Circuit, State Diagram, State Table

Circuits with Flip-Flop = Sequential Circuit

Circuit = State Diagram = State Table

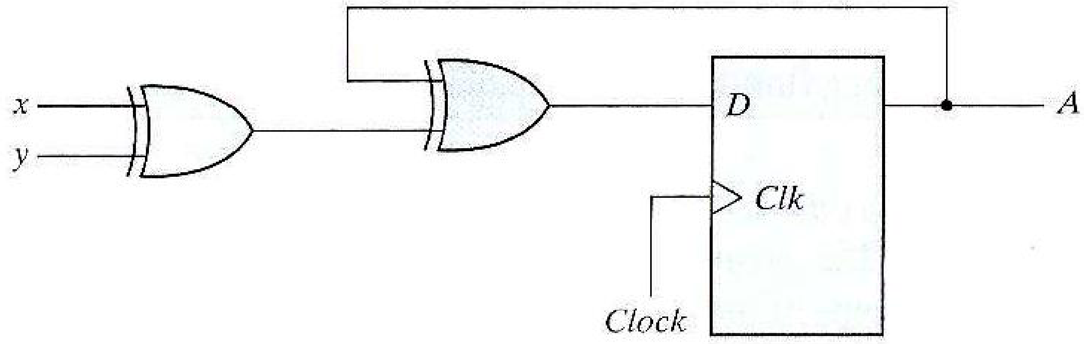
State Minimization

Sequential Circuit Design

Example: Sequence Detector

Example: Binary Counter

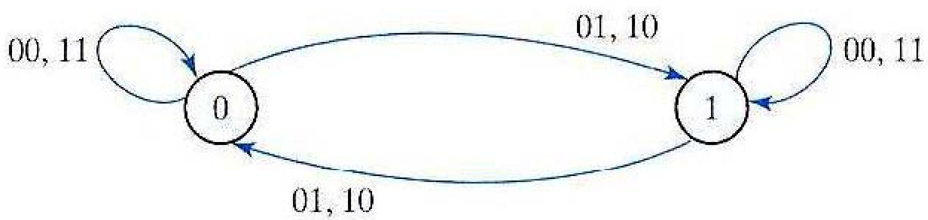
Circuit, State Diagram, State Table



(a) Circuit diagram

Present state	Inputs		Next state
A	x	y	A
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

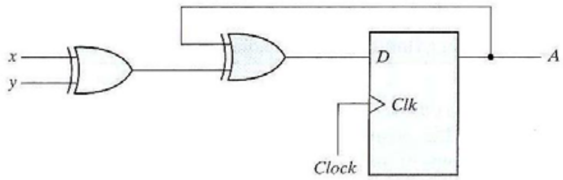
(b) State table



(c) State diagram

FIGURE 5.17
Sequential circuit with *D* flip-flop

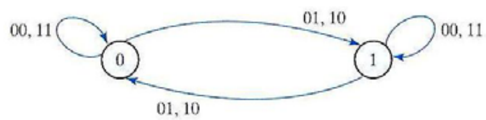
Circuit, State Diagram, State Table



(a) Circuit diagram

Present state	Inputs		Next state
A	*x*	*y*	*A*
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

Terms:

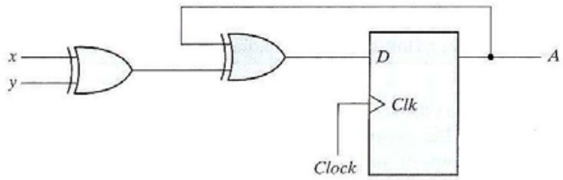
State: flip-flop output combination

Present state: before clock
Next state: after clock

State transition <= clock

1 flip-flop => 2 states
2 flip-flops => 4 states
3 flip-flops => 8 states
4 flip-flops => 16 states
... ...
N flip-flops => 2^N states

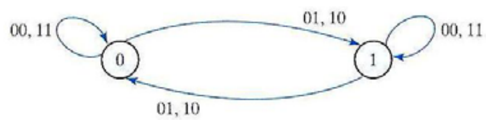
Circuit, State Diagram, State Table



(a) Circuit diagram

Present state	Inputs		Next state
A	*x*	*y*	*A*
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



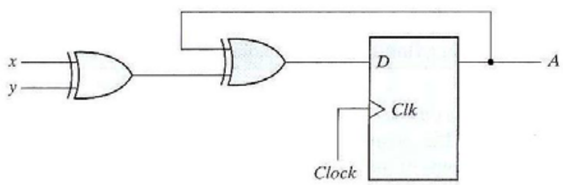
(c) State diagram

FIGURE 5.17
Sequential circuit with *D* flip-flop

Sequential circuit components:

Flip-flop(s)
Clock
Logic gates
Input
Output

Circuit, State Diagram, State Table



(a) Circuit diagram

Present state	Inputs		Next state
A	x	y	A
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

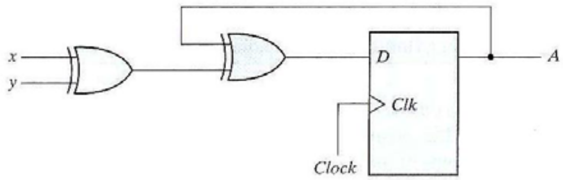
FIGURE 5.17
Sequential circuit with *D* flip-flop

State diagram:

Circle => state

Arrow => transition
input/output

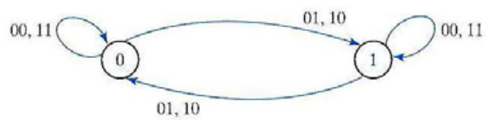
Circuit, State Diagram, State Table



(a) Circuit diagram

Present state	Inputs		Next state
A	x	y	A
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

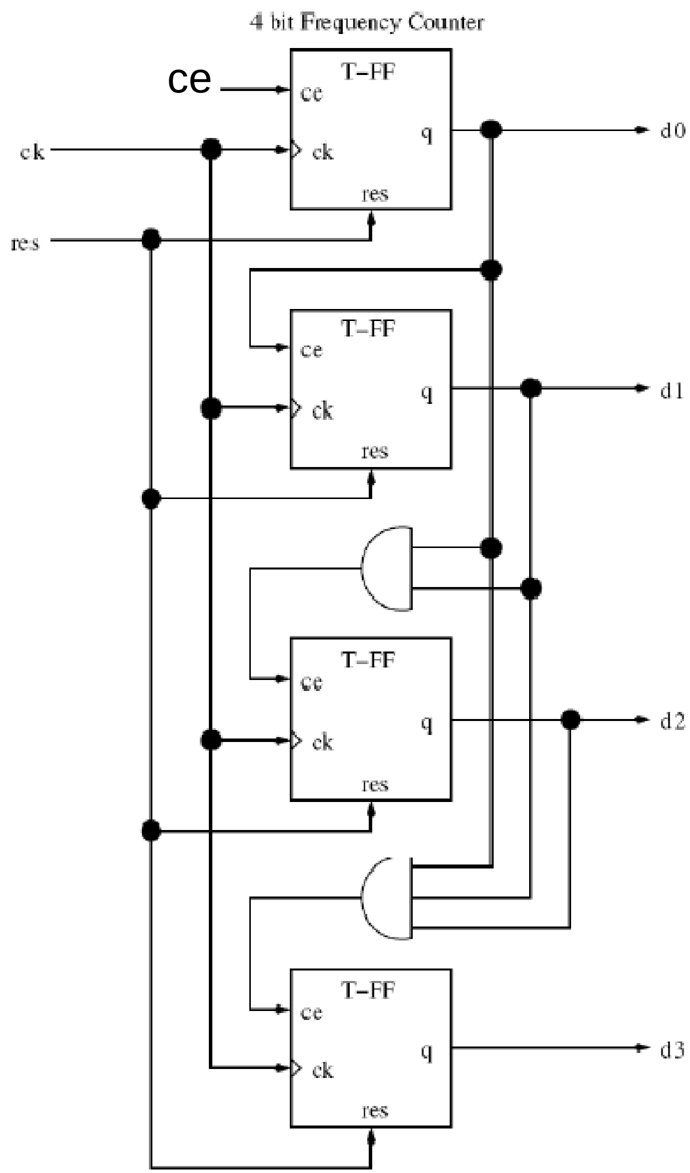
State table:

Left column => current state

Top row => input combination

Table entry => next state, output

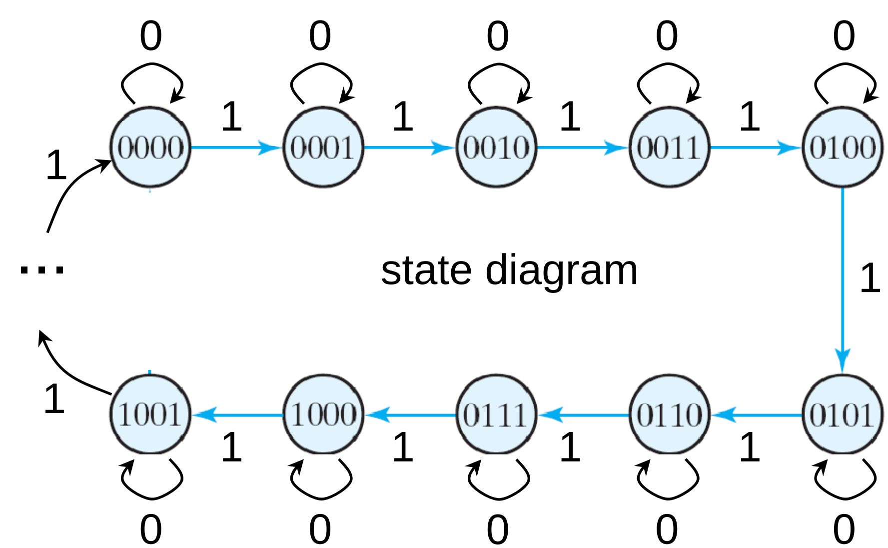
Example: Binary Counter



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

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

→ state table



state diagram

Circuit, State Diagram, State Table

Example:

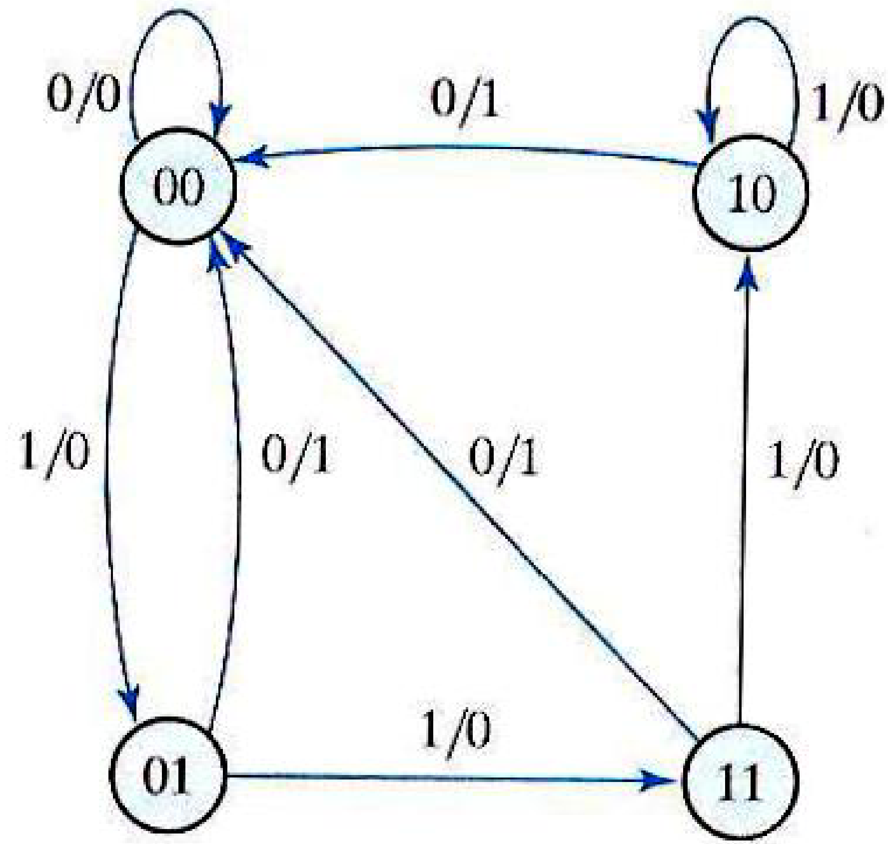


FIGURE 5.16
State diagram of the circuit of Fig. 5.15

Circuit, State Diagram, State Table

Example:

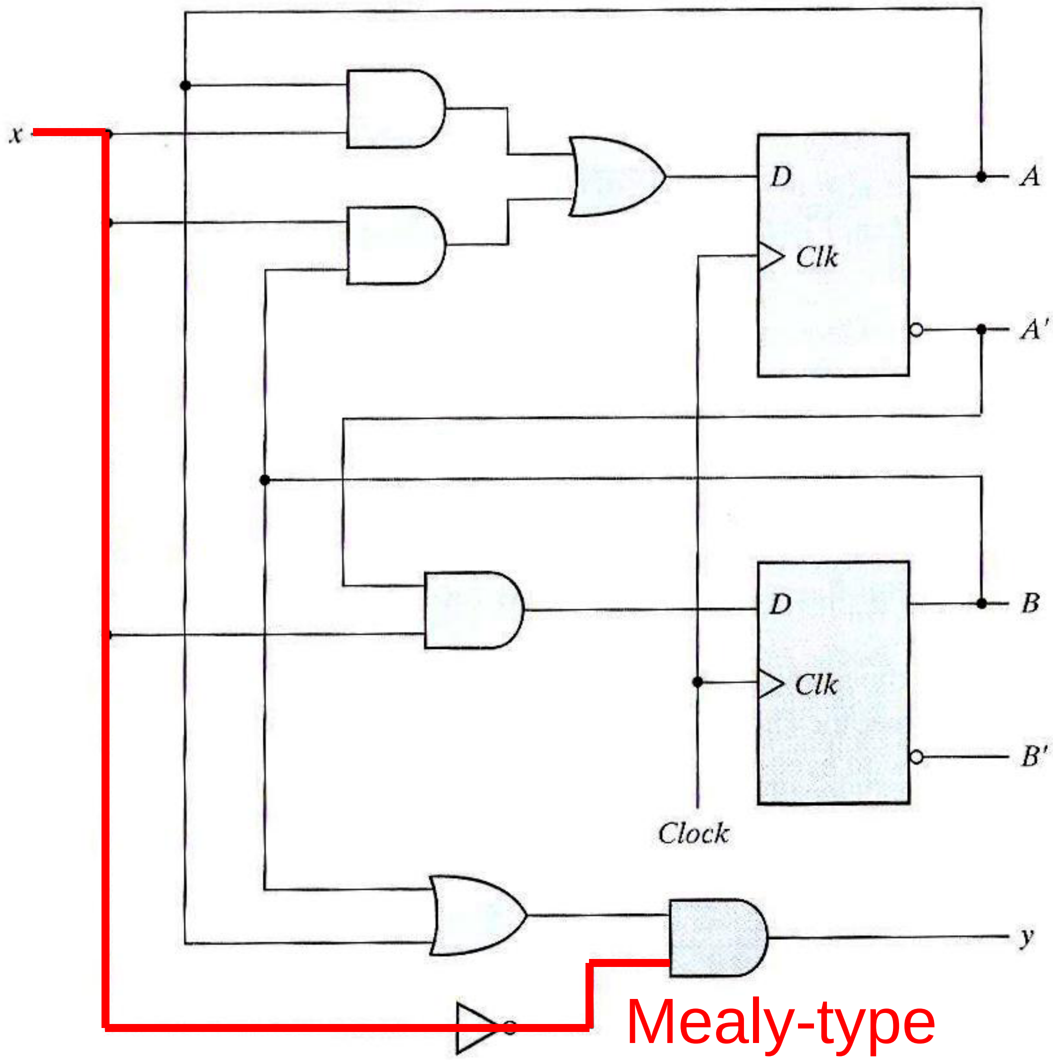
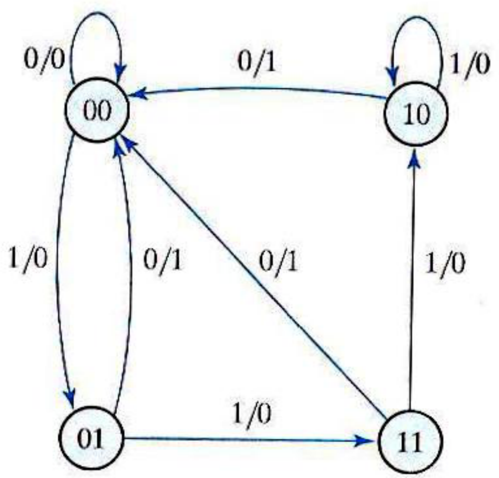


FIGURE 5.15
Example of sequential circuit

Input and output values separated by dash along the directed lines



of the circuit of Fig. 5.15

Circuit, State Diagram, State Table

Example:

Table 5.3
Second Form of the State 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

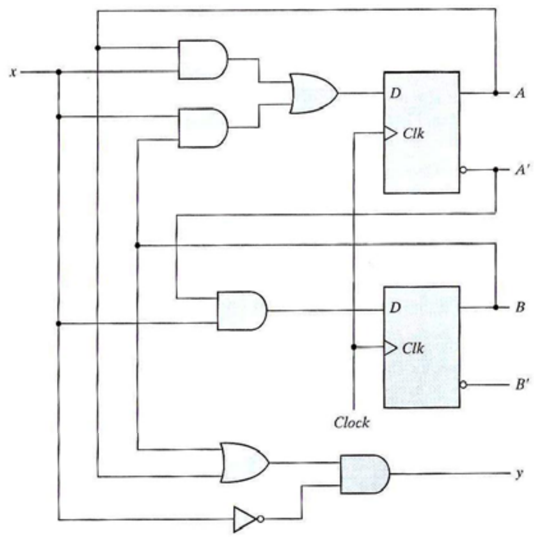


FIGURE 5.15
Example of sequential circuit

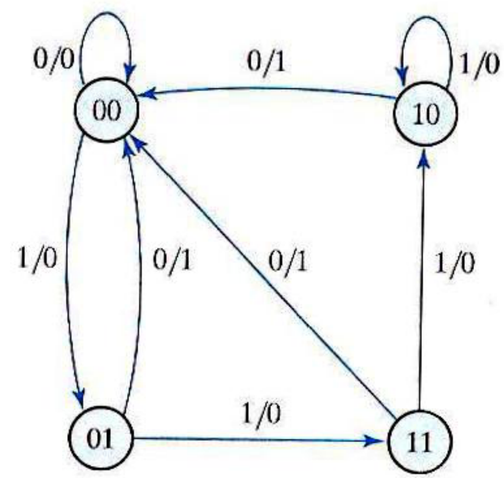


FIGURE 5.16
State diagram of the circuit of Fig. 5.15

Circuit, State Diagram, State Table

Example:

state diagram
➔ state table

Table 5.3
Second Form of the State Table

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

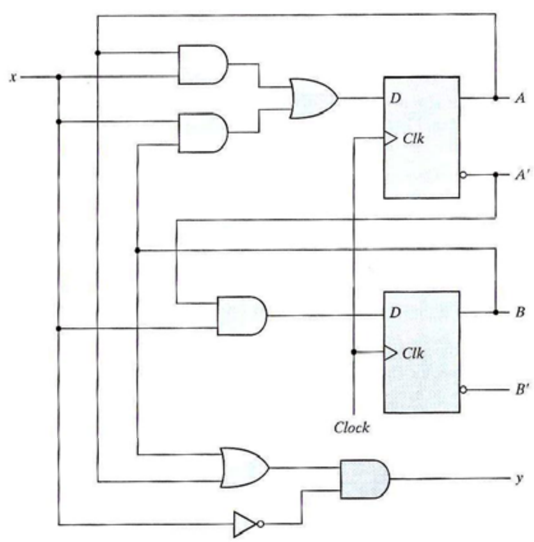


FIGURE 5.15
Example of sequential circuit

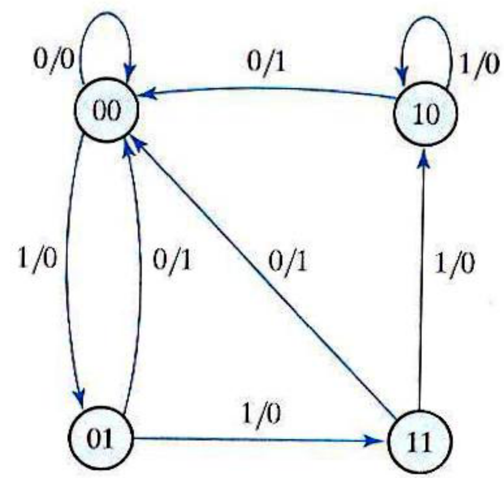
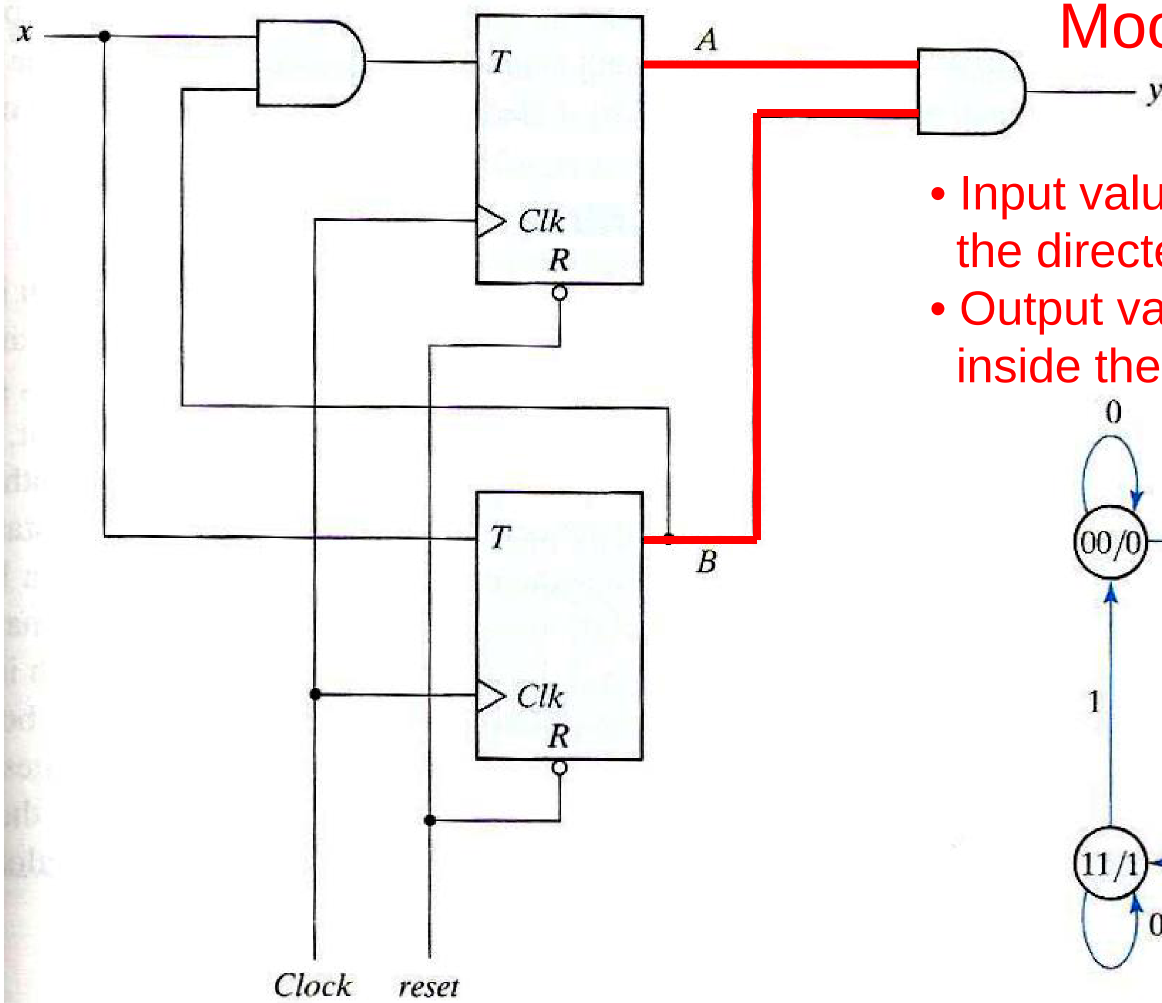


FIGURE 5.16
State diagram of the circuit of Fig. 5.15

Circuit, State Diagram, State Table

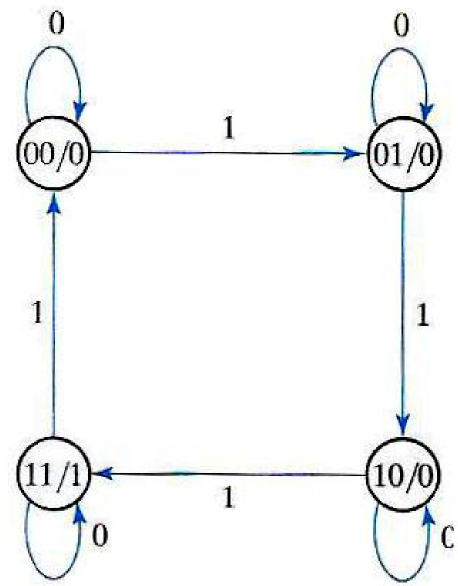
Example:



(a) Circuit diagram

Moore-type

- Input values labeled along the directed lines
- Output values indicated inside the circles

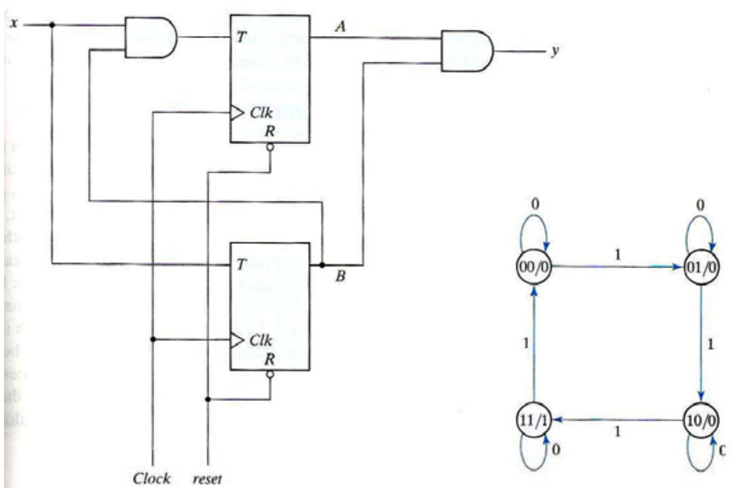


(b) State diagram

FIGURE 5.20
Sequential circuit with *T* flip-flops

Circuit, State Diagram, State Table

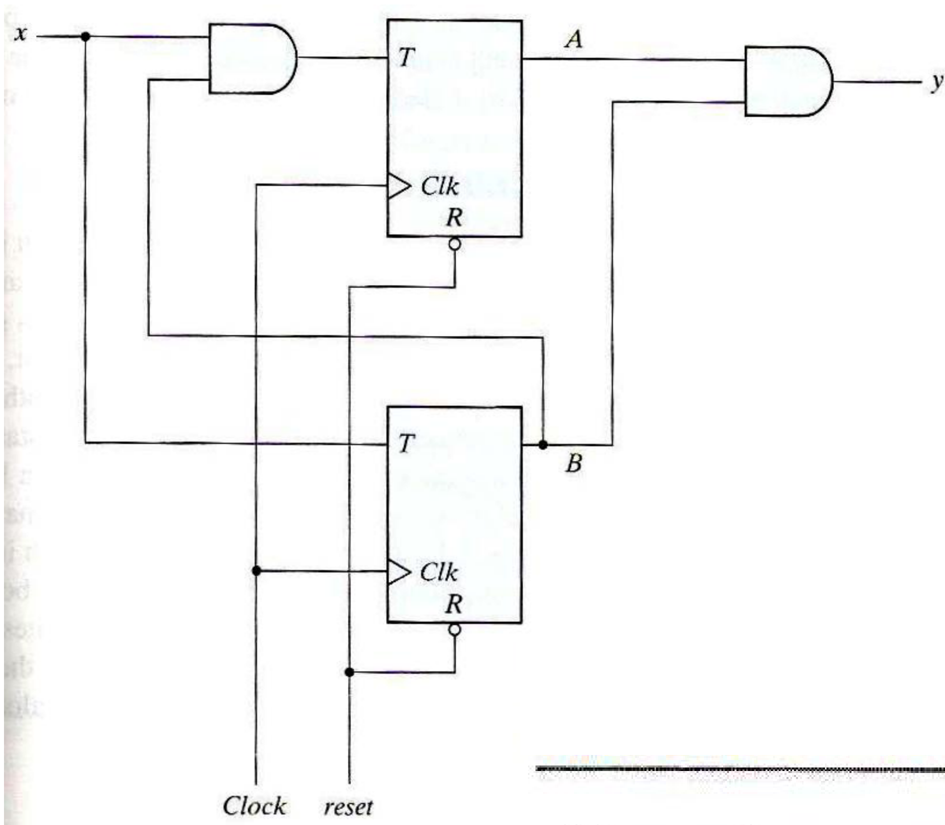
Example: Show the second form truth table similar to Table 5.3

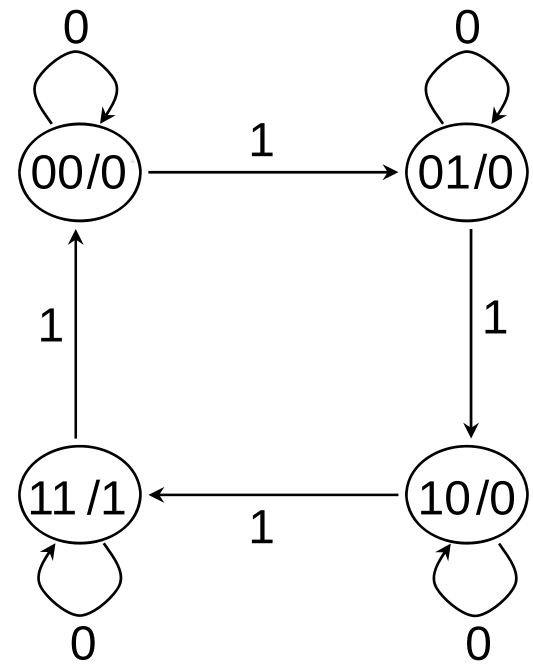


(a) Circuit diagram

(b) State diagram

FIGURE 5.20
Sequential circuit with *T* flip-flops





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

circuit

➔ state table

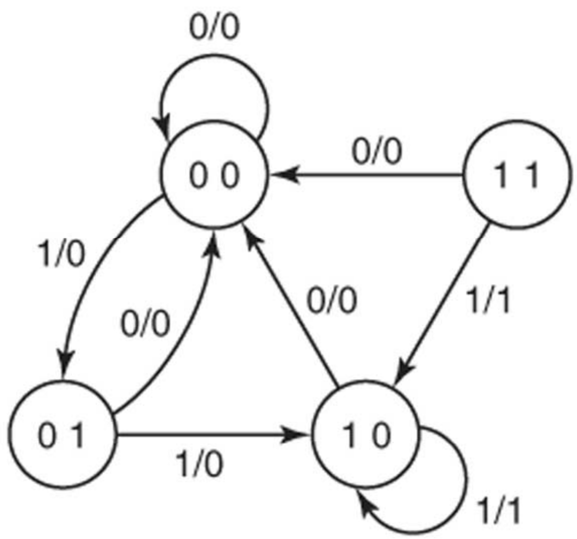
➔ state diagram

Circuit, State Diagram, State Table

Example: state diagram = state table

state table/state diagram

➔ circuit



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

D_A

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

$D_A = Ax + Bx$

D_B

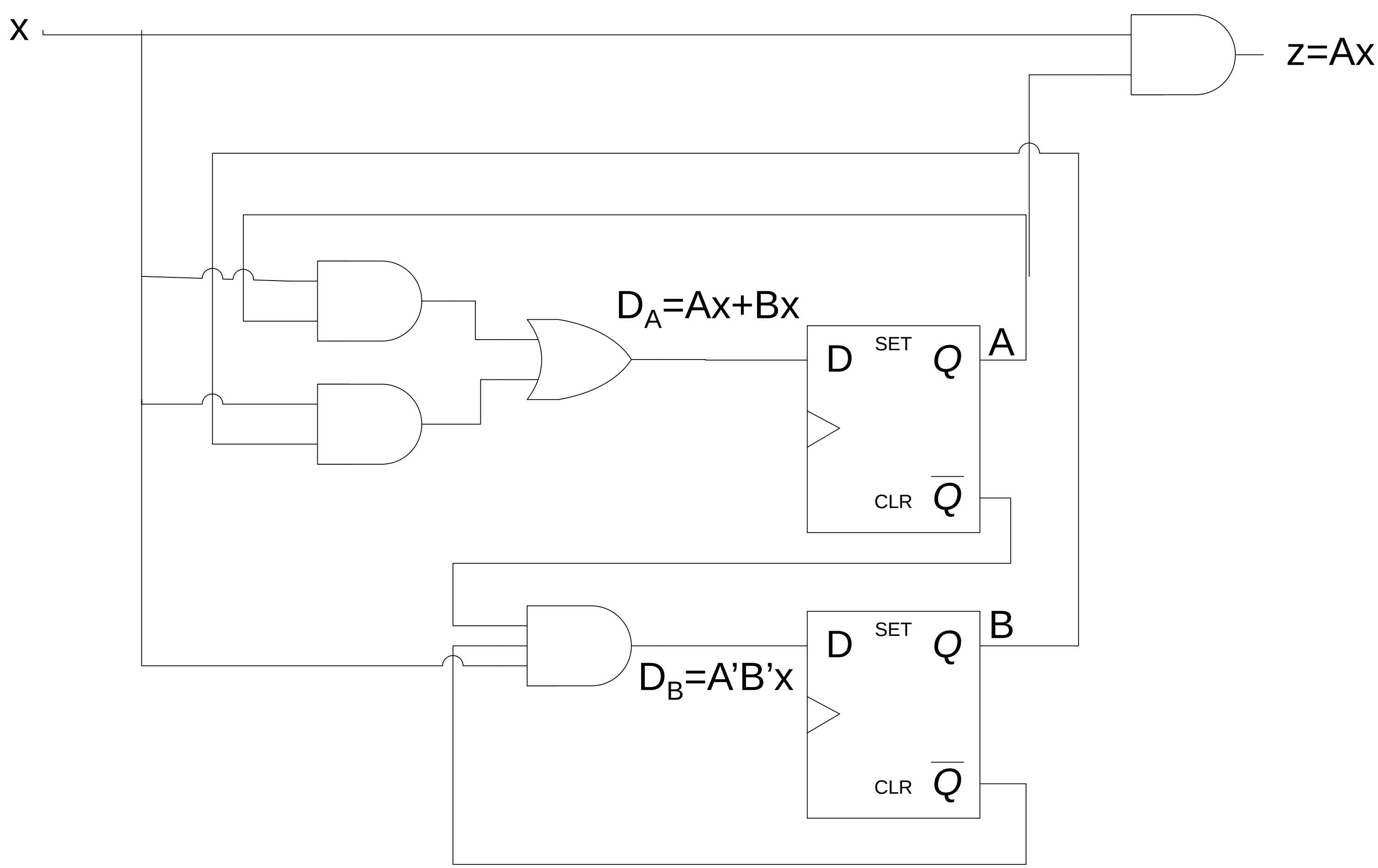
x \ AB	00	01	11	10
0	0	0	0	0
1	1	0	0	0

$D_B = A'B'x$

z

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

z=Ax


x
z=Ax
D_A=Ax+Bx
D
SET
Q
A
CLR
Q
D
SET
Q
B
D_B=A'B'x
CLR
Q

Circuit, State Diagram, State Table

Example: Show the state diagram of following circuit

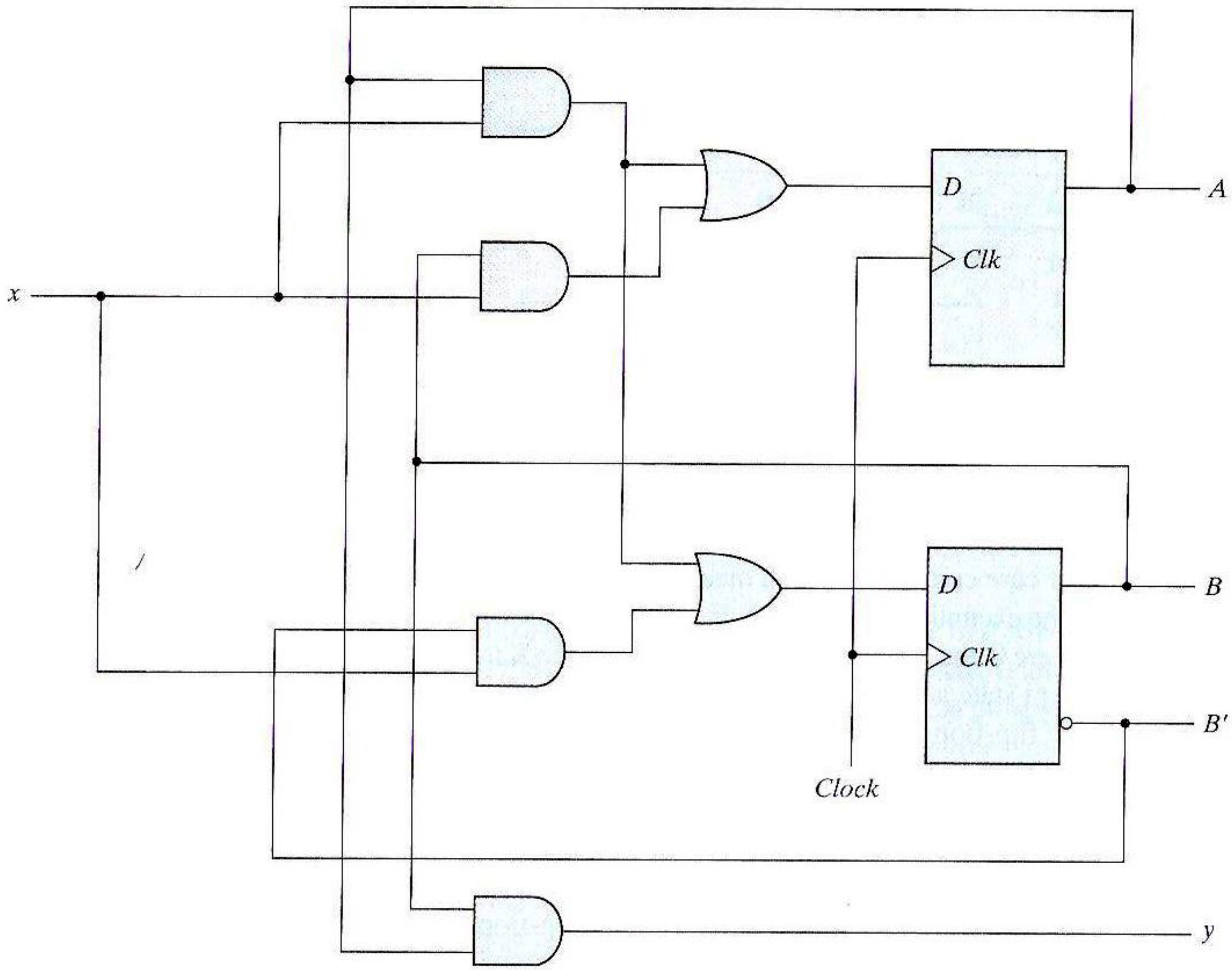


FIGURE 5.29
Logic diagram of sequence detector

Circuit, State Diagram, State Table

Example: Show the state diagram of following circuit

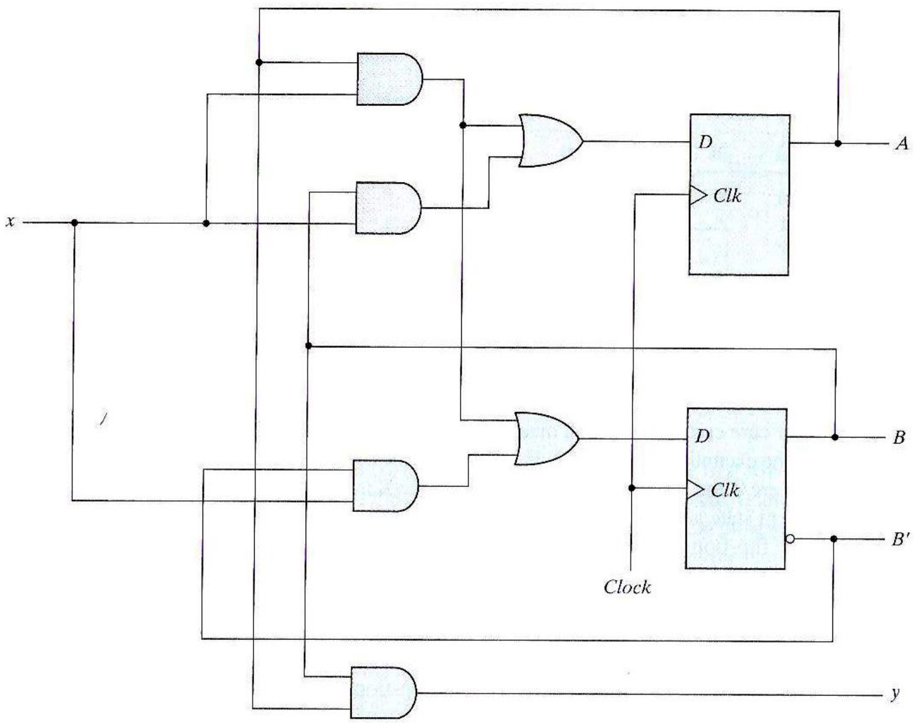
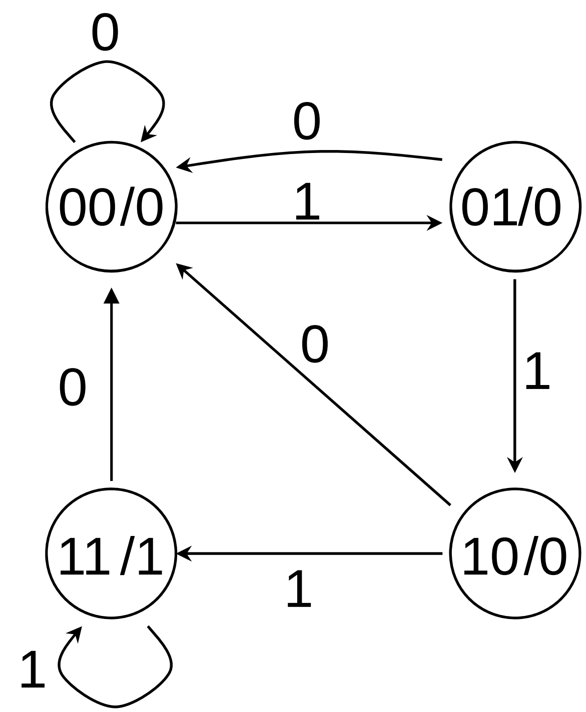


FIGURE 5.29
Logic diagram of sequence detector



$y = AB$

$D_A = Ax + Bx$

$D_B = Ax + B'x$

Circuit, State Diagram, State Table

Example: Show the second form truth table

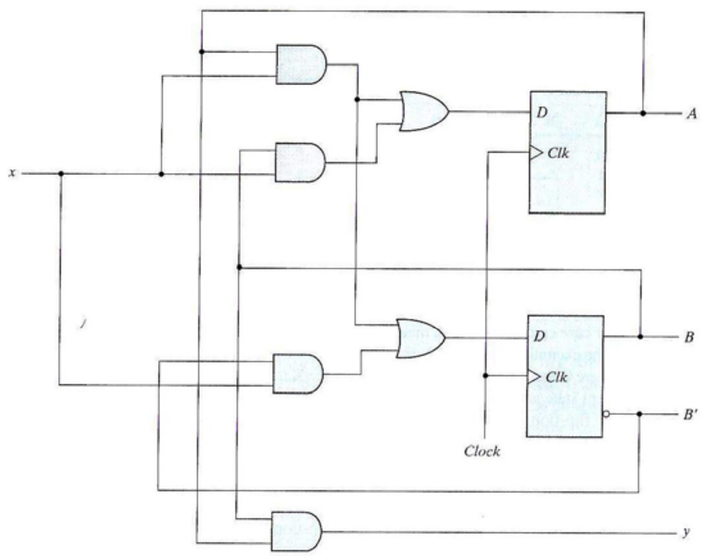


FIGURE 5.29
Logic diagram of sequence detector

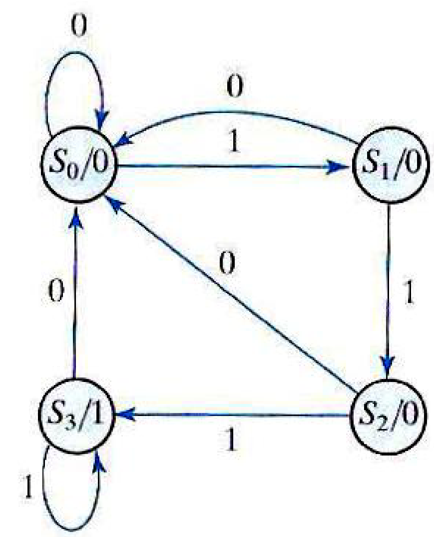


FIGURE 5.27
State diagram for sequence detector

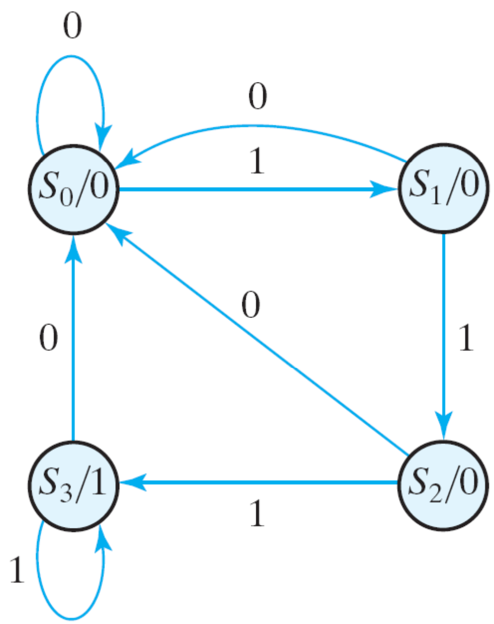
From circuit (equations)

$y = AB$
$D_A = Ax+Bx$
$D_B = Ax+B'x$

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

From state diagram



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

More Example: Binary Counter – show state diagram and table

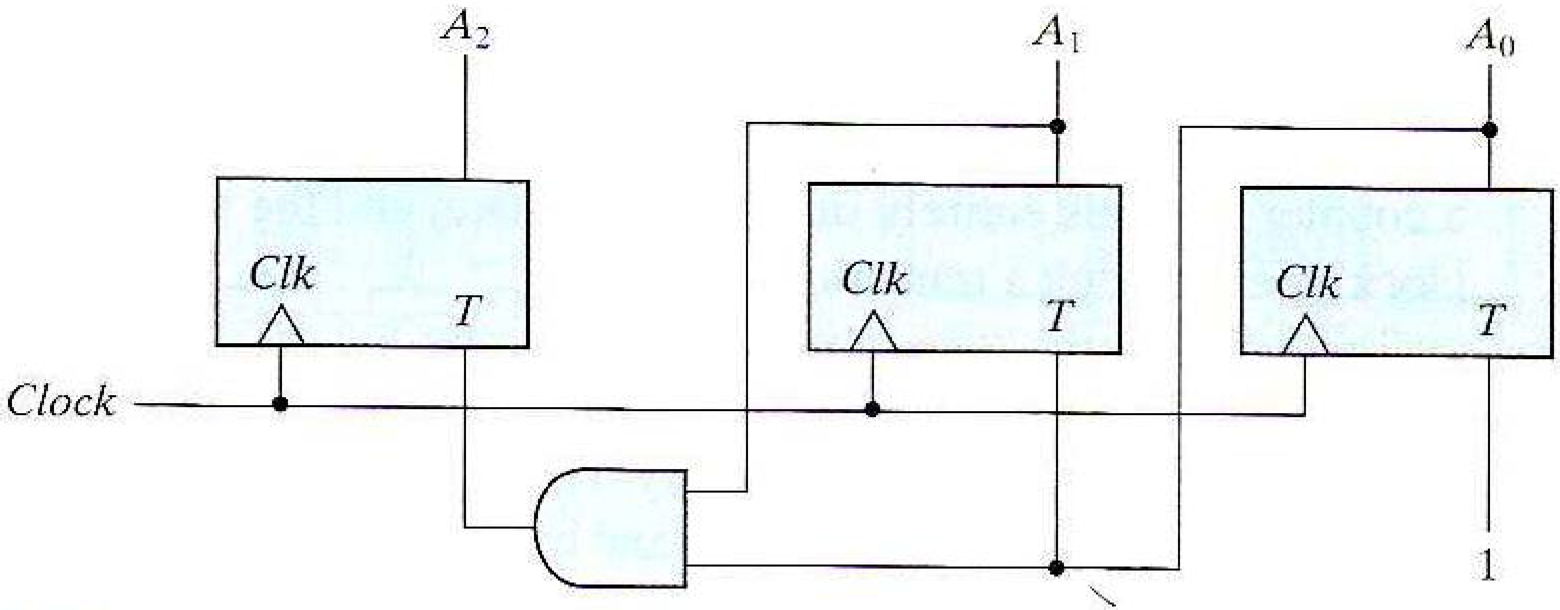


FIGURE 5.34
Logic diagram of three-bit binary counter

Circuit, State Diagram, State Table

More Example: Binary Counter – show state diagram and table

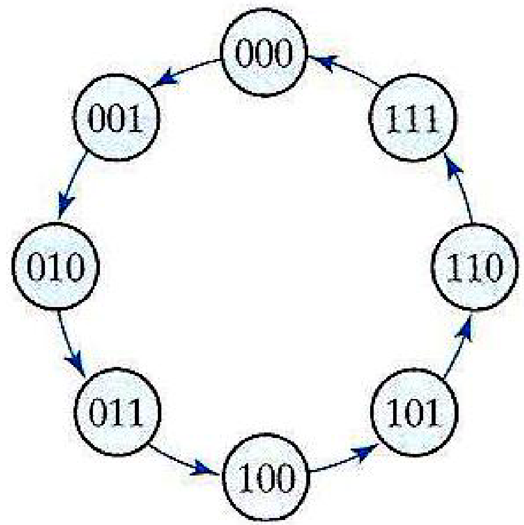


FIGURE 5.32
State diagram of three-bit binary counter

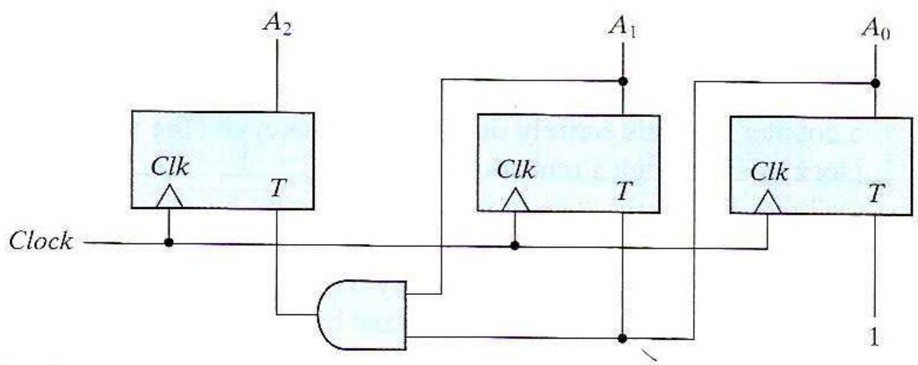


FIGURE 5.34
Logic diagram of three-bit binary counter

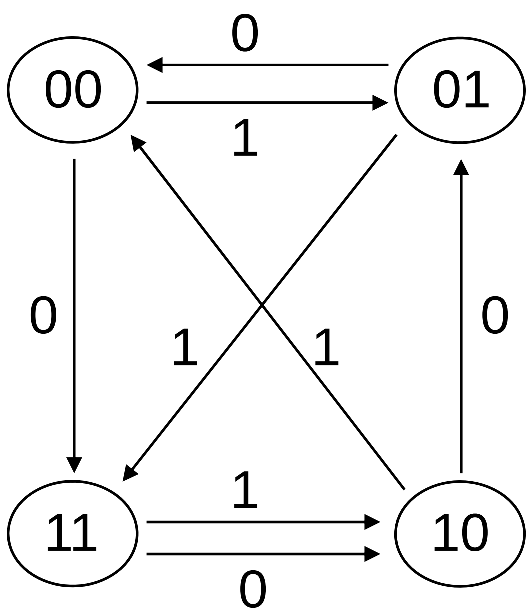
present state			next state		
A_2	A_1	A_0	A_2	A_1	A_0
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	1	0	1
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	0

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 (...→11→10→01→00→11→...)
- a Johnson counter when x=1 (...→00→01→11→10→00→...)



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

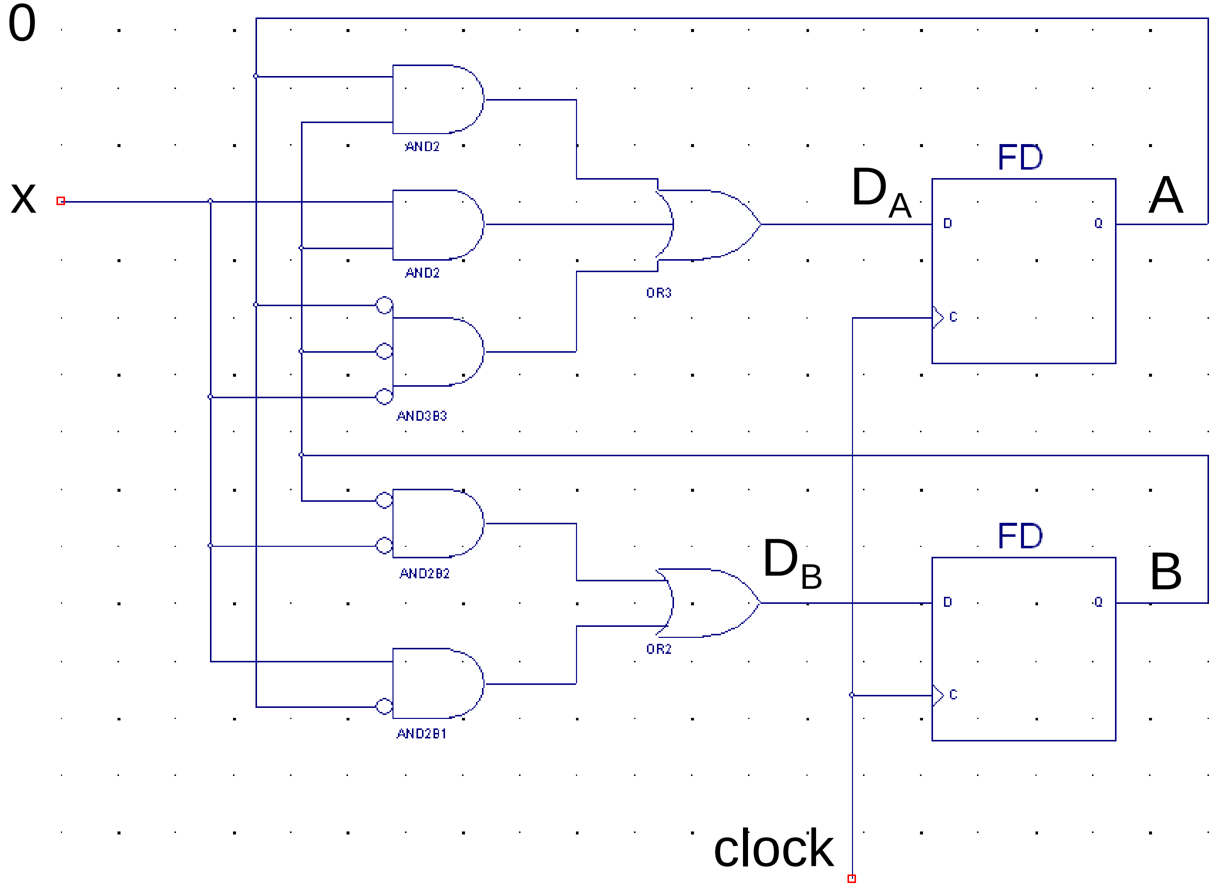
x \ AB	00	01	11	10
0	1	0	1	0
1	0	1	1	0

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

D_B

x \ AB	00	01	11	10
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

Circuit, State Diagram, State Table

Quiz: solution

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

Circuit, State Diagram, State Table

More Example:

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