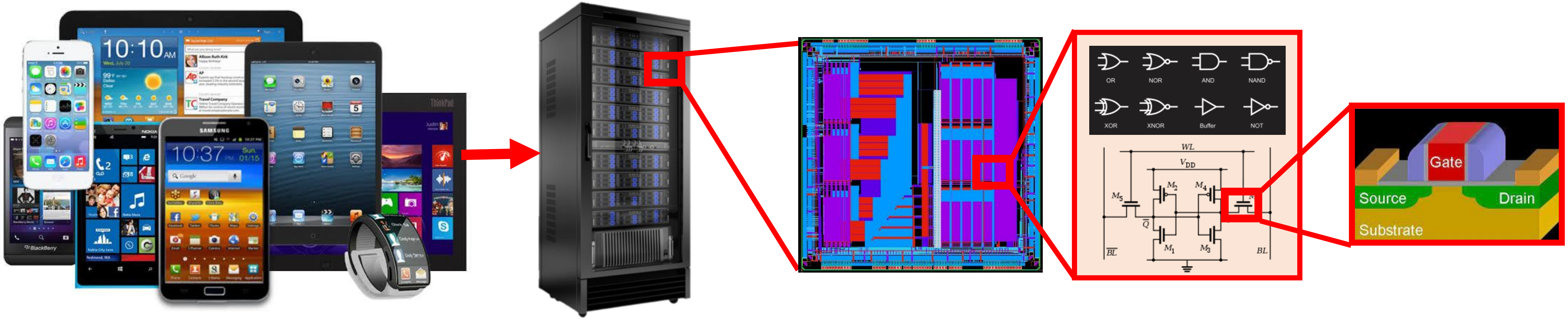

ESC201: Introduction to Electronics

Module 6: Digital Circuits

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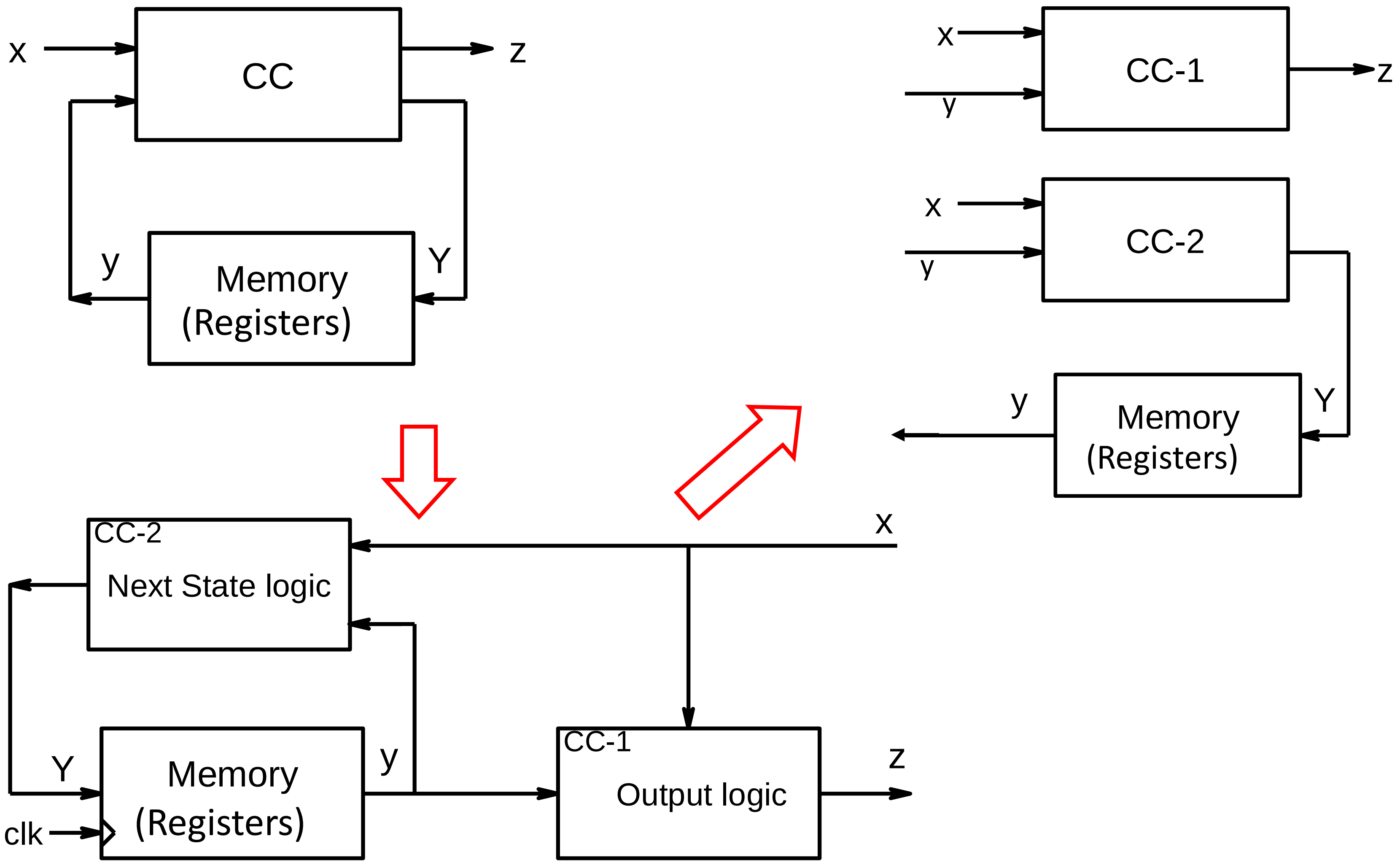
Department of Electrical Engineering,
IIT Kanpur

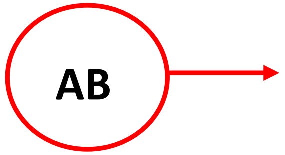
Visualising the Sequential Circuit



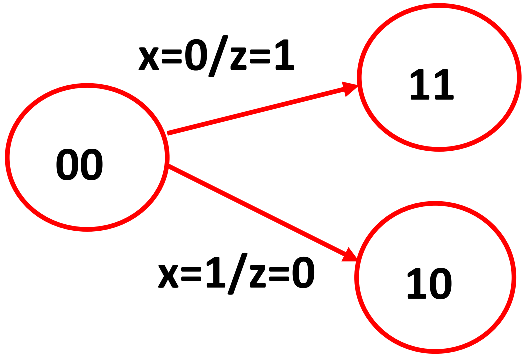
CC →Combinational Circuit

State Transition Diagrams

For Analysis, we want to visualise the sequential circuit as “State Transition Diagrams”.

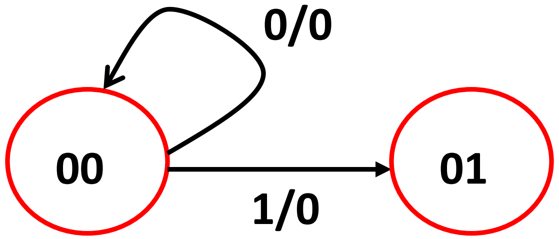


==**Memory state**== decided by contents of registers A& B



Initial state is 00. **Next state** can be 11 or 10 depending x.

Value of z is defined by current state and input x.



If x = 0 then z = 0

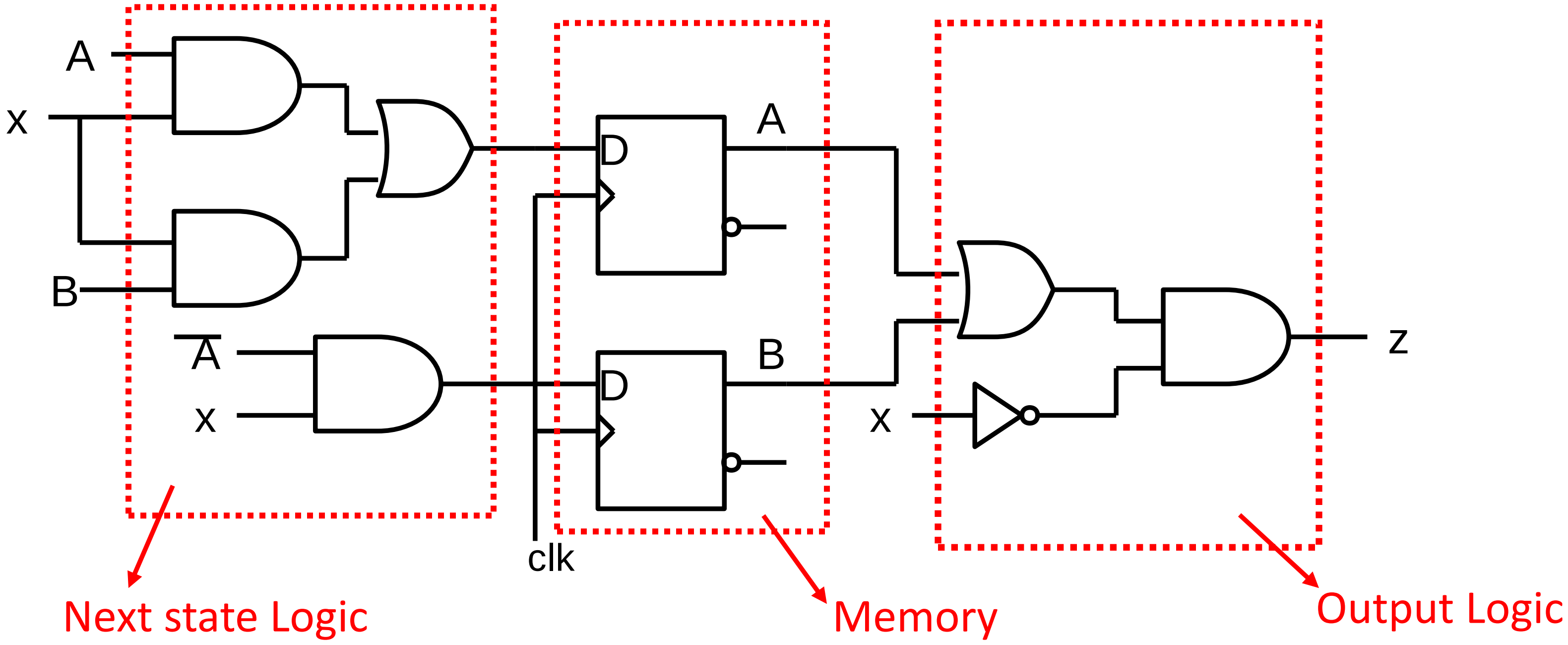
the system would stay in 00 state at clock edge.

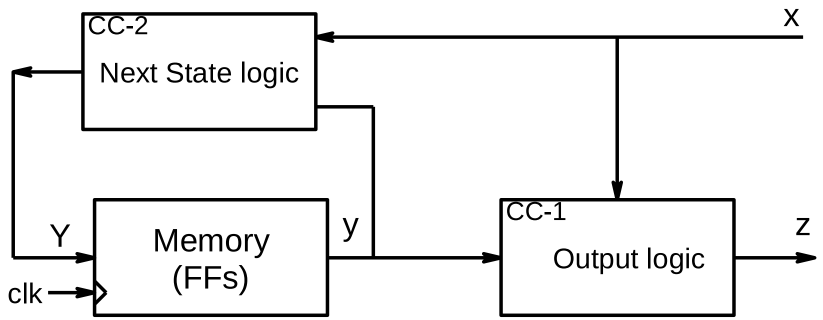
If x = 1 then z = 0.

the system would go to 01 state at clock edge.

Example

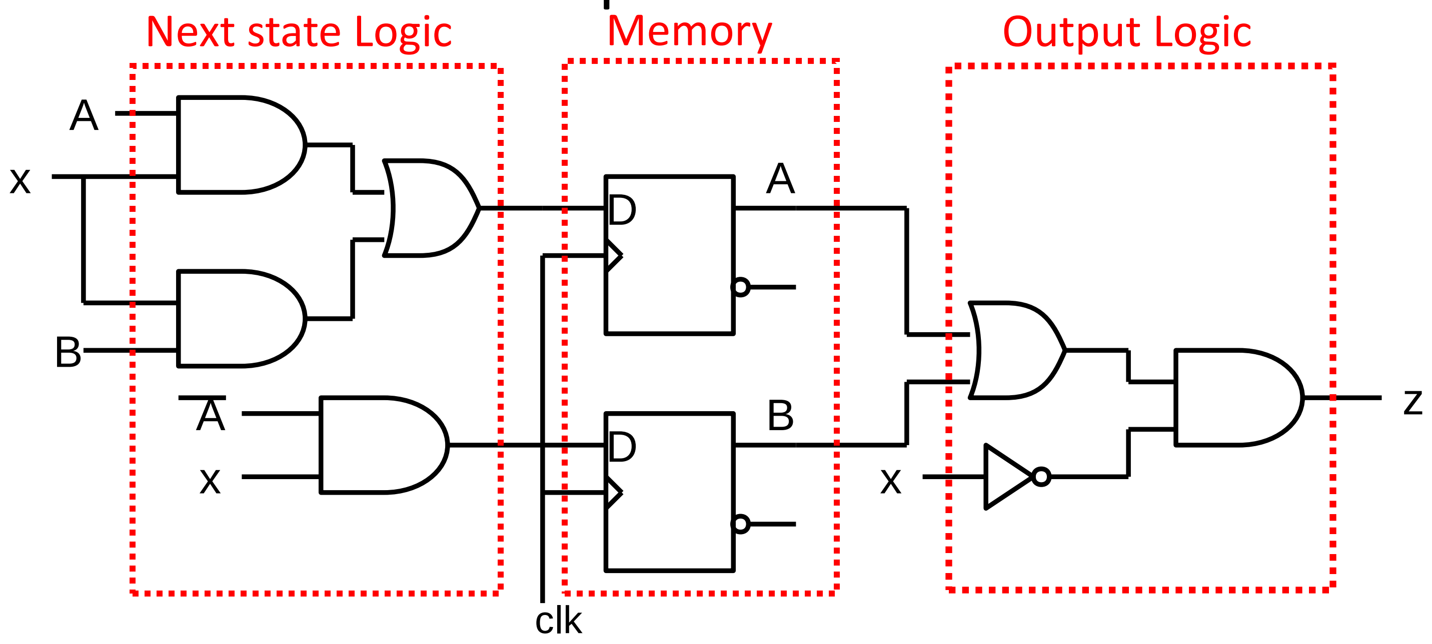
Sequential Circuit “Canonical Form”





Example - continued

What To Look for In Sequential Circuits



The dependence of output z on input x depends on the state of the memory (A,B)

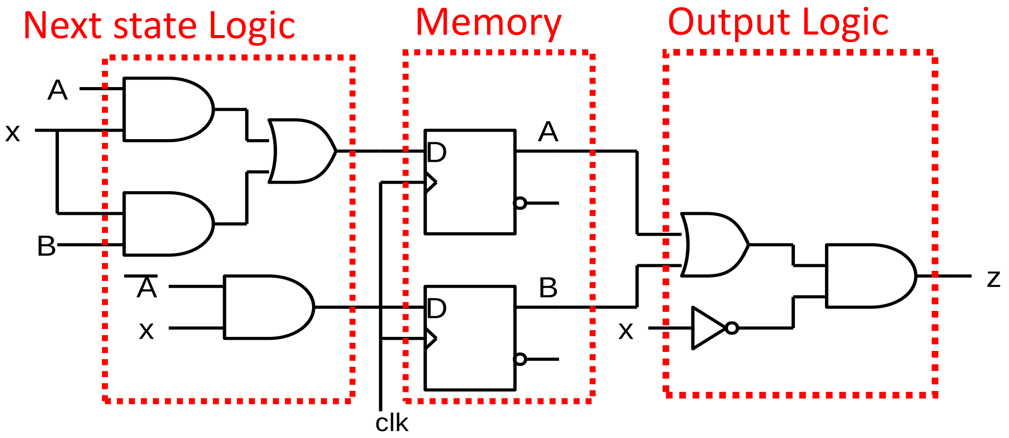
The memory has 2 registers and each register can be in state 0 or 1.

- 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

Obtaining State Transition Table



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

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

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

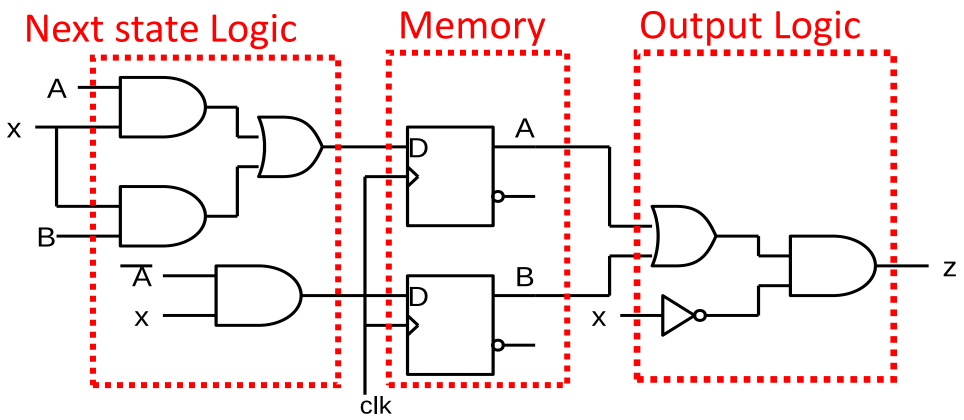
$$z = (A+B).\overline{x}$$

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**

Example - continued

Obtaining State Transition Diagram



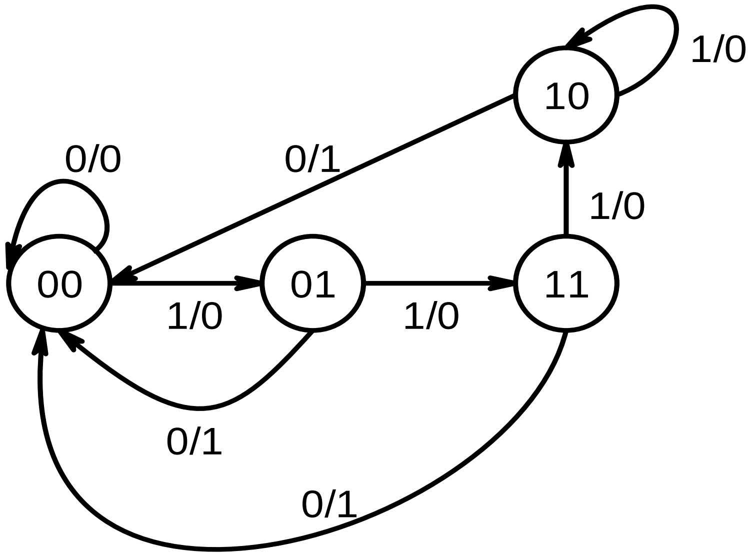
$$A(t+1) = A(t).x + B(t).x$$

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

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

State Transition Table

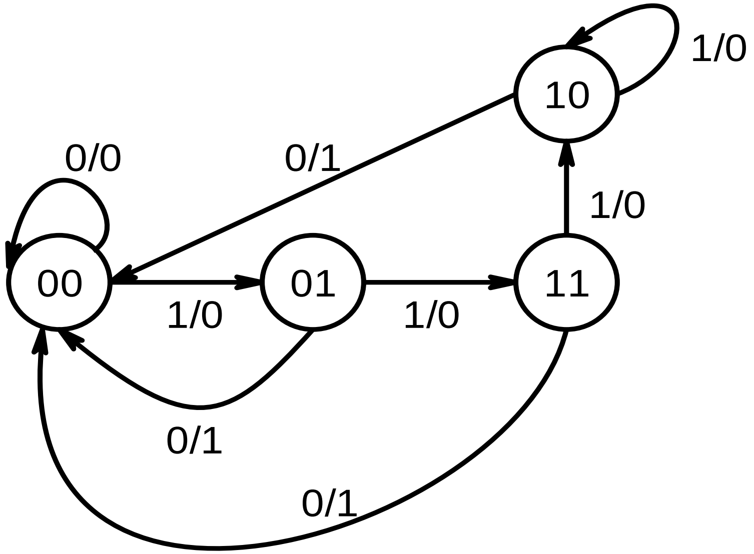
Present State A(t)	B(t)	Input x	Next State A(t+1)	B(t+1)	Output z
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0



State Transition Diagram

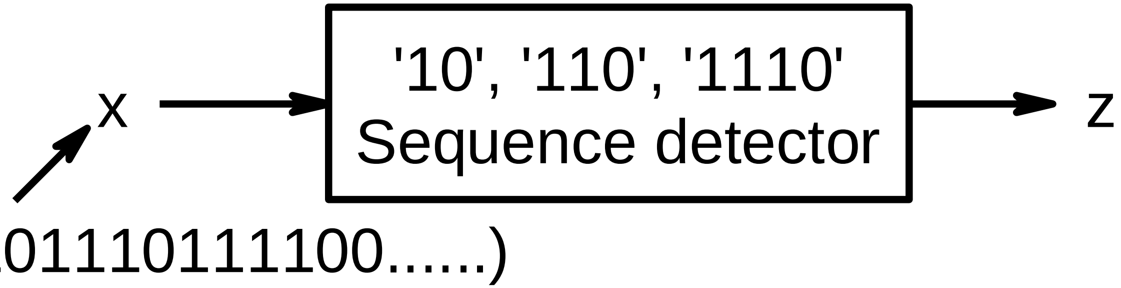
Example - continued

Understanding the Given Sequential Circuit



State Transition Diagram

From state transition diagram, one figures out the purpose of the sequential circuit



- Redraw circuit in “canonical form”
- Identify the blocks
- Determine logic for next state inputs and output
- Write out state transition table
- Draw state transition diagram

Designing of Sequential Circuits

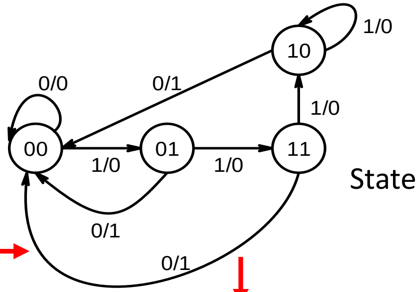
Specifications

State Diagram

Choose Register State Encoding

State Table

Synthsize Combinational Circuit

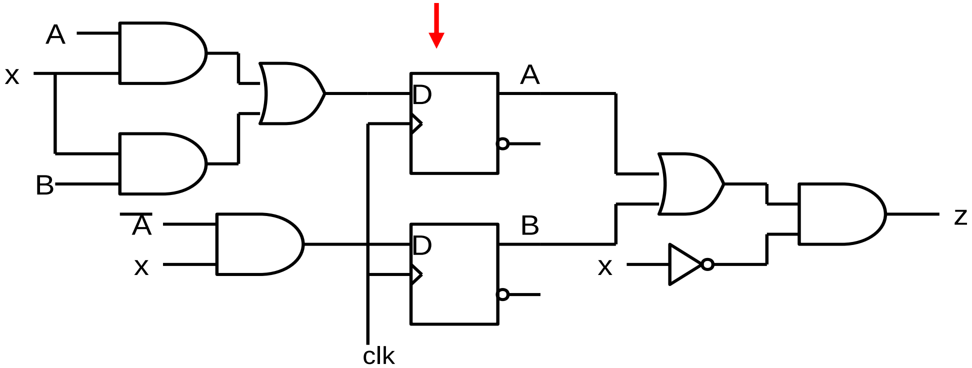


State Transition Diagram

State Transition Table

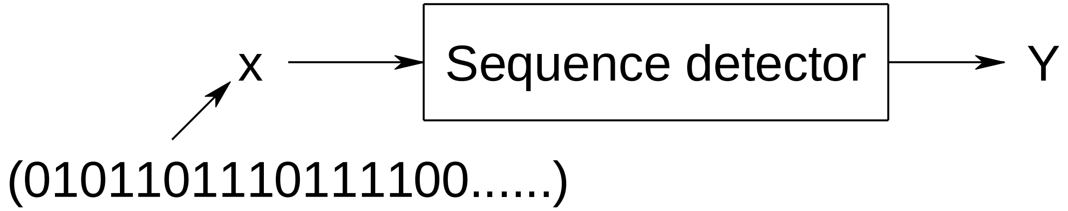
Present State A(t)	Present State B(t)	Input x	Next State A(t+1)	Next State B(t+1)	Output z
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0

Used to determine logic inputs for getting next state and output



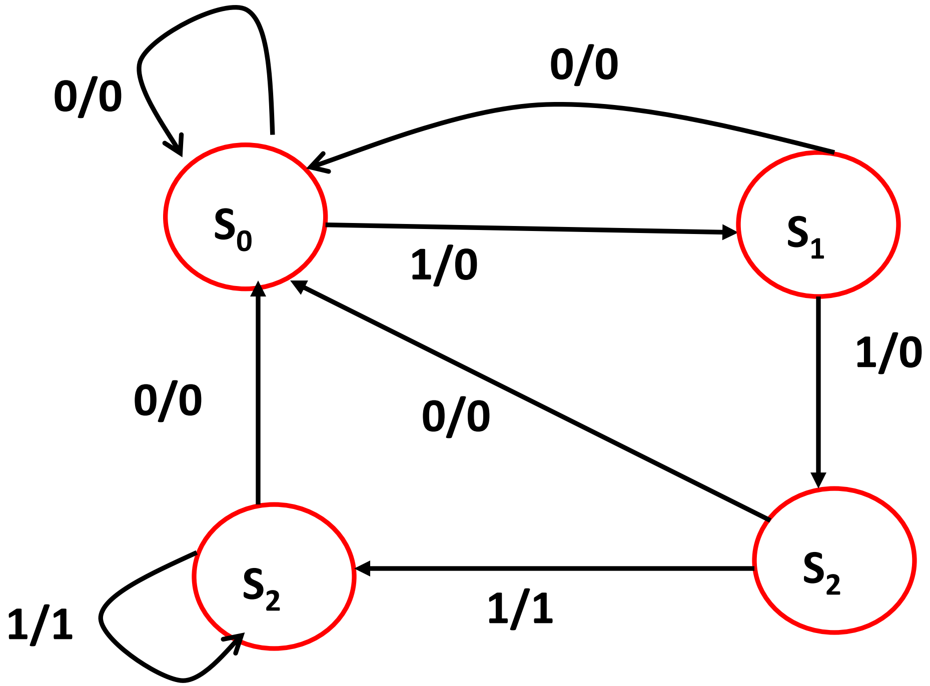
System specification to State diagram

Example-0



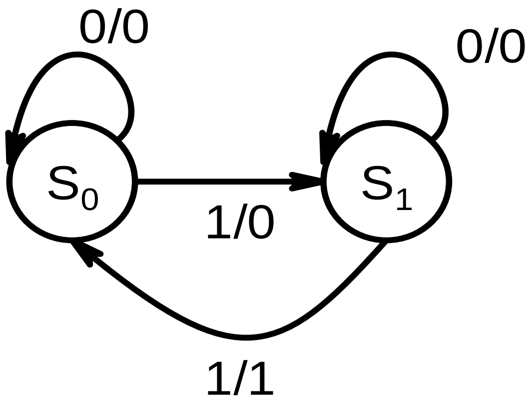
Detect 3 or more consecutive 1's in the input stream

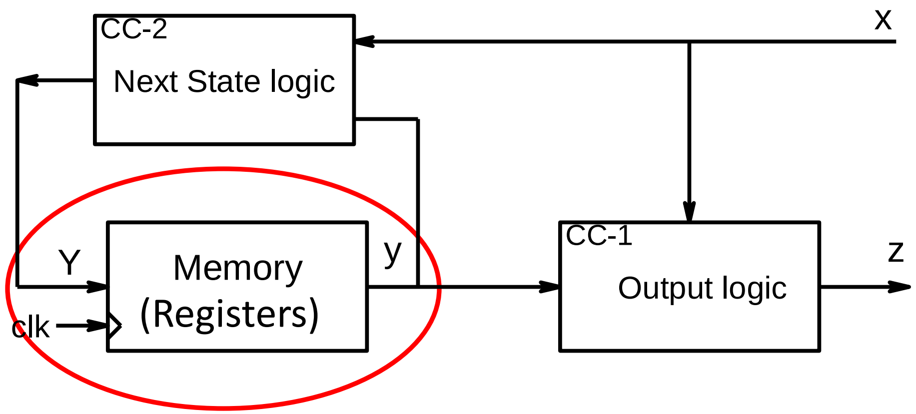
State Diagram



Example-1

Conversion of State transition graph to a circuit





3 blocks need to be designed

1. How many registers do we need?

N registers can represent 2^N states
→ so minimum is 1

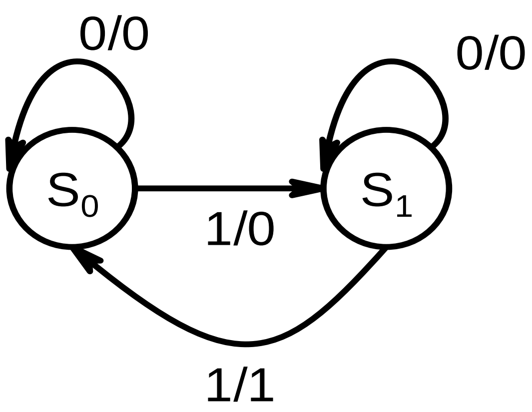
2. Which register do we choose?

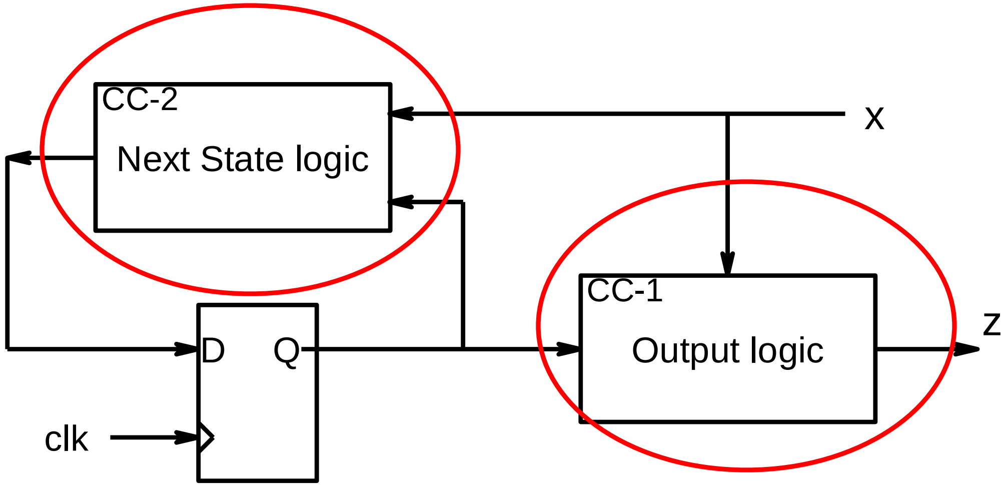
Say D register

3. How are the states encoded?

Say register output Q=0 represents S_0 and Q=1 represents S_1 state

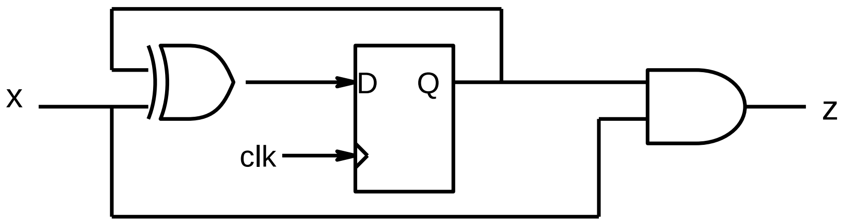
Example-1 continued





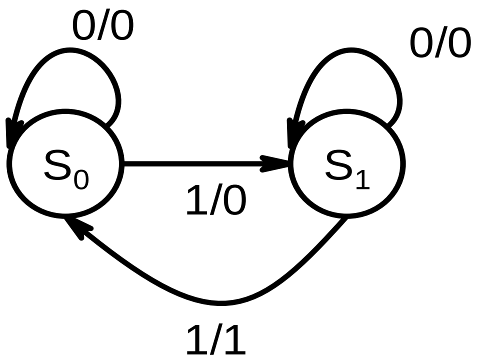
State Transition Table

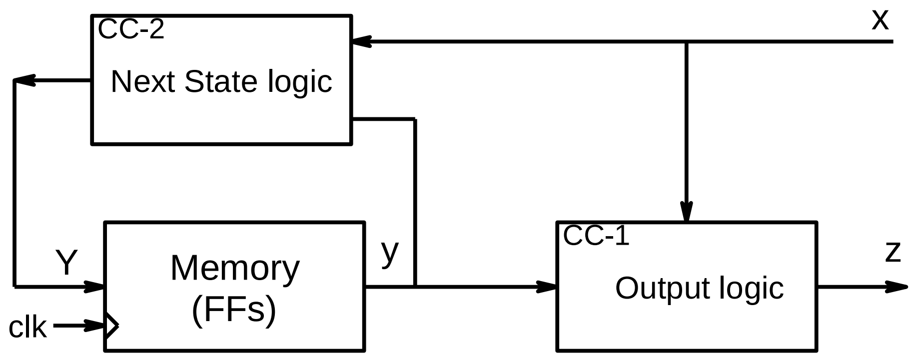
Present State Q(t)	Input x	Next State Q(t+1)	D	Output z
0	0	0	**0**	0
0	1	1	**1**	0
1	0	1	**1**	0
1	1	0	**0**	1



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

Example-2



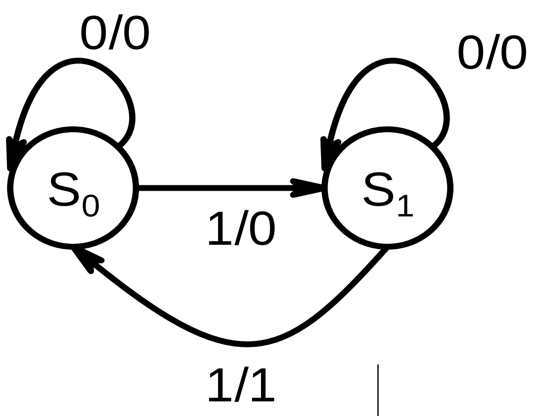


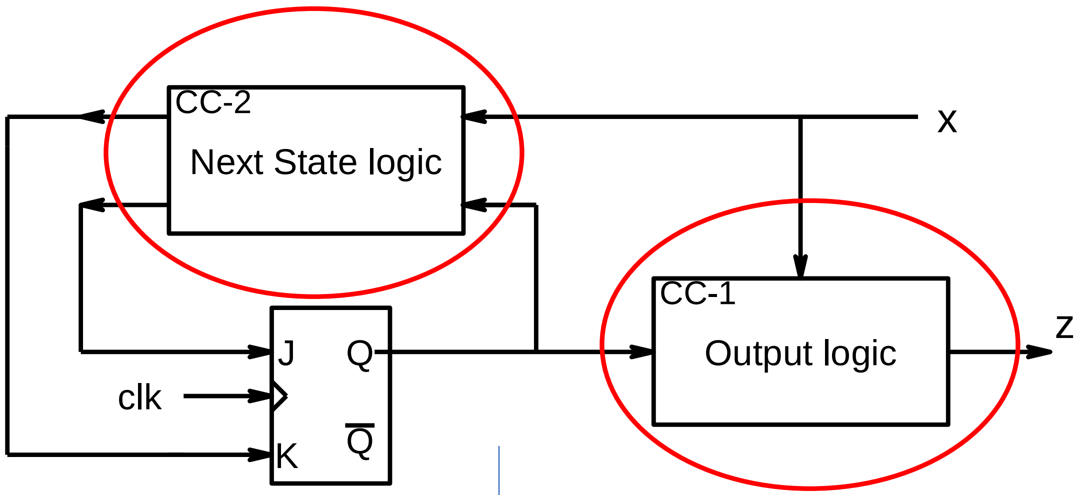
1. How many registers do we need? **1**

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

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

Example-2 continued



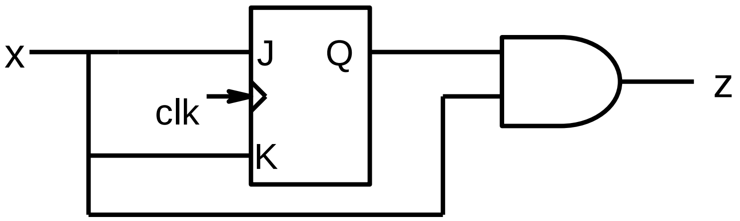


State Transition Table

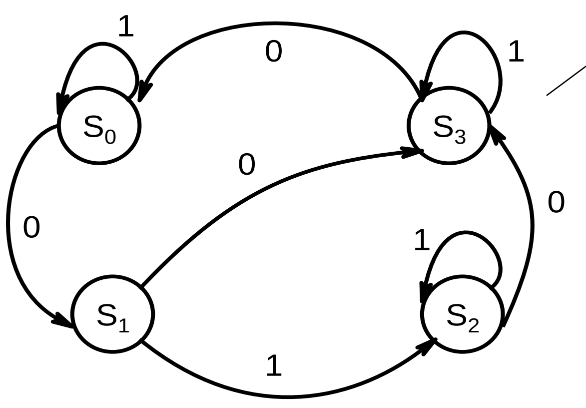
Present State Q(t)	Input x	Next State Q(t+1)	J K	Output z
0	0	0	**0 X**	0
0	1	1	**1 X**	0
1	0	1	**X 0**	0
1	1	0	**X 1**	1

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

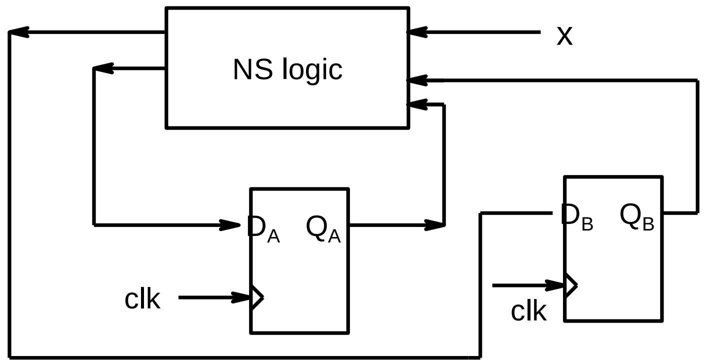
$$J = x \;; K = x; \;\; z = Q.x$$



Example-3



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



Present State		Input	Next State			
$A(t)$	$B(t)$	x	$A(t+1)$	$B(t+1)$	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

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

Example-3 continued

Present State $A(t)$	Present State $B(t)$	Input x	Next State $A(t+1)$	Next State $B(t+1)$	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

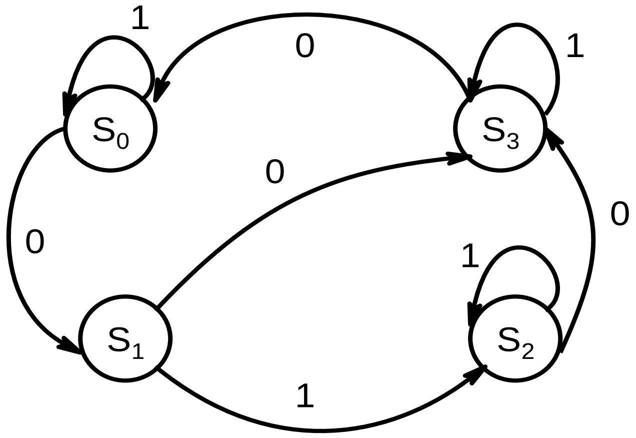
$$D_A = \overline{A}B + xB + A\overline{B}$$
$$= A \oplus B + x.B$$

D_B

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

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

Example-3 continued



With help of next state tables & K-map

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

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