State Equations/Table/Diagram

Sparsh Mittal

Analysis with *JK* Flip-Flops

For a D -type flip-flop, the state equation is the same as the input equation.

When a flip-flop other than the D type is used, such as JK or T, it is necessary to refer to the corresponding characteristic table or characteristic equation to obtain the next state values.

Procedure for finding next-state values

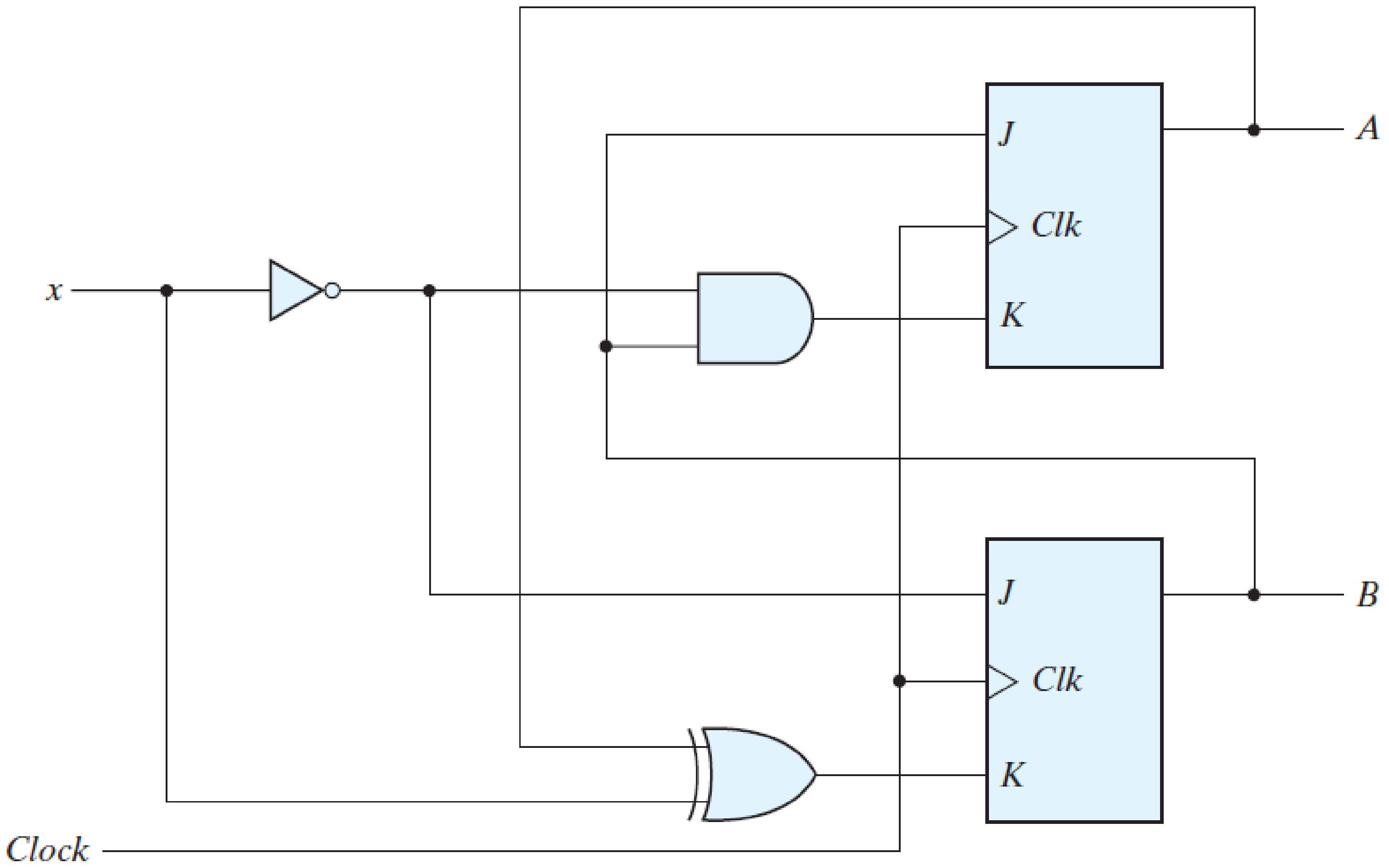
For a sequential circuit that uses JK - or T -type flip-flops

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.

Solved example



Write input flip-flop equations

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

Step1: List all combinations of input & present state

Present State		Input
A	*B*	*x*
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

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

Now, find values of J_A, K_A, J_B and K_B

Step2: Find intermediate values

Table 5.4
State Table for Sequential Circuit with JK Flip-Flops

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					

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

Table 5.1
Flip-Flop Characteristic Tables

JK Flip-Flop

J	K	$Q(t+1)$	
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	$Q'(t)$	Complement

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

Step3: Find next state

Table 5.4
State Table for Sequential Circuit with JK Flip-Flops

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

Table 5.1
Flip-Flop Characteristic Tables

JK Flip-Flop

J	K	Q(t + 1)	
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	$Q'(t)$	Complement

Step3: Find next state

Table 5.4
State Table for Sequential Circuit with JK Flip-Flops

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	1	0	0	1	0
0	0	1	0	0	0	0	0	1
0	1	0	1	1	1	1	1	0
0	1	1	1	0	1	0	0	1
1	0	0	1	1	0	0	1	1
1	0	1	1	0	0	0	0	0
1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	0	0	0

Table 5.1
Flip-Flop Characteristic Tables

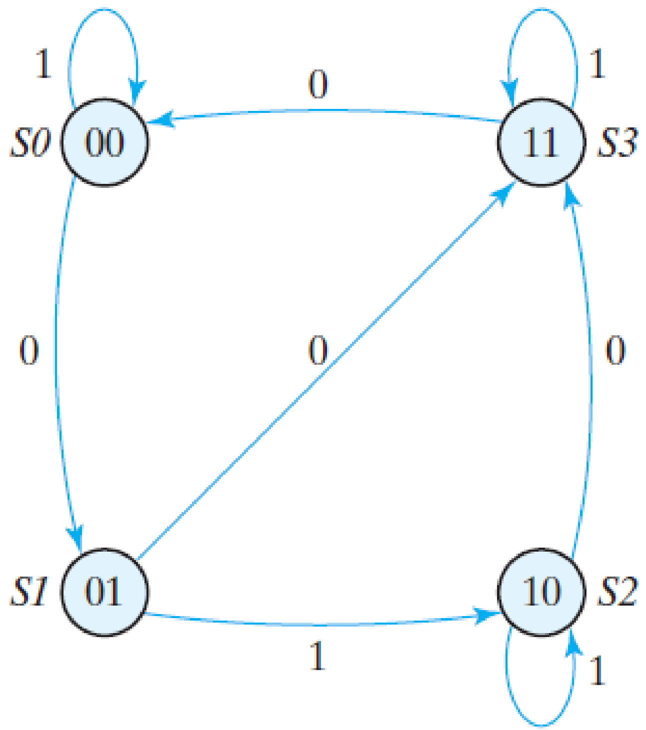
JK Flip-Flop

J	K	$Q(t+1)$	
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	$Q'(t)$	Complement

State diagram

Table 5.4
State Table for Sequential Circuit with JK Flip-Flops

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	1	0	0	1	0
0	0	1	0	0	0	0	0	1
0	1	0	1	1	1	1	1	0
0	1	1	1	0	1	0	0	1
1	0	0	1	1	0	0	1	1
1	0	1	1	0	0	0	0	0
1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	0	0	0



Obtaining next-state from state 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.

State Equation for Solved example

$$A(t+1) = JA' + K'A$$
$$B(t+1) = JB' + K'B$$

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

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

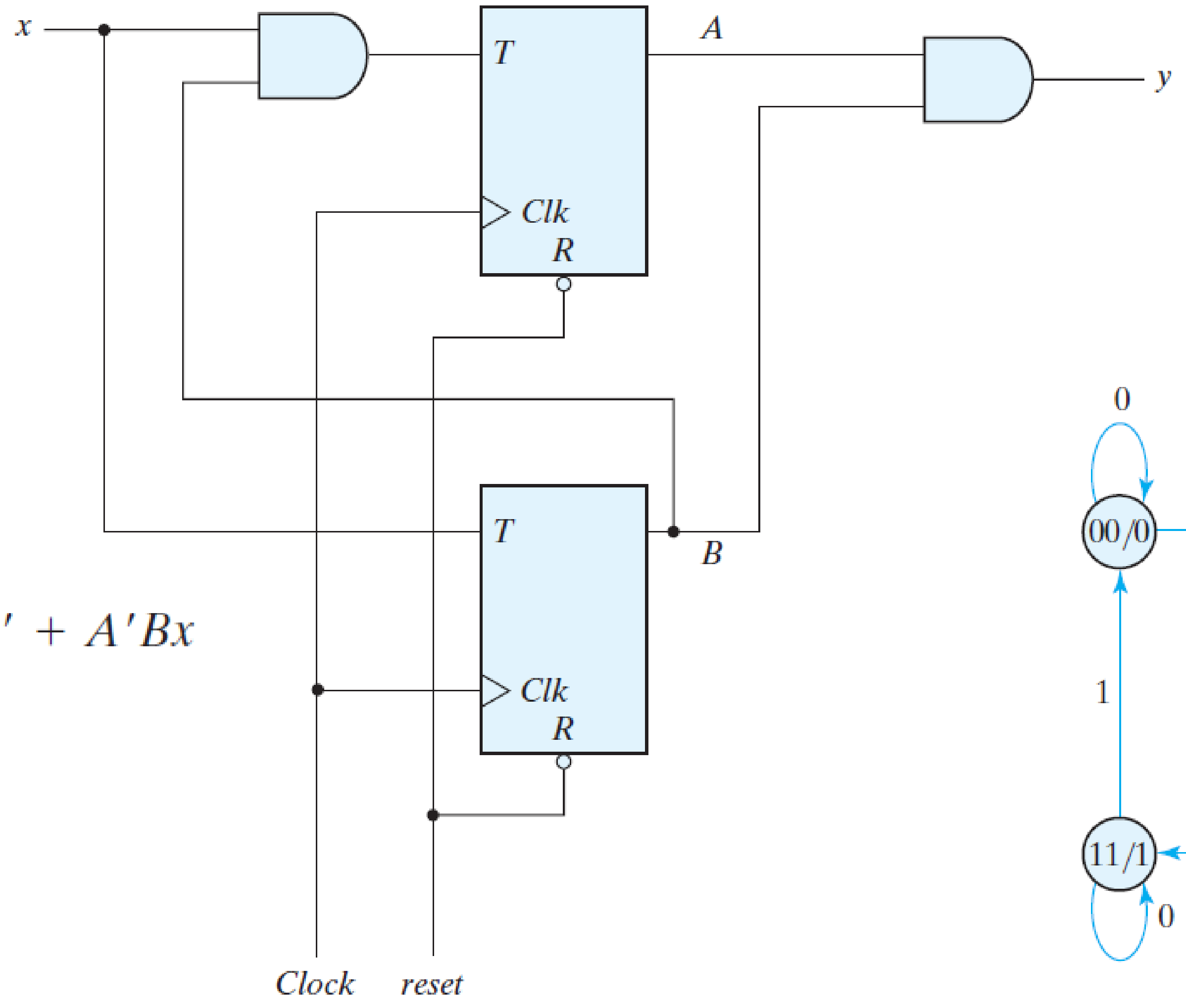
Analysis with T Flip-Flops

$$Q(t+1) = T \oplus Q = T'Q + TQ'$$

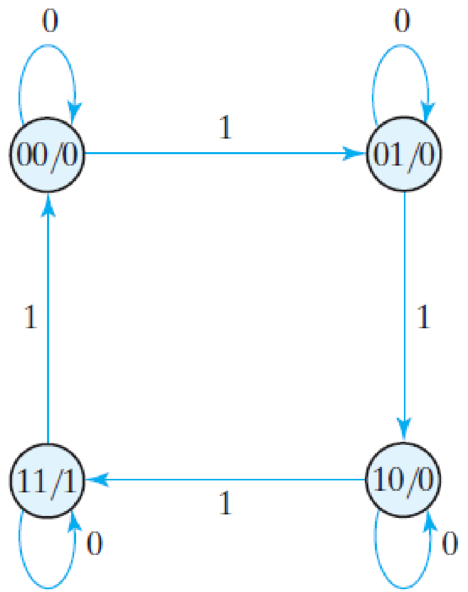
$$T_A = Bx$$
$$T_B = x$$
$$y = AB$$

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

Here, the output depends on the present state only and is independent of the input.



(a) Circuit diagram



(b) State diagram

State Table

Table 5.5
State Table for Sequential Circuit with T Flip-Flops

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	1	0
0	1	1	1	0	0
1	0	0	1	0	0
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	1

As long as input x is equal to 1, the circuit behaves as a binary counter with a sequence of states 00, 01, 10, 11, and back to 00.
When $x = 0$, the circuit remains in the same state.