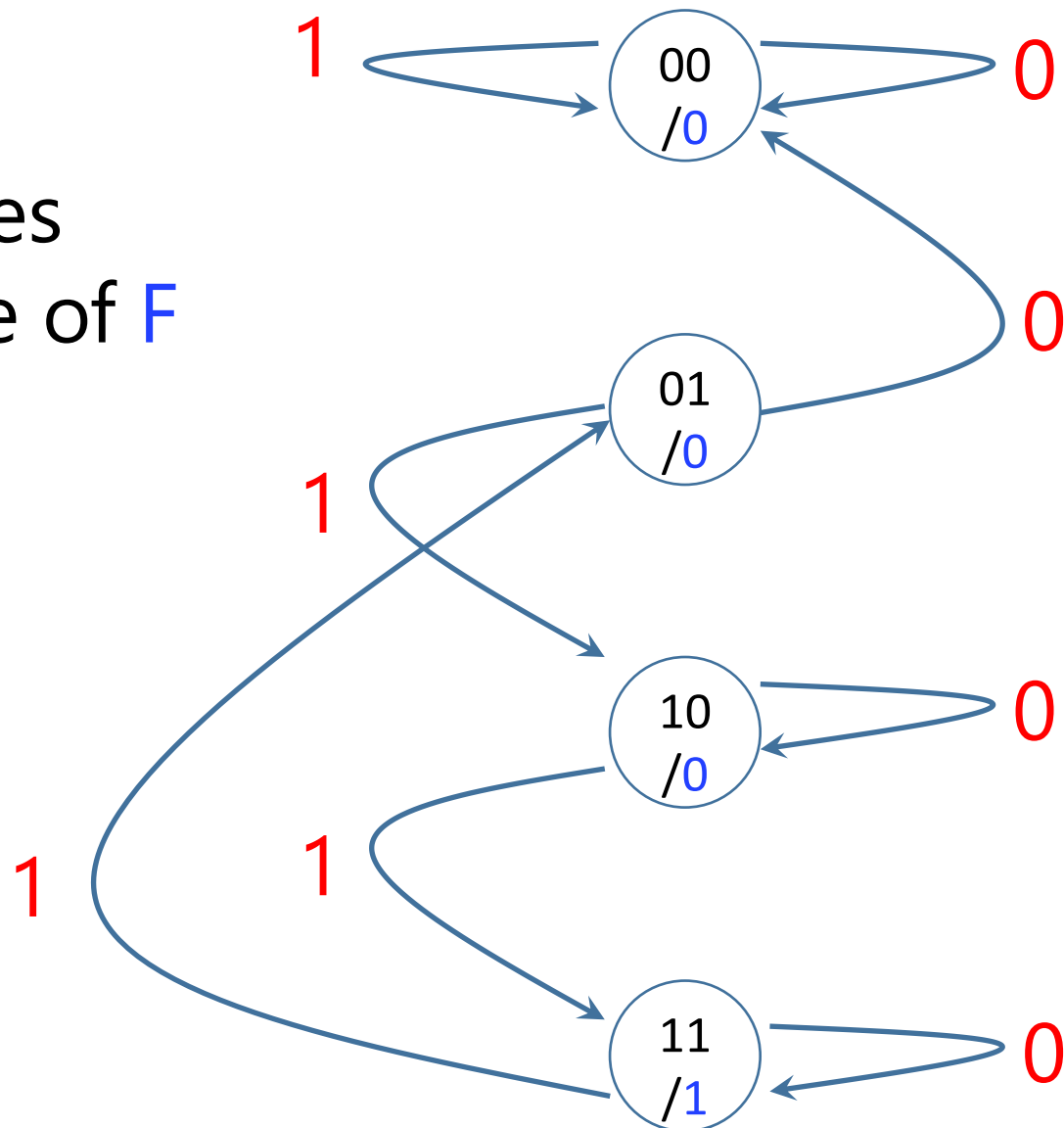
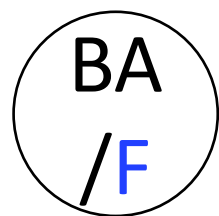


BA

Labels on edges
based on value of X



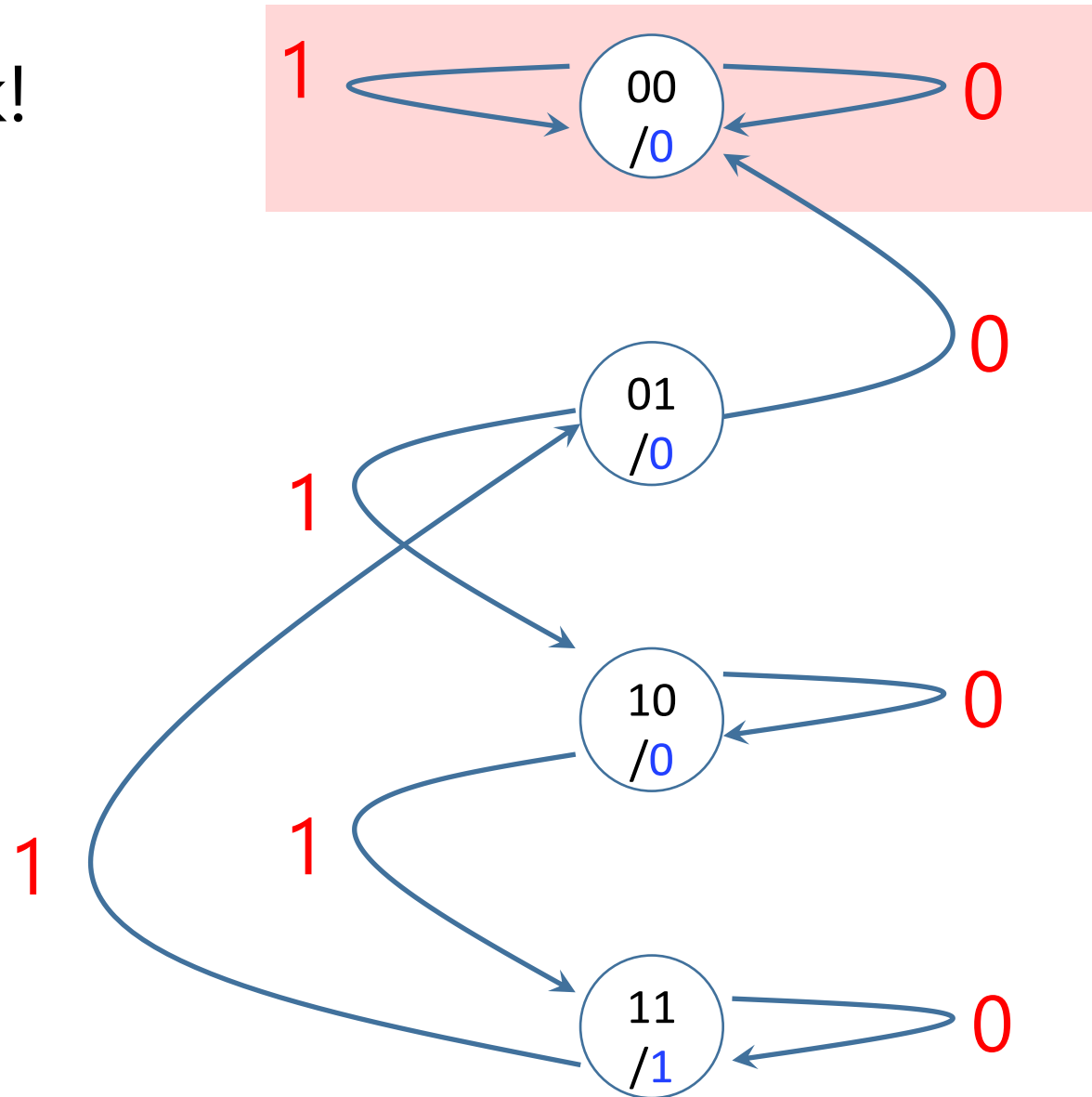
Labels on nodes
based on value of **F**



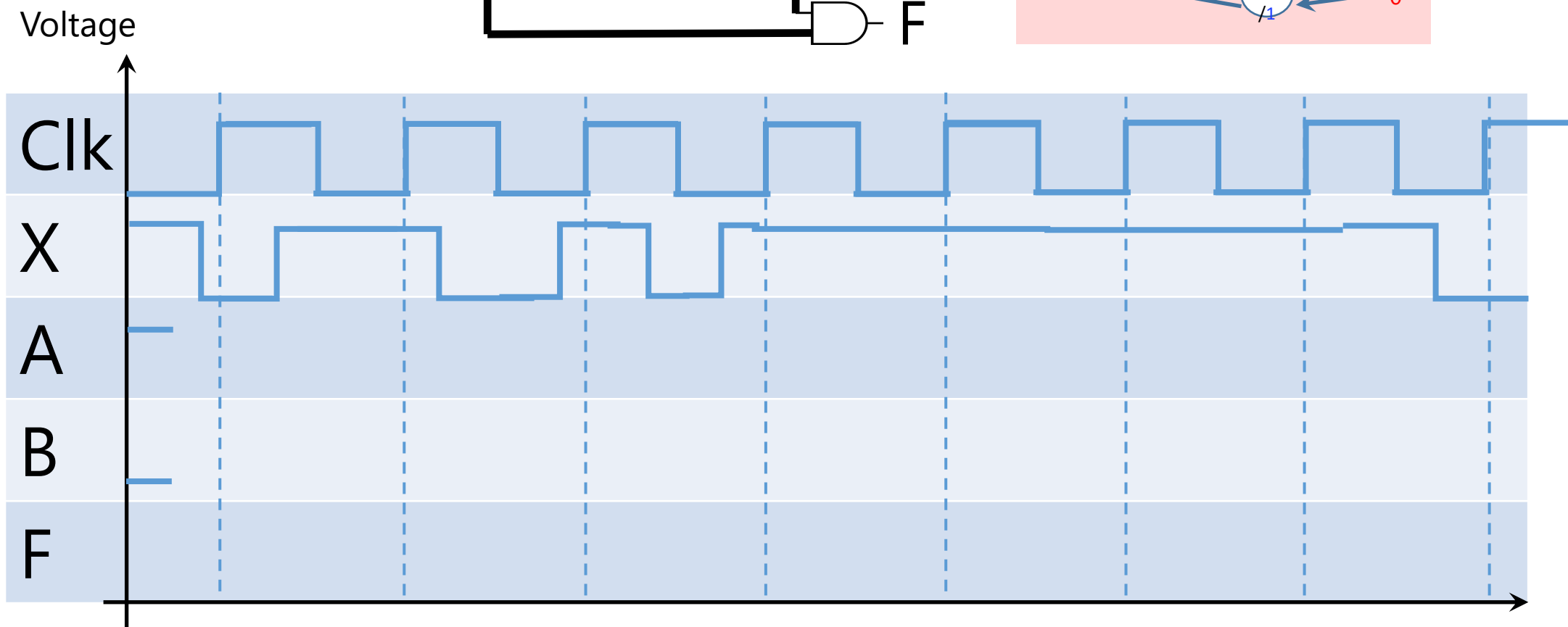
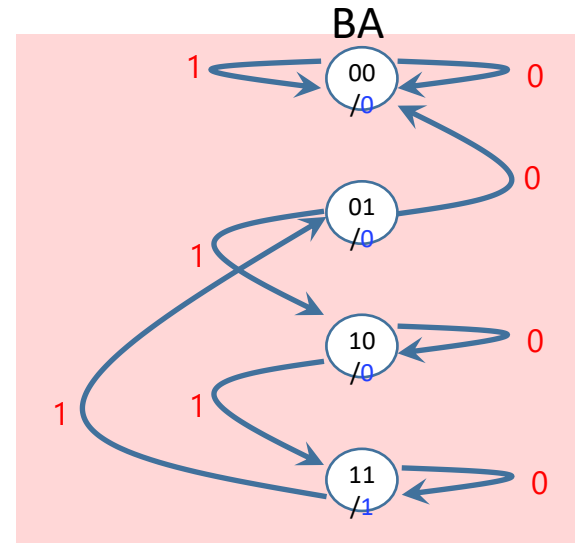
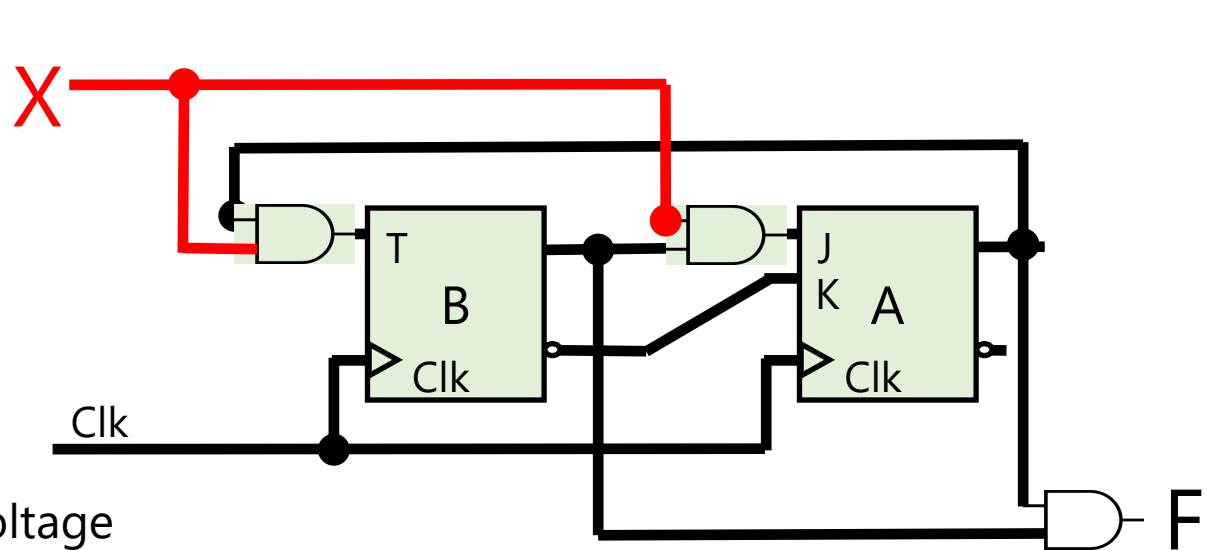
Analysis

6) (*Optional*) Path on State Transitions

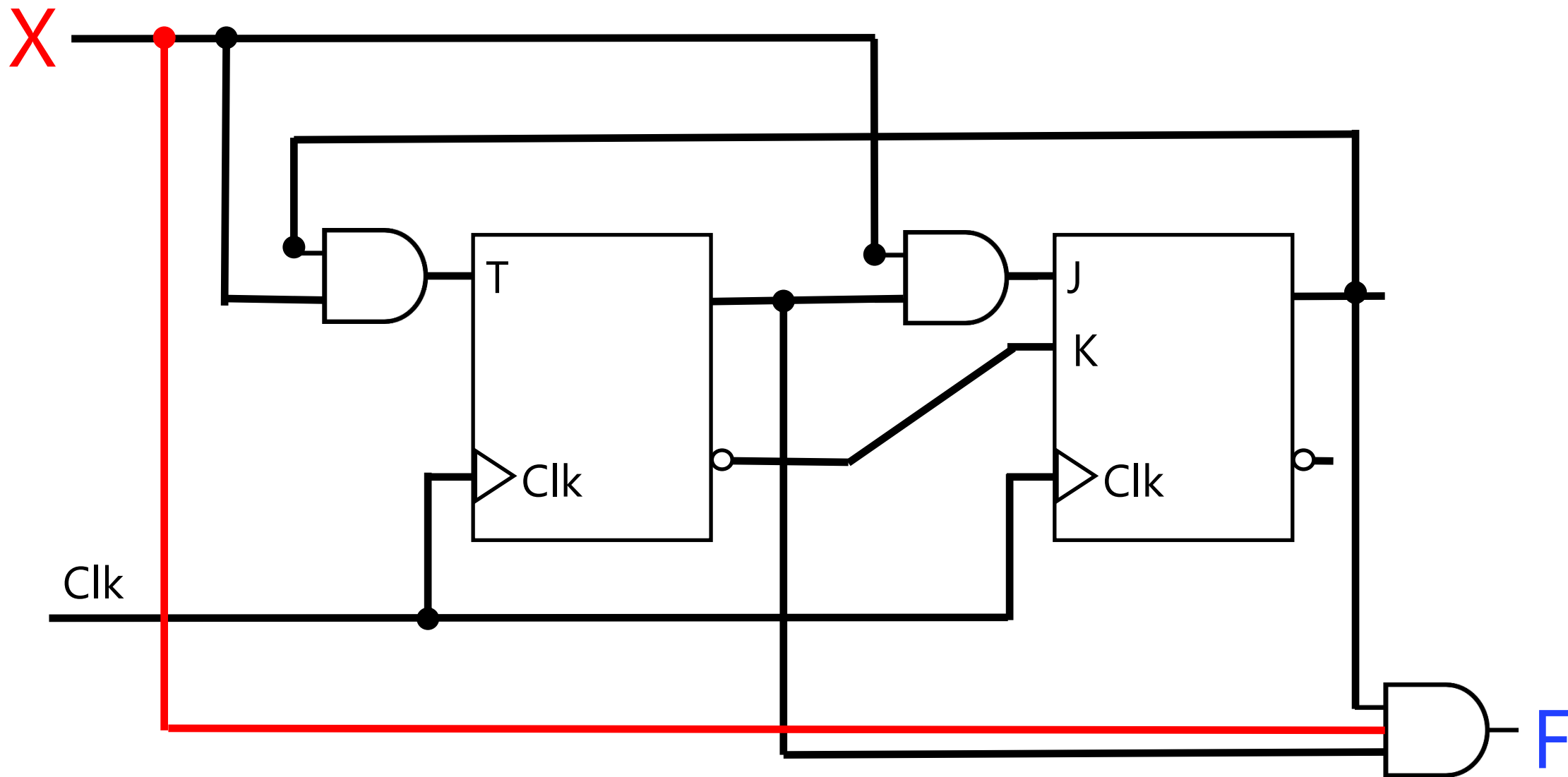
Life lock!



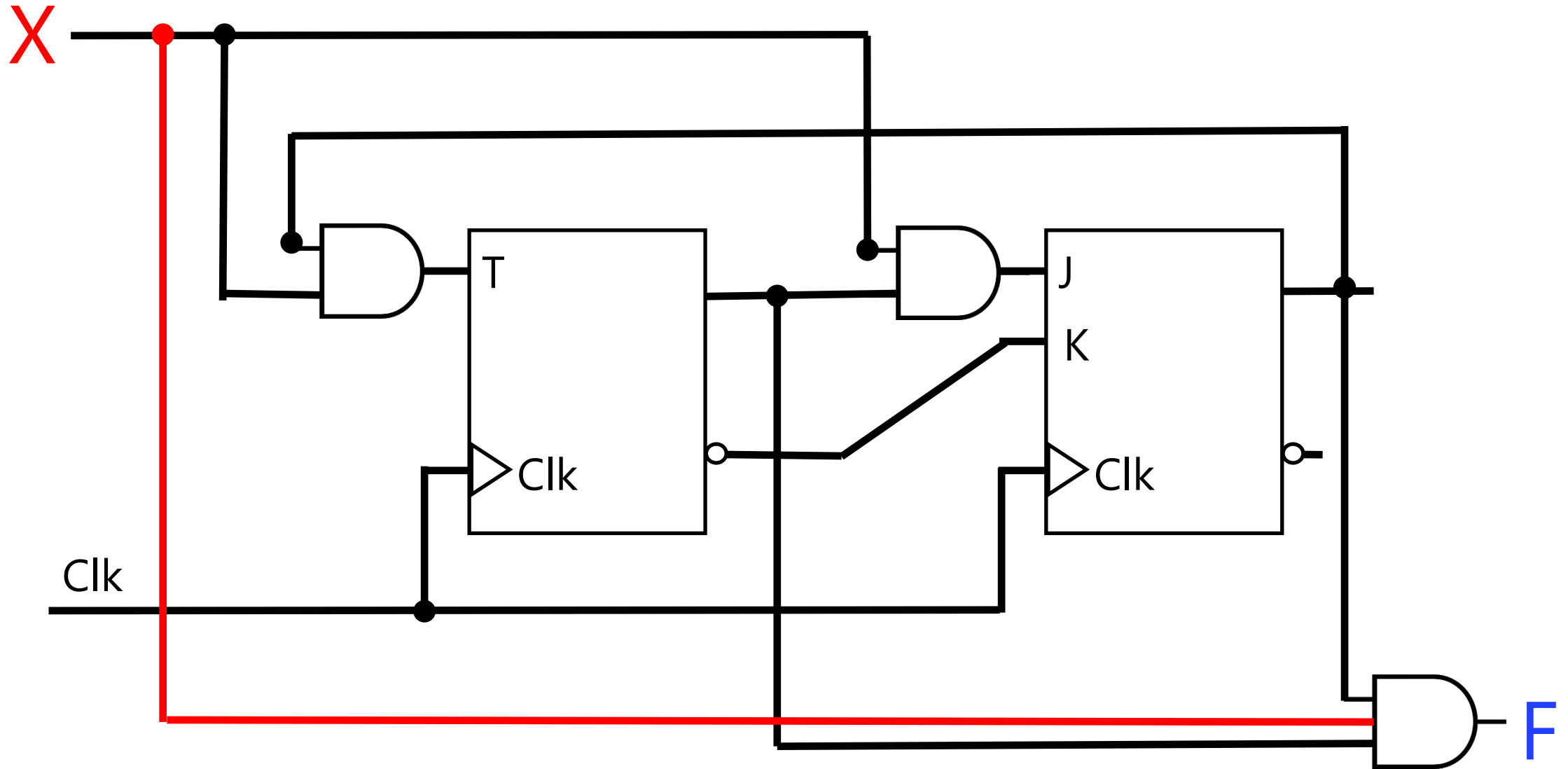
Synchronization



Asynchronized

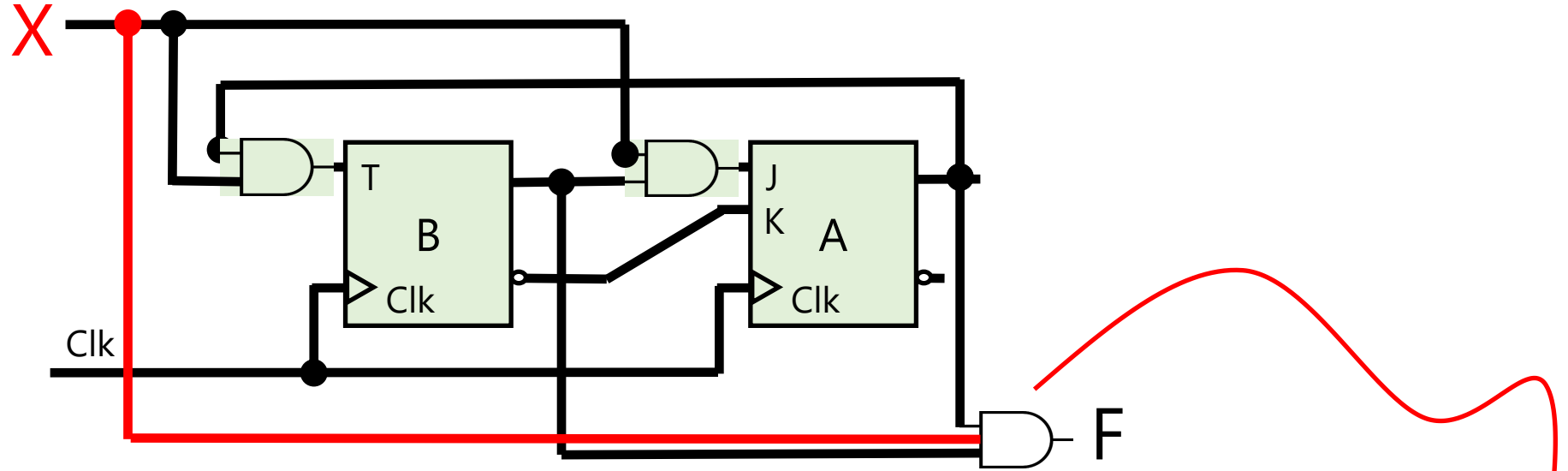


Mealy Model
 F depends on X



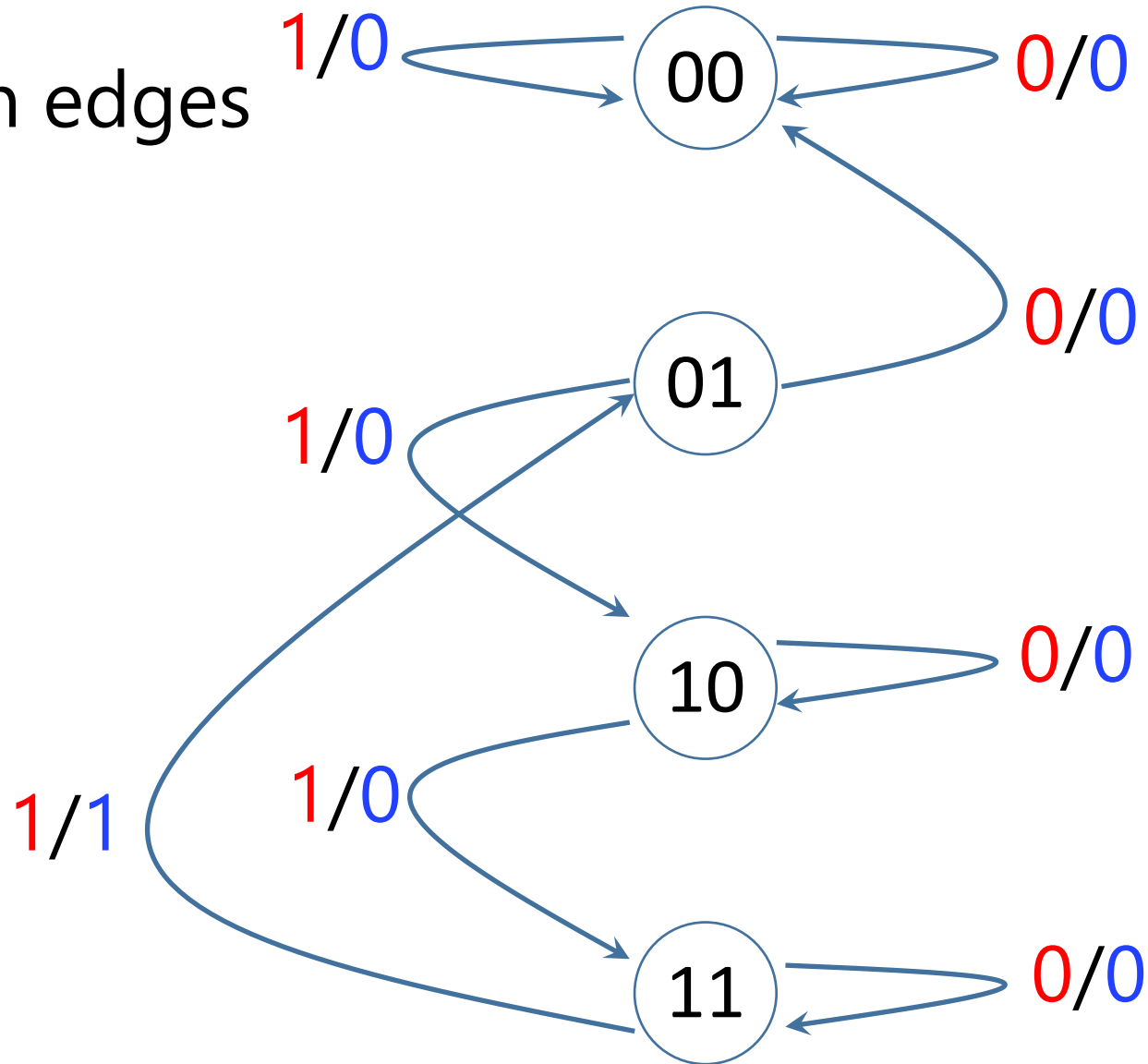
Mealy Model

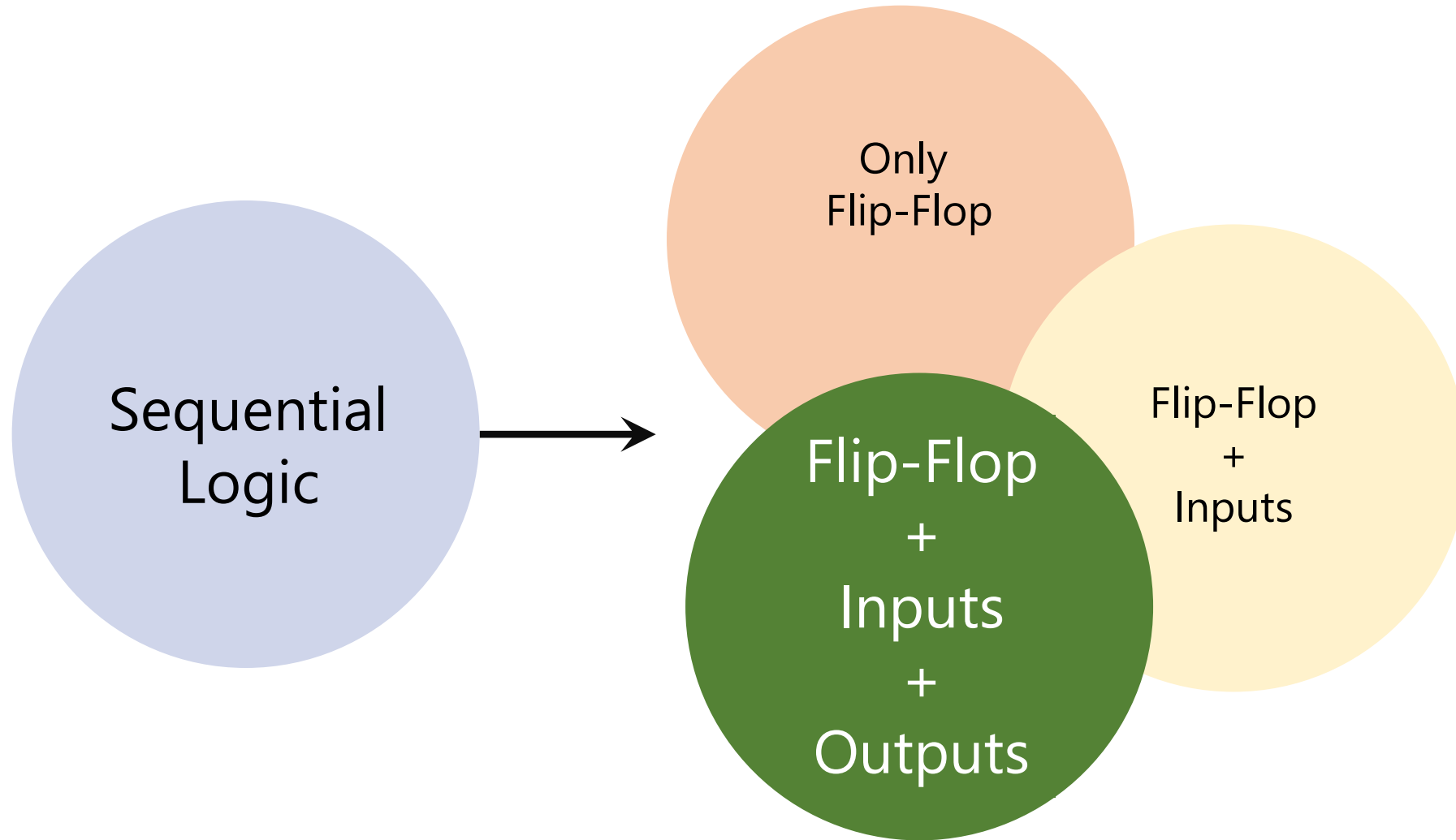
F depends on X , so, F can change out of Clk synchronization!



Inputs	Q(T)		Q(T+1)		Outputs
X	B	A	B	A	$F = X \oplus B \oplus A$
0	0	0	0	0	0
0	0	1	1	0	0
0	1	0	1	0	0
0	1	1	1	1	0
1	0	0	0	0	0
1	0	1	1	0	0
1	1	0	1	1	0
1	1	1	0	1	1

Labels go on edges
for F:





Design by an example

Counter Up-Down

Switch to count up from i to $i+1$

Switch to count down from i to $i-1$

Turn **on** the light if the current number is **even**

Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?

Counter up/down

$0 \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow \dots \rightarrow N-1 \rightarrow N$

$N \rightarrow N-1 \rightarrow \dots \rightarrow 3 \rightarrow 2 \rightarrow 1 \rightarrow 0$

Design (Recap)

- 0. Do we need combinational logic or sequential logic? Do we need memory?
- 1. How many storage (flip-flops)? #FF

Counter up/down N=7

000→001→010→011→100→101→110→111

000←001←010←011←100←101←110←111

For each intermediate state, we need 3 bits → 3 flip-flops

Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
1. How many storage (flip-flops)? #FF
2. How many input and output?

Counter up/down

N=7

000→001→010→011→100→101→110→111

000←001←010←011←100←101←110←111

We need to switch between up and down → 1 binary variable

X=0 Count Up

X=1 Count Down

Counter up/down

N=7

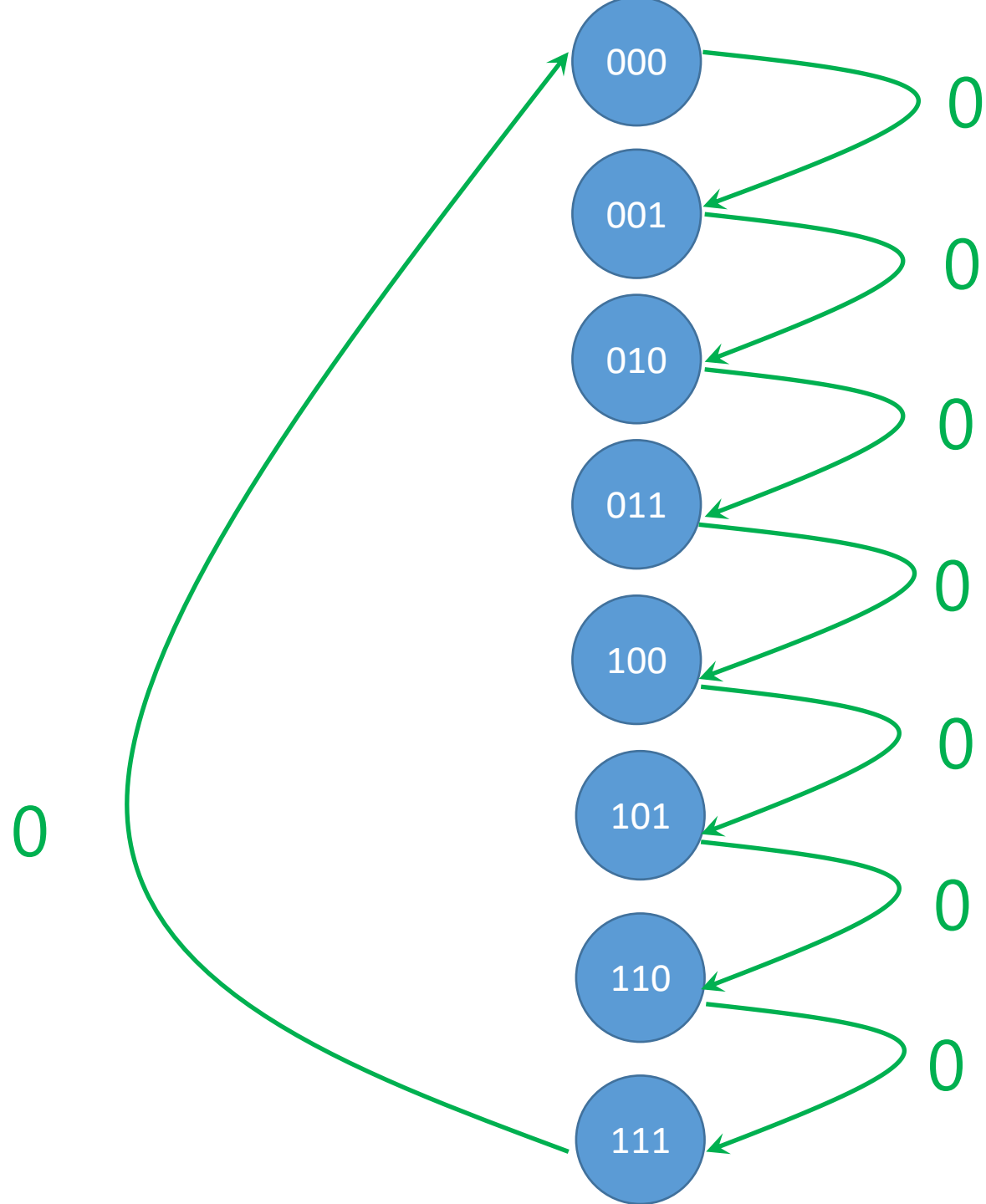
X=0: 000→001→010→011→100→101→110→111

X=1: 111→110→101→100→011→010→001→000

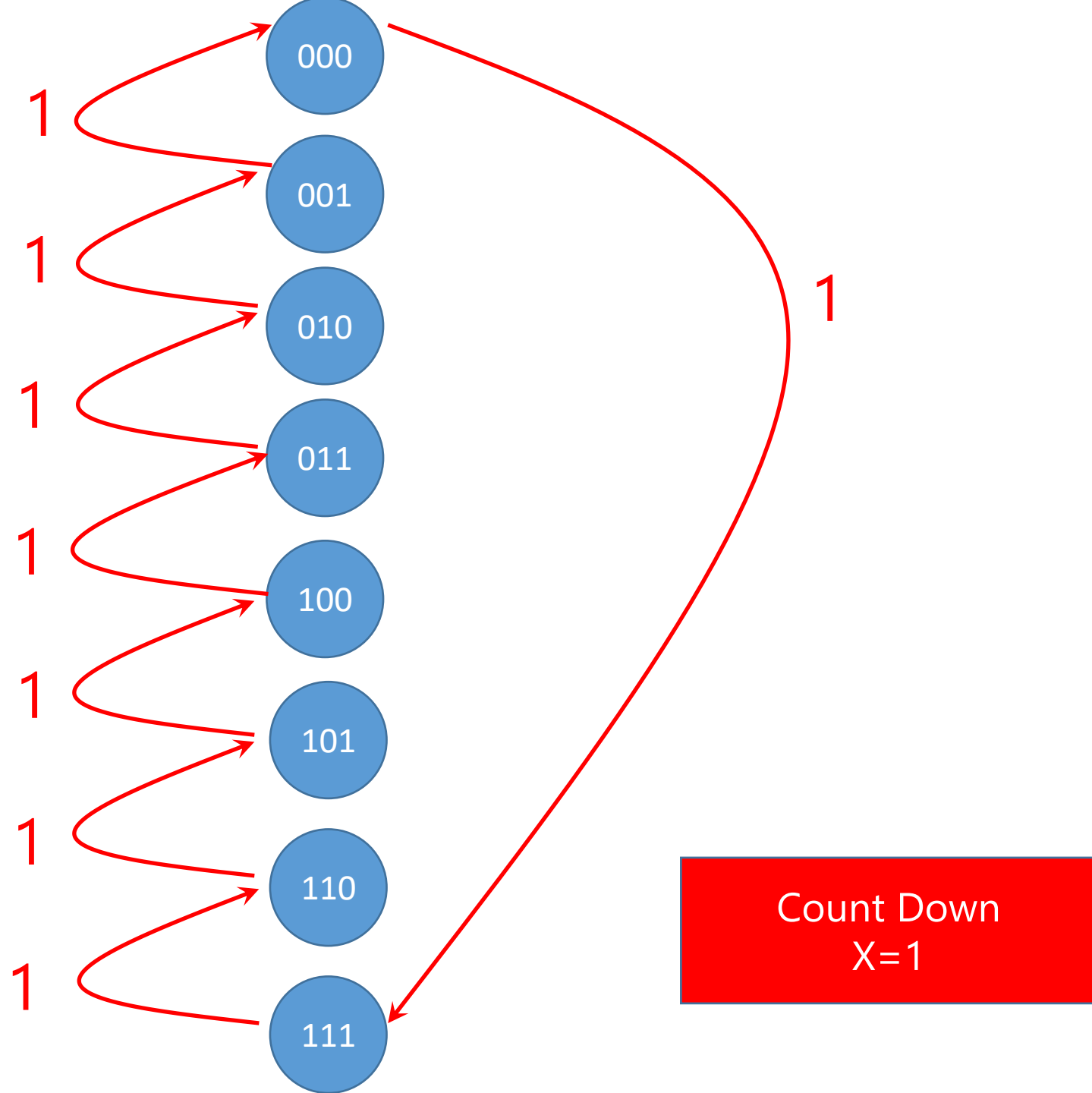
We need to turn on the light when the number is even
→ 1 binary variable → F

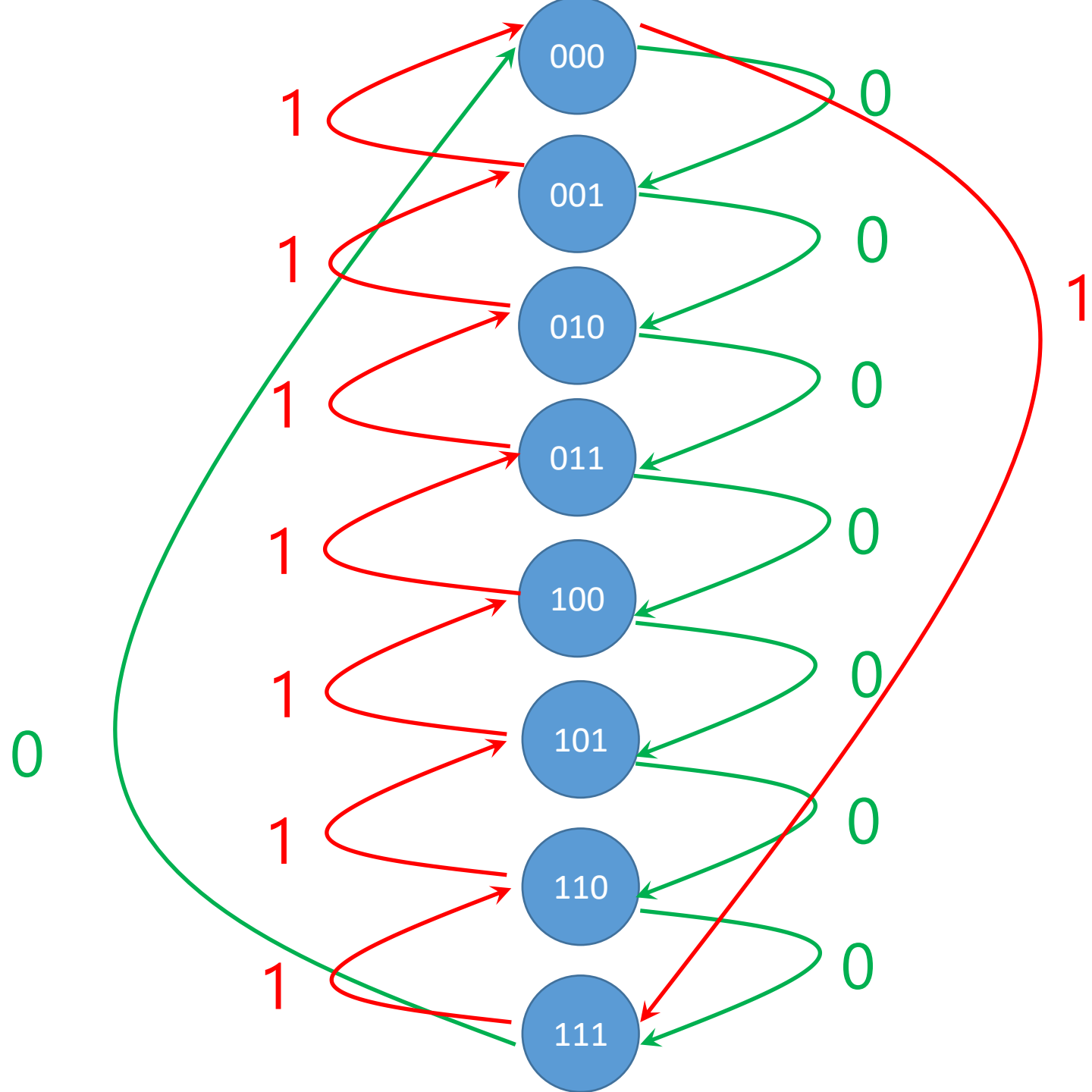
Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
 1. How many storage (flip-flops)? #FF
 2. How many input and output?
 3. Form the state (transition) diagram
-



Count Up
 $X=0$

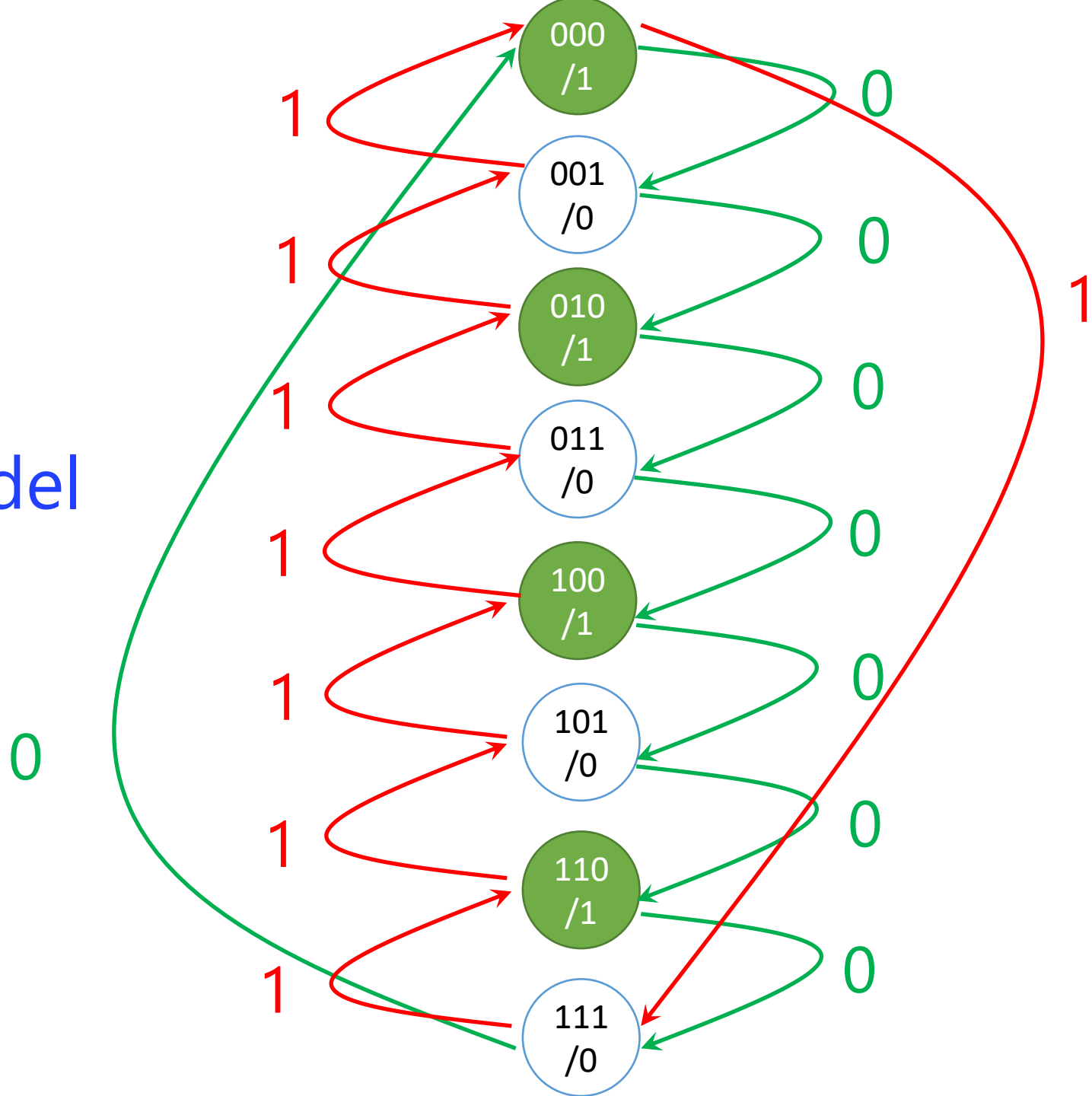




F=1 : even

F=0 : else

Moore model



Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
 1. How many storage (flip-flops)? #FF
 2. How many input and output?
 3. Form the state (transition) diagram
 4. Form the state table
 5. Fill the state table
-

Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	F
0	0	0	0	0	0	1	
0	0	0	1	0	1	0	
0	0	1	0	0	1	1	
0	0	1	1	1	0	0	Count Up X=0
0	1	0	0	1	0	1	
0	1	0	1	1	1	0	
0	1	1	0	1	1	1	
0	1	1	1	0	0	0	
1	0	0	0	1	1	1	
1	0	0	1	0	0	0	
1	0	1	0	0	0	1	
1	0	1	1	0	1	0	Count Down X=1
1	1	0	0	0	1	1	
1	1	0	1	1	0	0	
1	1	1	0	1	0	1	
1	1	1	1	1	1	0	

Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	F
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	0
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	1	1	1	1
0	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1
1	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	0	1	1	1
1	1	0	1	1	0	0	0
1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	0

F depends only on
current state of
CBA

Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	F
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	0
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	1	1	1	1
0	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1
1	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	0	1	1	1
1	1	0	1	1	0	0	0
1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	0

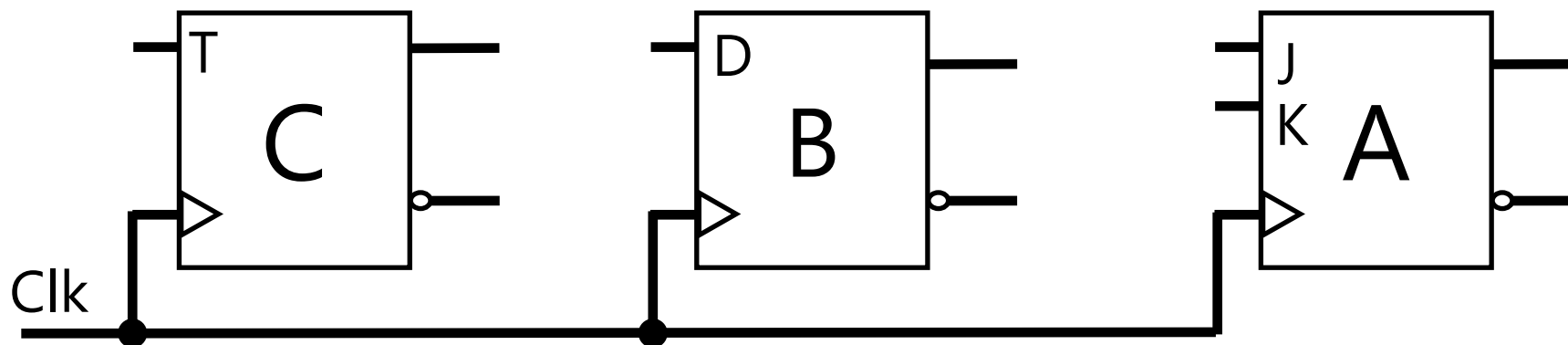
Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
 1. How many storage (flip-flops)? #FF
 2. How many input and output?
 3. Form the state (transition) diagram
 4. Form the state table
 5. Fill the state table
 6. What type of storage (flip-flop)? RS, D, T, JK, or Mixed
-

Counter Up/Down

Let's pick mix FFs: 1×T-FF, 1×D-FF, 1×JK-FF

X —



— F

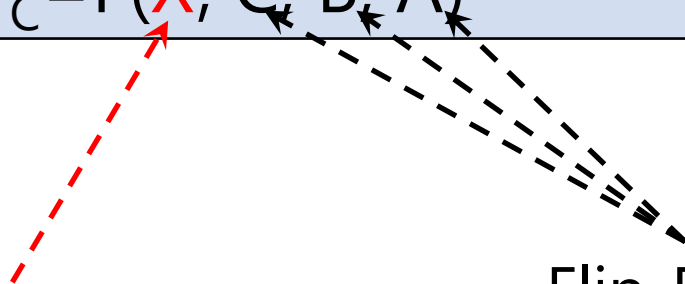
Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
 1. How many storage (flip-flops)? #FF
 2. How many input and output?
 3. Form the state (transition) diagram
 4. Form the state table
 5. Fill the state table
 6. What type of storage (flip-flop)? RS, D, T, JK, or Mixed
 7. Input (*excitation*) equations for each FF
 8. Minimization of input (*excitation*) equations
-

Excitation Equations		
A	$J_A = F(\textcolor{red}{X}, C, B, A)$	$K_A = F(\textcolor{red}{X}, C, B, A)$
B	$D_B = F(\textcolor{red}{X}, C, B, A)$	
C	$T_C = F(\textcolor{red}{X}, C, B, A)$	

Input

Flip-Flops



Excitation Equations

A	$J_A = F(X, C, B, A)$	$K_A = F(X, C, B, A)$
B	$D_B =$	
C	$T_C =$	

Inputs	Q(T)			Q(T+1)			Outputs	Excitation for A			
X	C	B	A		C	B	A	F	Action	J _A	K _A
0	0	0	0		0	0	1	1	Set/Cmp	1	×
0	0	0	1		0	1	0	0	Rst/Cmp	×	1
0	0	1	0		0	1	1	1	Set/Cmp	1	×
0	0	1	1		1	0	0	0	Rst/Cmp	×	1
0	1	0	0		1	0	1	1	Set/Cmp	1	×
0	1	0	1		1	1	0	0	Rst/Cmp	×	1
0	1	1	0		1	1	1	1	Set/Cmp	1	×
0	1	1	1		0	0	0	0	Rst/Cmp	×	1
1	0	0	0		1	1	1	1	Set/Cmp	1	×
1	0	0	1		0	0	0	0	Rst/Cmp	×	1
1	0	1	0		0	0	1	1	Set/Cmp	1	×
1	0	1	1		0	1	0	0	Rst/Cmp	×	1
1	1	0	0		0	1	1	1	Set/Cmp	1	×
1	1	0	1		1	0	0	0	Rst/Cmp	×	1
1	1	1	0		1	0	1	1	Set/Cmp	1	×
1	1	1	1		1	1	0	0	Rst/Cmp	×	1

Excitation Equations

A	$J_A = \sum(0,2,4,6,8,10,12,14) + d(1,3,5,7,9,11,13,15)$	$K_A = \sum(1,3,5,7,9,11,13,15) + d(0,2,4,6,8,10,12,14)$
B	$D_B =$	
C	$T_C =$	

Inputs	Q(T)				Q(T+1)			Outputs	Excitation for B		
X	C	B	A		C	B		A	F	Action	D _B
0	0	0	0		0	0		1	1	Rst	0
0	0	0	1		0	1		0	0	Set	1
0	0	1	0		0	1		1	1	Set	1
0	0	1	1		1	0		0	0	Rst	0
0	1	0	0		1	0		1	1	Rst	0
0	1	0	1		1	1		0	0	Set	1
0	1	1	0		1	1		1	1	Set	1
0	1	1	1		0	0		0	0	Rst	0
1	0	0	0		1	1		1	1	Set	1
1	0	0	1		0	0		0	0	Rst	0
1	0	1	0		0	0		1	1	Rst	0
1	0	1	1		0	1		0	0	Set	1
1	1	0	0		0	1		1	1	Set	1
1	1	0	1		1	0		0	0	Rst	0
1	1	1	0		1	0		1	1	Rst	0
1	1	1	1		1	1		0	0	Set	1

Excitation Equations

A	$J_A = \sum(0,2,4,6,8,10,12,14) + d(1,3,5,7,9,11,13,15)$	$K_A = \sum(1,3,5,7,9,11,13,15) + d(0,2,4,6,8,10,12,14)$
B	$D_B = \sum(1,2,5,6,8,11,12,15)$ <i>Never "don't care condition" happens in D-FF</i>	
C	$T_C =$	

Inputs	Q(T)			Q(T+1)			Outputs	Excitation for C	
X	C	B	A	C	B	A	F	Action	T _c
0	0	0	0	0	0	1	1	Store	0
0	0	0	1	0	1	0	0	Store	0
0	0	1	0	0	1	1	1	Store	0
0	0	1	1	1	0	0	0	Comp	1
0	1	0	0	1	0	1	1	Store	0
0	1	0	1	1	1	0	0	Store	0
0	1	1	0	1	1	1	1	Store	0
0	1	1	1	0	0	0	0	Comp	1
1	0	0	0	1	1	1	1	Comp	1
1	0	0	1	0	0	0	0	Store	0
1	0	1	0	0	0	1	1	Store	0
1	0	1	1	0	1	0	0	Store	0
1	1	0	0	0	1	1	1	Comp	1
1	1	0	1	1	0	0	0	Store	0
1	1	1	0	1	0	1	1	Store	0
1	1	1	1	1	1	0	0	Store	0

Excitation Equations

A	$J_A = \sum(0,2,4,6,8,10,12,14) + d(1,3,5,7,9,11,13,15)$	$K_A = \sum(1,3,5,7,9,11,13,15) + d(0,2,4,6,8,10,12,14)$
B	$D_B = \sum(1,2,5,6,8,11,12,15)$ Never "don't care condition" happens in D-FF	
C	$T_C = \sum(3,7,8,12)$ Never "don't care condition" happens in T-FF	

Minimization for excitation equations

?-Variable K-Map

Excitation Equations		
A	$J_A = \sum(0,2,4,6,8,10,12,14) + d(1,3,5,7,9,11,13,15)$	$K_A = \sum(1,3,5,7,9,11,13,15) + d(0,2,4,6,8,10,12,14)$
B	$D_B = \sum(1,2,5,6,8,11,12,15)$ Never "don't care condition" happens in D-FF	
C	$T_C = \sum(3,7,8,12)$ Never "don't care condition" happens in T-FF	

Minimization
 4-Variable K-Map
 $F(\textcolor{red}{X}, C, B, A)$

		BA			
		00	01	11	10
XC	00	0 m_0	0 m_1	1 m_3	0 m_2
	01	0 m_4	0 m_5	1 m_7	0 m_6
	11	1 m_{12}	0 m_{13}	0 m_{15}	0 m_{14}
	10	1 m_8	0 m_9	0 m_{11}	0 m_{10}

$$T_C = \sum(3, 7, 8, 12) \\ = X'BA + XB'A'$$

		BA			
		00	01	11	10
XC	00	0 m_0	1 m_1	0 m_3	1 m_2
	01	0 m_4	1 m_5	0 m_7	1 m_6
	11	1 m_{12}	0 m_{13}	1 m_{15}	0 m_{14}
	10	1 m_8	0 m_9	1 m_{11}	0 m_{10}

$$D_B = \sum(1, 2, 5, 6, 8, 11, 12, 15) \\ = X'B'A + X'BA' + XB'A' + XBA \\ = X'(B'A + BA') + X(B'A' + BA) \\ = X'(B \oplus A) + X(B \odot A) \\ = X \oplus B \oplus A$$

		BA			
		00	01	11	10
XC	00	1 m_0	X m_1	X m_3	1 m_2
	01	1 m_4	X m_5	X m_7	1 m_6
	11	1 m_{12}	X m_{13}	X m_{15}	1 m_{14}
	10	1 m_8	X m_9	X m_{11}	1 m_{10}

$$J_A = \sum(0, 2, 4, 6, 8, 10, 12, 14) + \\ d(1, 3, 5, 7, 9, 11, 13, 15) = 1$$

		BA			
		00	01	11	10
XC	00	X m_0	1 m_1	1 m_3	X m_2
	01	X m_4	1 m_5	1 m_7	X m_6
	11	X m_{12}	1 m_{13}	1 m_{15}	X m_{14}
	10	X m_8	1 m_9	1 m_{11}	X m_{10}

$$K_A = \sum(1, 3, 5, 7, 9, 11, 13, 15) + \\ d(0, 2, 4, 6, 8, 10, 12, 14) = 1$$

Excitation Equations

A	$J_A = 1$	$K_A = 1$
B	$D_B = F(X, C, B, A) = X \oplus B \oplus A$	
C	$T_C = F(X, C, B, A) = X'BA + XB'A'$	

Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
 1. How many storage (flip-flops)? #FF
 2. How many input and output?
 3. Form the state (transition) diagram
 4. Form the state table
 5. Fill the state table
 6. What type of storage (flip-flop)? RS, D, T, JK, or Mixed
 7. Input (*excitation*) equations for each FF
 8. Minimization of input (*excitation*) equations
 9. Boolean function for the output
 10. Minimization of output variable
-

Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	F
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	0
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	1	1	1	1
0	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1
1	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	0	1	1	1
1	1	0	1	1	0	0	0
1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	0

Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	Y
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	0
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	1	1	1	1
0	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1
1	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	0	1	1	1
1	1	0	1	1	0	0	0
1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	0

$$F = F(C,B,A) = \sum(0,2,4,6)$$

Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	Y
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	0
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	0	1	1	1
0	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1
1	0	0	1	0	0	0	0
1	0	1	0	0	0	1	1
1	0	1	1	0	1	0	0
1	1	0	0	0	1	1	1
1	1	0	1	1	0	0	0
1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	0

~~Incorrect but if we make
a mistake that X is
involved:
 $F = F(X, C, B, A) =$
 $\sum(0, 2, 4, 6, 8, 10, 12, 14)$~~

Minimization for output Y

3-Variable K-Map

~~Incorrectly 4-Variable K-Map~~

		BA			
		00	01	11	10
C	0	1 m_0	0 m_1	0 m_3	1 m_2
	1	1 m_4	0 m_5	0 m_7	1 m_6

$$F = F(C,B,A) = \sum(0,2,4,6) \\ = A'$$

Even if we consider the input, because Y does not depend on X in the state table, it will disappear in simplification!

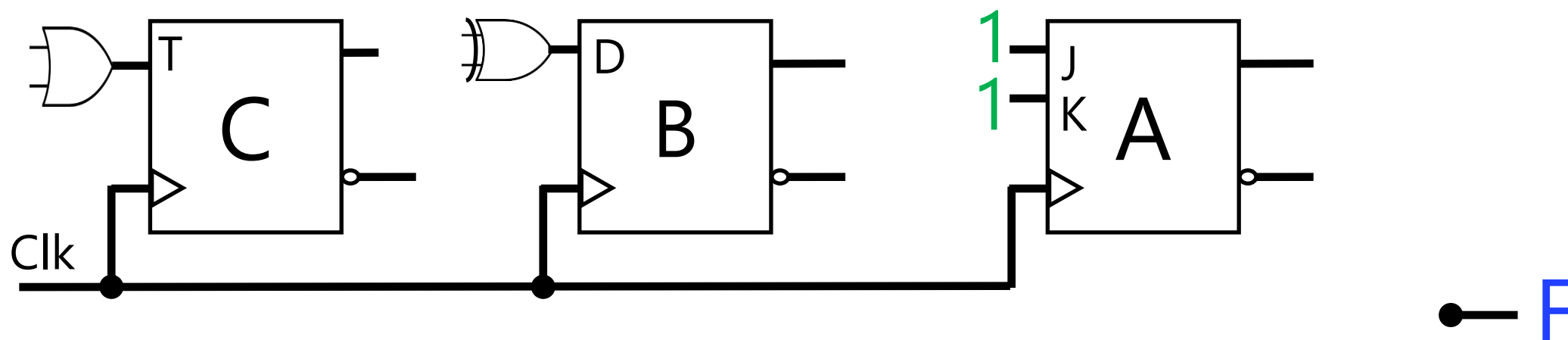
		BA			
		00	01	11	10
XC	00	1 m_0	0 m_1	0 m_3	1 m_2
	01	1 m_4	0 m_5	0 m_7	1 m_6
	11	1 m_{12}	0 m_{13}	0 m_{15}	1 m_{14}
	10	1 m_8	0 m_9	0 m_{11}	1 m_{10}

$$F = F(X,C,B,A) = \sum(0,2,4,6,8,10,12,14) \\ = A'$$

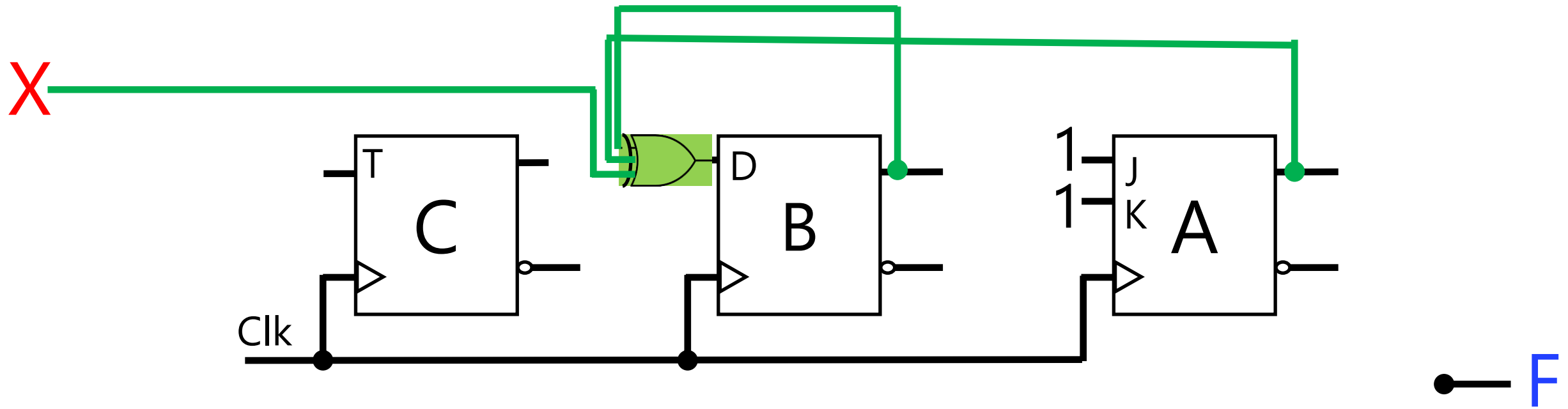
Design (Recap)

0. Do we need combinational logic or sequential logic? Do we need memory?
 1. How many storage (flip-flops)? #FF
 2. How many input and output?
 3. Form the state (transition) diagram
 4. Form the state table
 5. Fill the state table
 6. What type of storage (flip-flop)? RS, D, T, JK, or Mixed
 7. Input (*excitation*) equations for each FF
 8. Minimization of input (*excitation*) equations
 9. Boolean function for the output
 10. Minimization of output variable
 11. Draw/Sketch Logic Circuit
 12. (Optional) Test
-

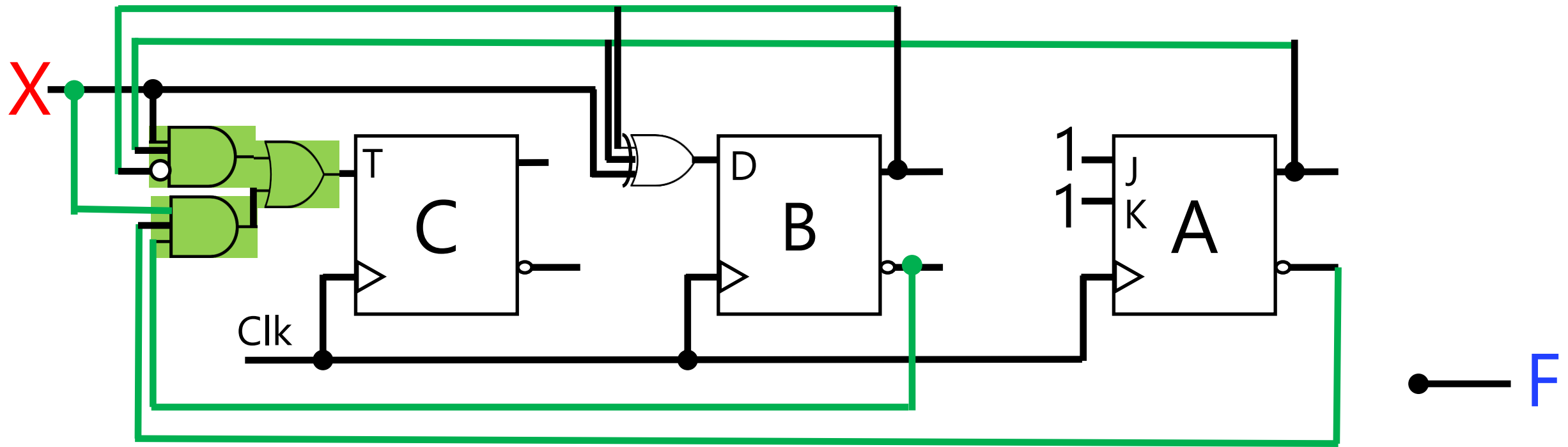
X —



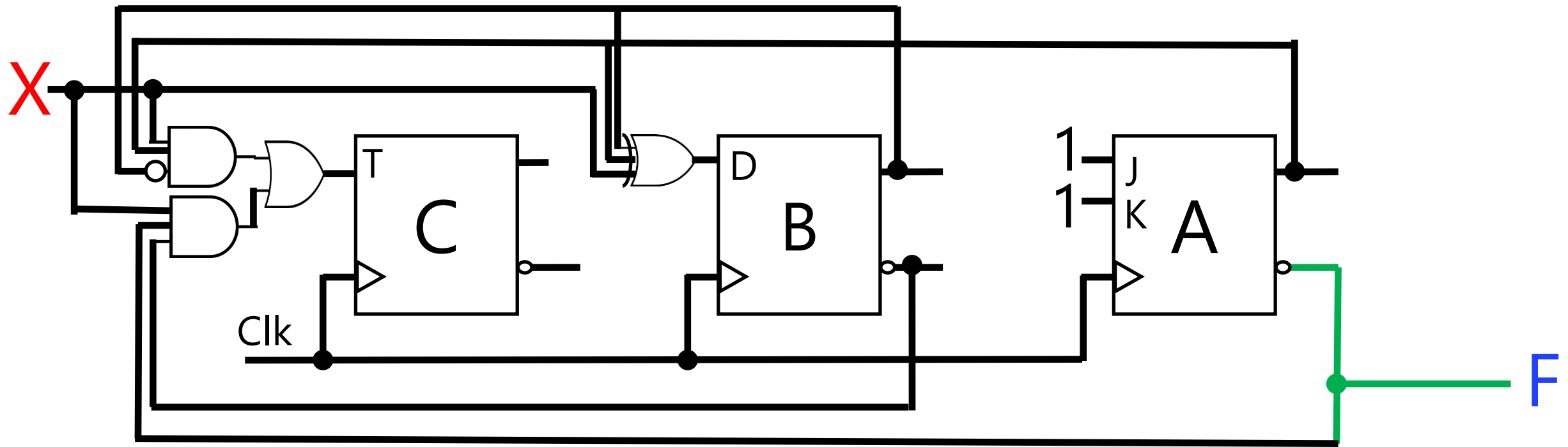
A	$J_A = 1$	$K_A = 1$
B	$D_B = F(X, C, B, A) = X \oplus B \oplus A$	
C	$T_C = F(X, C, B, A) = X'BA + XB'A'$	
F	$F(C, B, A) = A'$	



A	$J_A = 1$	$K_A = 1$
B	$D_B = F(X, C, B, A) = X \oplus B \oplus A$	
C	$T_C = F(X, C, B, A) = X'BA + XB'A'$	
F	$F(C, B, A) = A'$	



A	$J_A = 1$	$K_A = 1$
B	$D_B = F(X, C, B, A) = X \oplus B \oplus A$	
C	$T_C = F(X, C, B, A) = X'BA + XB'A'$	
F	$F(C, B, A) = A'$	



A	$J_A = 1$	$K_A = 1$
B	$D_B = F(X, C, B, A) = X \oplus B \oplus A$	
C	$T_C = F(X, C, B, A) = X'BA + XB'A'$	
F	$F(C, B, A) = A'$	

Synchronization

Practice Timing Diagram

Counter Up-Down

Example Mealy Model

Counting up and number is even

Counting up and number is odd

Counting down and number is odd

Counting down and number is even

Counter Up-Down

$X=0$: Count up from i to $i+1$

$X=1$: Count down from N_i to $i-1$

$F = 1$ when counting up ($X=0$) and number is even

$F = 0$ when counting up ($X=0$) and number is odd

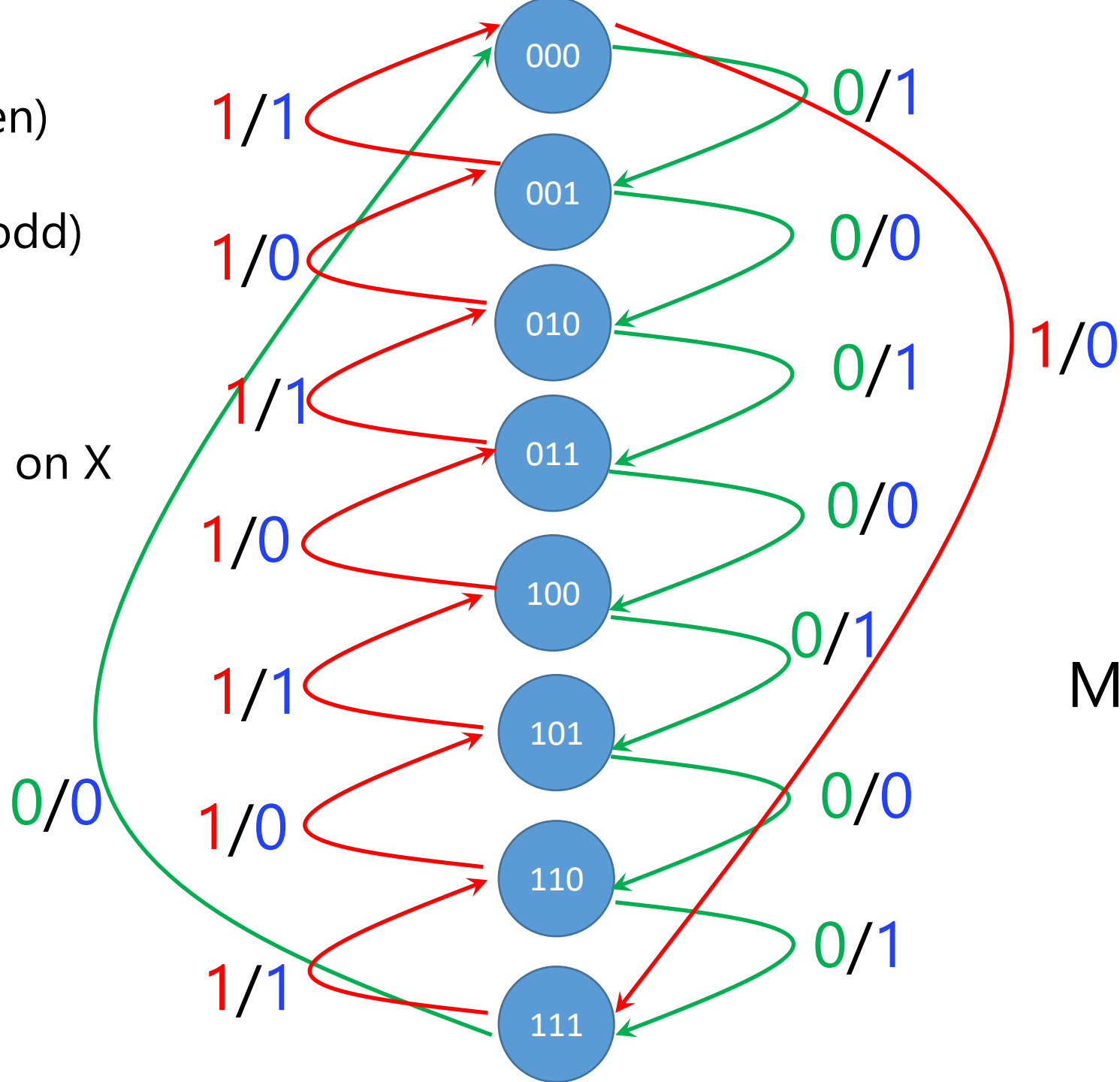
$F = 1$ when counting down ($X=1$) and number is odd

$F = 0$ when counting down ($X=1$) and number is even

$F=1$: (up AND even)
OR
(down AND odd)

$F=0$: else

Y clearly depends on X



Mealy Model

X/F



Inputs	Q(T)			Q(T+1)			Outputs
X	C	B	A	C	B	A	F
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	1	1
0	0	1	1	1	0	0	0
0	1	0	0	1	0	1	1
0	1	0	1	1	1	0	0
0	1	1	0	1	1	1	1
0	1	1	1	0	0	0	0
1	0	0	0	0	0	1	0
1	0	0	1	0	0	0	1
1	0	1	0	0	0	1	0
1	0	1	1	0	1	0	1
1	1	0	0	0	1	1	0
1	1	0	1	1	0	0	1
1	1	1	0	1	0	1	0
1	1	1	1	1	1	0	1

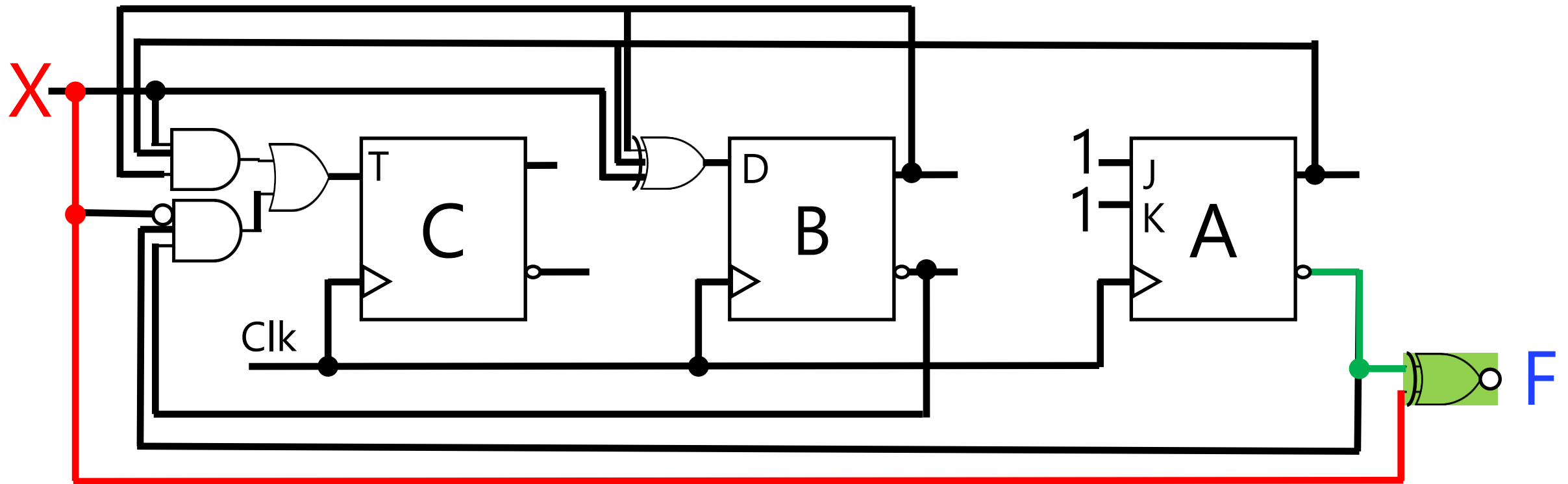
$$Y = F(\underline{X}, C, B, A) = \sum(0,2,4,6,9,11,13,15)$$

Minimization for output F

4-Variable K-Map

		BA			
		00	01	11	10
XC	00	1 m_0	0 m_1	0 m_3	1 m_2
	01	1 m_4	0 m_5	0 m_7	1 m_6
	11	0 m_{12}	1 m_{13}	1 m_{15}	0 m_{14}
	10	0 m_8	1 m_9	1 m_{11}	0 m_{10}

$$\begin{aligned}
 F &= F(\underline{X}, C, B, A) = \sum(0, 2, 4, 6, 9, 11, 13, 15) \\
 &= X'A' + XA \\
 &= X \odot A
 \end{aligned}$$



A	$J_A = 1$	$K_A = 1$
B	$D_B = F(X, C, B, A) = X \oplus B \oplus A$	
C	$T_C = F(X, C, B, A) = X'BA + XB'A'$	
F	$F(C, B, A) = X \odot A$	

Asynchronization

Practice Timing Diagram
