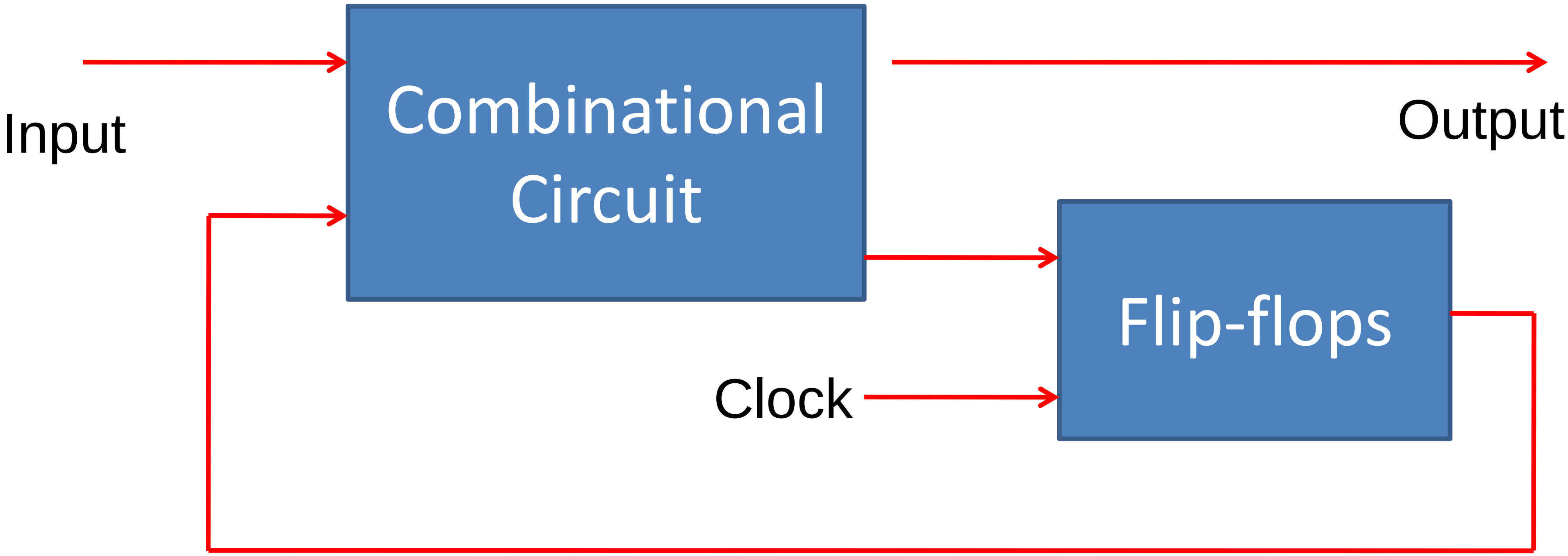
ESc201 : Introduction to Electronics

Sequential Circuits

Amit Verma
Dept. of Electrical Engineering
IIT Kanpur

Synchronous Sequential Circuits

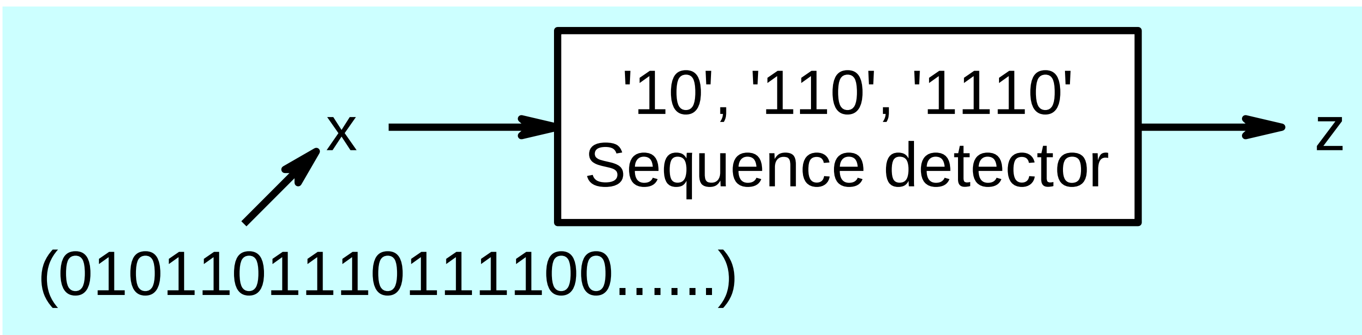


Employs signals that affect the storage elements only at discrete instants of time.

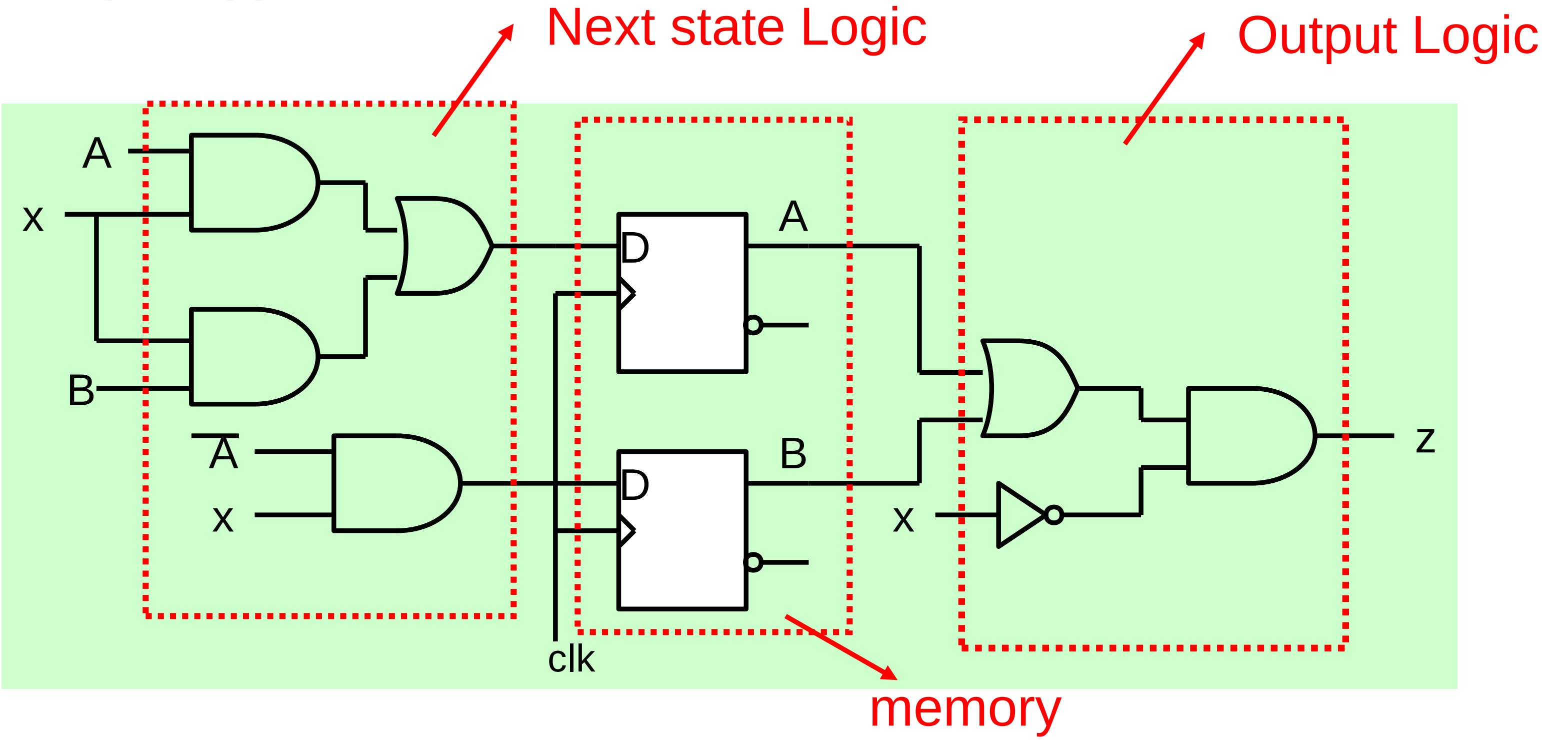
Synchronization is achieved via the ***clock pulses***.

Synchronous Clocked Sequential Circuits

Synchronous Sequential Circuit Example



Analysis (recap)



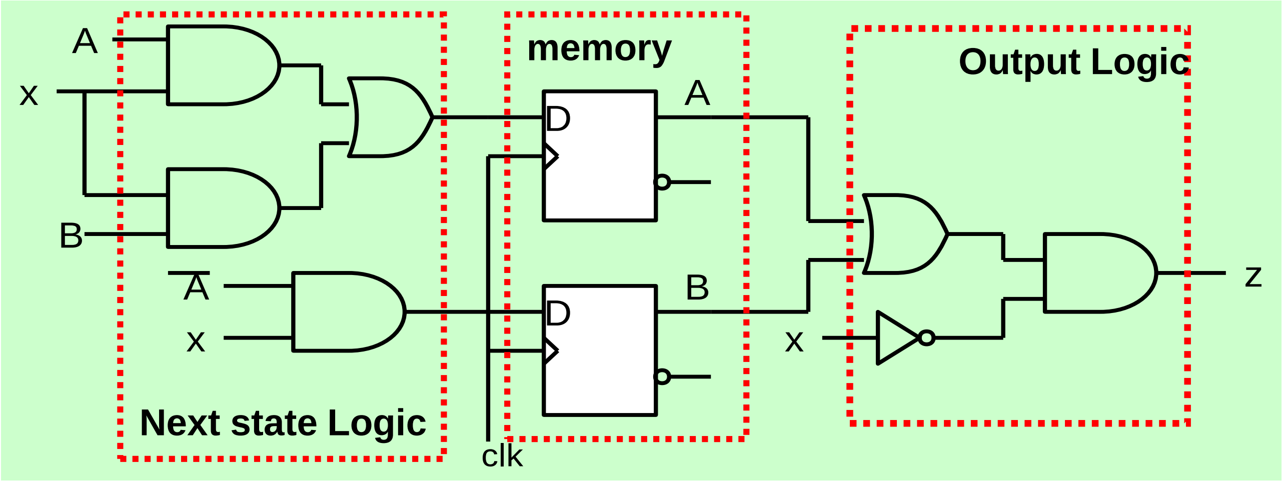
Output z depends on the input x and on the current state of the memory (A,B)

The memory has 2 FFs and each FF can be in state 0 or 1. Thus there are four possible states: AB: 00,01,10,11.

To describe the behavior of a sequential circuit, we need to show

1. How the system goes from one memory state to the next as the input changes
2. How the output responds to input in each state

Analysis of Sequential Circuits (recap)



$$D_A = A.x + B.x \quad ; \; D_B = \overline{A}.x \, ; z = (A+B).\overline{x}$$

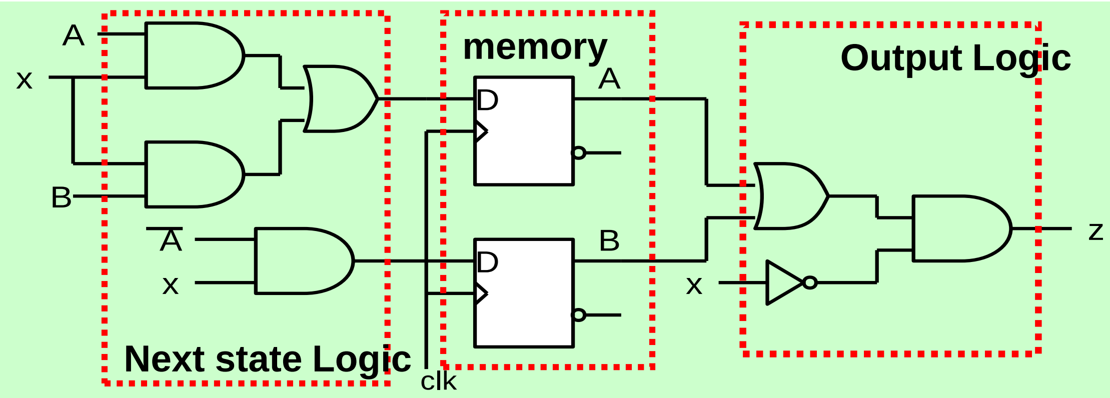
$$A(t+1) = A(t).x + B(t).x$$

$$B(t+1) = \overline{A(t)}.x$$

$$z = (A+B).\overline{x}$$

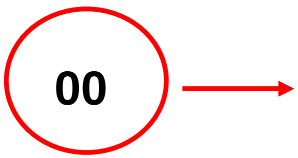
State Transition Table

Present State		Input	Next State		Output
A	B	x	A	B	z
0	0	0	**0**	**0**	**0**
0	0	1	**0**	**1**	**0**
0	1	0	**0**	**0**	**1**
0	1	1	**1**	**1**	**0**
1	0	0	**0**	**0**	**1**
1	0	1	**1**	**0**	**0**
1	1	0	**0**	**0**	**1**
1	1	1	**1**	**0**	**0**

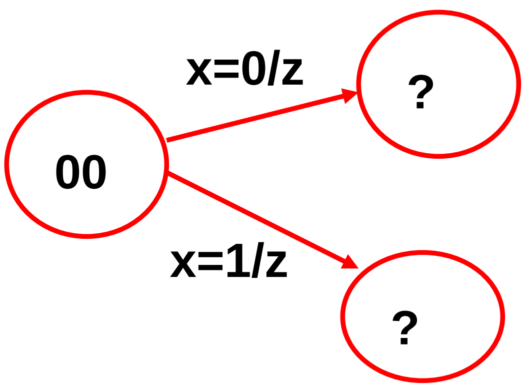


State Transition Table

Present State A	Present State B	Input x	Next State A	Next State B	Output z
0	0	0	**0**	**0**	**0**
0	0	1	**0**	**1**	**0**
0	1	0	**0**	**0**	**1**
0	1	1	**1**	**1**	**0**
1	0	0	**0**	**0**	**1**
1	0	1	**1**	**0**	**0**
1	1	0	**0**	**0**	**1**
1	1	1	**1**	**0**	**0**

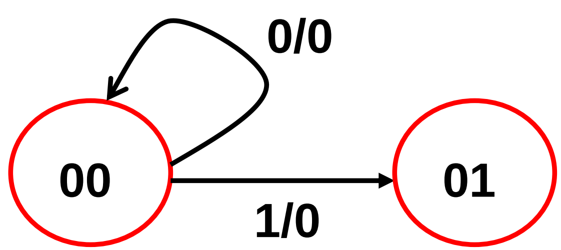


Memory state in which FF A& B have output values 00

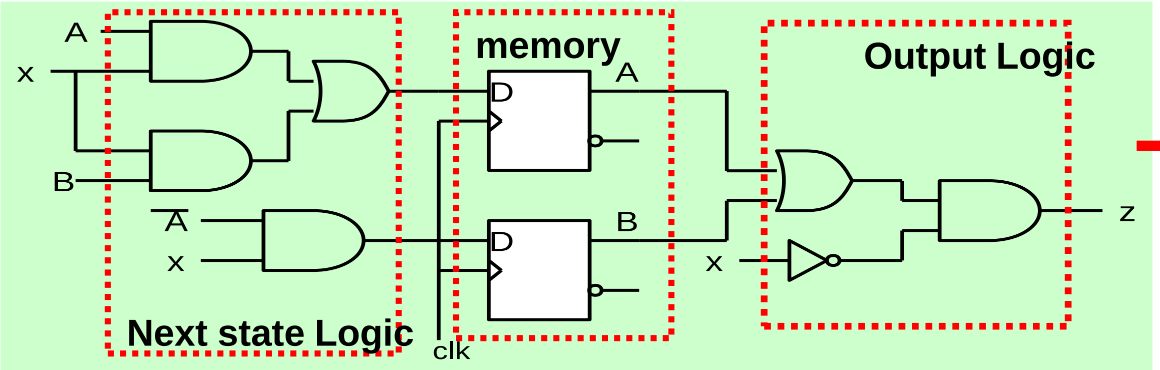


If x = 0 then z = 0, When the clock edge comes the system would stay in 00 state.

If x = 1 then z = 0. When the clock edge comes the system would go to 01 state.



Analysis of Sequential Circuits



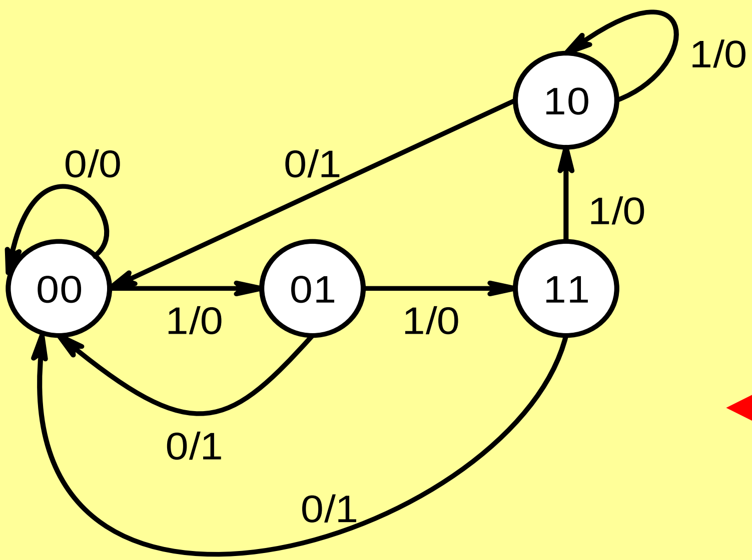
$$A(t+1) = A(t).x + B(t).x$$

$$B(t+1) = \overline{A(t)}.x$$

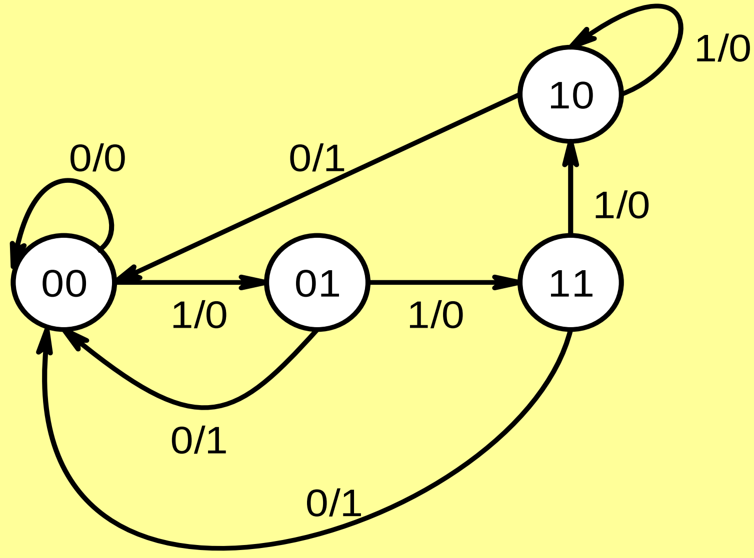
$$z = (A+B).\overline{x}$$

State Transition Table

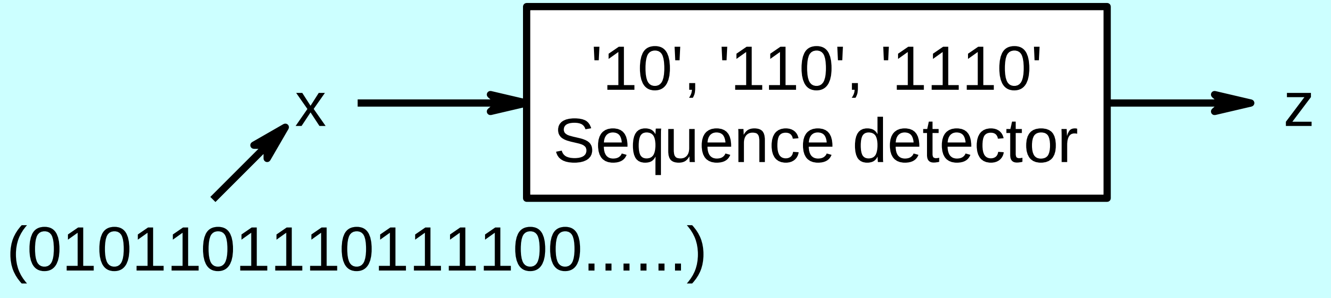
Present State A	Present State B	Input x	Next State A	Next State B	Output z
0	0	0	**0**	**0**	**0**
0	0	1	**0**	**1**	**0**
0	1	0	**0**	**0**	**1**
0	1	1	**1**	**1**	**0**
1	0	0	**0**	**0**	**1**
1	0	1	**1**	**0**	**0**
1	1	0	**0**	**0**	**1**
1	1	1	**1**	**0**	**0**



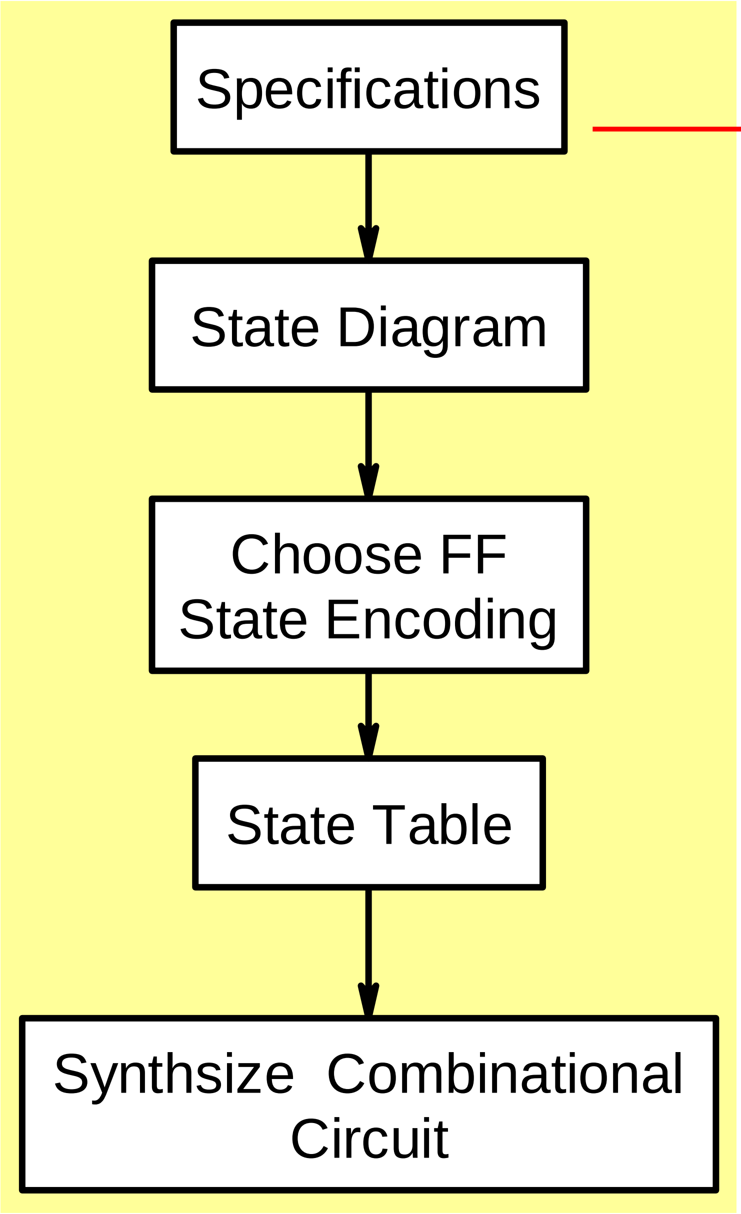
State transition Graph

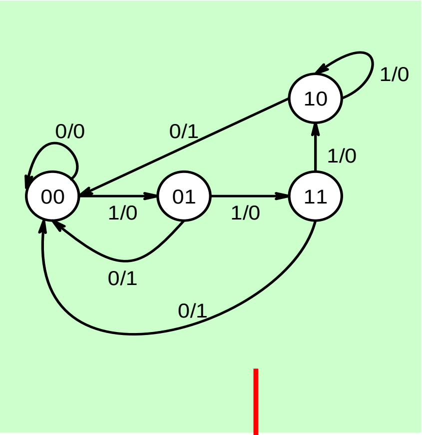


State transition Graph



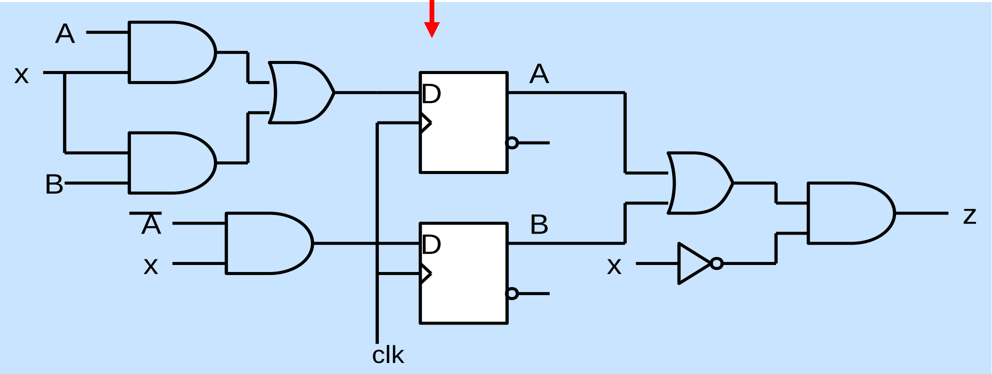
Design of Sequential Circuits



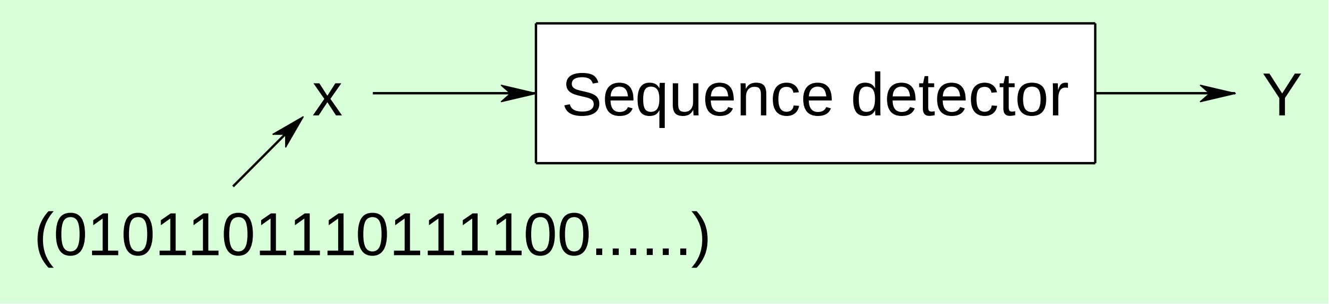


State Transition Table

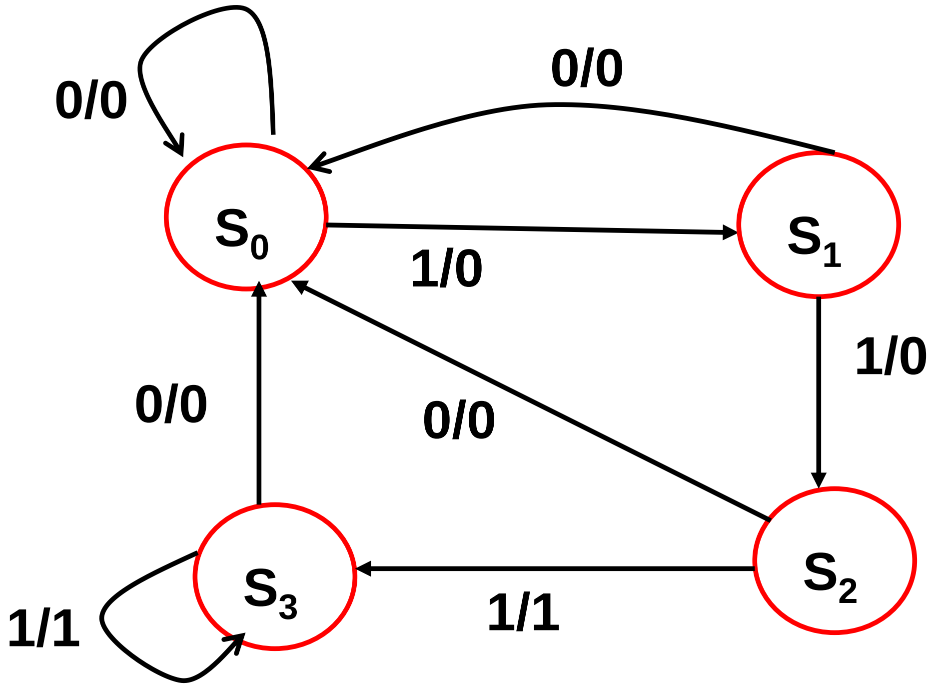
Present State		Input	Next State		Output
A	B	x	A	B	z
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0



System specification to State diagram

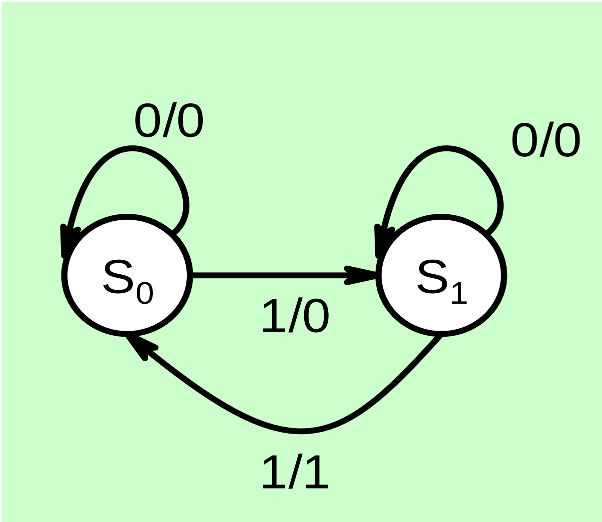


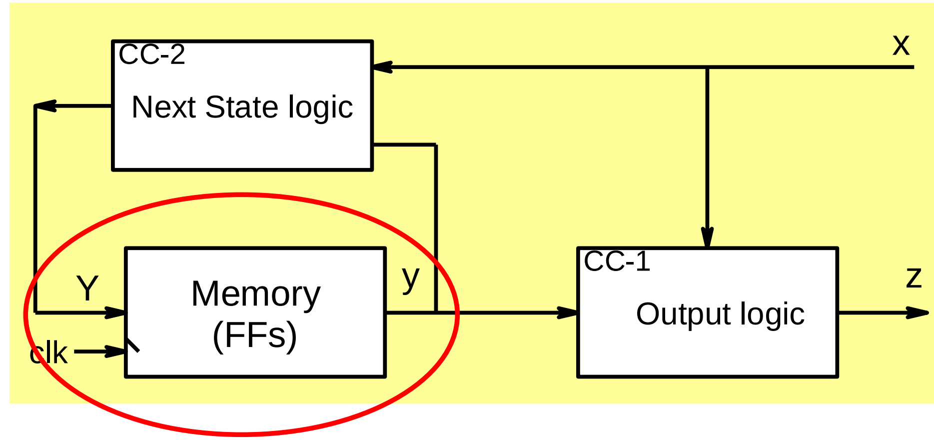
Detect 3 or more consecutive 1's in the input stream



Conversion of State transition graph to a circuit

Example-1



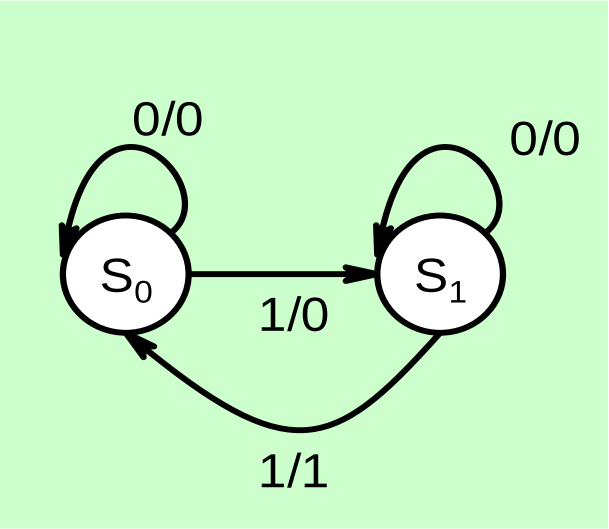


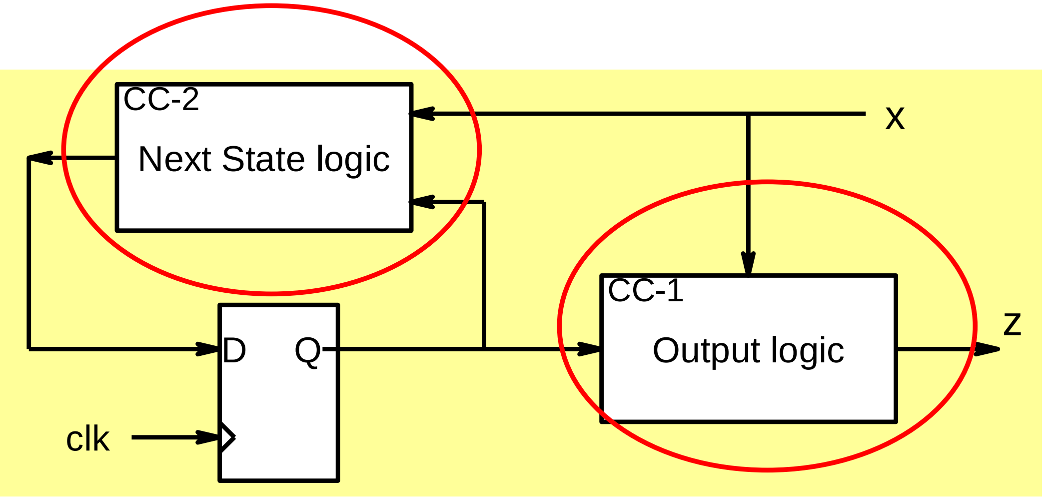
3 blocks need to be designed

1. How many FFs do we need? **N FFS can represent 2^N states so Minimum is 1**

2. Which FF do we choose? **Say D FF**

3. How are the states encoded? **Say FF output Q=0 represents S_0 and Q=1 represents S_1 state**

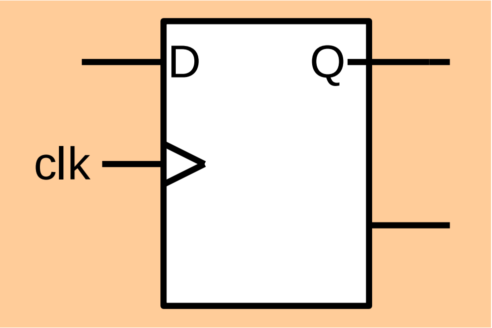




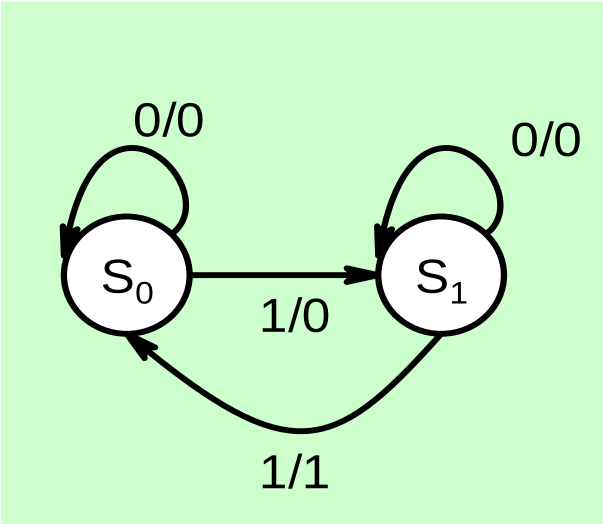
State Transition Table

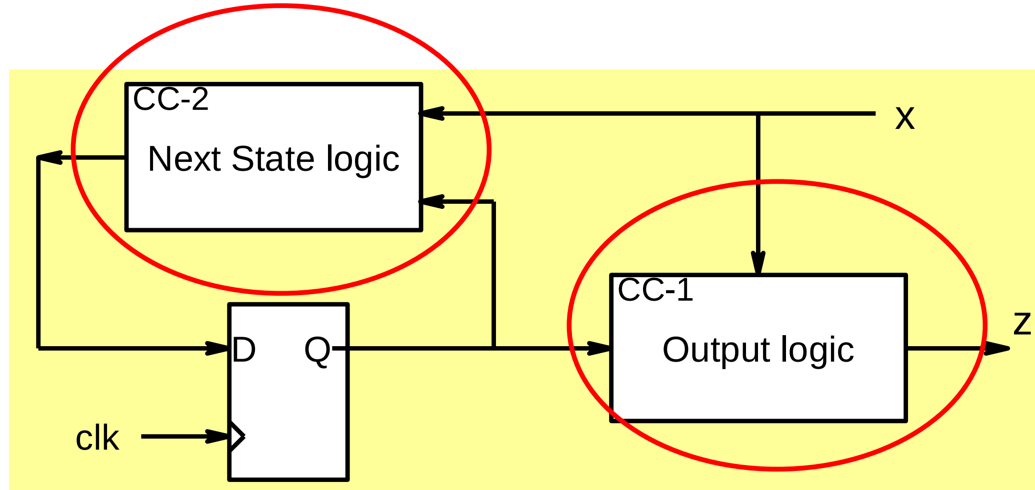
Present State Q(t)	Input x	Next State Q(t+1)	D	Output z
0	0	0		0
0	1	1		0
1	0	1		0
1	1	0		1

Excitation Table



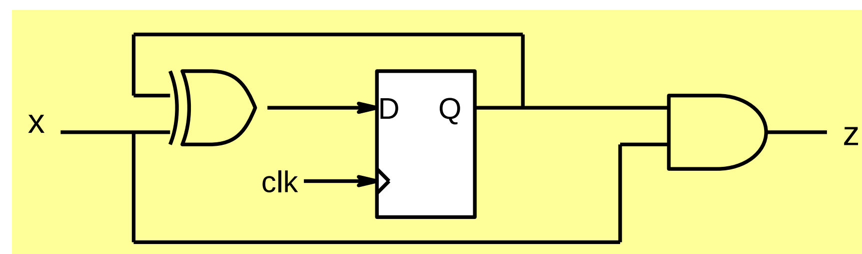
		Inputs
Q(t)	Q(t+1)	**D**
0	0	**0**
0	1	**1**
1	0	**0**
1	1	**1**





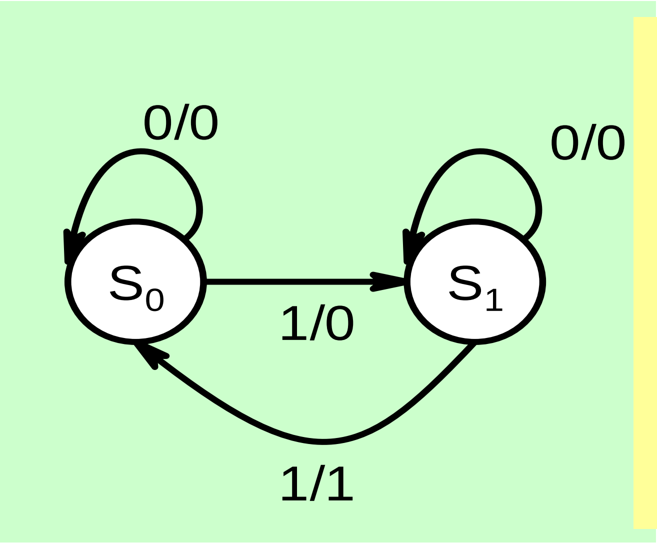
State Transition Table

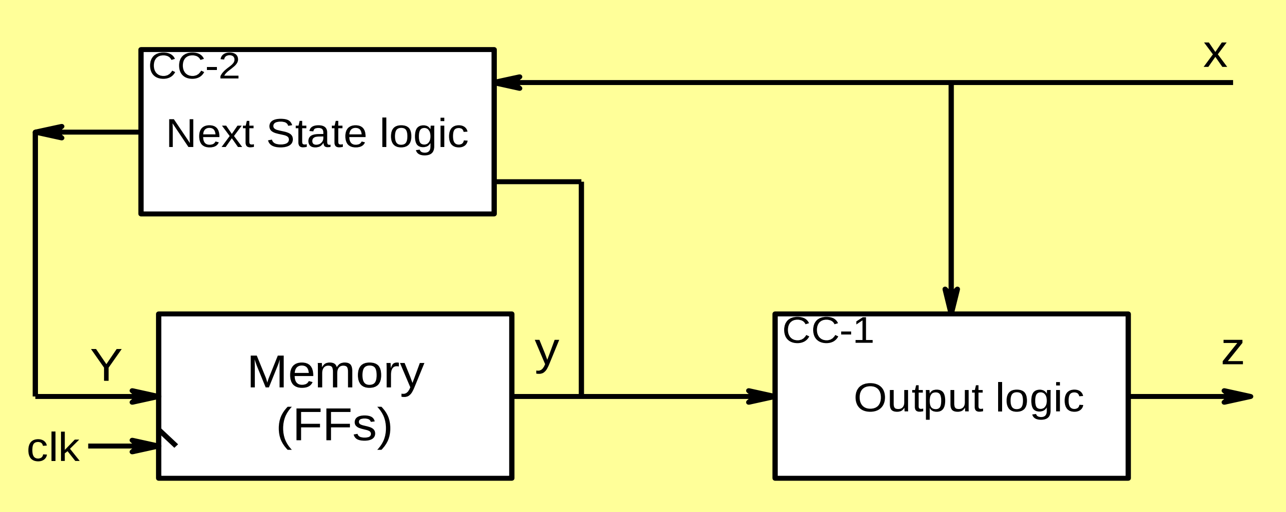
Present State Q(t)	Input x	Next State Q(t+1)	D	Output z
0	0	0	**0**	0
0	1	1	**1**	0
1	0	1	**1**	0
1	1	0	**0**	1



$$D = \overline{Q}.x + Q.\overline{x} \quad ; \quad z = Q.x$$

Example-2

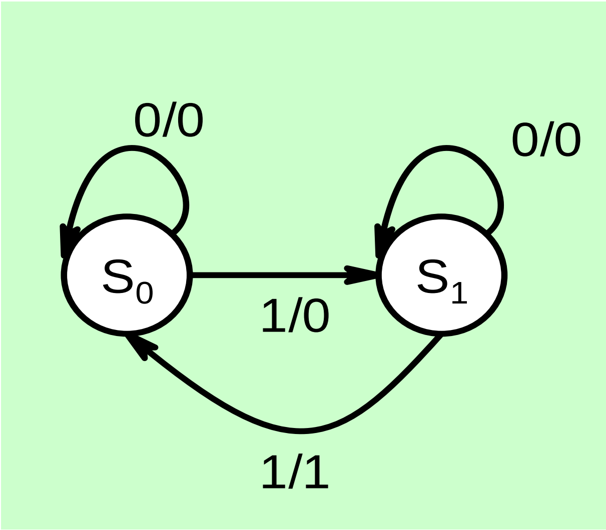


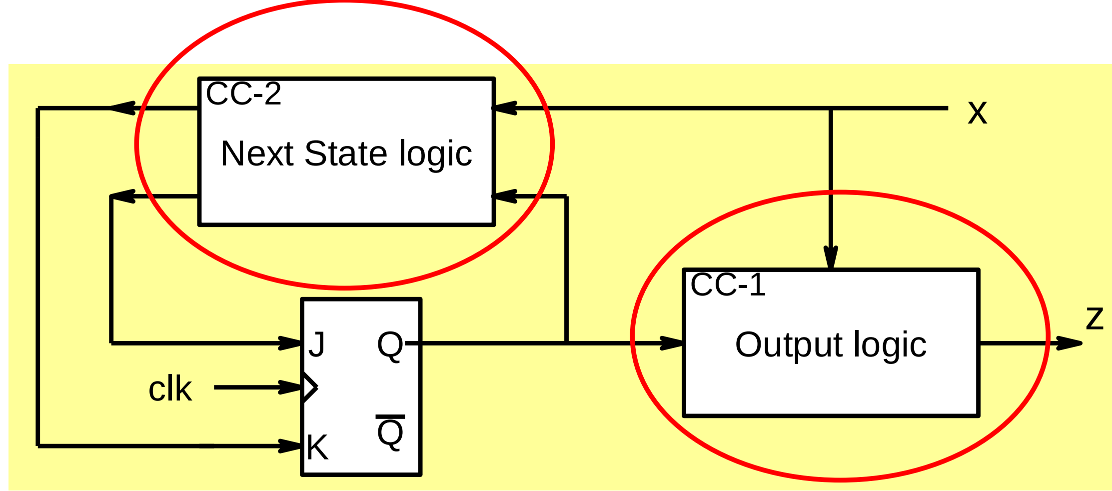


1. How many FFs do we need? **1**

2. Which FF do we choose? **Say JK FF**

3. How are the states encoded? **Say FF output Q=0 represents S_0 and Q=1 represents S_1 state**

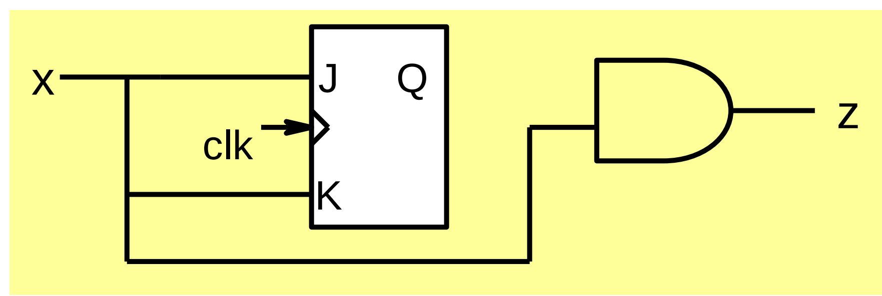




Q(t)	Q(t+1)	J K
0	0	0 X
0	1	1 X
1	0	X 1
1	1	X 0

State Transition Table

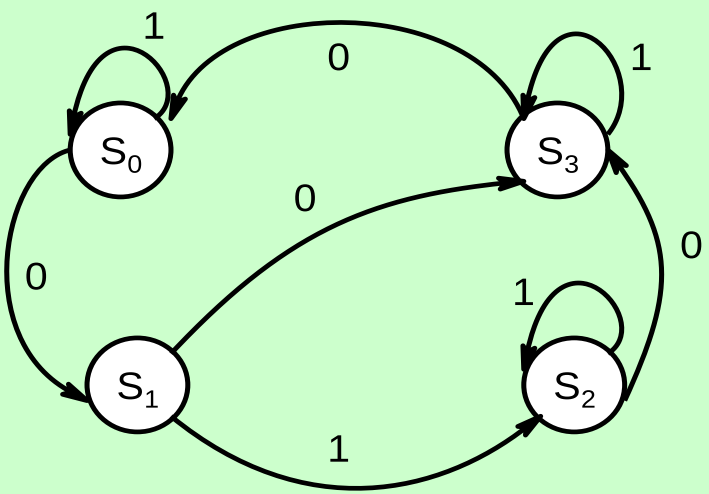
Present State Q(t)	Input x	Next State Q(t+1)	J K	Output z
0	0	0	**0 X**	0
0	1	1	**1 X**	0
1	0	1	**X 0**	0
1	1	0	**X 1**	1

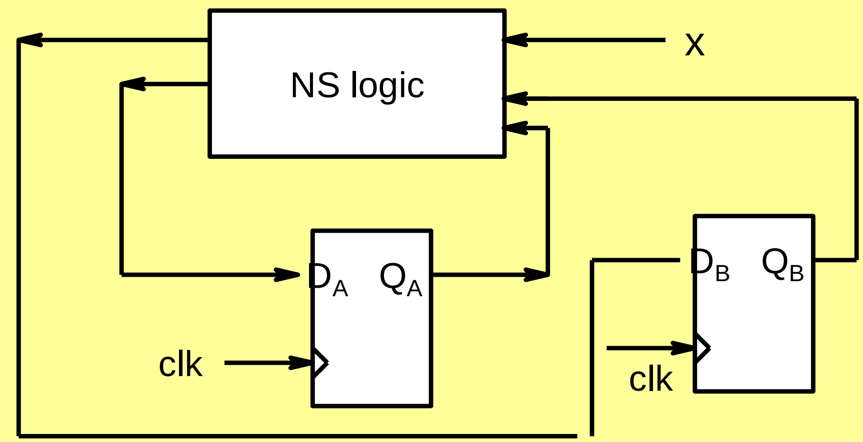


$$J = x \;\; ; K = x; \;\; z = Q.x$$

Example-3

For 4 states a minimum of two FFs will be required. Let us choose 2 D FFs A &B





State	FF O/P A	B
S_0	0	0
S_1	0	1
S_2	1	0
S_3	1	1

Present State A	B	Input x	Next State A	B	D_A	D_B
0	0	0	0	1	0	1
0	0	1	0	0	0	0
0	1	0	1	1	1	1
0	1	1	1	0	1	0
1	0	0	1	1	1	1
1	0	1	1	0	1	0
1	1	0	0	0	0	0
1	1	1	1	1	1	1

Present State		Input	Next State			
A	B	x	A	B	D_A	D_B
0	0	0	0	1	0	1
0	0	1	0	0	0	0
0	1	0	1	1	1	1
0	1	1	1	0	1	0
1	0	0	1	1	1	1
1	0	1	1	0	1	0
1	1	0	0	0	0	0
1	1	1	1	1	1	1

D_A

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

$$D_A = \overline{A}B + xB + A\overline{B}$$
$$= A \oplus B + x.B$$

D_B

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

$$D_B = \overline{x}.\overline{A} + \overline{x}.\overline{B} + x.A.B$$
$$= \overline{x}.(\overline{A} + \overline{B}) + x.A.B$$
$$= \overline{x}.\overline{AB} + x.AB = \overline{x \oplus AB}$$

$$D_A = A \oplus B + x.B$$

$$D_B = \overline{x \oplus AB}$$