

Circuit, State Diagram, State Table

Circuits with Flip-Flop = Sequential Circuit

Circuit = State Diagram = State Table

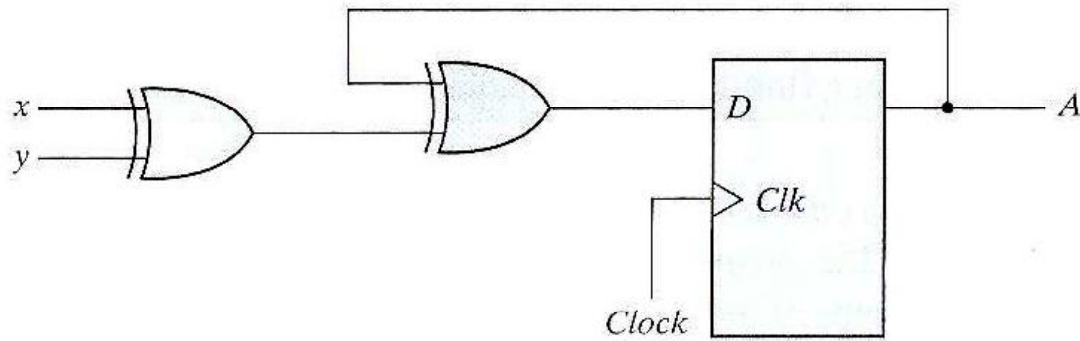
State Minimization

Sequential Circuit Design

Example: Sequence Detector

Example: Binary Counter

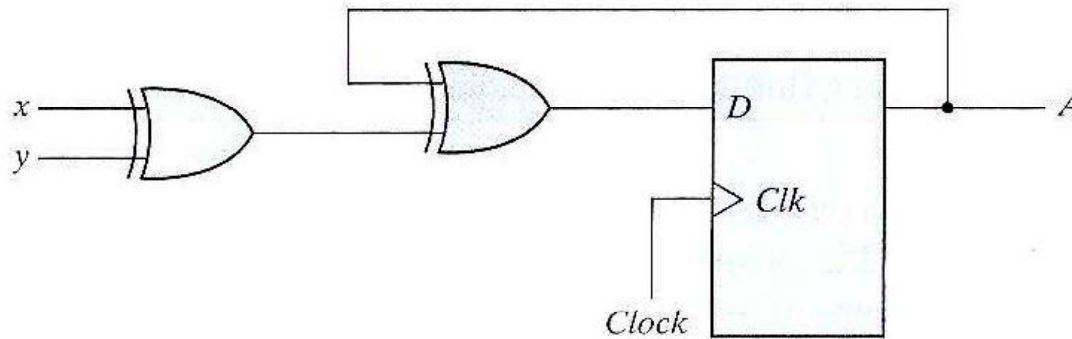
Circuit, State Diagram, State Table



(a) Circuit diagram

FIGURE 5.17
Sequential circuit with D flip-flop

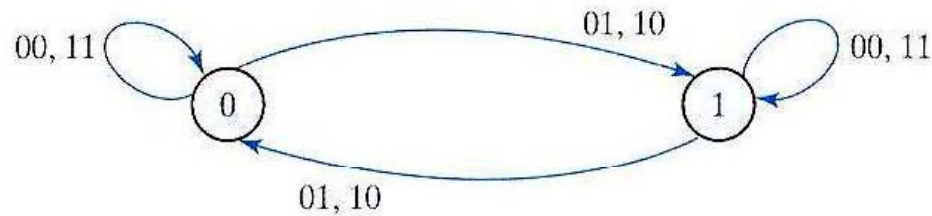
Circuit, State Diagram, State Table



(a) Circuit diagram

Present state	Inputs		Next state
<i>A</i>	<i>x</i>	<i>y</i>	<i>A</i>
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

(b) State table



(c) State diagram

FIGURE 5.17
Sequential circuit with *D* flip-flop

Circuit, State Diagram, State Table

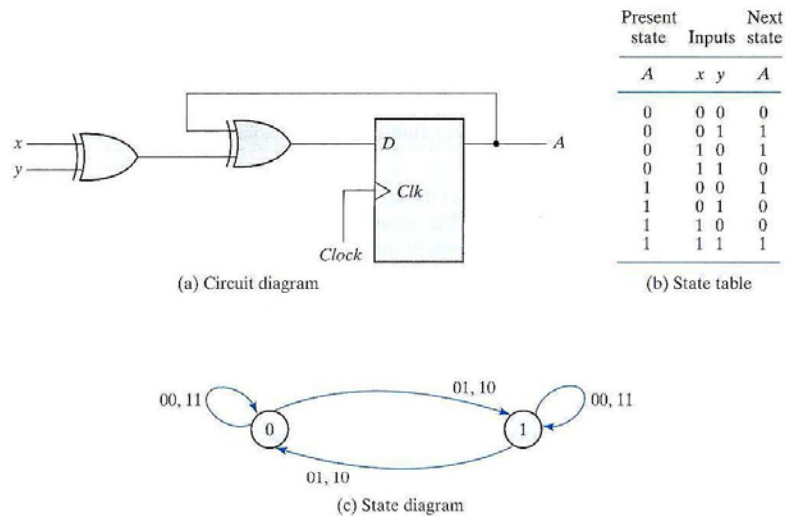


FIGURE 5.17
Sequential circuit with D flip-flop

Terms:

State: flip-flop output combination

Present state: before clock

Next state: after clock

State transition \leq clock

1 flip-flop \Rightarrow 2 states

2 flip-flops \Rightarrow 4 states

3 flip-flops \Rightarrow 8 states

4 flip-flops \Rightarrow 16 states

...

N flip-flops \Rightarrow 2^N states

...

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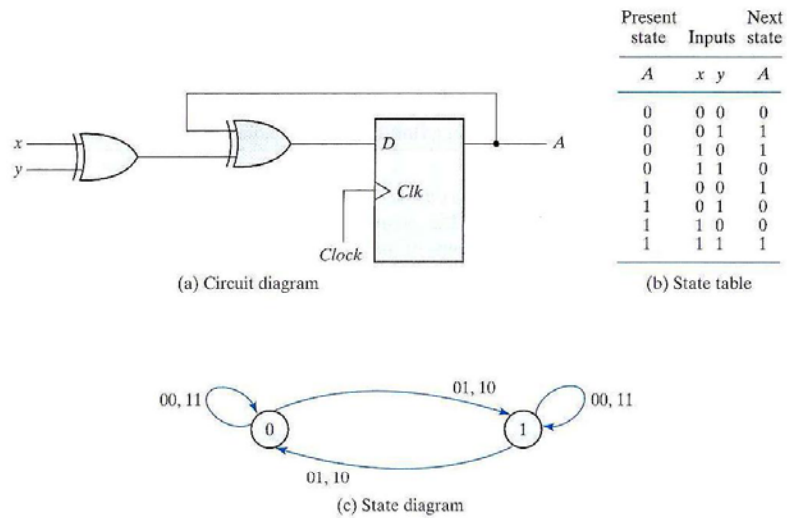
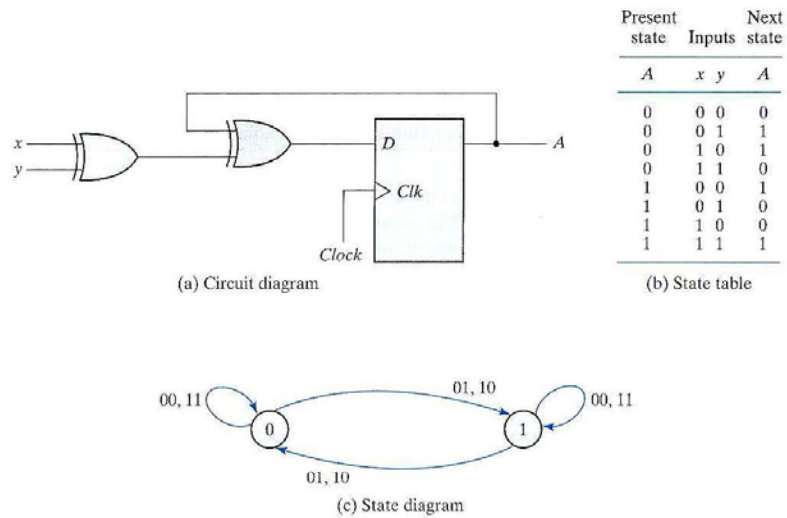


FIGURE 5.17
Sequential circuit with *D* flip-flop

Sequential circuit components:

- Flip-flop(s)
- Clock
- Logic gates
- Input
- Output

Circuit, State Diagram, State Table



State diagram:

Circle => state

Arrow => transition
input/output

FIGURE 5.17
Sequential circuit with *D* flip-flop

Circuit, State Diagram, State Table

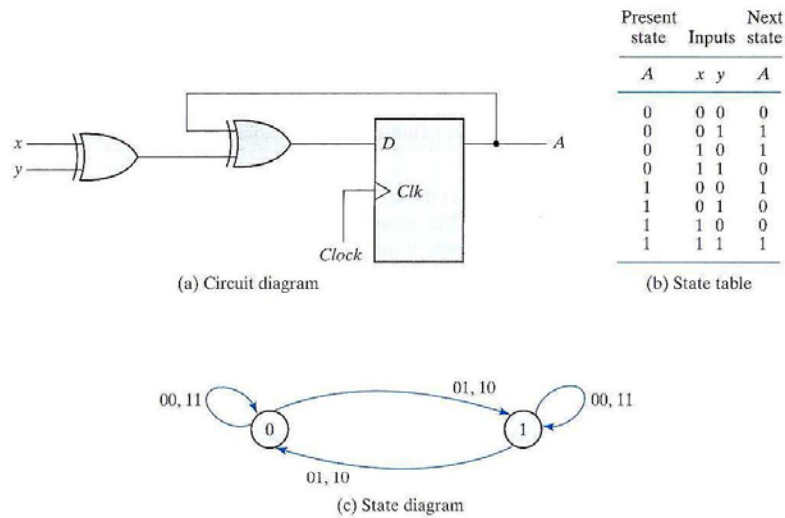


FIGURE 5.17
Sequential circuit with *D* flip-flop

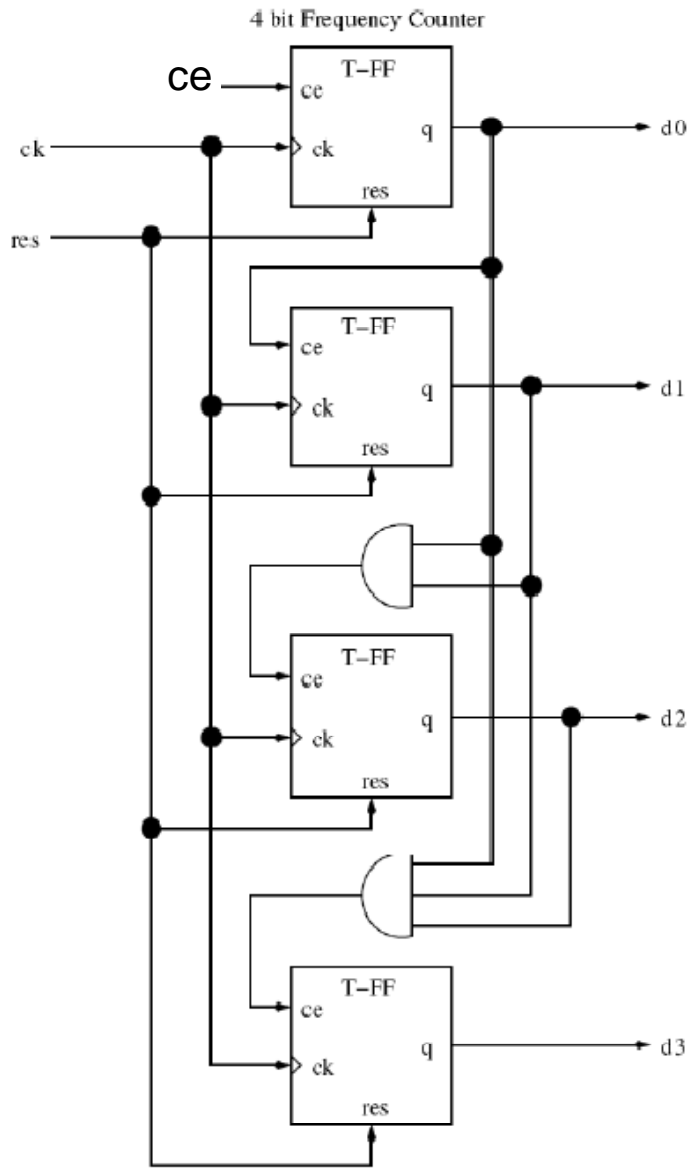
State table:

Left column => current state

Top row => input combination

Table entry => next state, output

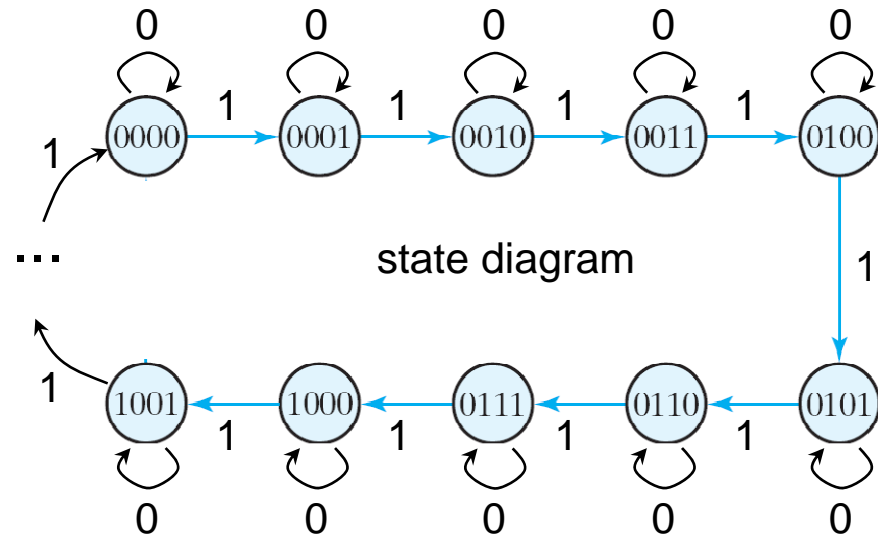
Example: Binary Counter



... → 1110 → 1111 → 0000 → 0001 →
0010 → 0011 → 0100 → 0101 → ...

present state	next state	
	ce=0	ce=1
0000	0000	0001
0001	0001	0010
0010	0010	0011
...
1101	1101	1110
1110	1110	1111
1111	1111	0000

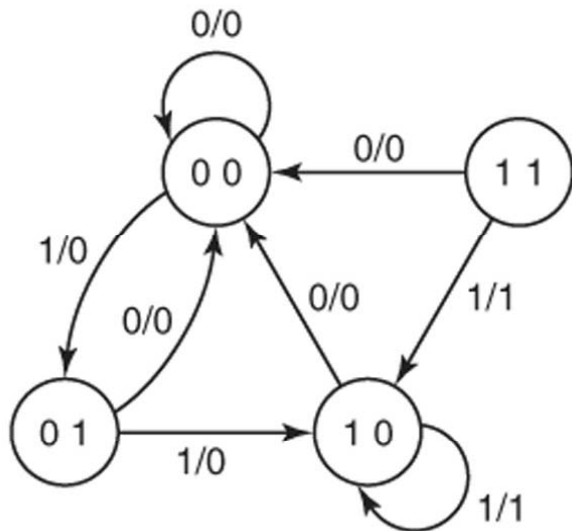
→ state table



Circuit, State Diagram, State Table

Example: state diagram = state table
state table/state diagram

→ circuit



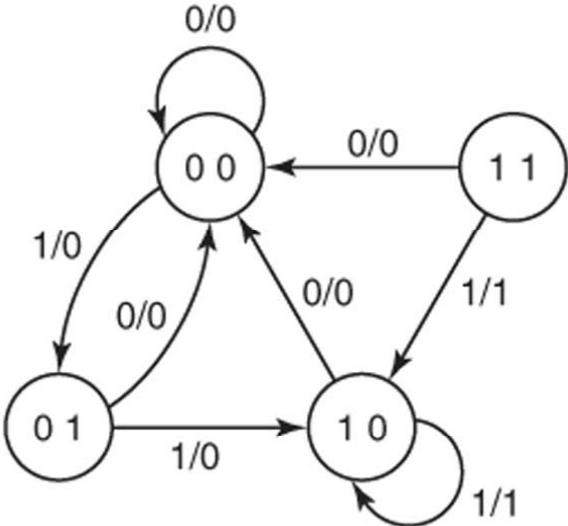
q	q^*		z	
	$x = 0$	$x = 1$	$x = 0$	$x = 1$
0 0	0 0	0 1	0	0
0 1	0 0	1 0	0	0
1 0	0 0	1 0	0	1
1 1	0 0	1 0	0	1

D-FF characteristic eq: $D = Q^*$

Circuit, State Diagram, State Table

Example: state diagram = state table
state table/state diagram

→ circuit



<i>q</i>	<i>q*</i>		<i>z</i>	
	<i>x</i> = 0	<i>x</i> = 1	<i>x</i> = 0	<i>x</i> = 1
0 0	0 0	0 1	0	0
0 1	0 0	1 0	0	0
1 0	0 0	1 0	0	1
1 1	0 0	1 0	0	1

D-FF characteristic eq: $D = Q^*$

		AB			
		00	01	11	10
<i>D_A</i>	<i>x</i>				
	0	0	0	0	0
1	0	1	1	1	

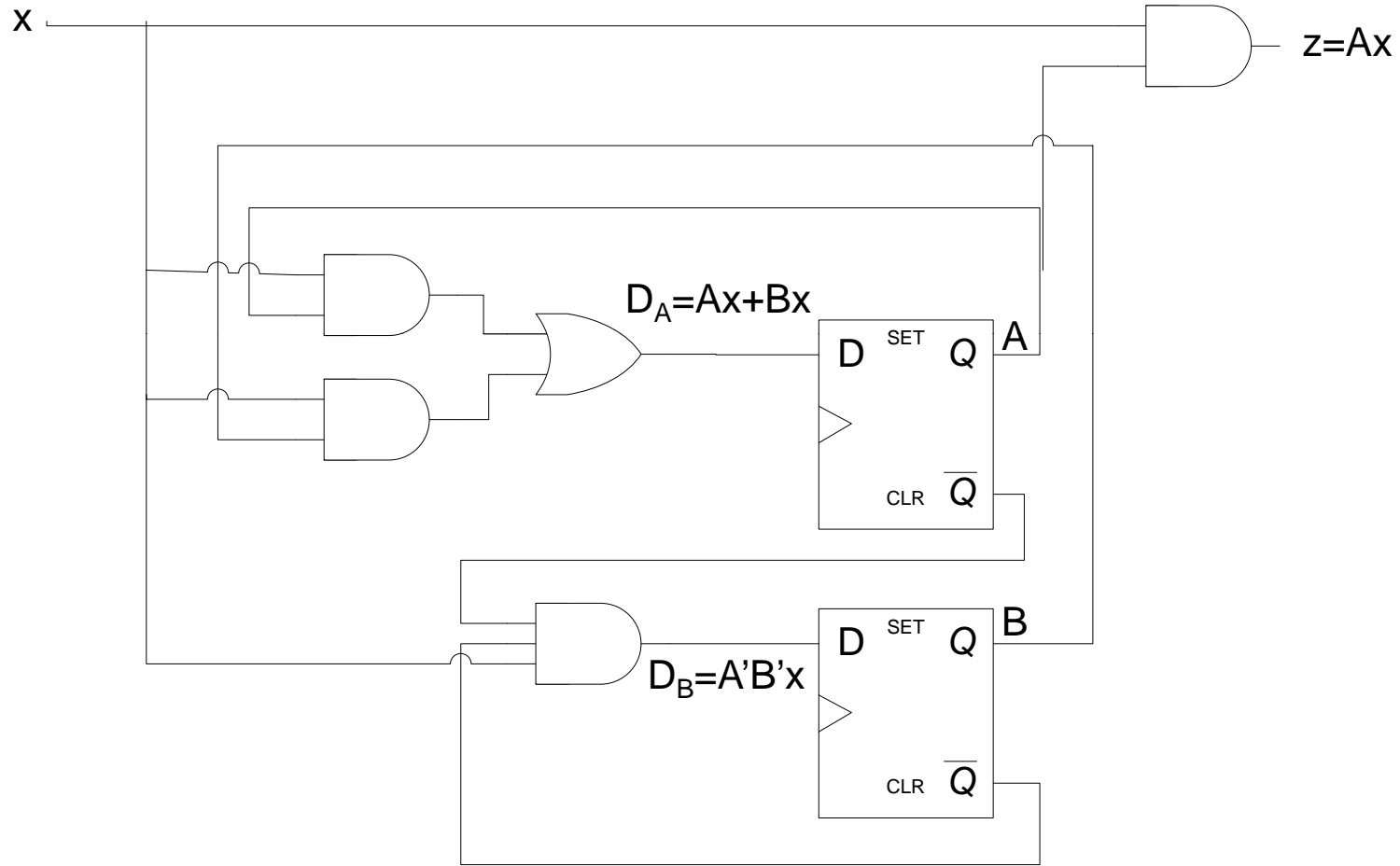
$D_A = Ax + Bx$

		AB			
		00	01	11	10
<i>D_B</i>	<i>x</i>				
	0	0	0	0	0
1	1	0	0	0	

$D_B = A'B'x$

		AB			
		00	01	11	10
<i>z</i>	<i>x</i>				
	0	0	0	0	0
1	0	0	1	1	

$z = Ax$



Circuit, State Diagram, State Table

Example: Show the state diagram of following circuit

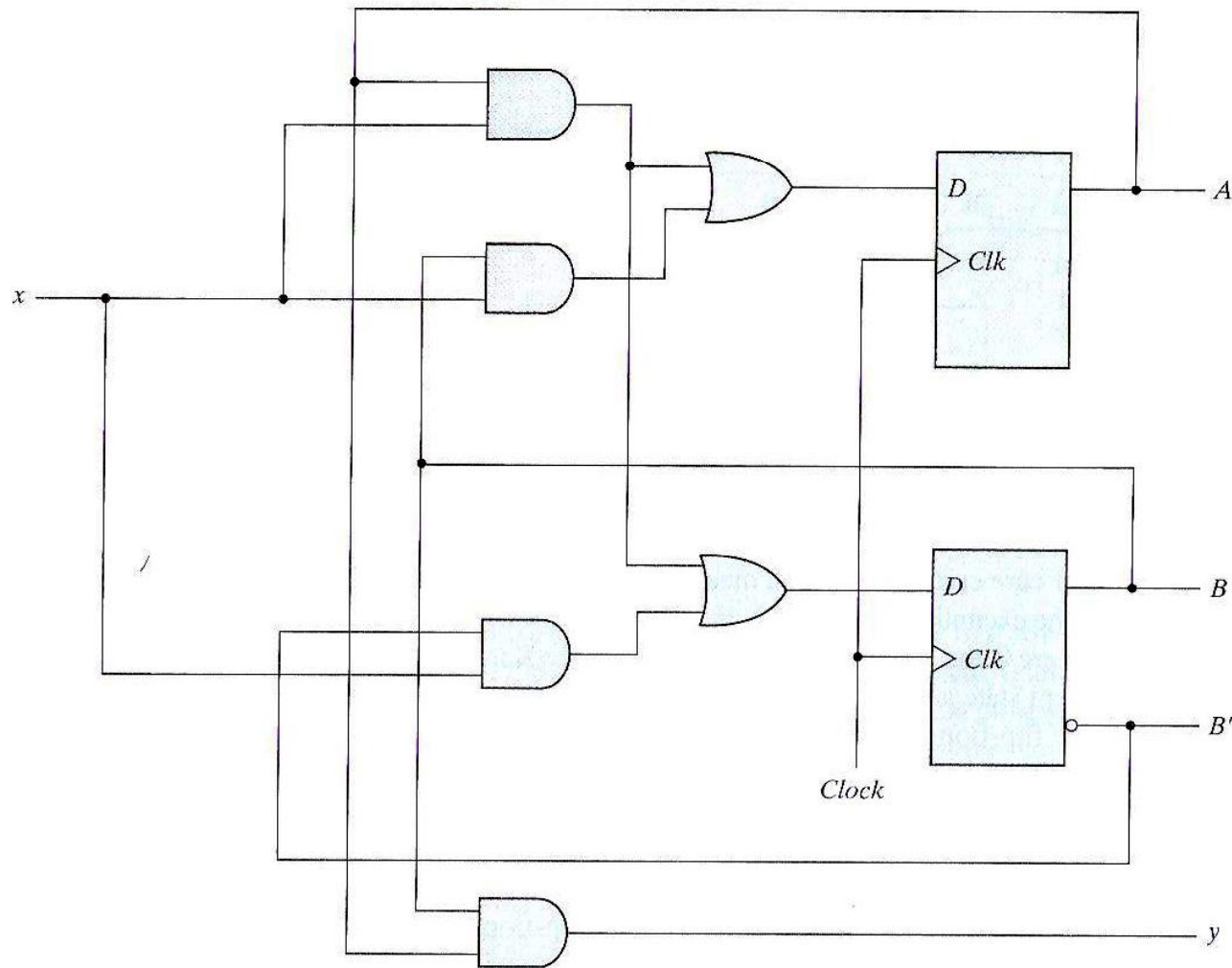


FIGURE 5.29
Logic diagram of sequence detector

Circuit, State Diagram, State Table

Example: Show the state diagram of following circuit

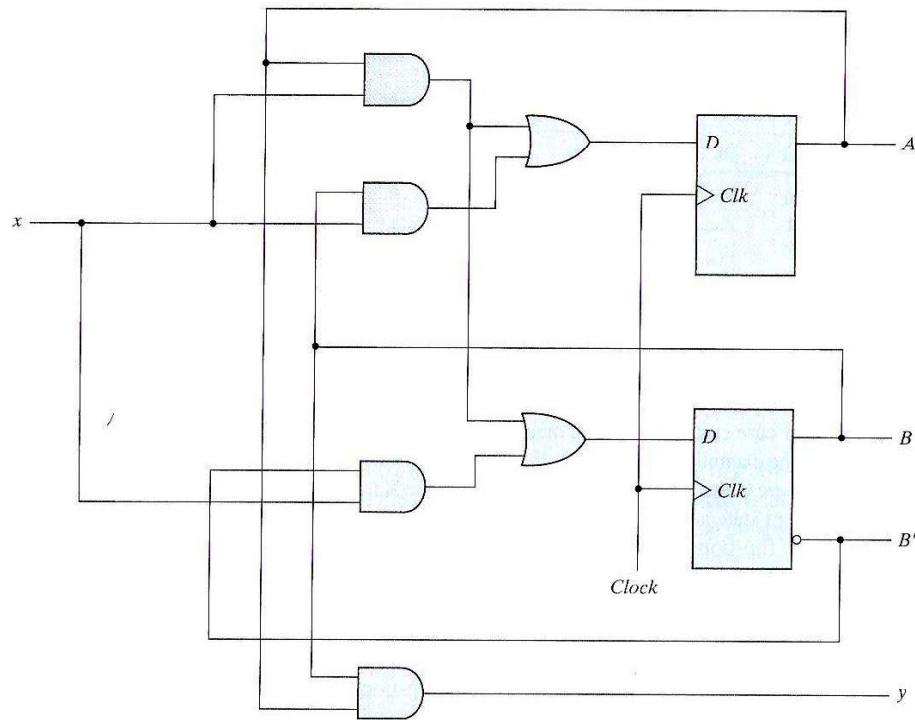


FIGURE 5.29
Logic diagram of sequence detector

$$y = AB$$

$$D_A = Ax + Bx$$

$$D_B = Ax + B'x$$

From circuit (equations)

$$y = AB$$

$$D_A = Ax + Bx$$

$$D_B = Ax + B'x$$

x: input, y: output

A, B: present state

D_A, D_B : next state (D-FF)

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

Circuit, State Diagram, State Table

Example: Show the state diagram of following circuit

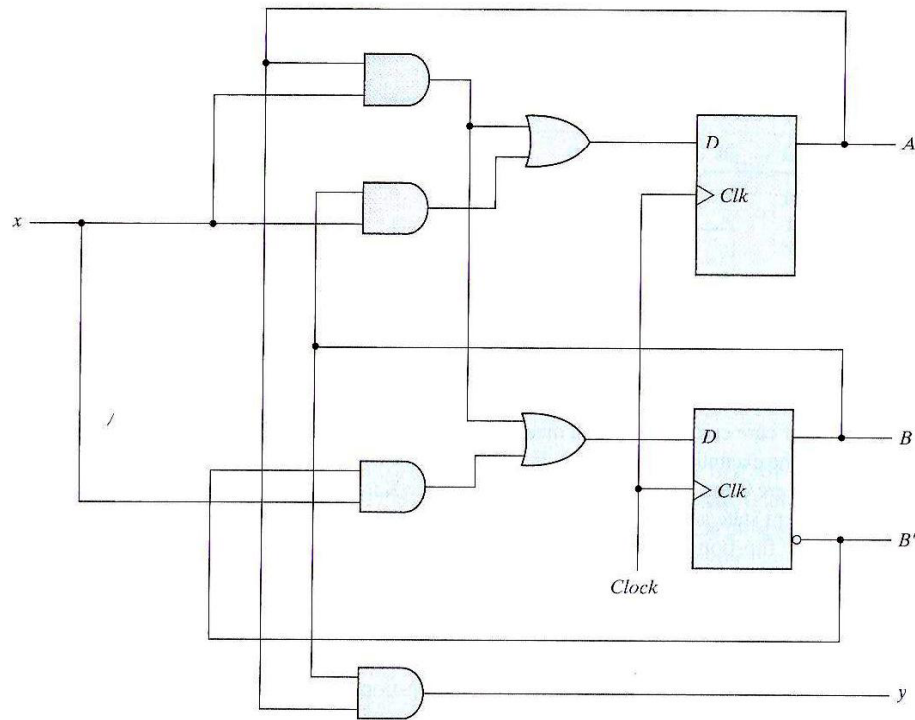
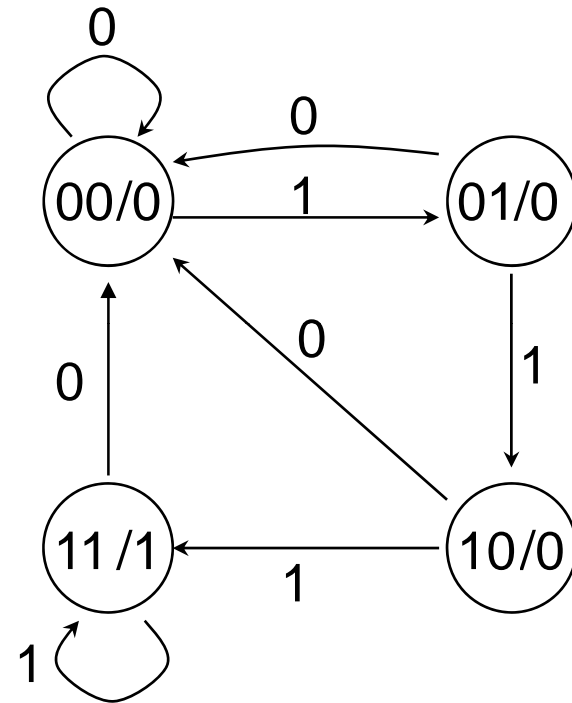


FIGURE 5.29
Logic diagram of sequence detector

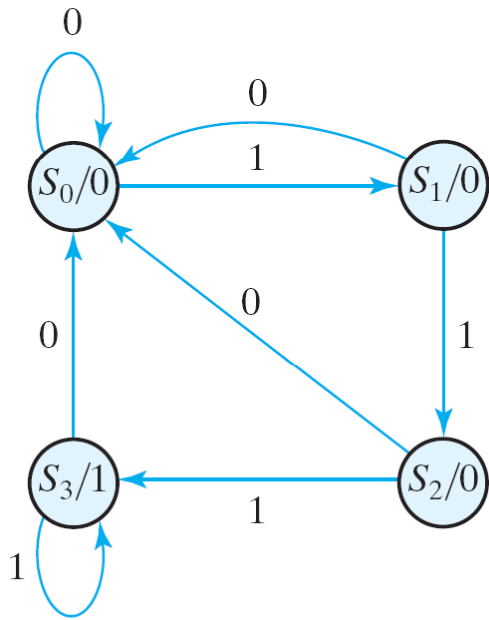


$$y = AB$$

$$D_A = Ax + Bx$$

$$D_B = Ax + B'x$$

From state diagram



Present State		Next State				Output
		$x = 0$		$x = 1$		
<i>A</i>	<i>B</i>	<i>A</i>	<i>B</i>	<i>A</i>	<i>B</i>	<i>Y</i>
		0	0	0	1	0
		0	0	1	0	0
		0	0	1	1	0
		0	0	1	1	1

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More Example: Binary Counter – show state diagram and table

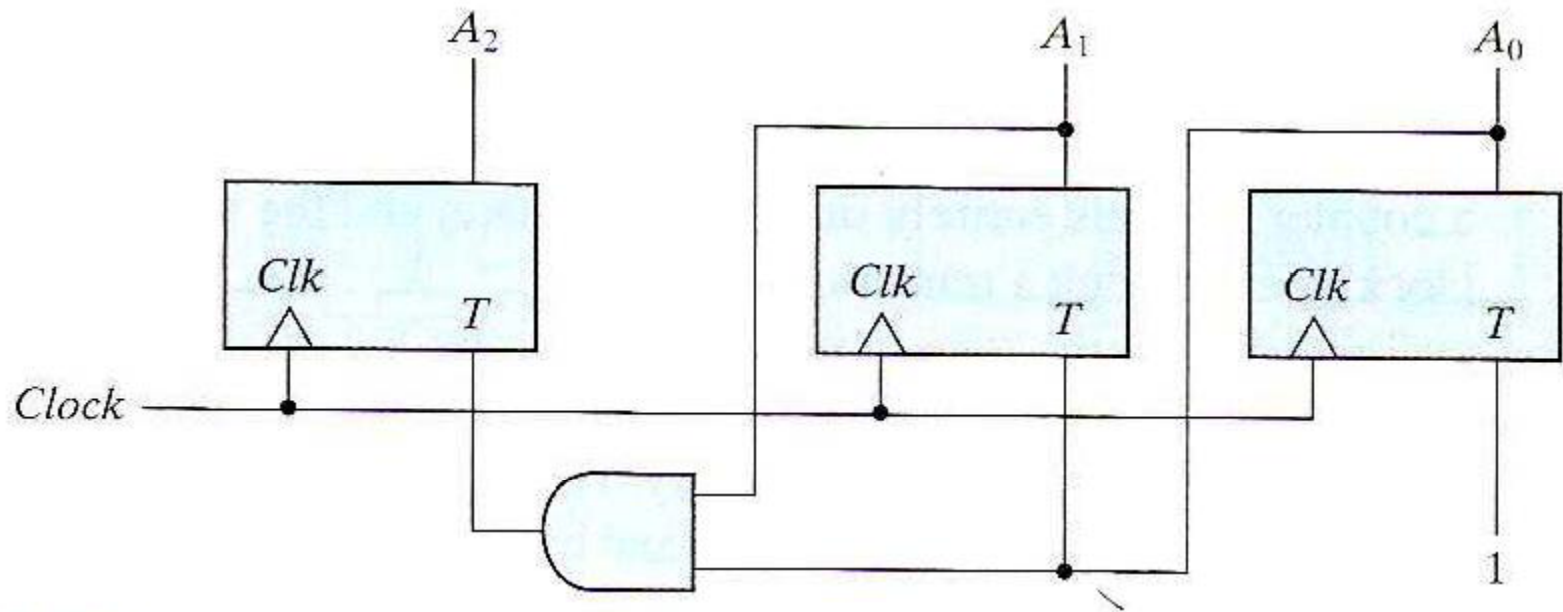


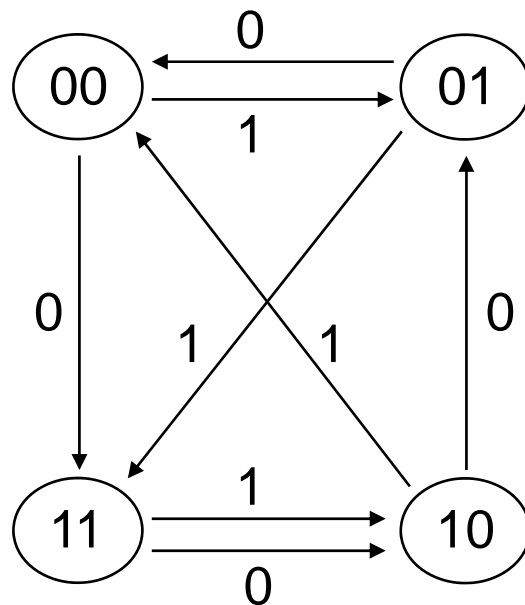
FIGURE 5.34
Logic diagram of three-bit binary counter

Circuit, State Diagram, State Table

More Example: Word Problem

Design a 2-bit complex counter with one input x that can be

- a down counter when $x=0$ ($\dots \rightarrow 11 \rightarrow 10 \rightarrow 01 \rightarrow 00 \rightarrow 11 \rightarrow \dots$)
- a Johnson counter when $x=1$ ($\dots \rightarrow 00 \rightarrow 01 \rightarrow 11 \rightarrow 10 \rightarrow 00 \rightarrow \dots$)



present state	next state	
	$x=0$	$x=1$
A B	A B	A B
0 0	1 1	0 1
0 1	0 0	1 1
1 0	0 1	0 0
1 1	1 0	1 0

present state	next state	
	x=0	x=1
A B	A B	A B
0 0	1 1	0 1
0 1	0 0	1 1
1 0	0 1	0 0
1 1	1 0	1 0

D_A

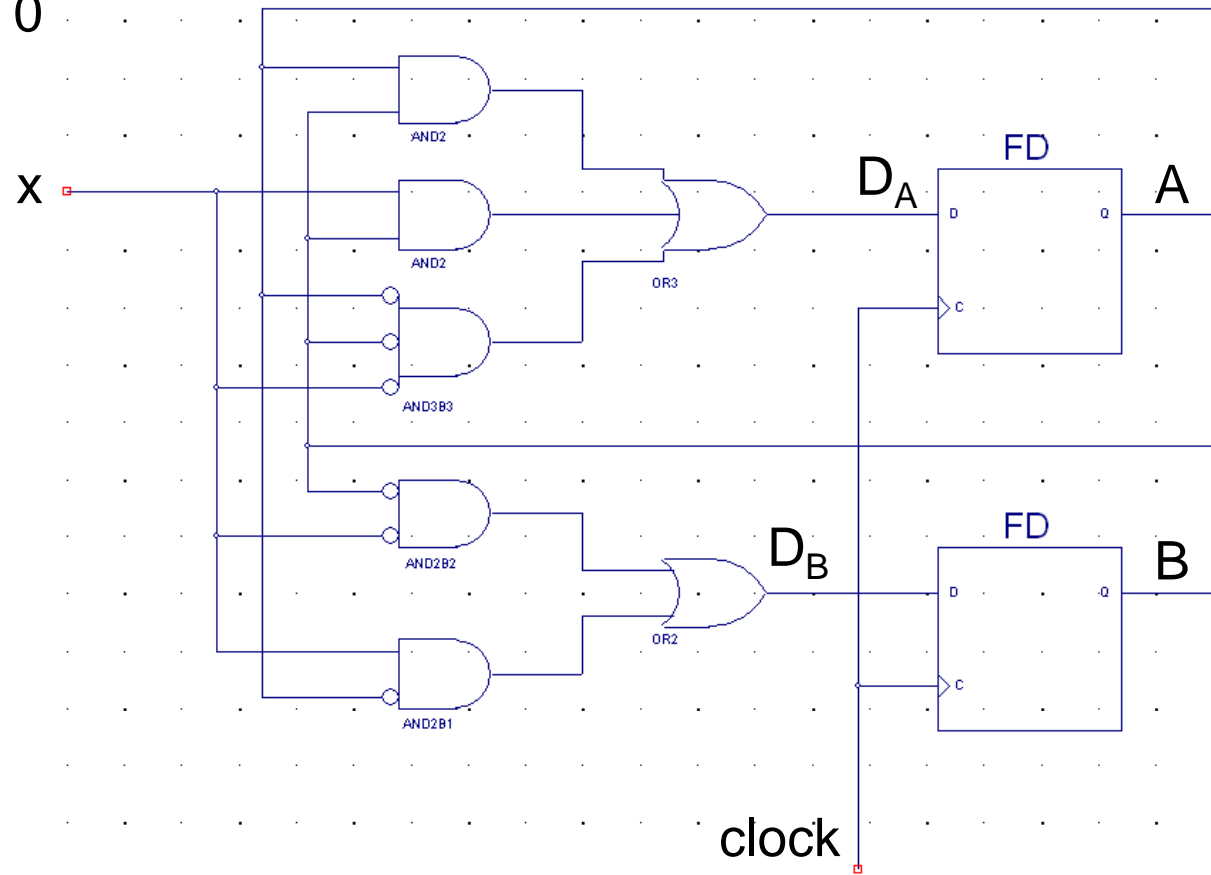
		AB			
		00	01	11	10
x	0	1	0	1	0
	1	0	1	1	0

$$D_A = AB + Bx + A'B'x'$$

D_B

		AB			
		00	01	11	10
x	0	1	0	0	1
	1	1	1	0	0

$$D_B = B'x' + A'x$$



Circuit, State Diagram, State Table

Quiz:

http://www.eelab.usyd.edu.au/digital_tutorial/part3/t-diag.htm

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Quiz: solution

http://www.eelab.usyd.edu.au/digital_tutorial/part3/t-diag.htm

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More Example:

http://www.eelab.usyd.edu.au/digital_tutorial/part3/example1-1.htm