EE200 DIGITAL LOGIC CIRCUIT DESIGN

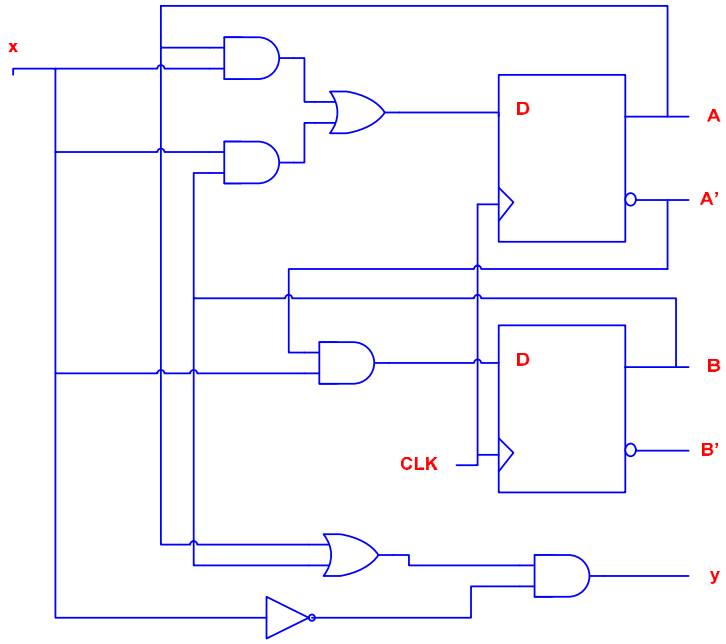
The material covered in this lecture will be as follows:

- ⇒Analysis of clocked sequential circuits.
- ⇒State table.
- ⇒State diagram.
- ⇒Analysis with JK flip-flops.
- ⇒Analysis with T flip-flops.
- ⇒Mealy and Moore models.

After finishing this lecture, you should be able to:

- ⇒ Understand and be able to analyze any clocked sequential circuit.
- ⇒ Obtain the state table for a given sequential circuit.
- ⇒ Obtain the state diagram for a given sequential circuit.
- ⇒ Analyze sequential circuits containing any type of flip flops, such as D, JK or T.
- ⇒ Recognize Mealy and Moore models of sequential circuits.

Analysis of Clocked Sequential Circuits



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

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

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

State Table →

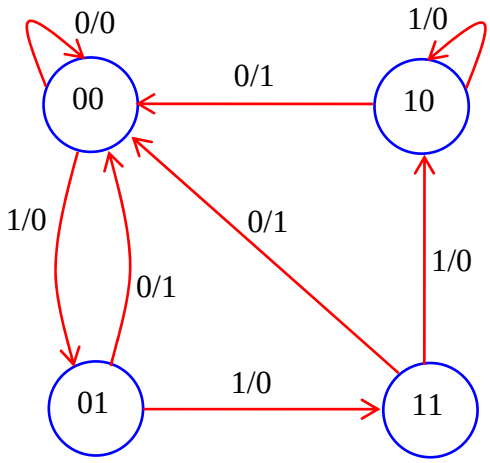
P.S.		Input	N.S.		Output
A	B	x	A	B	y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0

The state table can also be put in the following different form.

P.S.		N.S.				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

The information in the state table can be presented pictorially in the form of a state diagram. A state is represented by a circle. A transition from present state to next state is represented by an arrow with the inputs and outputs written on that transition with a slash in between inputs and outputs. The state diagram of the previous sequential circuit is given below.



Analysis with JK flip-flops

It is easy to obtain the state table and diagram of sequential circuits with D flip-flops, because the state equation is the same as the input equation

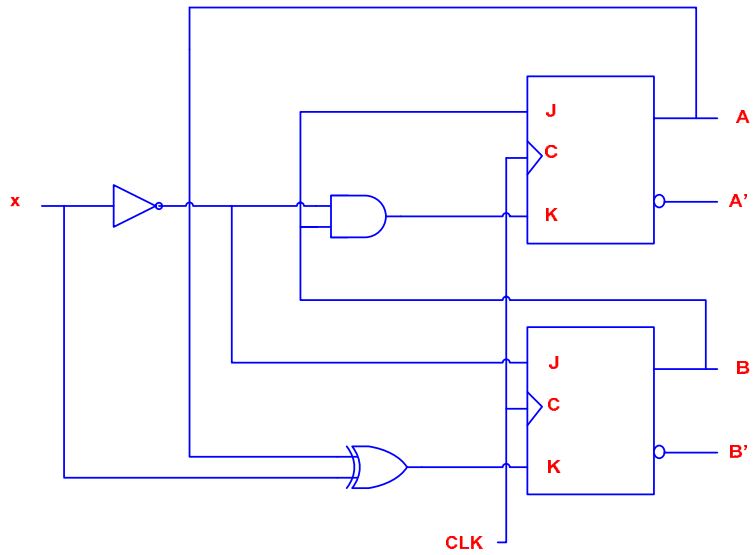
Example: $D_A = Ax + Bx$ → $A_{(t+1)}=Ax + Bx$

When other types of flip-flops are used such as JK and T, then we have to use the characteristic table or characteristic equation to obtain the next state.

The analysis procedure in this case consists of:

1. Determine the flip-flop input equations in terms of the present state and input variables.
2. List the binary values of each input equation.

3. Use the corresponding flip-flop characteristic table to determine the next state values.



The flip-flop input equations are given by:

$J_A = B$, $K_A = Bx'$, $J_B = x'$, and $K_B = A \oplus x$

The flip-flop inputs are obtained first and then the next state can be found using the JK flip-flop characteristic table.

P.S.		Input	N.S.		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

The state table could also be completed by using the flip-flop input equations and substituting it in the characteristic equation for the flip-flop. Then the next state columns can be filled.

The characteristic equation of the JK flip-flop is given by:

$$Q_{t+1} = JQ' + K'Q$$

Replacing Q with A and B, produces the following two equations:

1. $A_{t+1} = J_A A' + K'_A A$

2. $B_{t+1} = J_B B' + K'_B B$

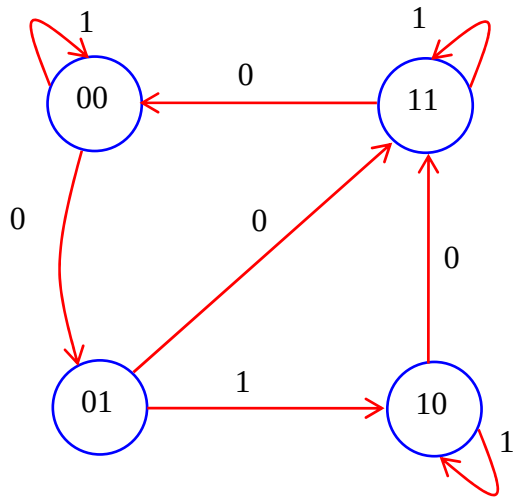
Substituting for J_A, K_A, J_B, and K_B:

$$A_{t+1} = BA' + (Bx')'A = A'B + AB' + Ax$$

and $$B_{t+1} = x'B' + (A \oplus x)'B = B'x' + ABx + A'B'x'$$

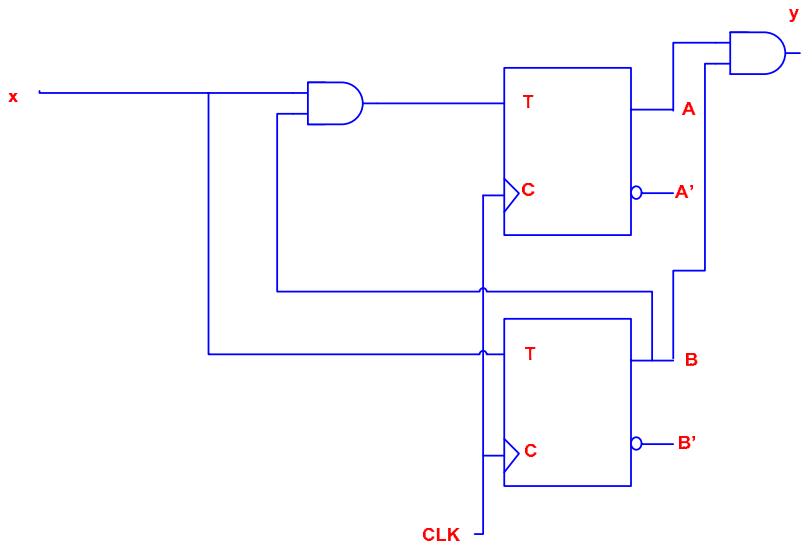
The next state columns can then be filled using these last equations.

The sate diagram of the previous circuit is given next.



Analysis with T flip-flops

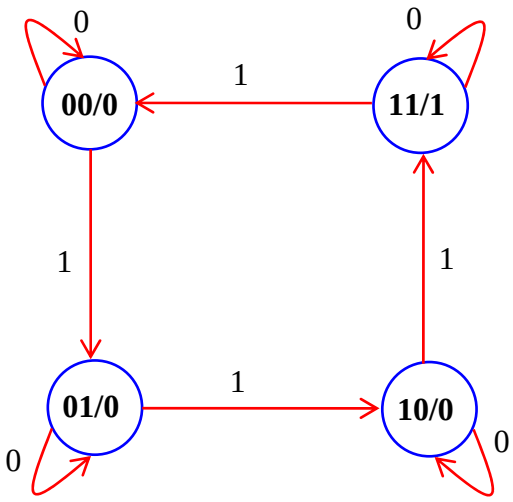
The analysis of a sequential circuit with T flip-flop follows the same procedure as for circuits with JK flip-flops.



T_A= Bx, T_B=x, and y=AB

The state table for the previous circuit can be obtained either by using the characteristic table or writing the characteristic equations for the T flip flops.

P.S.		Input	N.S.		Output	f/f Inputs	
A	B	x	A	B	y	TA	TB
0	0	0	0	0	0	0	0
0	0	1	0	1	0	0	1
0	1	0	0	1	0	0	0
0	1	1	1	0	0	1	1
1	0	0	1	0	0	0	0
1	0	1	1	1	0	0	1
1	1	0	1	1	1	0	0
1	1	1	0	0	1	1	1



Mealy and Moore Models

The Mealy model is characterized by the outputs being a function of the present state and the inputs. The first circuit we analyzed with D flip-flops is an example of a Mealy model. On the other hand, the Moore model is characterized by the outputs being a function of the present state only. Examples are the circuits we analyzed with JK and T flip-flops.