Sri SAI RAM ENGINEERING COLLEGE
INSTITUTE OF TECHNOLOGY
West Tambaram, Chennai - 44

YEAR II SEM III

CS 8351

DIGITAL PRINCIPLES AND SYSTEM DESIGN
(Common to CSE & IT)

UNIT NO.3

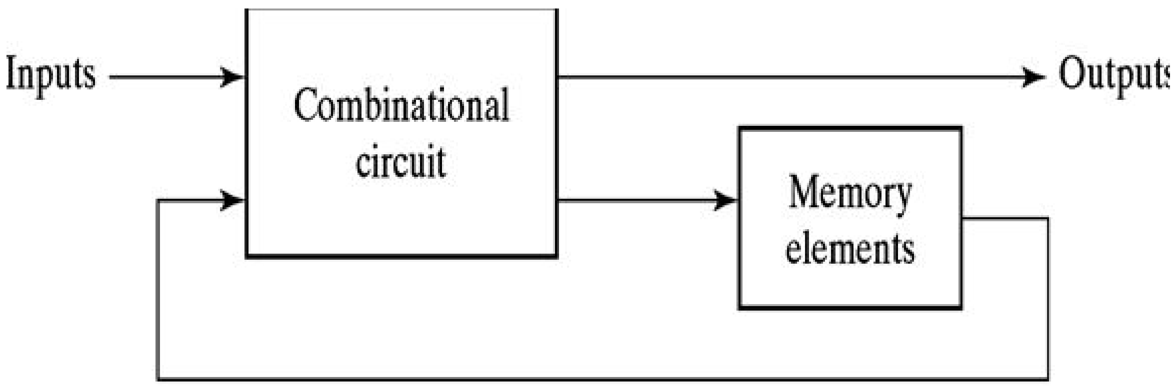
3.3 ANALYSIS OF CLOCKED SEQUENTIAL CIRCUITS

Version: 1.0

ANALYSIS OF CLOCKED SEQUENTIAL CIRCUITS

SEQUENTIAL CIRCUITS

- Consist of a combinational circuit to which storage elements are connected to form a feedback path
- State – the state of the memory devices now, also called **current state**
- Next states and outputs are functions of inputs and present states of storage elements



SEQUENTIAL CIRCUIT ANALYSIS

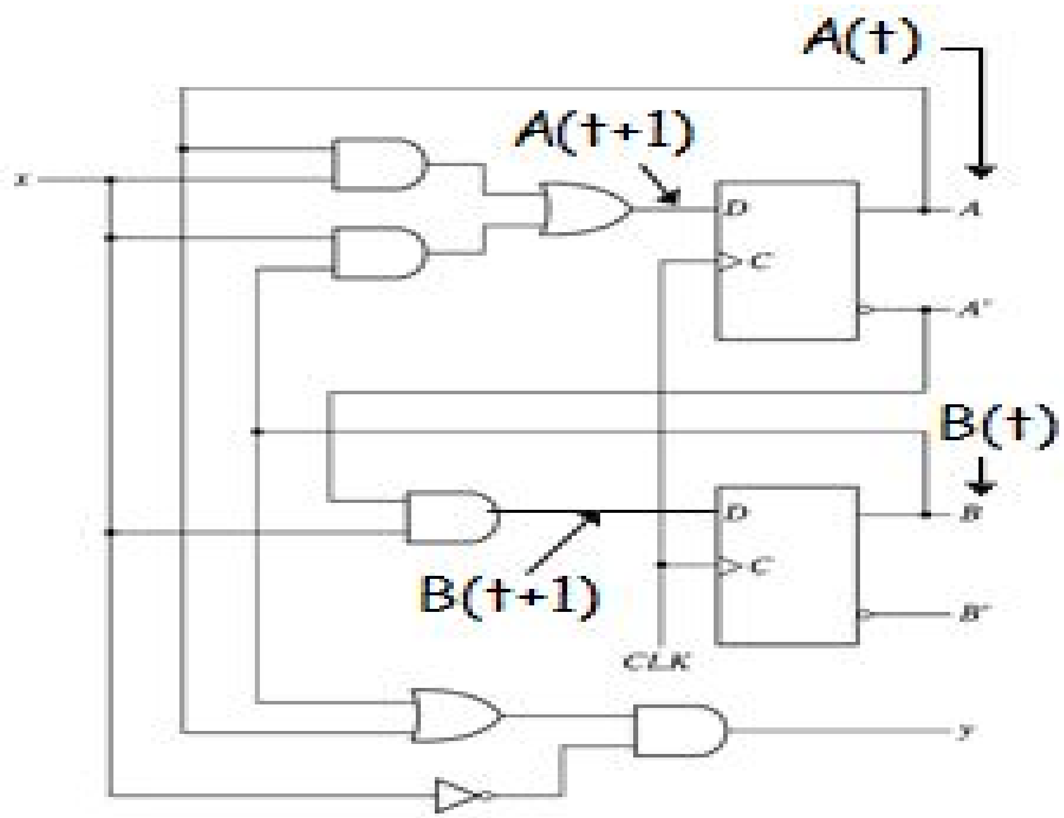
- The behavior of a clocked sequential circuit is determined from
  - The inputs
  - The outputs
  - The state of its flip-flops
  - The outputs and the next state are both a function of the inputs and the present state
  - To analyze a sequential circuit, we can use
    - State equations
    - State table
    - State diagram
    - Flip-Flop input equations

STATE EQUATIONS

- Specify the next state as a function of present state and inputs.
- Also called transition equation.

- Analyze the combinational part directly

Consider the logic diagram:



EX:

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

$A(t+1) = Ax + Bx$

$B(t+1) = A'(t)\,x(t)$

(ie) $B(t+1) = A'x$

$y(t)=[A(t)+B(t)]\,x(t)$

(ie) $y=(A+B)x'$

STATE TABLE

- Enumerate the time sequence of inputs, outputs, and flip-flop states
  - Also called transition table
  - Similar to list the truth table of state equations
- Consist of four sections
  - Present state, input, next state, and output
- A sequential circuit with m flip-flops and n inputs need 2^{m+n} rows in the state table

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	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

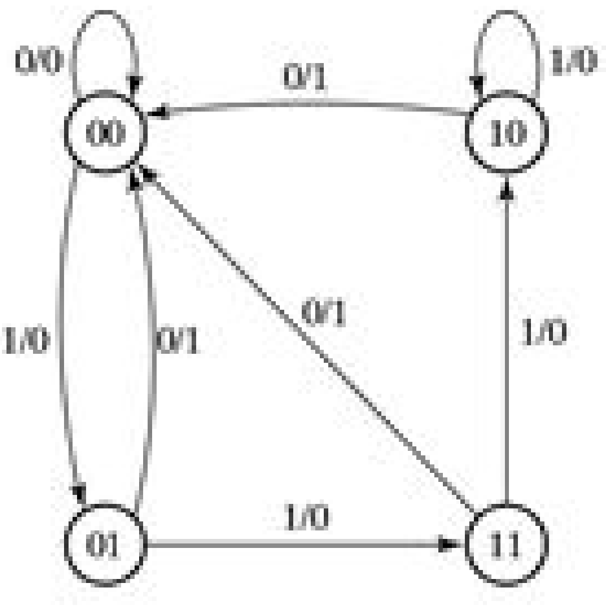
SECOND FORM OF STATE TABLE

- The state table has only three section: present state, next state, and output
- The input conditions are enumerated under next state and output sections

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

STATE DIAGRAM

- Graphically represent the information in a state table
  - Circle: a state (with its state value inside)
  - Directed lines: state transitions (with inputs/outputs above)
- Ex: starting from state 00
  - If the input is 0, it stays at state 00 with output=0
  - If the input is 1, it goes to state 01 with output=0



FLIP-FLOP INPUT EQUATIONS

- To draw the logic diagram of a sequential circuit, we need
  - The type of flip-flops
  - A list of Boolean expressions of the combinational circuits
- The Boolean functions for the circuit that generates external outputs is called output equations
- The Boolean functions for the circuit that generates the inputs to flip-flops is flip-flop input equations
- Sometimes called excitation equations
- The flip-flop input equations provide a convenient form for specifying the logic diagram of a sequential circuit

Input: D_A=Ax+Bx

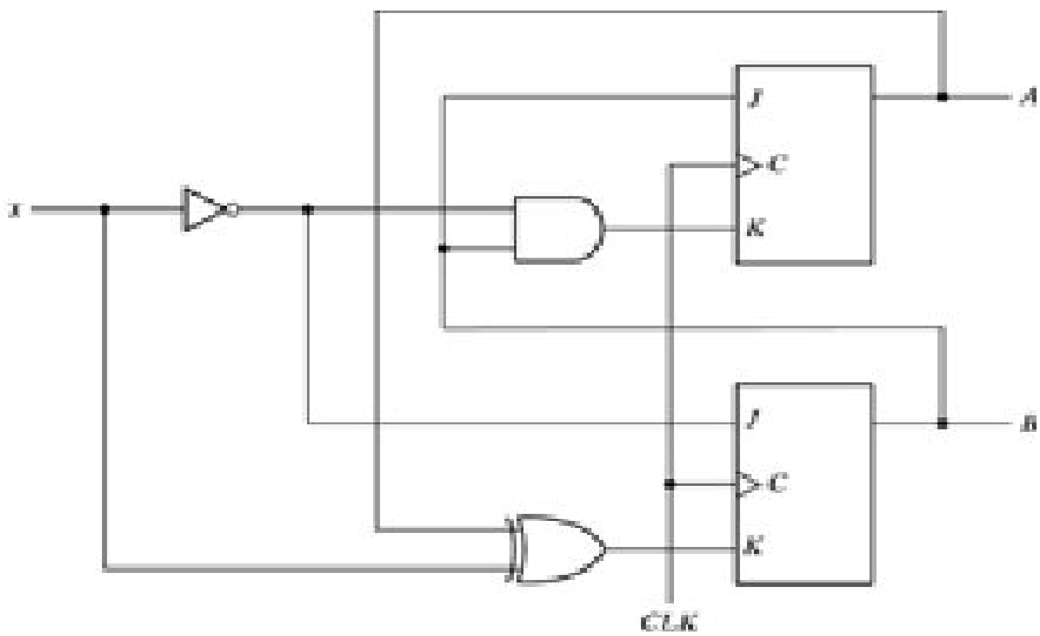
D_B=A'x

Output:y=(A+B)x'

ANALYSIS WITH OTHER FLIP-FLOPS

- The sequential circuit using other flip-flops such as JK or T type can be analyzed as follows
- Determine the flip-flop input equations in terms of the present state and input variables
- List the binary values of each input equation
- Use the corresponding flip-flop characteristic table to determine th state values in the state table

ANALYSIS WITH JK FLIP-FLOPS (1/2)



Step 1: input equations

$J_A = B$,

$K_A = Bx'$

$J_B = x'$

$K_B = A \oplus x'$

Step 2: state equations

$A(t+1) = JA' + K'A$

$= BA' + (Bx')'A$

$= A'B + AB' + Ax$

$B(t+1) = JB' + K'B$

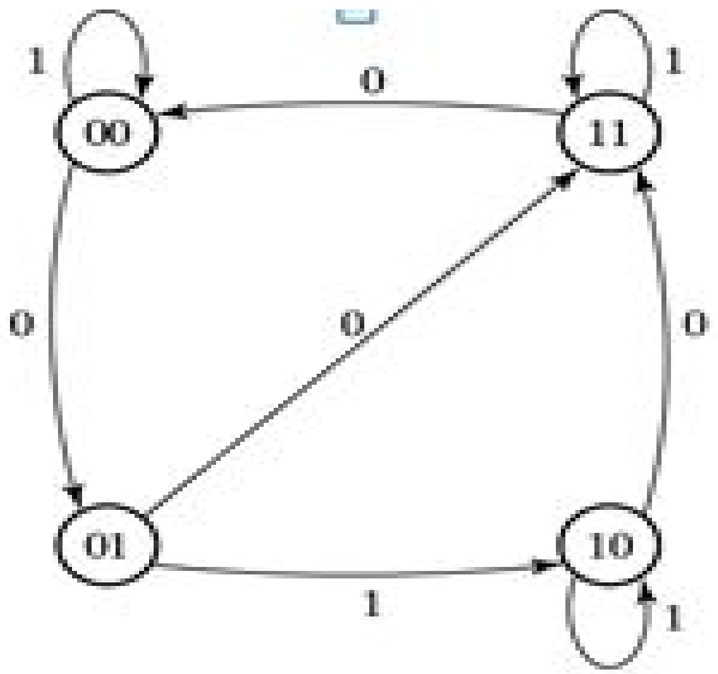
$= x'B' + (A \oplus x)'B$

$B(t+1) = B'x' + ABx + A'Bx'$

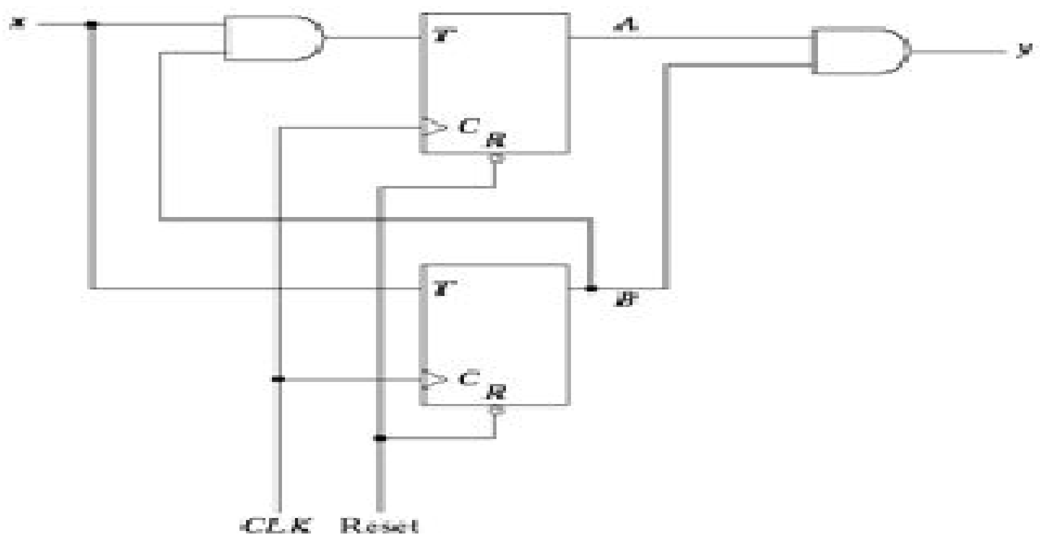
STEP 3:STATE TABLE

Present state		Input	Next state		Flip-Flop Inputs			
A	B	X	A	B	J_A	K_A	J_B	K_B
0	0	0	0	1	0	0	1	0
0	0	1	0	0	0	0	0	1
0	1	0	1	1	1	1	1	0
0	1	1	1	0	1	0	0	1
1	0	0	1	1	0	0	1	1
1	0	1	1	0	0	0	0	0
1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	0	0	0

STEP 4: STATE DIAGRAM



ANALYSIS WITH T FLIP-FLOPS (1/2)



Step 1: input equations

$T_A = Bx$

$T_B = x$

$y = AB$

Step 2: state equations

$A(t+1) = T'A + TA'$

$= (Bx)'A + (Bx)A'$

$= AB' + Ax' + A'Bx$

$B(t+1) = T'B + TB'$

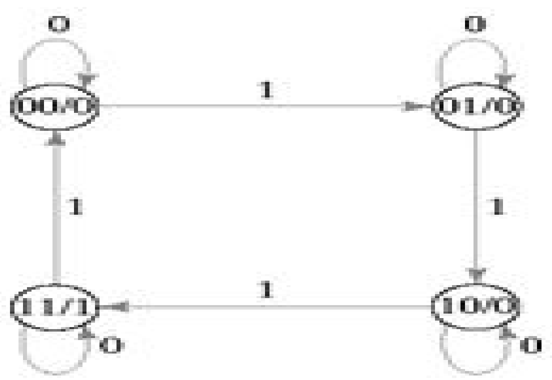
$= x'B + xB'$

$= x \oplus B$

STEP 3: STATE TABLE

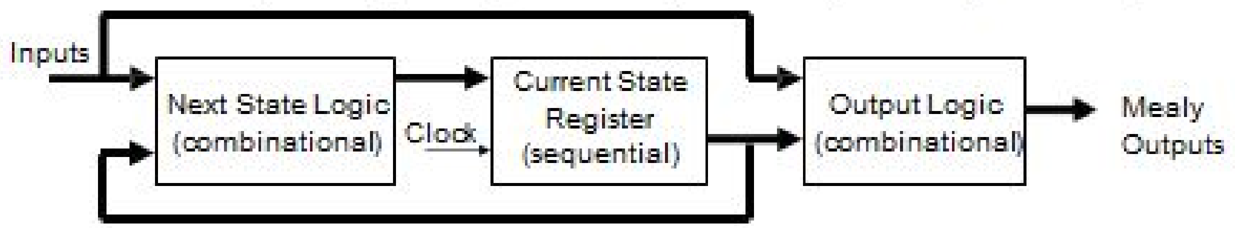
Present state		Input	Next state		Output
A	B	X	A	B	y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	1	0
0	1	1	1	0	0
1	0	0	1	0	0
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	1

STEP 4: STATE DIAGRAM



MEALY AND MOORE MODEL

- Mealy model :
  - The output is a function of **both** the present state and input
  - The output may change if the inputs change during a clock cycle



MOOREMODEL

The output is a function of the **present state only**

The output are **synchronized** with the clock