Analysis of Flip Flop Circuits

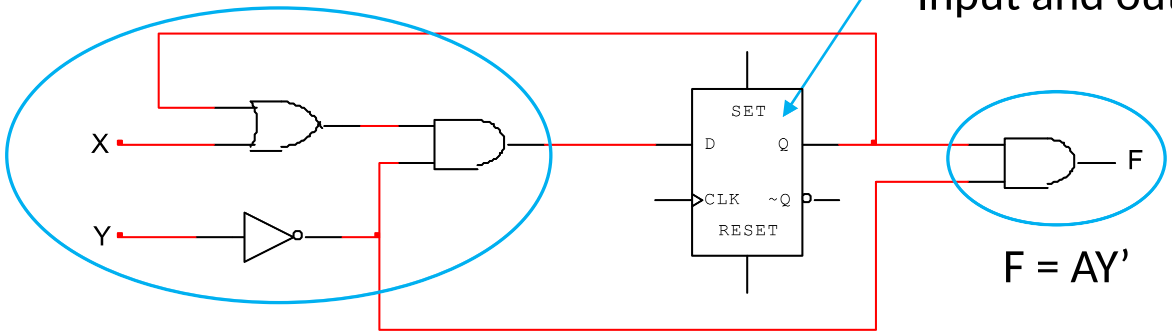
Analysis of Sequential Logic Circuits

* State equations are similar to Boolean expressions from combinational logic
  * Describe the output and transition logic of circuit
* State table is similar to a truth table
  * Describes state transition and output given combination of inputs
* State diagrams are visual representations of the state table

Circuit to State Equation

* State equation is the Boolean expression for circuit
* Will have multiple equations
  - One for output of circuit (F)
  - One to describe, state, or input to flip flops

* Each flip flop is designated A,B,C, ...etc.
* Input and output to flip flop is A

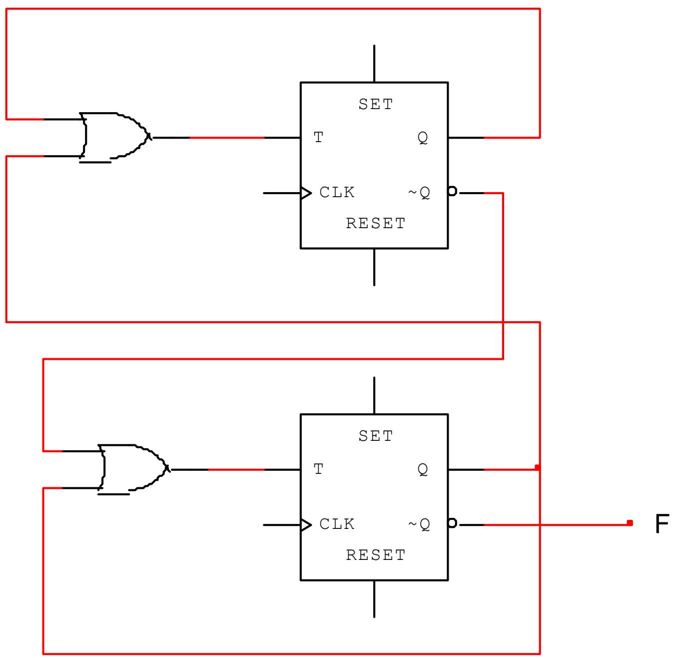


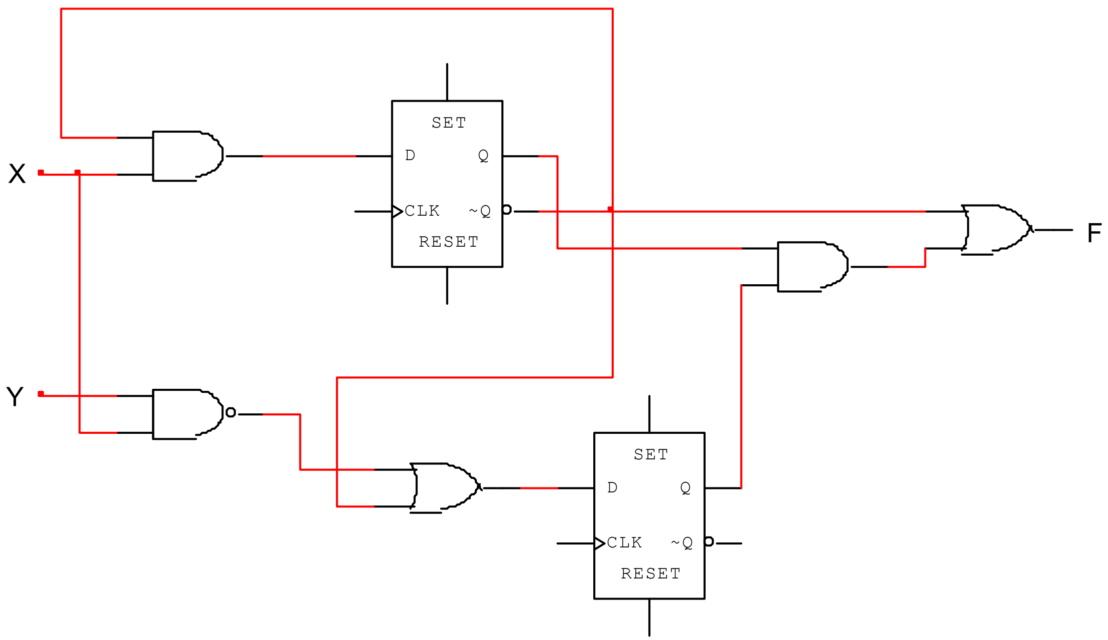
$A = (A + X)Y'$

$F = AY'$

Example

What are the state equations for following circuits?





State Table

* Similar to a truth table, it describes all the possible outputs given input combinations
  * Inputs include current output of flip flops (A,B,..etc.) and input of circuit (X,Y,..etc.)
  * Outputs include next output of flip flops (A,B,..etc.) and output of circuit (F,G,..etc.)

Input to circuit

Flip Flops next output

Flip Flops current output

Output of circuit

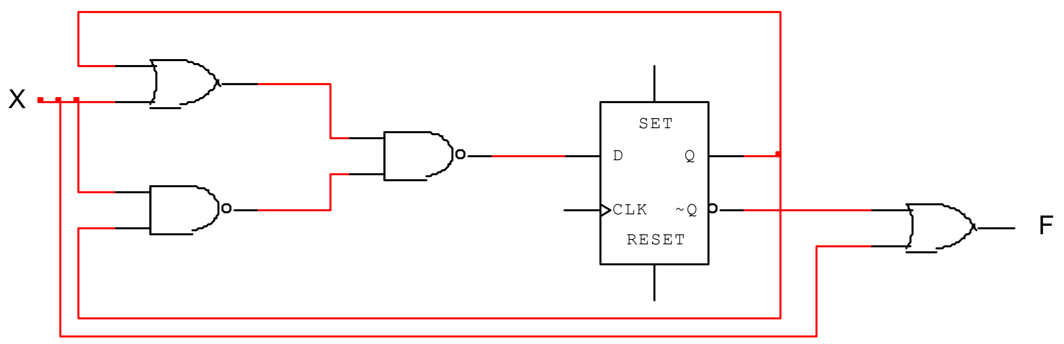
Present State		Input	Next State		Output
A	**B**	**x**	**A**	**B**	**F**
0	0	0	0	0	1
0	0	1	0	1	1
0	1	0	1	1	0
0	1	1	0	0	0
1	0	0	1	0	1
1	0	1	0	1	1
1	1	0	0	1	0
1	1	1	1	1	1

Input to state table

Output of state table

Example

Create a State Table for the following circuit



Present State	Input	Next State	Output
A	X	A	F
0	0		
0	1		
1	0		
1	1		

State Table to K-map

* Each column of a state table output can be simplified with a K - map

Present State		Input	Next State		Output
A	B	x	A	B	F
0	0	0	0	0	1
0	0	1	0	1	1
0	1	0	1	1	0
0	1	1	0	0	0
1	0	0	1	0	1
1	0	1	0	1	1
1	1	0	0	1	0
1	1	1	1	1	1

3 K – maps in total

Example

Use K – Map to draw the logic circuit from the state table

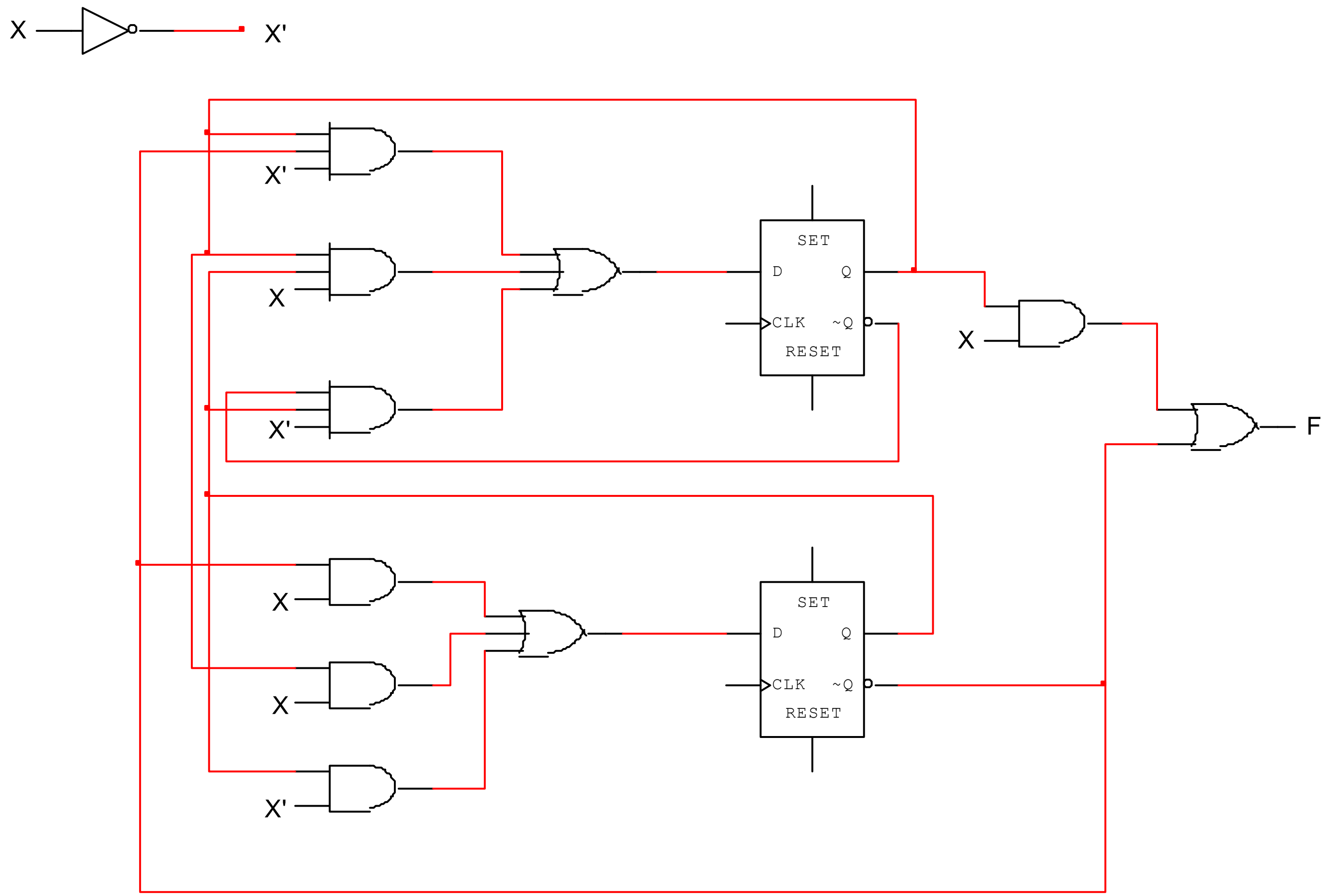
Present State		Input	Next State		Output
A	B	x	A	B	F
0	0	0	0	0	1
0	0	1	0	1	1
0	1	0	1	1	0
0	1	1	0	0	0
1	0	0	1	0	1
1	0	1	0	1	1
1	1	0	0	1	0
1	1	1	1	1	1

	00	01	11	10
0				
1				

	00	01	11	10
0				
1				

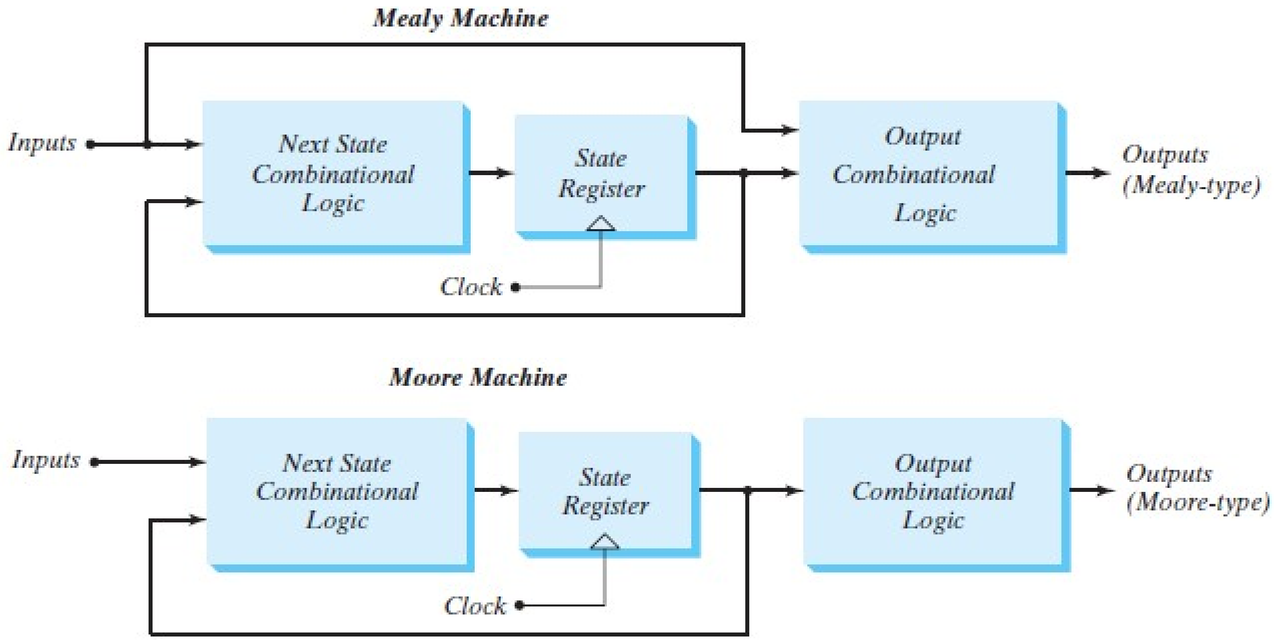
	00	01	11	10
0				
1				

Example

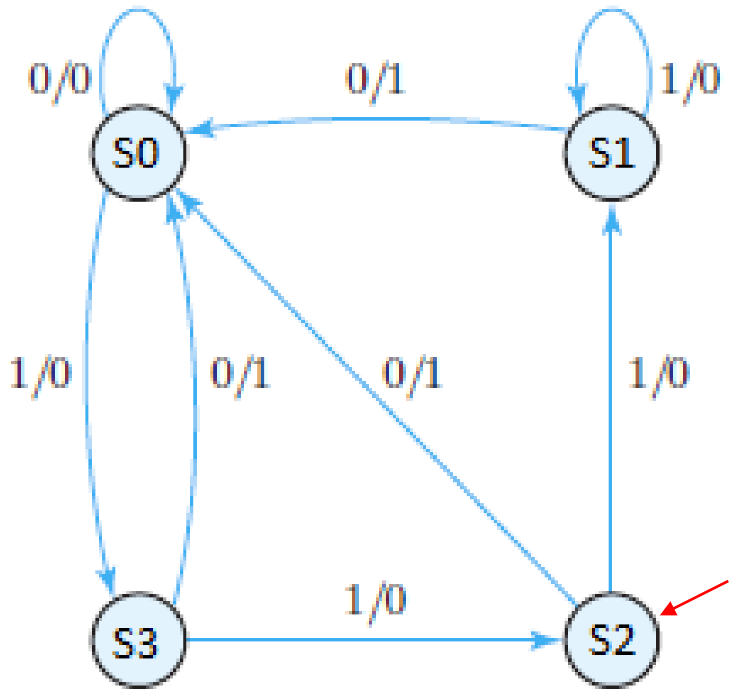


Finite State Machine

* Diagram showing all states, how to transition from state to state, and output at each state
* **Mealy** – Output depends on current state and input. Output changes immediately
* **Moore** – Output only depends on current state. Output changes on next clocking event

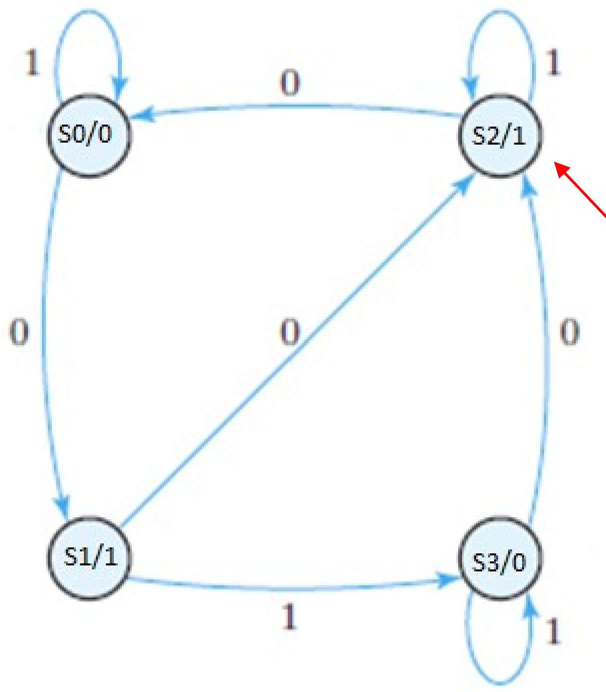


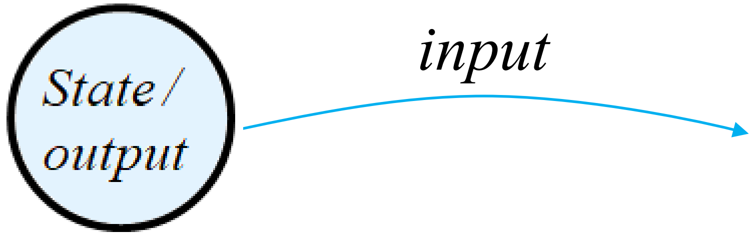
Mealy State Diagram



When in state 2, transition to state 1 if input is 1, output becomes 0.
If input is 0, transition to state 0, output becomes 1.
Get to state 2 from state 3 if input is 1, output becomes 0.

Moore State Diagram

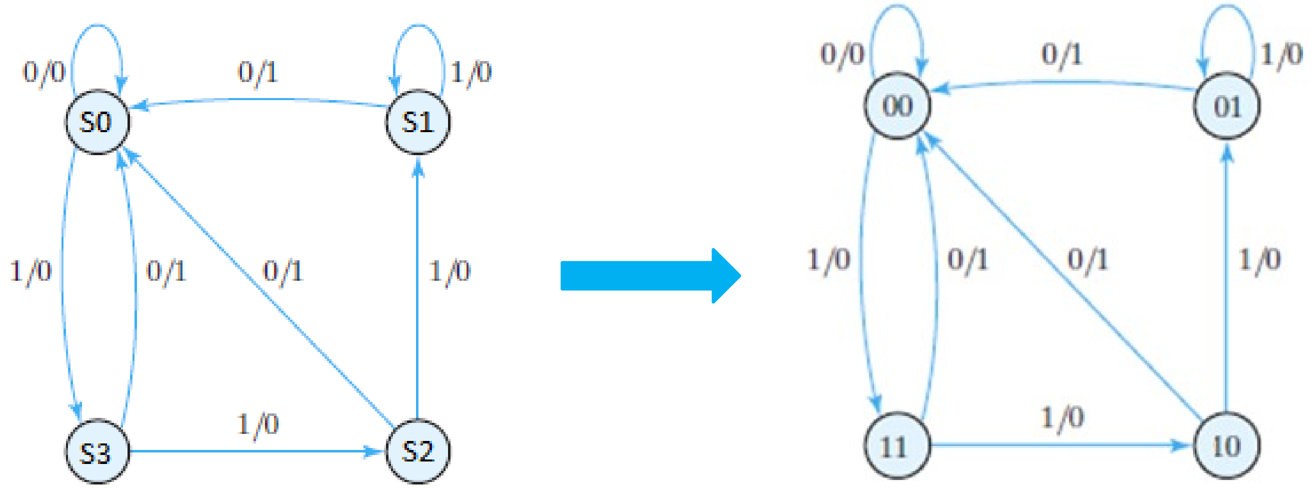




When in state 2, output is 1. Transition to state 0 if input is 0.
Stay in state 2 if input is 1, output is 1.
Get to state 2 from state 1 if input is 0, output is 1.
Get to state 2 from state 3 if input is 0, output is 1.

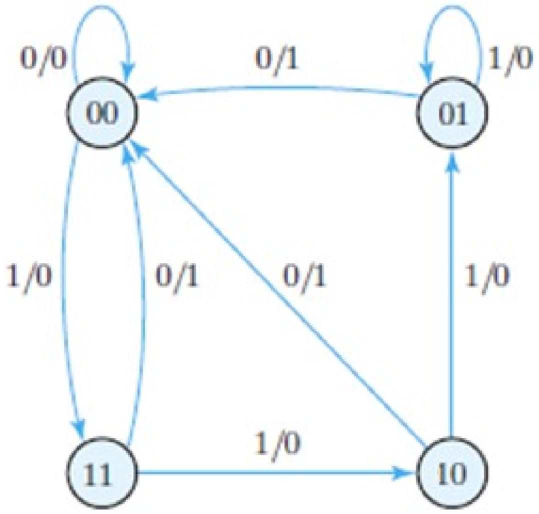
Encode States

* States are encoded as binary values to design state diagram into a logic circuit
* Make each state a binary number
* Previous examples had 4 states, so 2 bits are used to represent each state. Each bit is 1 flip flop
  * S0 -> 00
  * S1 -> 01
  * S2 -> 10
  * S3 -> 11



Creating State Table

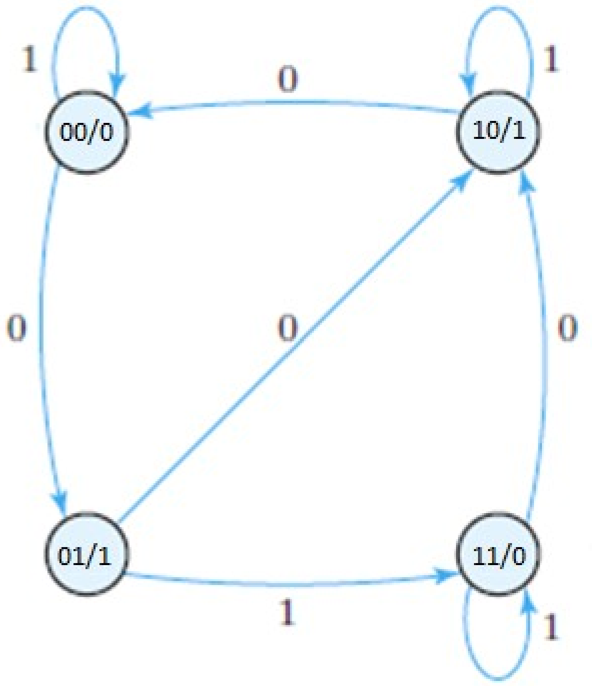
* Use encoded state values and input to create table for next state and output. A and B are a single bit from state encoding.



	Present State		Input	Next State		Output
	A	B	x	A	B	y
S0	0	0	0	0	0	0
	0	0	1	1	1	0
S1	0	1	0	0	0	1
	0	1	1	0	1	0
S2	1	0	0	0	0	1
	1	0	1	0	1	0
S3	1	1	0	0	0	1
	1	1	1	1	0	0

Mealy FSM

Moore State Table



Present State		Input	Next State		Output
A	B	x	A	B	y
0	0	0	0	1	0
0	0	1	0	0	0
0	1	0	1	0	1
0	1	1	1	1	1
1	0	0	0	0	1
1	0	1	1	0	1
1	1	0	1	0	0
1	1	1	1	1	0

Output is dependent on present state

K – Map State Table

Inputs on K-Map

Present State		Input	Next State		Output
A	B	*x*	A	B	*y*
0	0	0	0	0	0
0	0	1	1	1	0
0	1	0	0	0	1
0	1	1	0	1	0
1	0	0	0	0	1
1	0	1	0	1	0
1	1	0	0	0	1
1	1	1	1	0	0

K-Map outputs (each column will need a K-Map)

K - Map

Present state and input from state table

A \ Bx	00	01	11	10
0		1		
1			1	

A

A \ Bx	00	01	11	10
0		1	1	
1		1		

B

Next state from state table

A \ Bx	00	01	11	10
0				1
1	1			1

y

output from state table

K - Map

A \ Bx	00	01	11	10
0		1		
1			1	

A

A \ Bx	00	01	11	10
0		1	1	
1		1		

B

A \ Bx	00	01	11	10
0				1
1	1			1

y

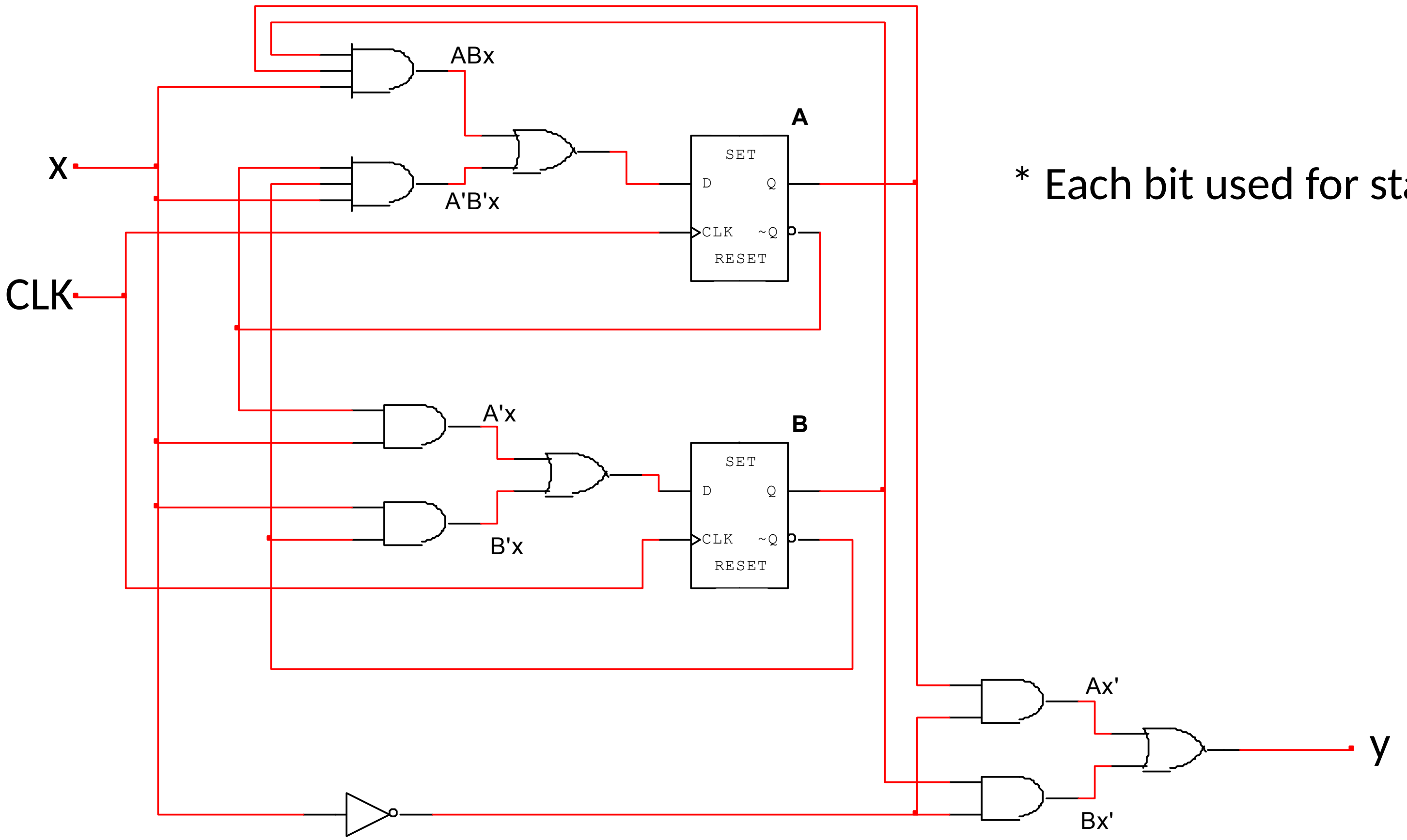
A = A’B’x + ABx

B = B’x + A’x

y = Bx’ + Ax’

Build Logic Circuit

* A and B are flip flop output and fed back into flip flop input. (Using D Flip Flop in example)



* Each bit used for state encoding is a flip flop

What if State Doesn’t Exist?

* Mark states that don’t exist as “don’t care”, or X on a state table
* Same applies if a transition does not exist as well
* Use the X when creating k-map to try and simplify circuit

Example

* Given the following state diagram create the state table and logic circuit