Lecture 19 – Sequential circuits 5

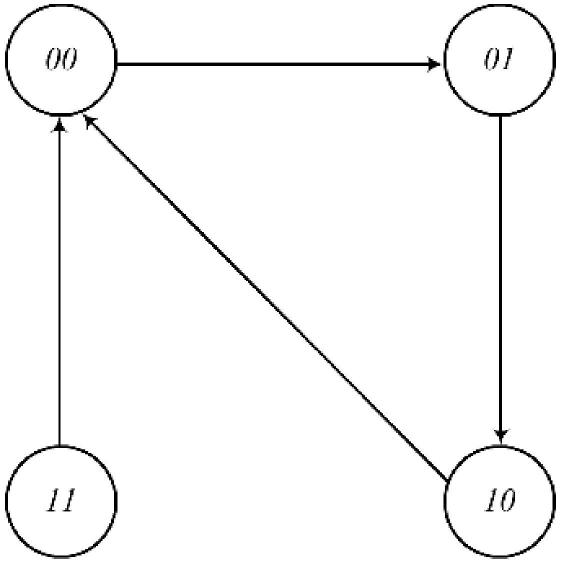
Chapter 5

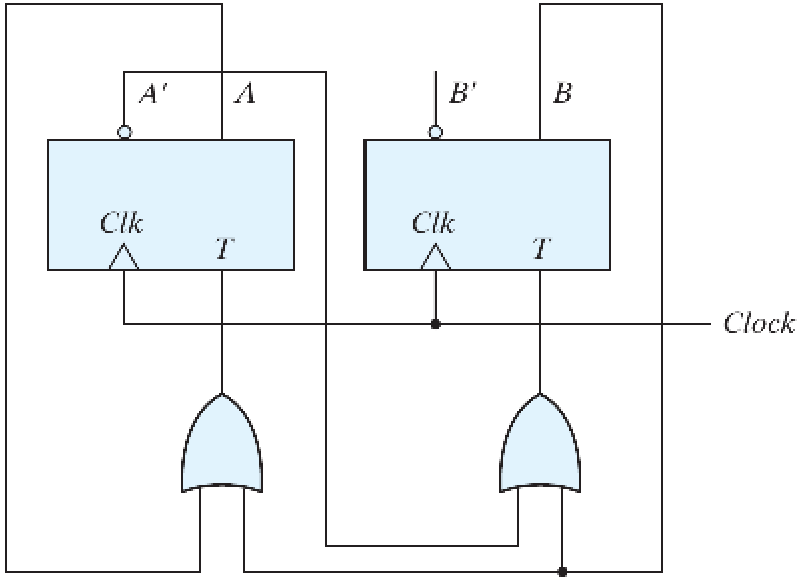
Sequential circuits - Analysis

$$T_A = A + B$$
$$T_B = A' + B$$

State Table:

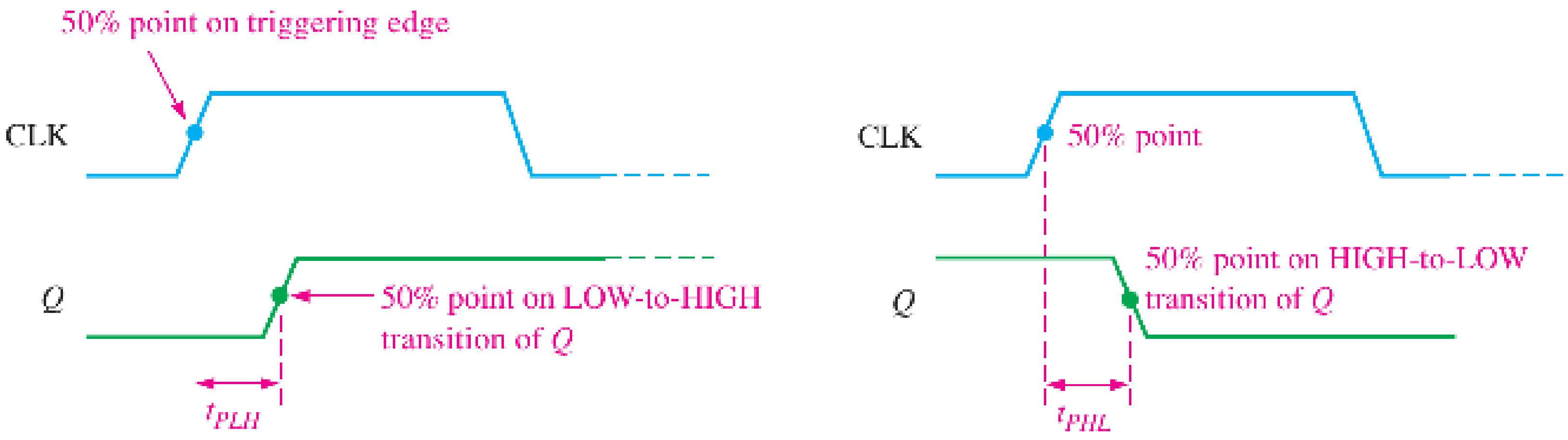
Present State		Next State		FF Inputs	
A	B	A	B	T_A	T_B
0	0	0	1	0	1
0	1	1	0	1	1
1	0	0	0	1	0
1	1	0	0	1	1





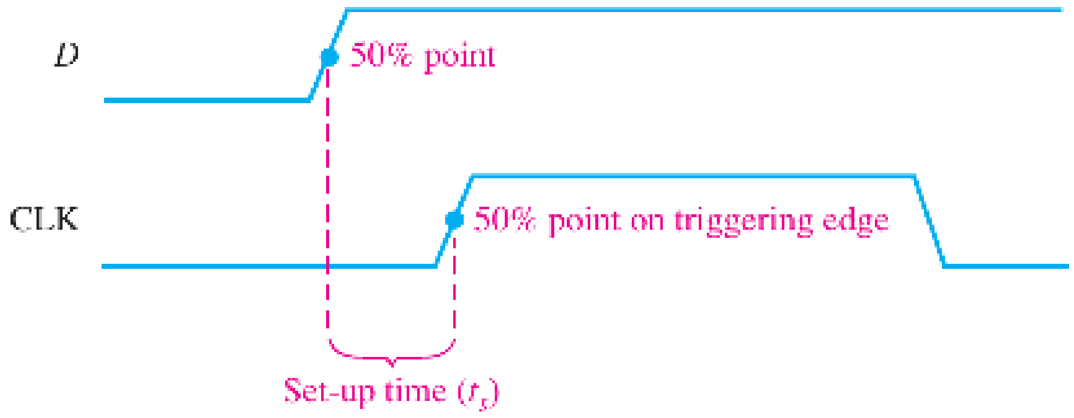
Sequential circuits

Propagation delay time is the interval of time required after an input signal has been applied for the resulting output change to occur

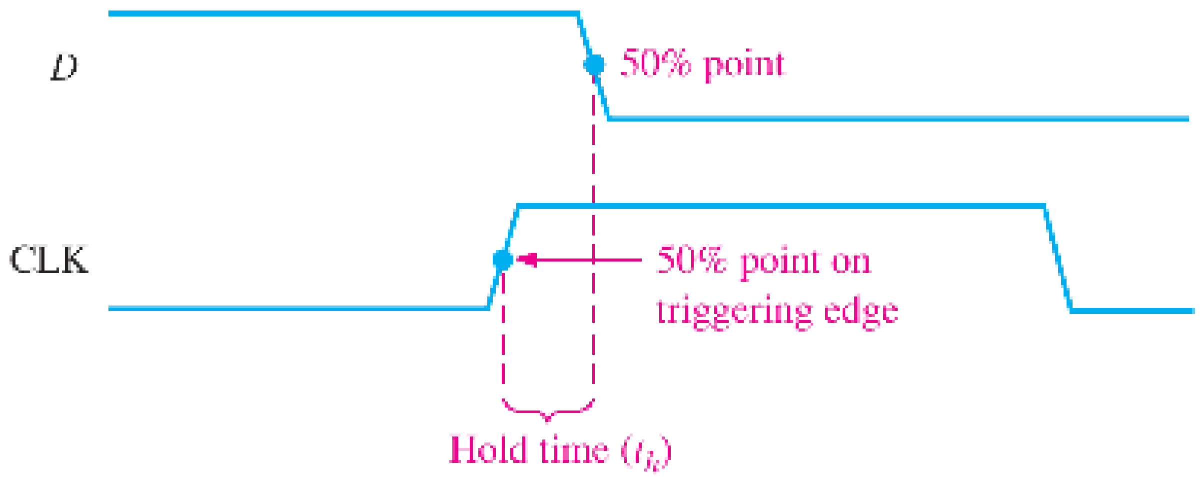


Sequential circuits

Set-up time (t_s): The logic level must be present on the input for a time equal to or greater than t_s before the triggering edge of the clock pulse for reliable data entry.



The hold time (t_h): is the minimum interval required for the logic levels to remain on the inputs after the triggering edge of the clock pulse in order for the levels to be reliably clocked into the flip-flop



Design procedure

- The procedure for designing synchronous sequential circuits can be summarized by a list of recommended steps:

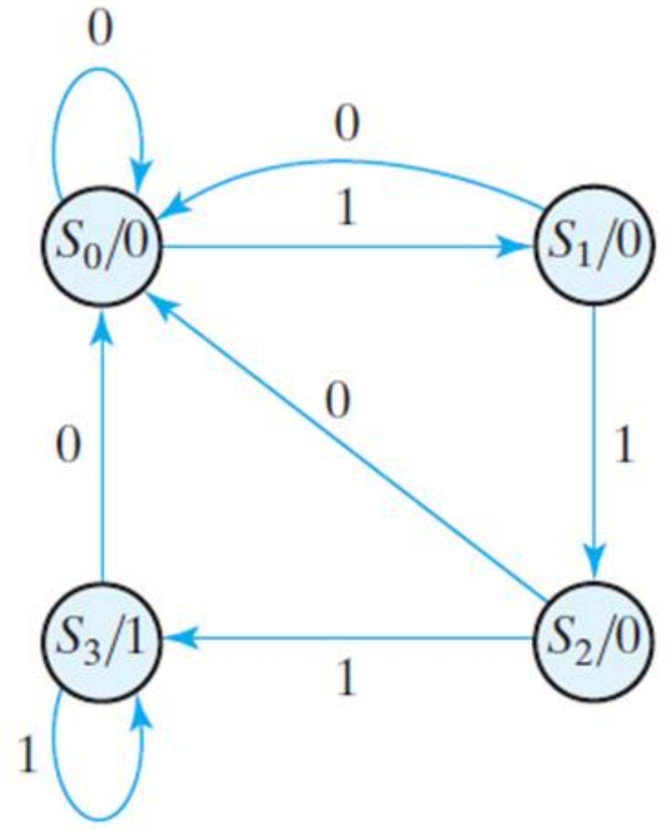
1. Derive a state diagram for the circuit
2. Assign binary values to the states
3. Obtain the binary-coded state table
4. Derive the simplified flip-flop input equations and output equations
5. Draw the logic diagram

The sequence of three detector

Sequence of three

- Suppose we wish to design a circuit that detects a sequence of three or more consecutive 1's in a string of bits coming through an input line (i.e., the input is a *serial bit stream*)
- We start with state S_0, the reset state
- If the input is 0, the circuit stays in S_0, but if the input is 1, it goes to state S_1 to indicate that a 1 was detected
- If the next input is 1, the change is to state S_2 to indicate the arrival of two consecutive 1's, but if the input is 0, the state goes back to S_0

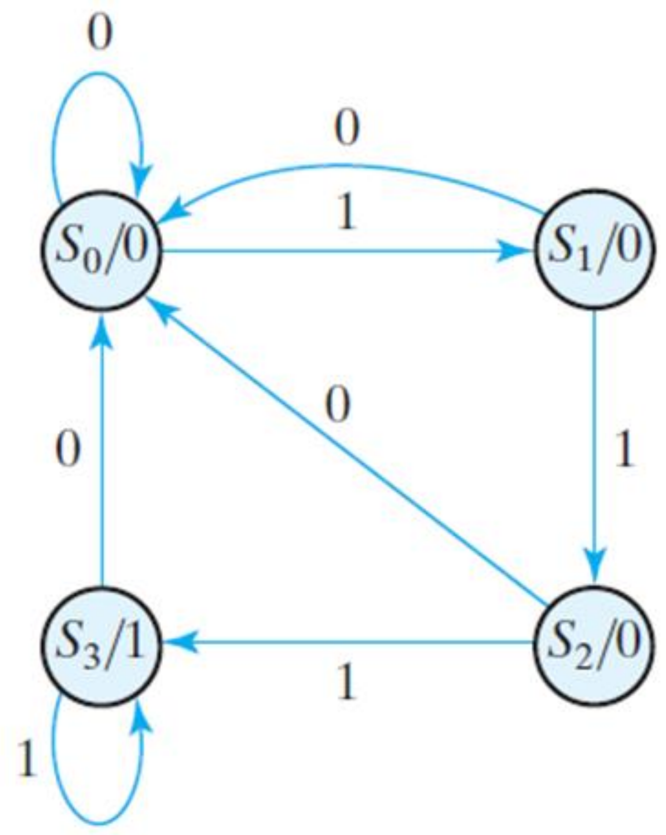
… 0111001111001 …



Sequence of three

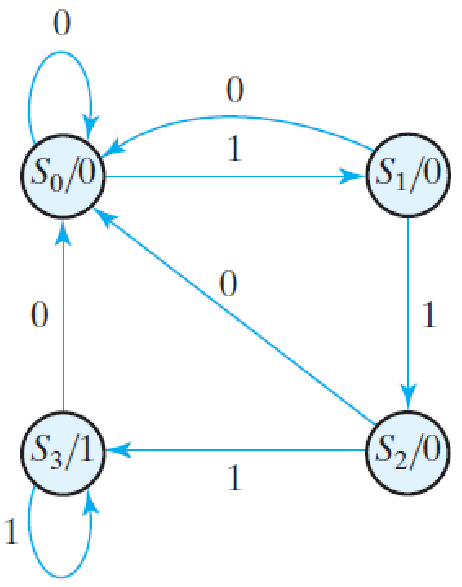
- The third consecutive 1 sends the circuit to state S_3
- If more 1's are detected, the circuit stays in S_3
- Thus, the circuit stays in S_3 as long as there are three or more consecutive 1's received
- The output is 1 when the circuit is in state S_3 and is 0 otherwise

… 0111001111001 …



Sequence of three

- To design the circuit, we need to assign binary codes to the states and list the state table
- The table is derived from the state diagram with a sequential binary assignment
- We choose two *D* flip-flops to represent the four states, and we label their outputs *A* and *B*
- There is one input *x* and one output *y*



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

Sequence of three

- The flip-flop input equations can be obtained directly from the next-state columns of *A* and *B* and expressed in sum-of-minterms form as:

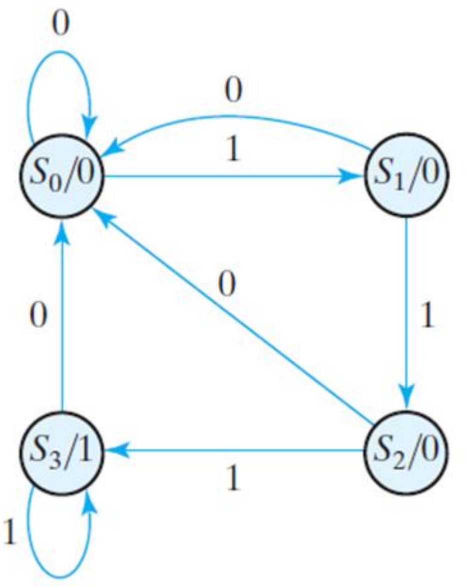
$$A(t+1) = D_A(A,B,x) = \sum(3,5,7)$$

$$B(t+1) = D_B(A,B,x) = \sum(1,5,7)$$

$$y(A,B,x) = \sum(6,7)$$

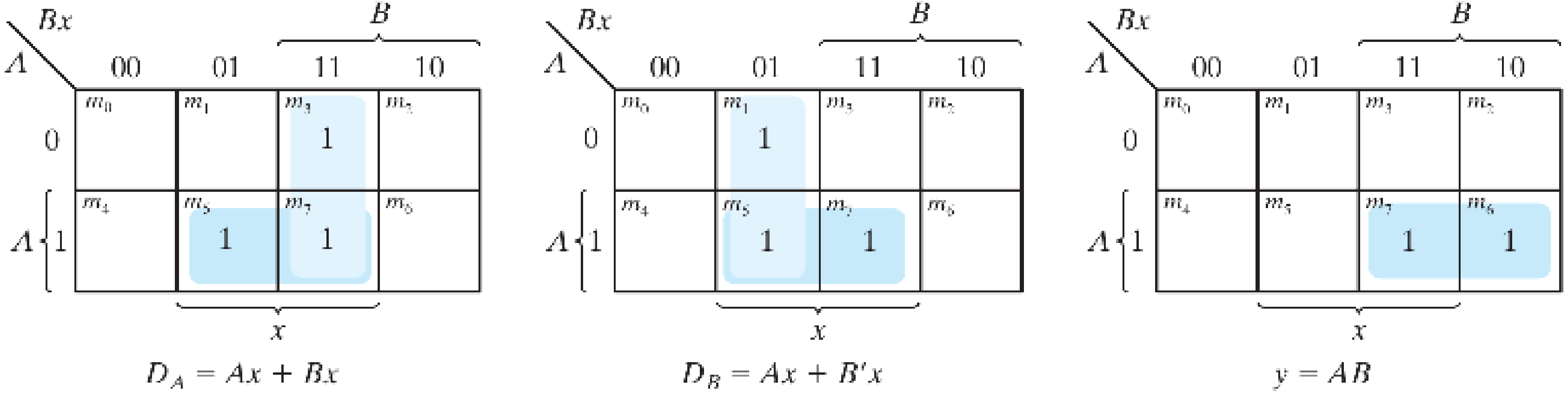
- Using K-maps, we can find the expressions for D_A, D_B and y as:

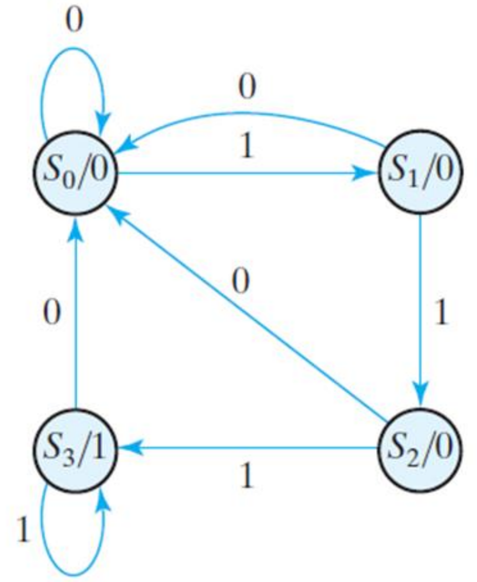
$$D_A = Ax + Bx$$
$$D_B = Ax + B'x$$
$$y = AB$$



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

Sequence of three





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

- Using K-maps, we can find the expressions for D_A, D_B and y as:

$$D_A = Ax + Bx$$
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$$y = AB$$

Sequence of three

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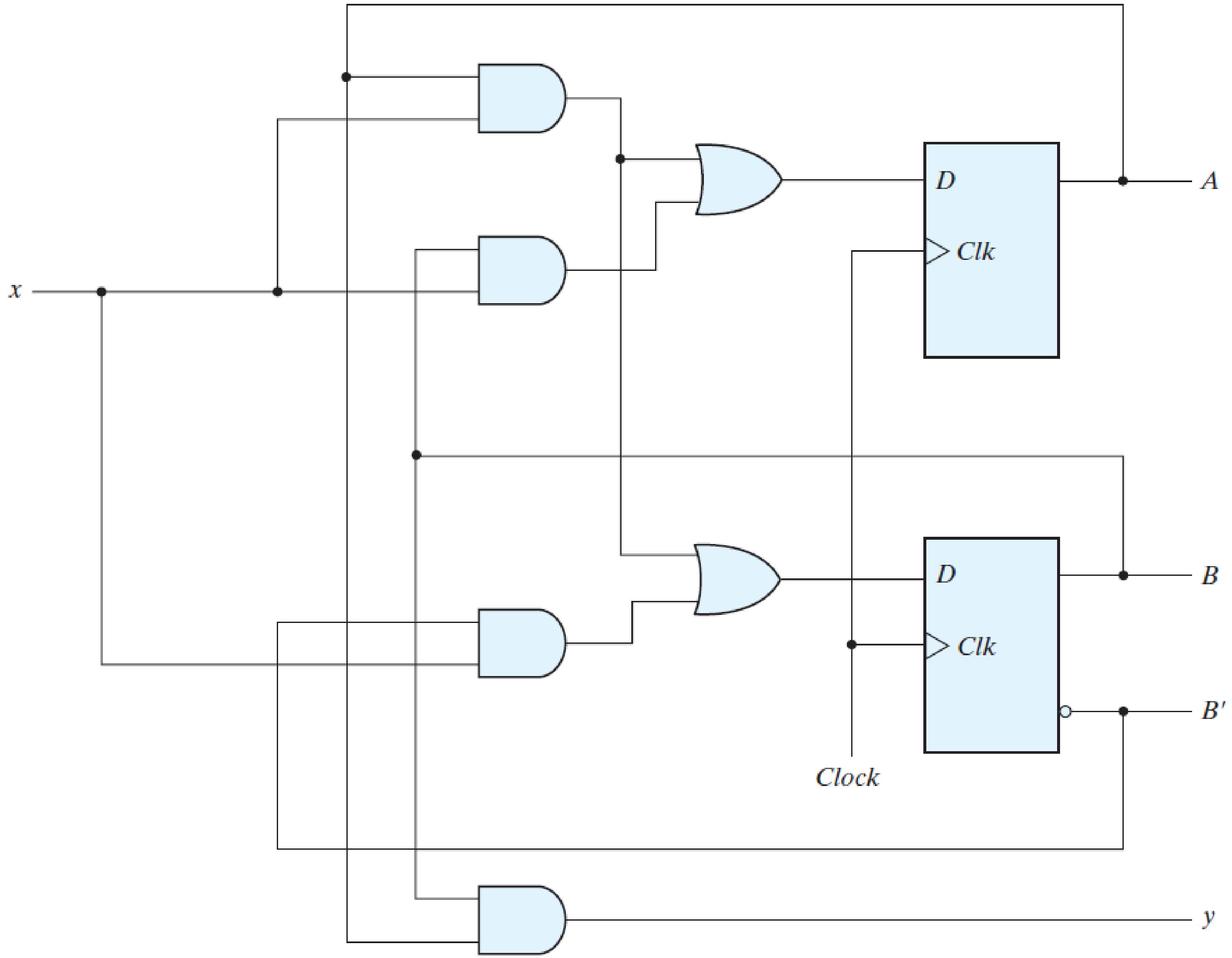
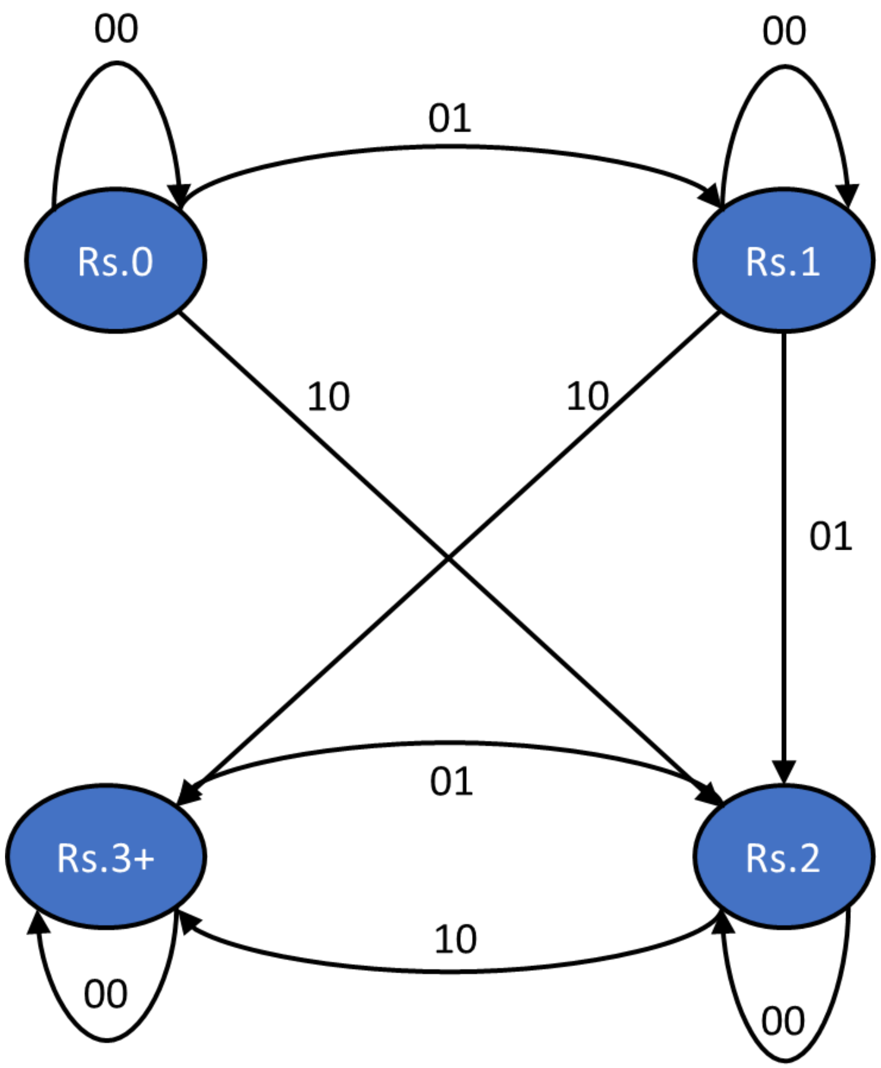


The vending machine

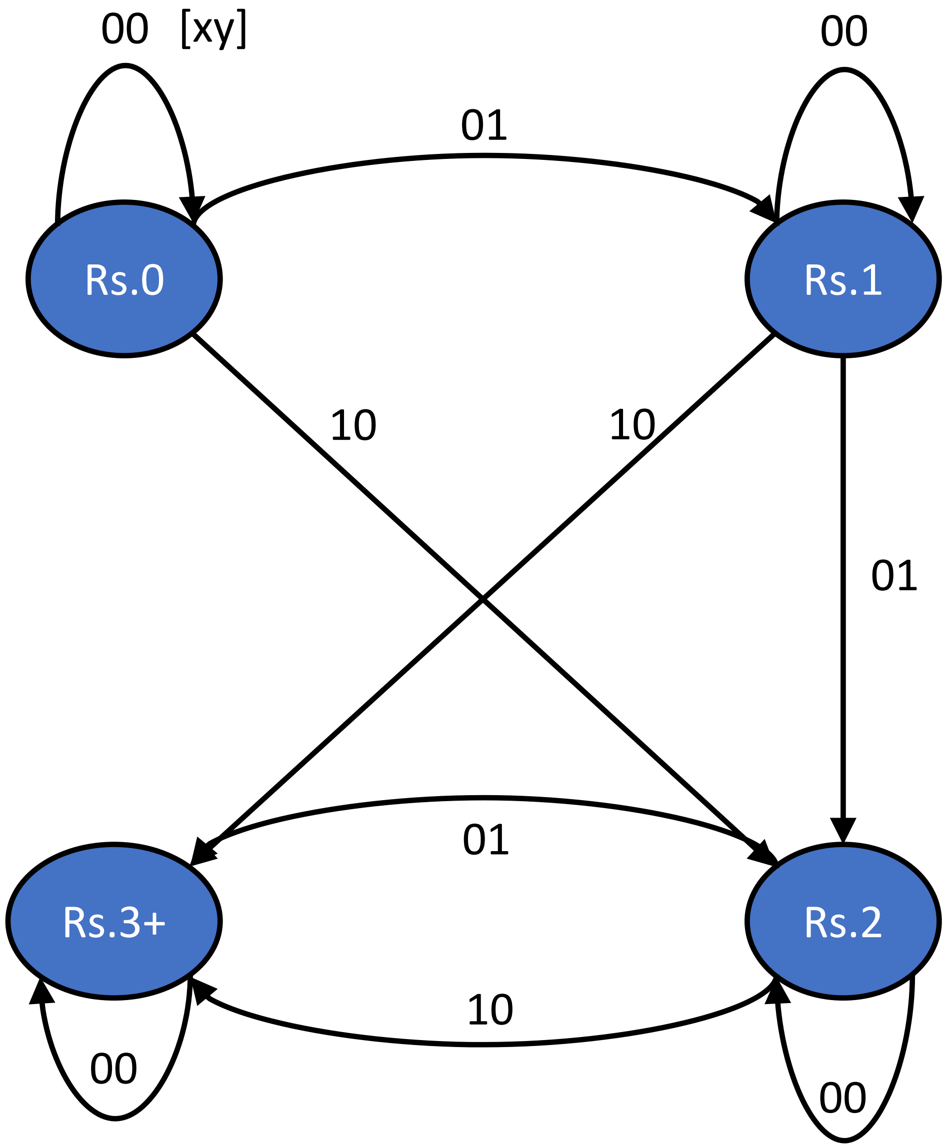
The vending machine

- Lets say we are asked to design a circuit for a vending machine that dispenses candy for Rs. 3
- The input consists of a coin slot that can accept Rs. 1 and Rs. 2 coins
- The deposit of these coins by the user is detected by a circuit that gives out two outputs x and y –
  - when Rs. 1 is inserted, y goes to one,
  - when Rs. 2 is inserted, x goes to one for one clock cycle.
  - x and y are at zero by default
- Only one coin can be entered at once
- We need to design a circuit that takes x and y as inputs and outputs 1 if the sum is ≥ 3, so that the machine can dispense the candy



The vending machine

A	B	x	y	A(t+1)	B(t+1)	z
0	0	0	0	0	0	0
0	0	0	1	0	1	0
0	0	1	0	1	0	0
0	0	1	1	X	X	0
0	1	0	0	0	1	0
0	1	0	1	1	0	0
0	1	1	0	1	1	0
0	1	1	1	X	X	0
1	0	0	0	1	0	0
1	0	0	1	1	1	0
1	0	1	0	1	1	0
1	0	1	1	X	X	0
1	1	0	0	1	1	1
1	1	0	1	1	1	1
1	1	1	0	1	1	1
1	1	1	1	X	X	1



The vending machine

A(t+1)

AB \ xy	00	01	11	10
00	m_0 0	m_1 0	m_3 X	m_2 1
01	m_4 0	m_5 1	m_7 X	m_6 1
11	m_{12} 1	m_{13} 1	m_{15} X	m_{14} 1
10	m_8 1	m_9 1	m_{11} X	m_{10} 1

x

B

A

y

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

The vending machine

B(t+1)

x

AB \ xy	00	01	11	10
00	m_0 0	m_1 1	m_3 X	m_2 0
01	m_4 1	m_5 0	m_7 X	m_6 1
11	m_{12} 1	m_{13} 1	m_{15} X	m_{14} 1
10	m_8 0	m_9 1	m_{11} X	m_{10} 1

B

A

y