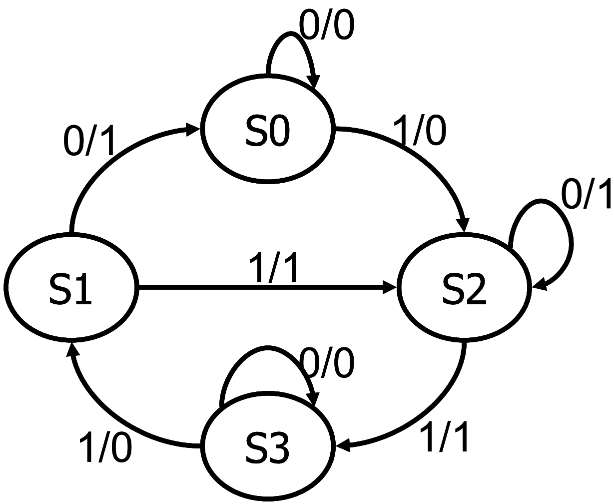
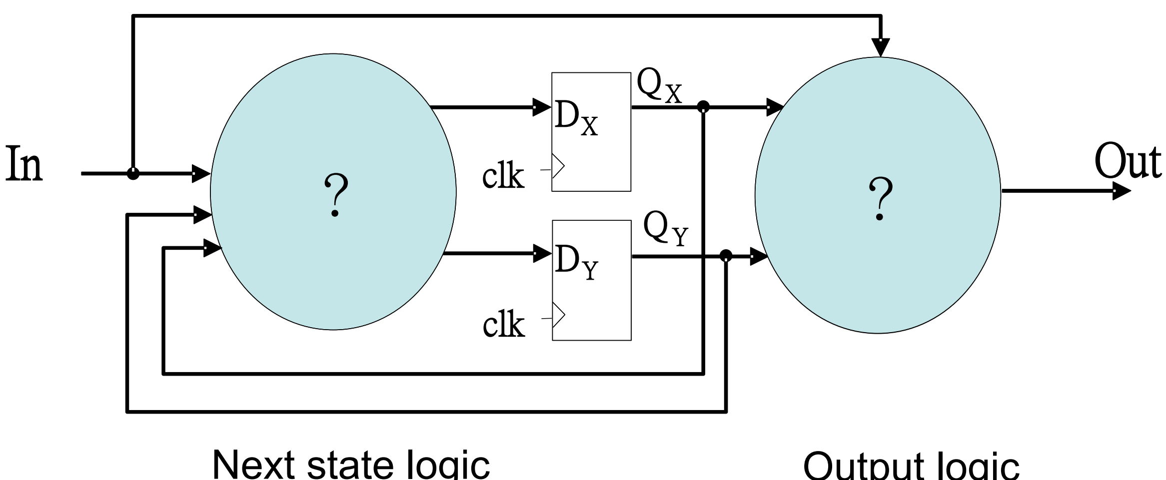
Using D flip-flop



Input			Output		
	Current state		Next state		Output
In	$Q_X(t)$	$Q_Y(t)$	$Q_X(t+1)$	$Q_Y(t+1)$	Out
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	1	0	1
0	1	1	1	1	0
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	1	1	1
1	1	1	0	1	0



Input			Output		
	Current state		Next state		Output
In	$Q_X(t)$	$Q_Y(t)$	$Q_X(t+1)$	$Q_Y(t+1)$	Out
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	1	0	1
0	1	1	1	1	0
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	1	1	1
1	1	1	0	1	0

D_X ($Q_X(t+1)$)

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	0	0	1	1
1	1	1	0	1

D_Y ($Q_Y(t+1)$)

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	0	0	1	0
1	0	0	1	1

Out

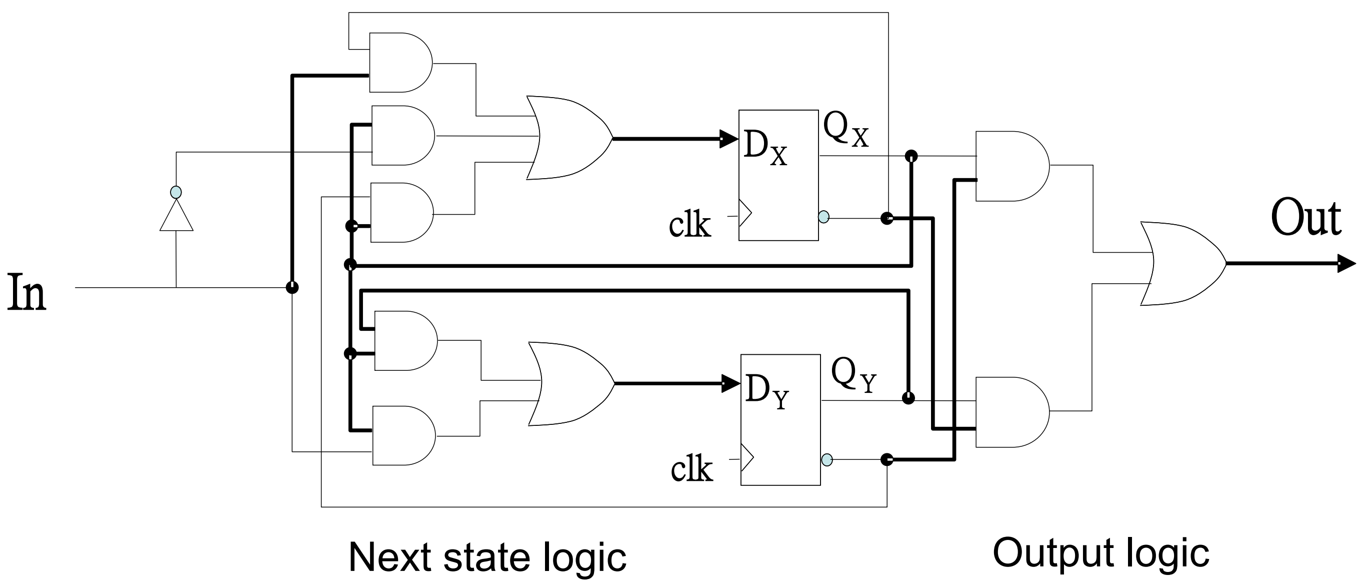
In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	0	1	0	1
1	0	1	0	1

$$D_X = InQ_X'(t) + In'Q_X(t) + Q_X(t)Q_Y'(t)$$
$$D_Y = Q_X(t)Q_Y(t) + InQ_X(t)$$

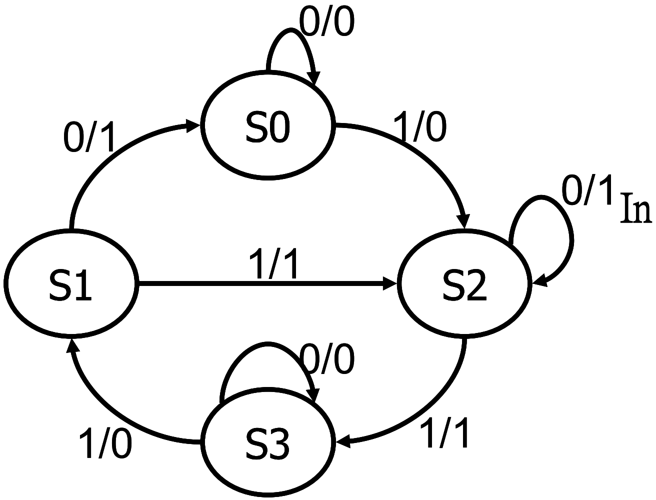
$$Out = Q_X(t)Q_Y'(t) + Q_X'(t)Q_Y(t)$$

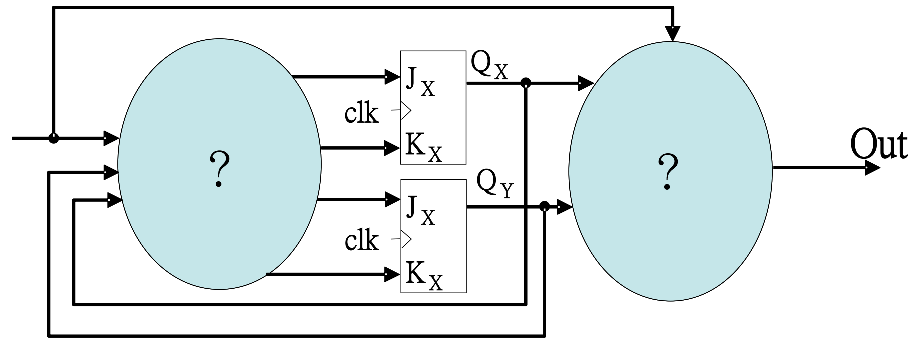
$D_X = InQ_X'(t) + In'Q_X(t) + Q_X(t)Q_Y'(t)$
$D_Y = Q_X(t)Q_Y(t) + InQ_X(t)$

$Out = Q_X(t)Q_Y'(t) + Q_X'(t)Q_Y(t)$



Using JK flip-flop





Next state logic

Output logic

Input			Output							
	current state		next state		X		Y		Out
In	**$Q_X(t)$**	**$Q_Y(t)$**	**$Q_X(t+1)$**	**$Q_Y(t+1)$**	**J_X**	**K_X**	**J_Y**	**K_Y**	**Out**
0	0	0	0	0	0	X	0	X	0
0	0	1	0	0	0	X	X	1	1
0	1	0	1	0	X	0	0	X	1
0	1	1	1	1	X	0	X	0	0
1	0	0	1	0	1	X	0	X	0
1	0	1	1	0	1	X	X	1	1
1	1	0	1	1	X	0	1	X	1
1	1	1	0	1	X	1	X	0	0

Synthesis using JK flip-flops

- A state diagram ⇒ flip-flop input functions
  - straightforward for D flip-flops
  - we need excitation tables for JK and T flip-flops

J	K	D	Q(t+1)	Function
0	0	Q(t)	Q(t)	no change
0	1	0	0	reset FF to 0
1	0	1	1	set FF to 1
1	1	Q'(t)	Q'(t)	complement output

T	D	Q(t+1)	
0	Q	Q(t)	no change
1	Q'	Q'(t)	complement

Table 5.12
Flip-Flop Excitation Tables

$Q(t)$	$Q(t = 1)$	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

(a) JK

$Q(t)$	$Q(t = 1)$	T
0	0	0
0	1	1
1	0	1
1	1	0

(b) T

Input			Output						
	current state		next state		X		Y		Out
In	$Q_X(t)$	$Q_Y(t)$	$Q_X(t+1)$	$Q_Y(t+1)$	J_X	K_X	J_Y	K_Y	Out
0	0	0	0	0	0	X	0	X	0
0	0	1	0	0	0	X	X	1	1
0	1	0	1	0	X	0	0	X	1
0	1	1	1	1	X	0	X	0	0
1	0	0	1	0	1	X	0	X	0
1	0	1	1	0	1	X	X	1	1
1	1	0	1	1	X	0	1	X	1
1	1	1	0	1	X	1	X	0	0

$Q(t)$	$Q(t+1)$	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

J_X

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	0	0	X	X
1	1	1	X	X

K_X

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	X	X	0	0
1	X	X	1	0

J_Y

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	0	X	X	0
1	0	X	X	1

K_Y

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	X	1	0	X
1	X	1	0	X

Out

In \ $Q_X(t)\,Q_Y(t)$	00	01	11	10
0	0	1	0	1
1	0	1	0	1

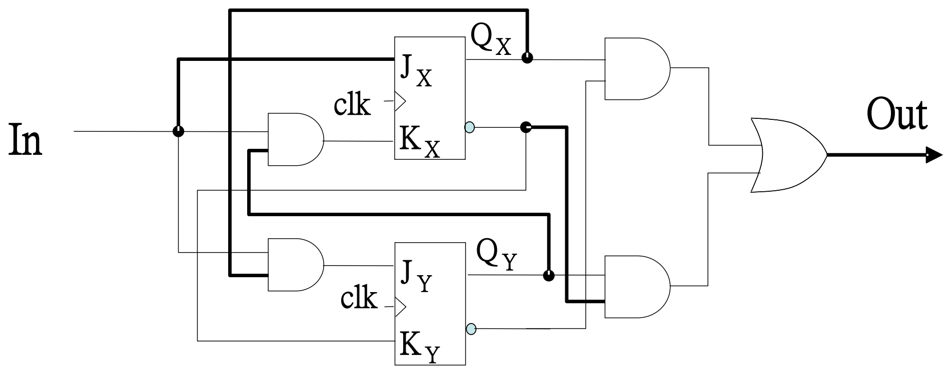
$J_X = \text{In} \qquad K_X = \text{In}\,Q_Y(t)$

$J_Y = \text{In}\,Q_X(t) \qquad K_Y = Q_X'(t)$

$\text{Out} = Q_X(t)Q_Y'(t)+Q_X'(t)Q_Y(t)$

$$J_X = In \qquad K_X = InQ_Y(t)$$
$$J_Y = InQ_X(t) \qquad K_Y = Q_X'(t)$$

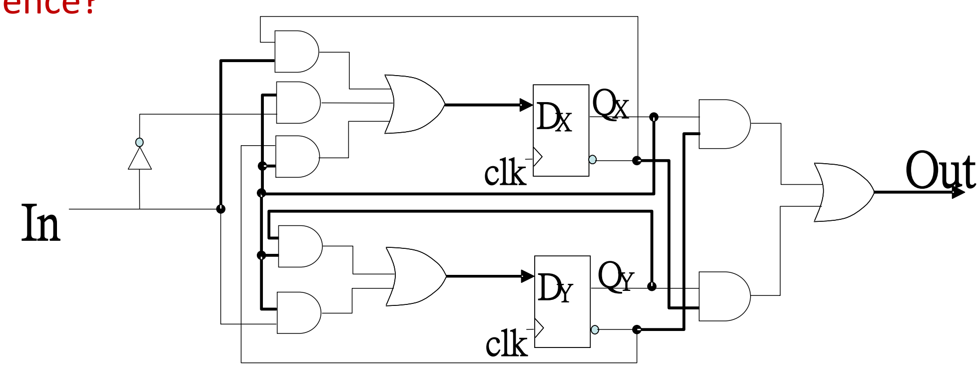
$$Out = Q_X(t)Q_Y'(t) + Q_X'(t)Q_Y(t)$$



Next state logic

Output logic

Difference?

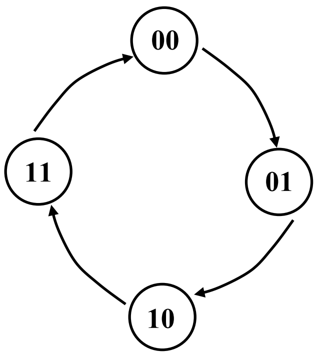


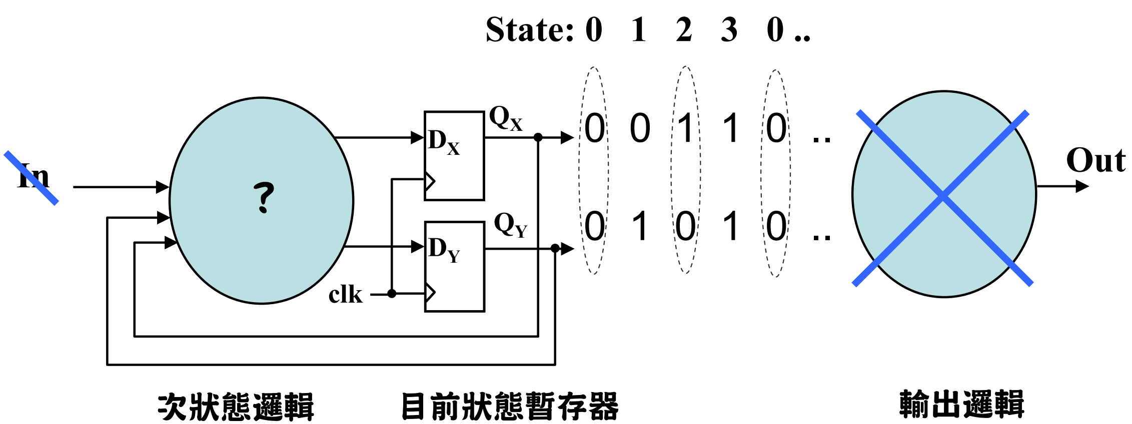
Next state logic

Output logic

Synchronous Counter

00、01、10、11

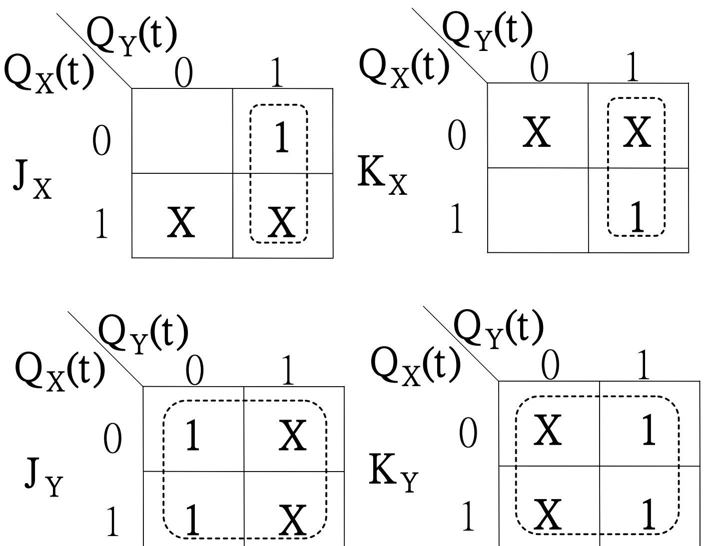




Using JK flip-flop

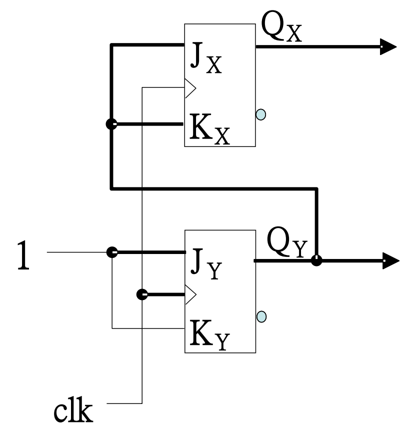
00、01、10、11

Input		Output					
current state		Next state		X		Y	
$Q_X(t)$	$Q_Y(t)$	$Q_X(t+1)$	$Q_Y(t+1)$	J_X	K_X	J_Y	K_Y
0	0	0	1	0	X	1	X
0	1	1	0	1	X	X	1
1	0	1	1	X	0	1	X
1	1	0	0	X	1	X	1



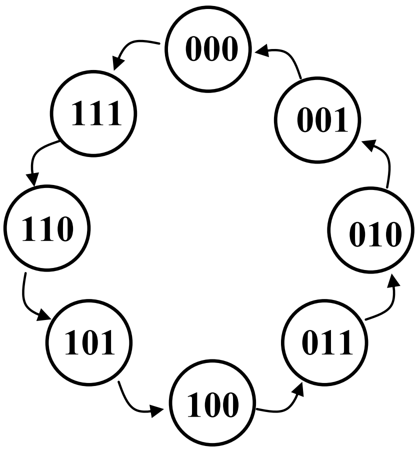
$$J_X = Q_Y(t) \quad K_X = Q_Y(t)$$
$$J_Y = 1 \quad K_Y = 1$$

$$J_X = Q_Y(t) \quad K_X = Q_Y(t)$$
$$J_Y = 1 \qquad K_Y = 1$$



Next state logic

Using D flip-flop



Current state			Next state		
$Q_X(t)$	$Q_Y(t)$	$Q_Z(t)$	$Q_X(t+1)$	$Q_Y(t+1)$	$Q_Z(t+1)$
0	0	0	1	1	1
0	0	1	0	0	0
0	1	0	0	0	1
0	1	1	0	1	0
1	0	0	0	1	1
1	0	1	1	0	0
1	1	0	1	0	1
1	1	1	1	1	0

D_X $Q_X(t+1)$

$Q_X(t)$ \ $Q_Y(t)Q_Z(t)$	00	01	11	10
0	1			
1		1	1	1

D_Y $Q_Y(t+1)$

$Q_X(t)$ \ $Q_Y(t)Q_Z(t)$	00	01	11	10
0	1		1	
1	1		1	

D_Z $Q_Z(t+1)$

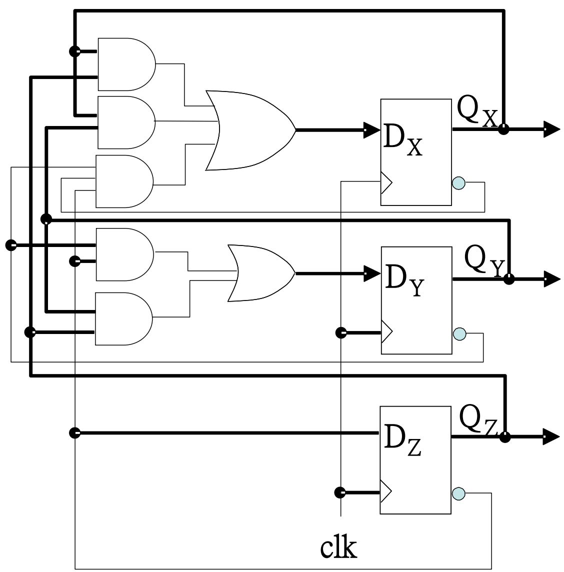
$Q_X(t)$ \ $Q_Y(t)Q_Z(t)$	00	01	11	10
0	1			1
1	1			1

$Q_X(t+1) = D_X = Q_X(t)Q_Z(t)+Q_X(t)Q_Y(t)+Q_X'(t)Q_Y'(t)Q_Z'(t)$ 。

$Q_Y(t+1) = D_Y = Q_Y'(t)Q_Z'(t)+Q_Y(t)Q_Z(t)$ 。

$Q_Z(t+1) = D_Z = Q_Z'(t)$ 。

$Q_X(t+1) = D_X = Q_X(t)Q_Z(t)+Q_X(t)Q_Y(t)+Q_X'(t)Q_Y'(t)Q_Z'(t)$。
$Q_Y(t+1) = D_Y = Q_Y'(t)Q_Z'(t)+Q_Y(t)Q_Z(t)$。
$Q_Z(t+1) = D_Z = Q_Z'(t)$。



Next state logic