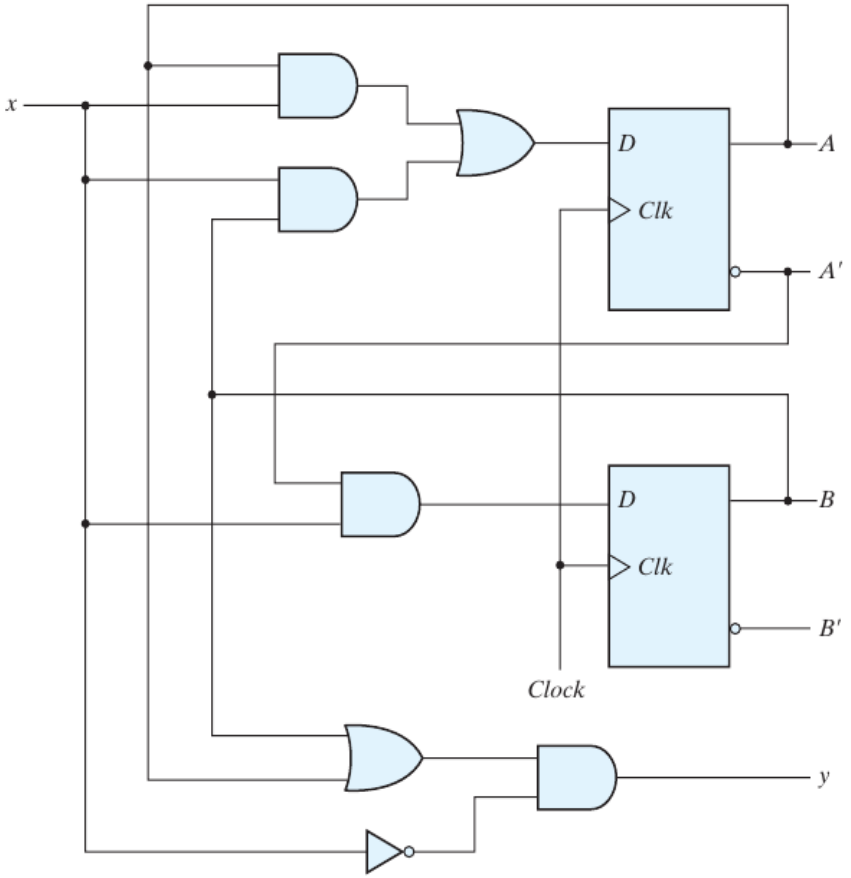
Chap 5
Synchronous Sequential Logic (3)

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Digital Circuit Analysis

- That is, when the circuit is given,
- To analyze it through deriving the state equations, state table and state diagram, etc.



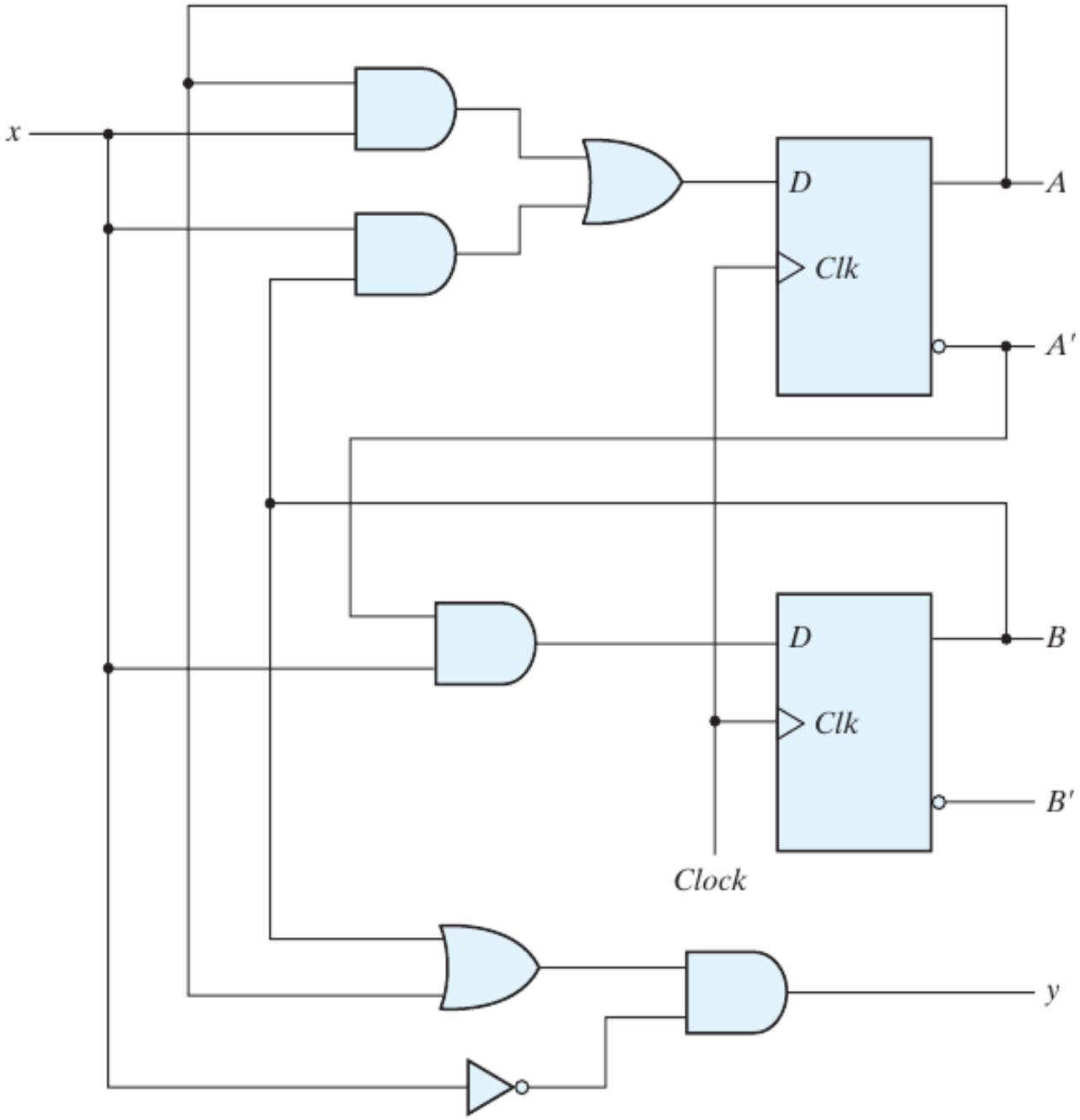
State Equation

$$A(t+1) = A(t)x(t) + B(t)x(t)$$

$$B(t+1) = A'(t)x(t)$$

Output

$$y(t) = [A(t) + B(t)]x'(t)$$



State Table (=Transition Table)

State Equation

$$A(t+1) = A(t)x(t) + B(t)x(t)$$

$$B(t+1) = A'(t)x(t)$$

Output

$$y(t) = [A(t) + B(t)]x'(t)$$

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

Second Term of State Table

- It is sometimes convenient to express the state table as:

State Equation

$$A(t+1) = A(t)x(t) + B(t)x(t)$$

$$B(t+1) = A'(t)x(t)$$

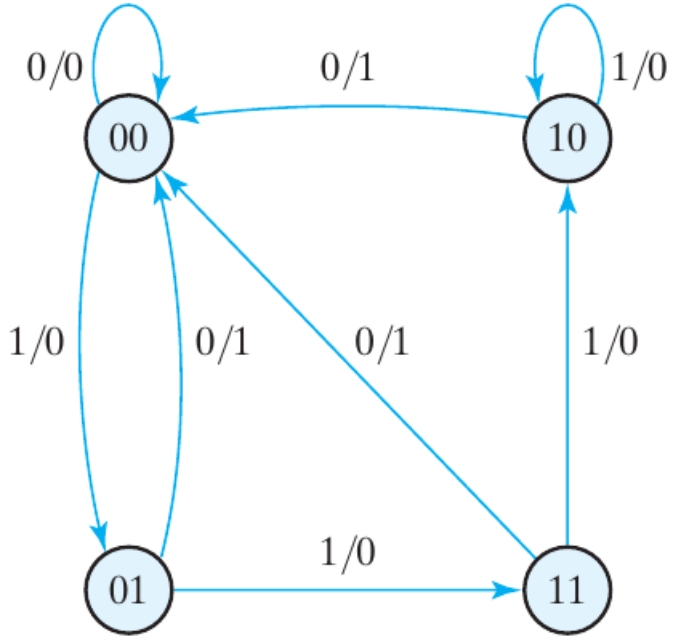
Output

$$y(t) = [A(t) + B(t)]x'(t)$$

Present State		Next State				Output	
		$x = 0$		$x = 1$		$x = 0$	$x = 1$
A	B	A	B	A	B	y	y
0	0	0	0	0	1	0	0
0	1	0	0	1	1	1	0
1	0	0	0	1	0	1	0
1	1	0	0	1	0	1	0

State Diagram

- The state diagram gives a pictorial view of state transitions and is the form more suitable for human interpretation of the circuit's operation .



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

State Diagram from 2nd Term of Table

Present State		Next State				Output	
		$x = 0$		$x = 1$		$x = 0$	$x = 1$
A	B	A	B	A	B	y	y
0	0	0	0	0	1	0	0
0	1	0	0	1	1	1	0
1	0	0	0	1	0	1	0
1	1	0	0	1	0	1	0

Steps For Analyzing

- Circuit diagram → Equations → State table → State diagram

Output Equation & Flip Flop Input Equations

- The logic diagram consists of flip-flops and gates.
- The interconnections among the gates form a combinational circuit and is specified with Boolean expressions.
- The combinational circuit generating outputs is described by a set of Boolean functions: **output equations**
- The circuit generating the inputs to flip-flops is described by a set of Boolean functions: **flip-flop input equations**.

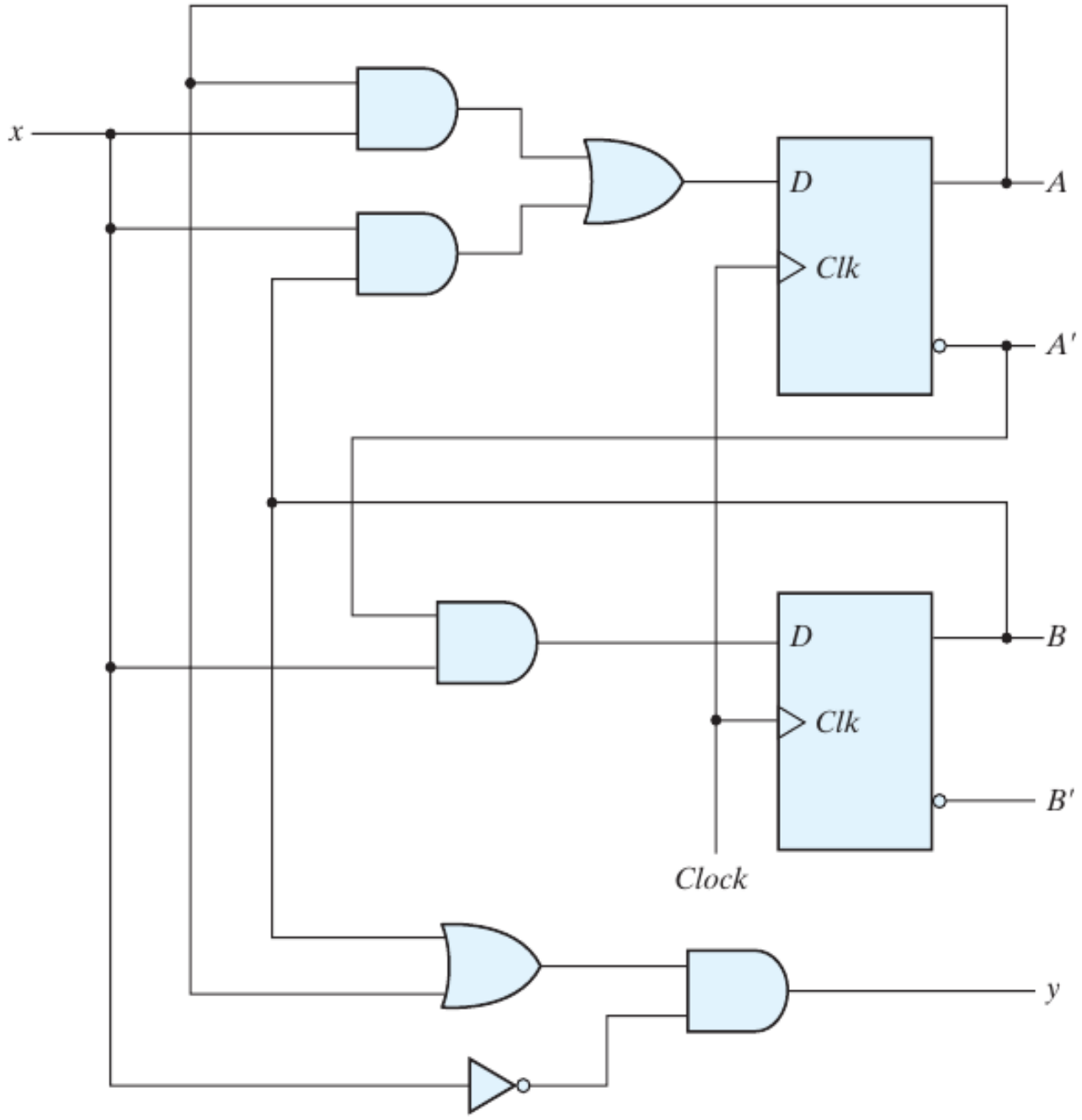
Input equations

$$D_A = Ax + Bx$$

$$D_B = A'x$$

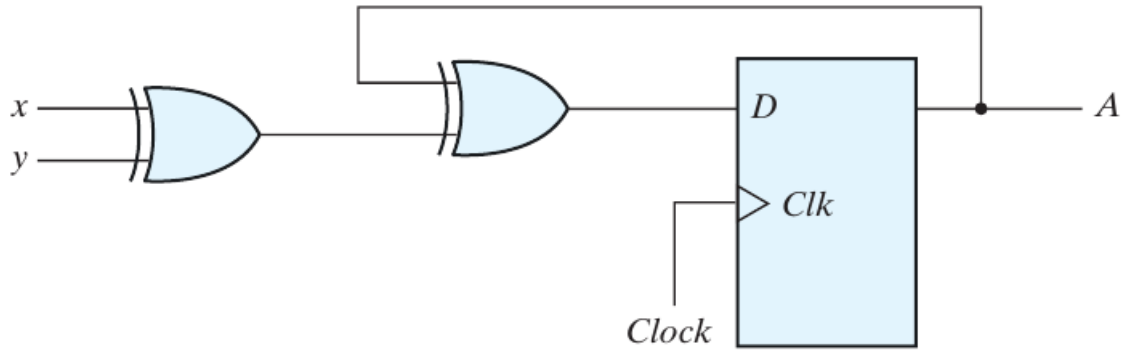
Output equation

$$y = (A + B)x'$$



Circuit Example1

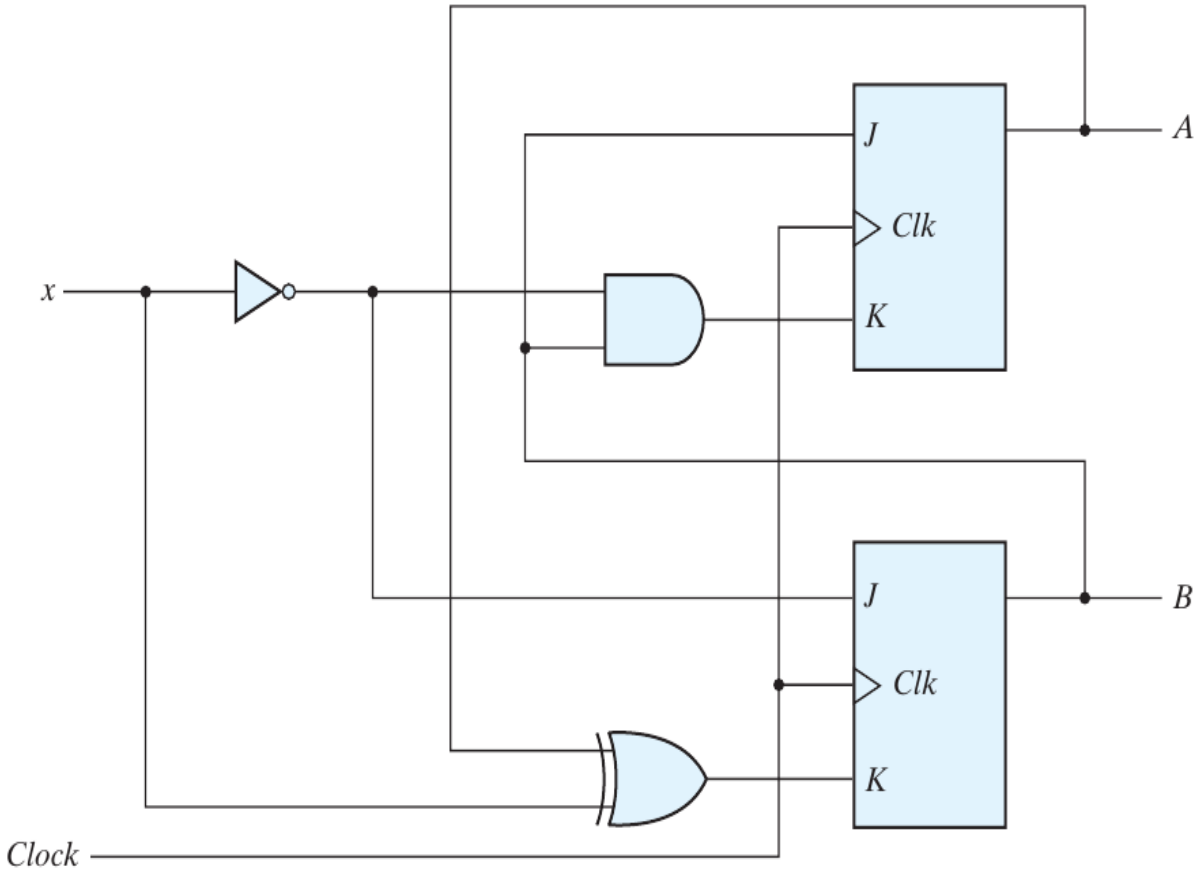
- Input Equation/State Equation/Table/State Diagram



Analysis on the Circuit with JK Flip Flop or T Flip Flop

- For a D -type flip-flop, the state equation is the same as the input equation, but for JK FF or T FF, it is not.
- The next-state values of a sequential circuit that uses JK - or T-type flip-flops can be derived as follows:
  1) Determine the flip-flop input equations in terms of the present state and input variables.
  2) List the binary values of each input equation.
  3) Use the corresponding flip-flop characteristic table to determine the next-state values in the state table.

Input equations?



FF inputs table

Present State		Input	Flip-Flop Inputs			
A	**B**	**x**	J_A	K_A	J_B	K_B
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

State Table

- You can fill the next state according to J, K values of FFs, then complete the state table.

Present State		Input	Next State		Flip-Flop Inputs			
A	*B*	*x*	*A*	*B*	J_A	K_A	J_B	K_B
0	0	0			0	0	1	0
0	0	1			0	0	0	1
0	1	0			1	1	1	0
0	1	1			1	0	0	1
1	0	0			0	0	1	1
1	0	1			0	0	0	0
1	1	0			1	1	1	1
1	1	1			1	0	0	0

You Can Use Characteristic Equation!

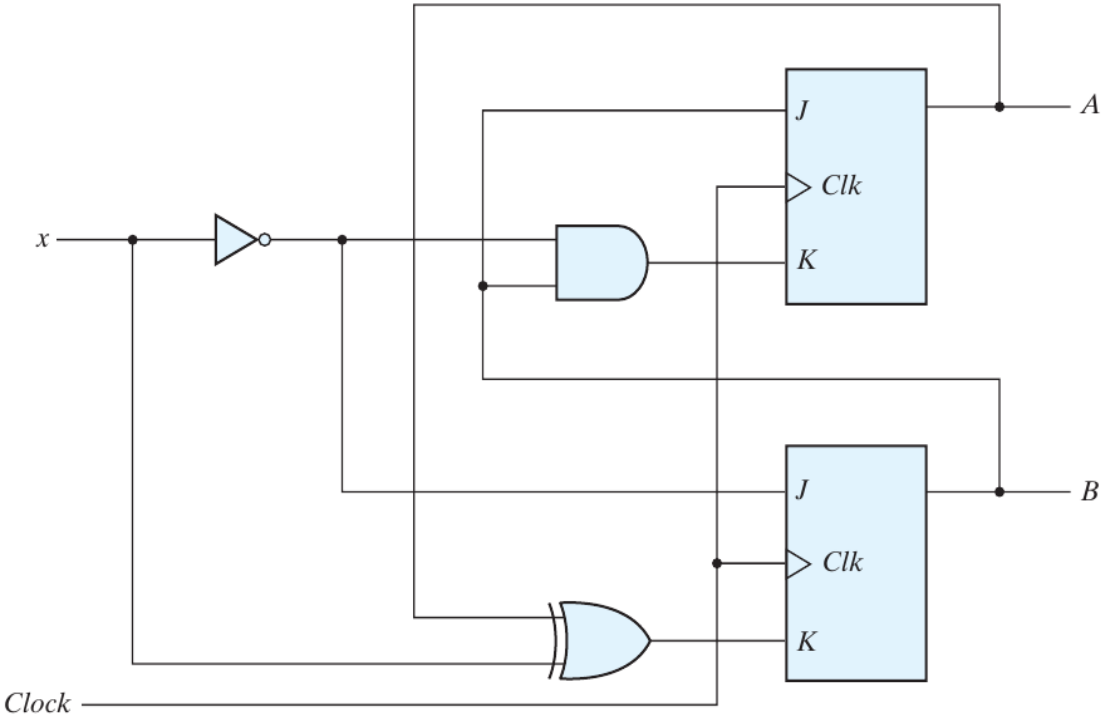
- Characteristic equations of JK FF: $A(t+1) = JA' + K'A$
  $B(t+1) = JB' + K'B$

- You can combine the above with input equations:

$$J_A = B \quad K_A = Bx'$$
$$J_B = x' \quad K_B = A'x + Ax' = A \oplus x$$

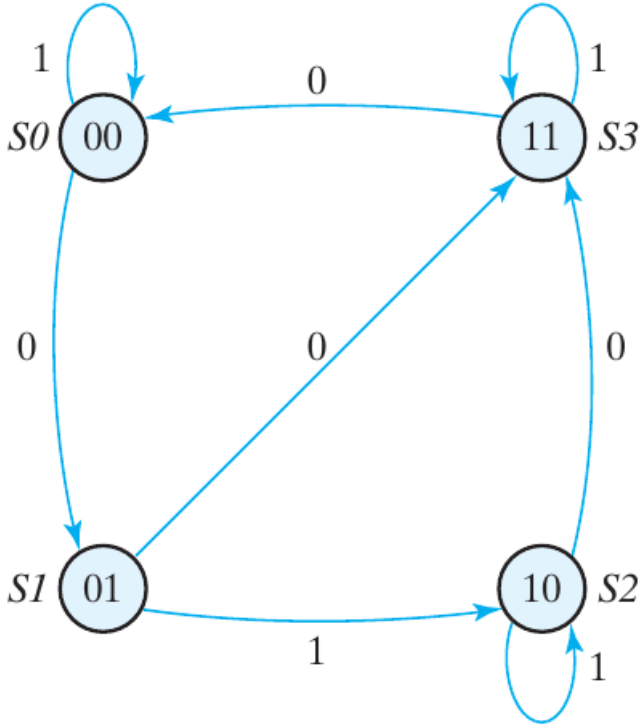
$$A(t+1) = BA' + (Bx')'A$$
$$= A'B + AB' + Ax$$

$$B(t+1) = x'B' + (A \oplus x)'B$$
$$= B'x' + ABx + A'Bx'$$



- Next state can be obtained.

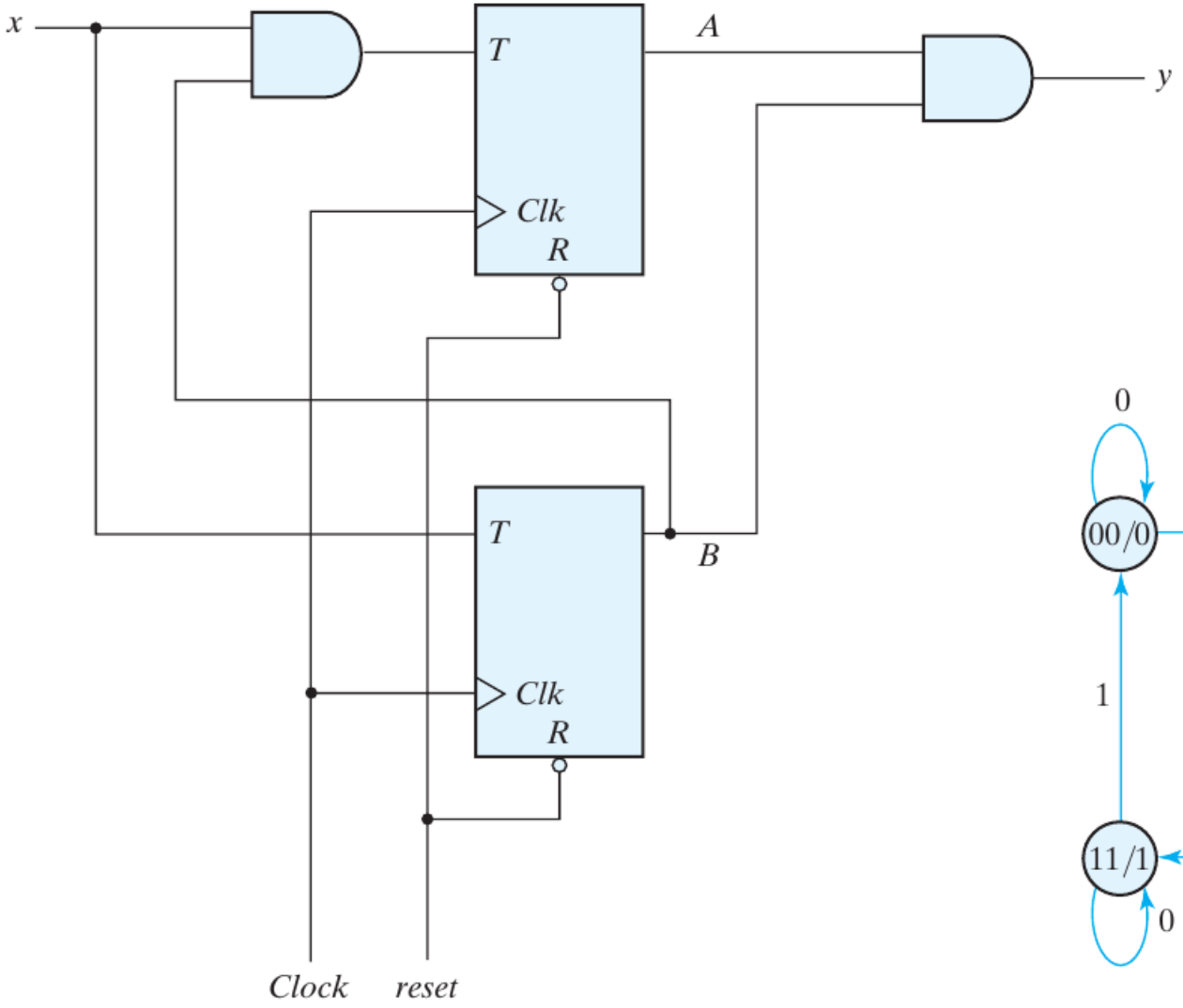
State Diagram

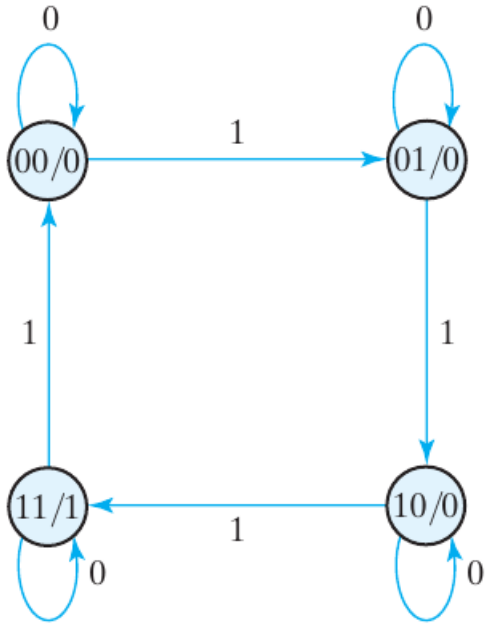


Obtaining Next States for JK-FF or T-FF by Characteristic Equations

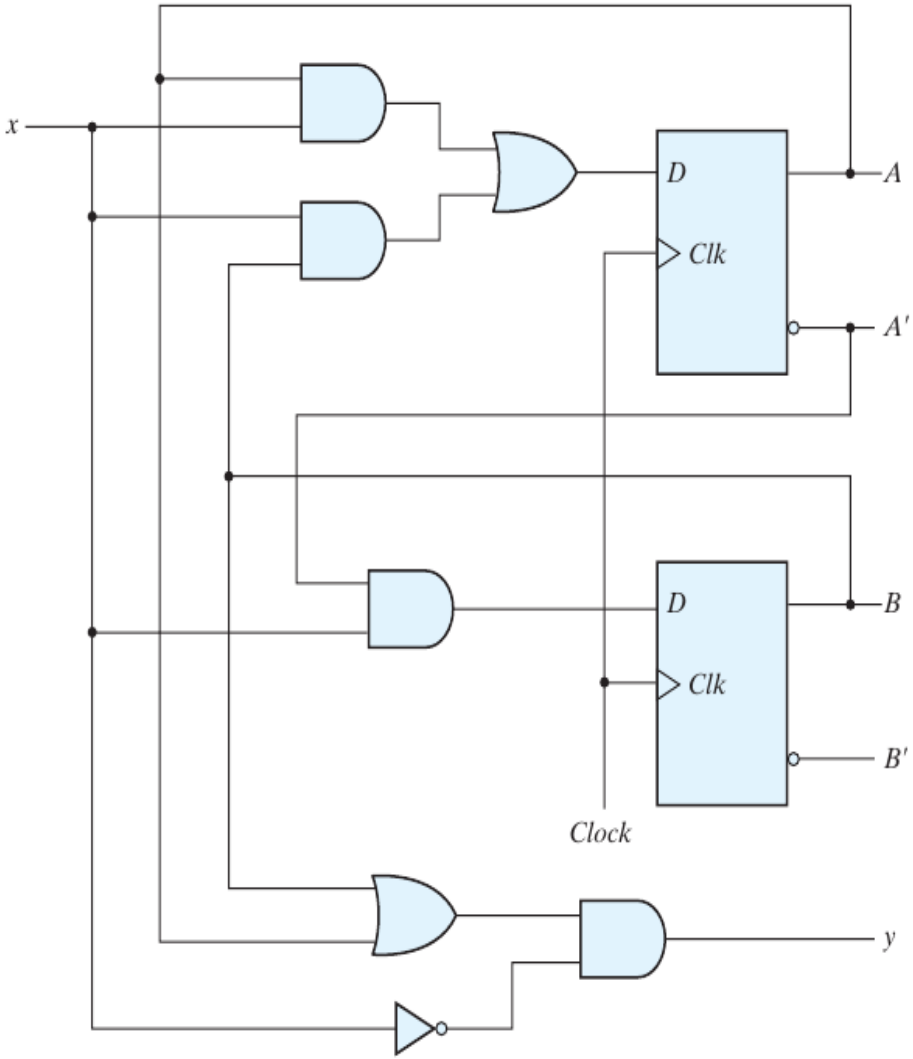
1) Determine the flip-flop input equations in terms of the present state and input variables.
2) Substitute the input equations into the flip-flop characteristic equation to obtain the state equations.
3) Use the corresponding state equations to determine the next-state values in the state table.

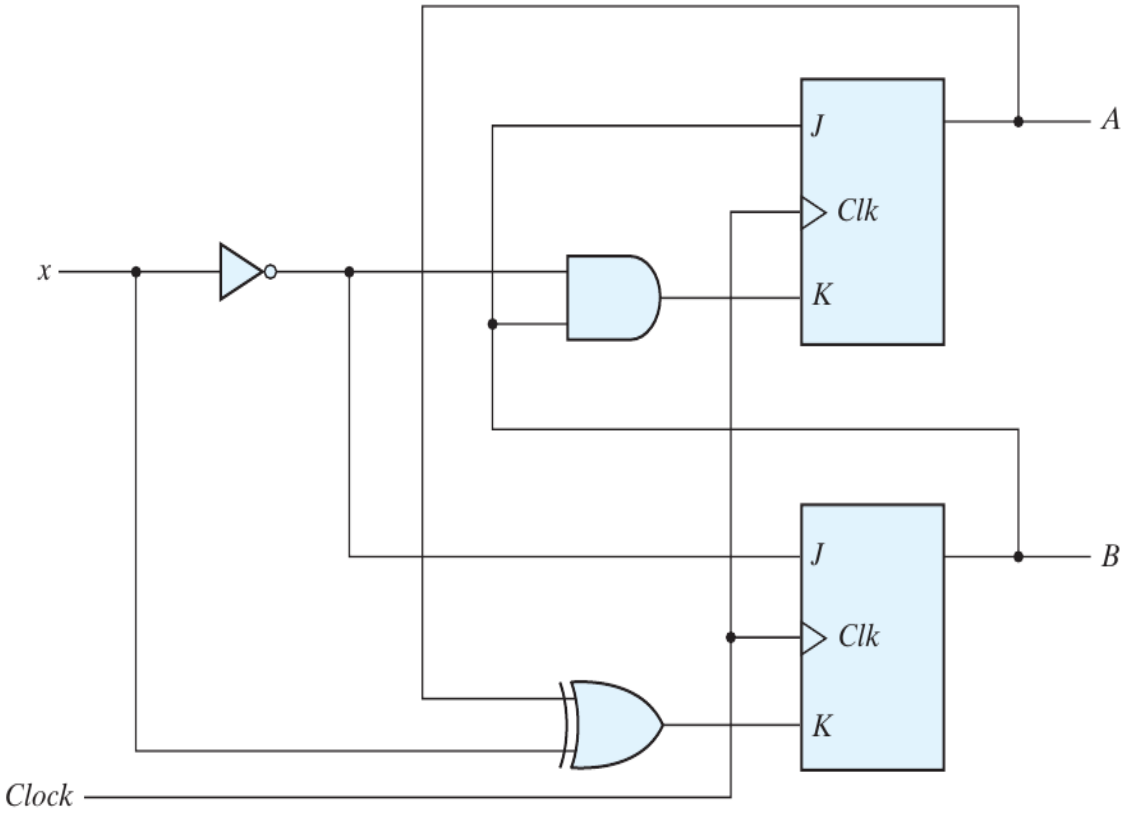
You Can Apply in T-FF Case As Well!





You See Difference?





What We Have Learned

- What we do is so called circuit analysis
- This is nothing but we can determine from the circuit
  - State transition table
  - State diagram
  - FF input equation and table
- So that we can better understand the circuit operation