CE232 DIGITAL SYSTEM

Topic 9. Sequential Circuit Analysis

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Subtopic

9.1 State Table and State Diagram

9.2 Circuit to State Diagram

9.3 State Diagram to Circuit

9.1 State Table and State Diagram

9.1 State Table and State Diagram

- **State table** is a table that describes how the sequential circuits behave for the input variables and state variables
- By using the state table, we know how input and output are connected

9.1 State Table and State Diagram

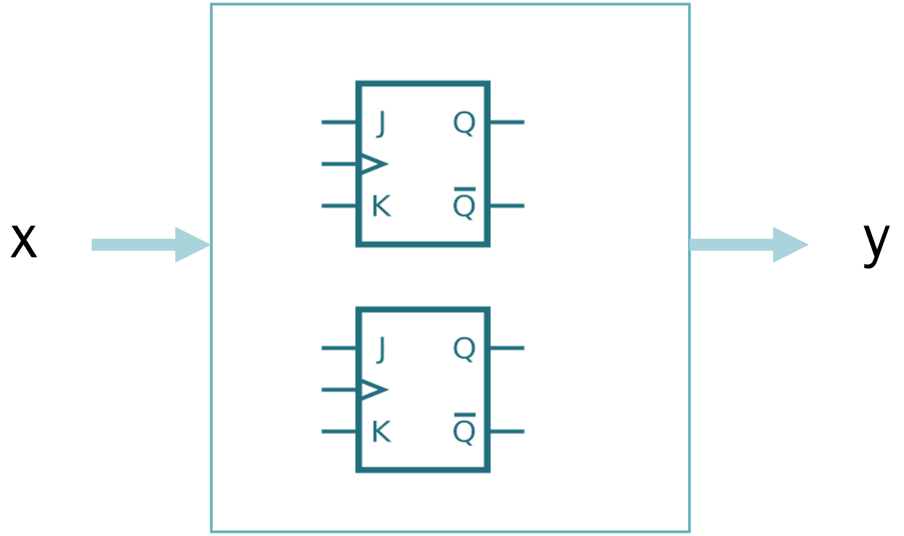
State table – a multiple variable table with the following four sections:

- *Present State* – the values of the state variables for each allowed state.
- *Input* – the input combinations allowed.
- *Next-state* – the value of the state at time (t+1) based on the <u>present state</u> and the <u>input</u>.
- *Output* – the value of the output as a function of the <u>present state</u> and (sometimes) the <u>input</u>.

Present state		Input	Next stage		output
A	$\boldsymbol{B}$	x	A_{T+1}	B_{T+1}	y

9.1 State Table and State Diagram

Example of state table



Present state		x	Next stage		y
Q_A	Q_B		Q_A^+	Q_B^+	

9.1 State Table and State Diagram

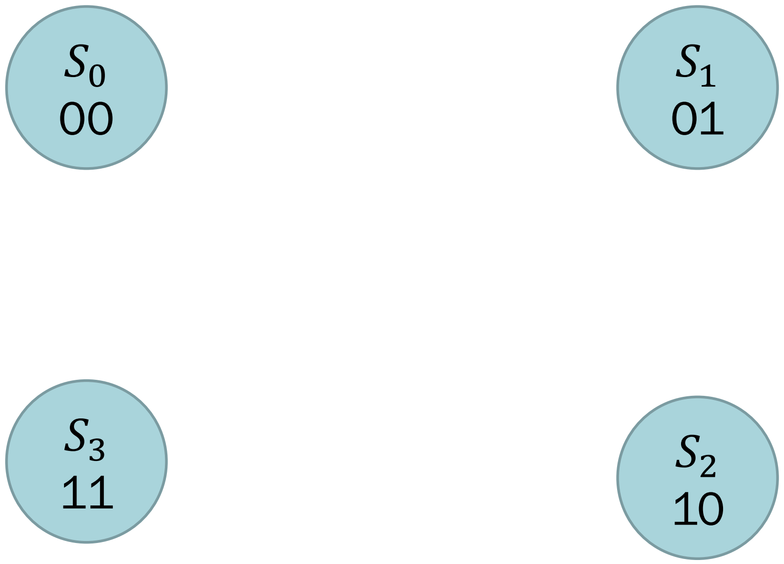
Present state		x	Next stage		y
Q_A	Q_B		Q_A^+	Q_B^+	

Because there are 2 flip flop, there will be 2^2 state

State	Q_A	Q_B
S_0	0	0
S_1	0	1
S_2	1	0
S_3	1	1

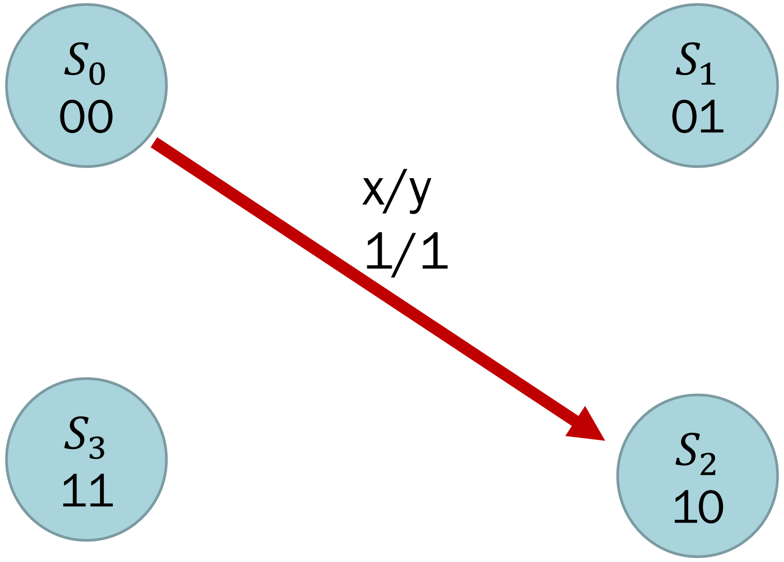
9.1 State Table and State Diagram

Each state will be represented as bubble, and therefore there will be 4 bubble



9.1 State Table and State Diagram

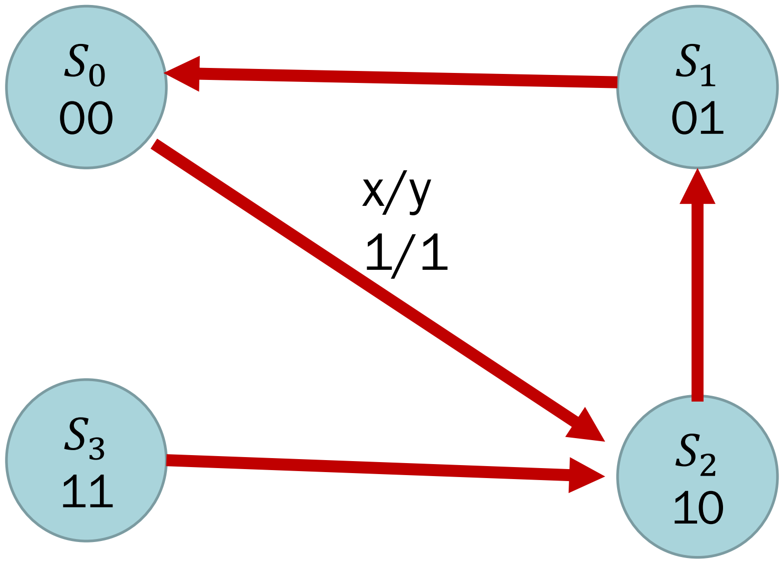
For example, if the present stage, x and next stage is given below



Present state		x	Next stage		y
Q_A	Q_B		Q_A^+	Q_B^+	
0	0	1	1	0	1

9.1 State Table and State Diagram

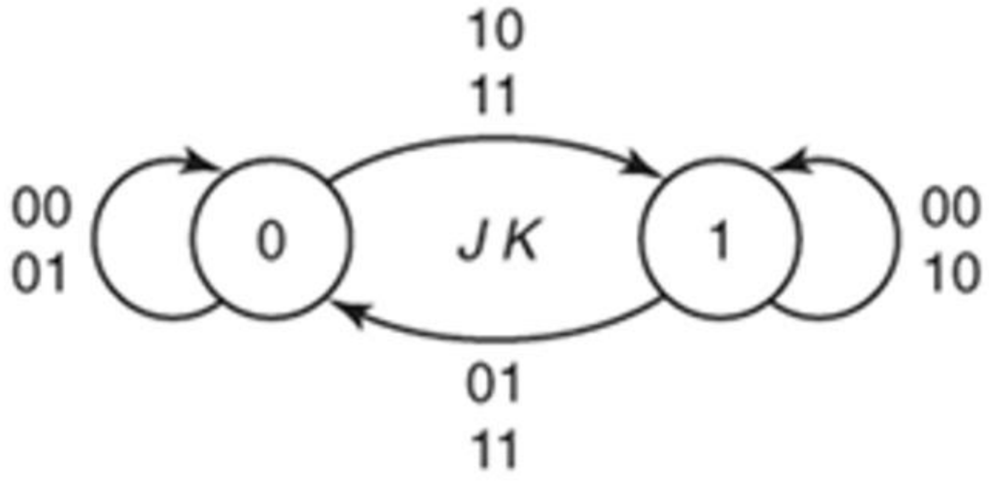
Example of state diagram



9.1 State Table and State Diagram

Example of state diagram for JK Flip flop

For single flipflop, the stage are $S_0 = 0$ and $S_1 = 1$



P.S	Input/Output		N.S
Qn	J	K	Qn+1
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

9.1 State Table and State Diagram

Conclusion

- State diagram gets confusing for large circuits
- For small circuits, it usually easier to understand the state diagram

9.2 Circuit to State Diagram

9.2 Circuit to State Diagram

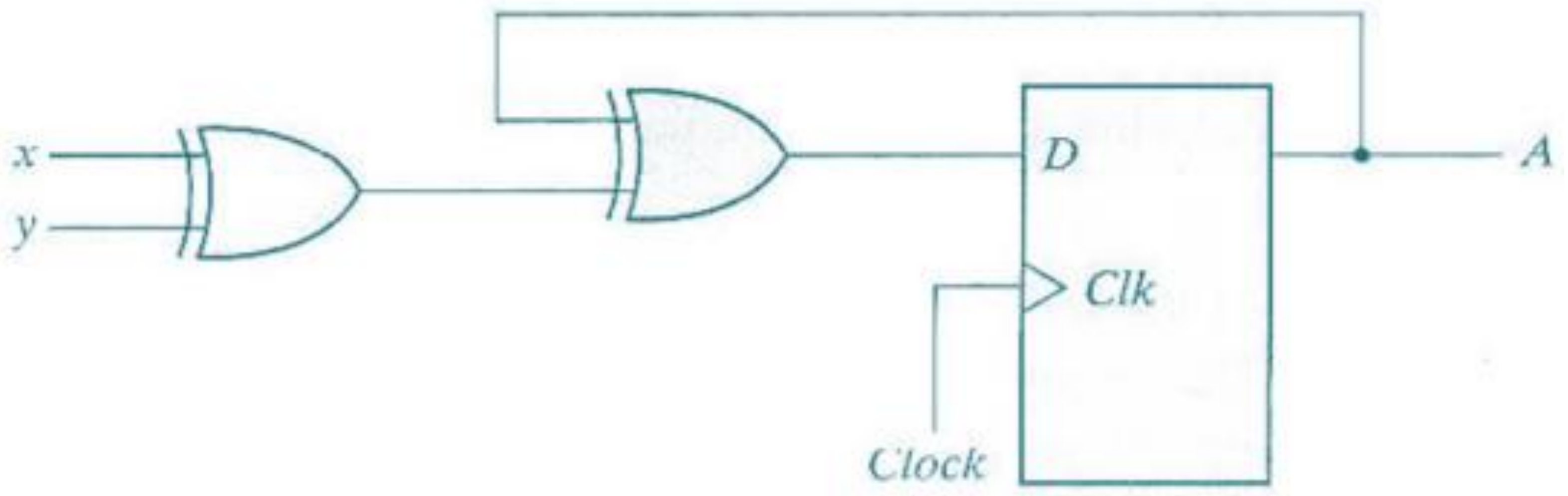
Step

1. Find the input output equation (if any)
2. Make the state table
3. Make the state diagram

9.2 Circuit to State Diagram

Example.

Find the state table and state diagram for the given circuit



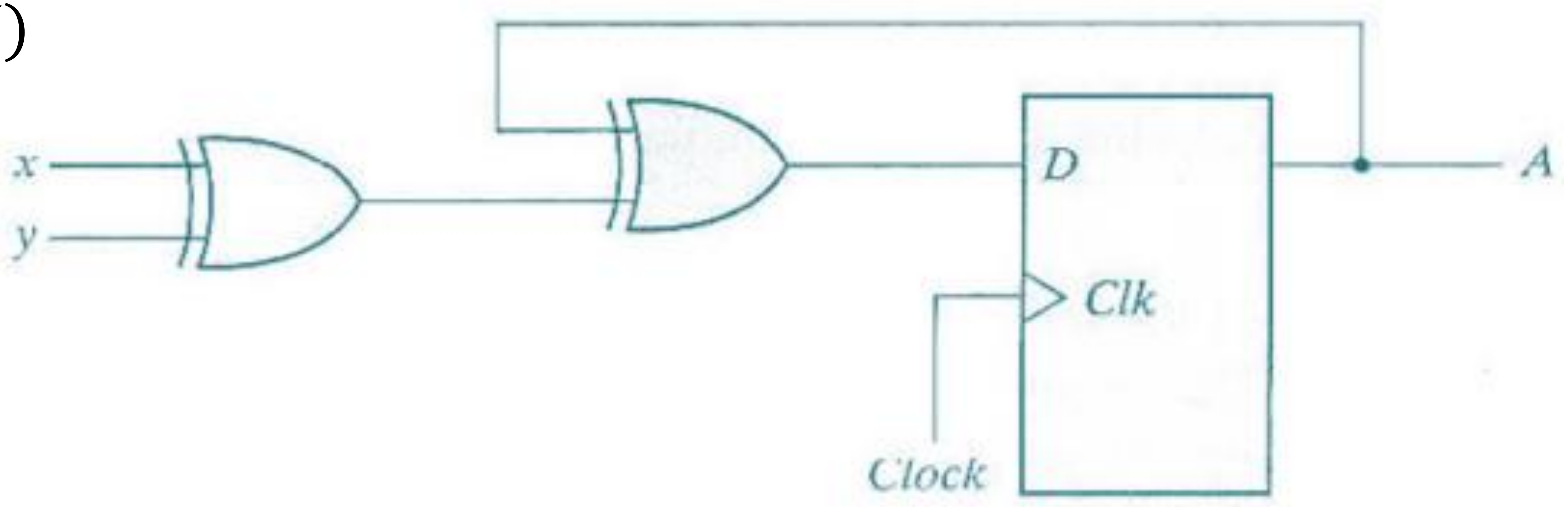
9.2 Circuit to State Diagram

Step 1. Find the input output equation (if any)

There is no output from the circuit

The input for D is

$D = A\ \boldsymbol{XOR}\ (X\ \boldsymbol{XOR}\ Y)$



9.2 Circuit to State Diagram

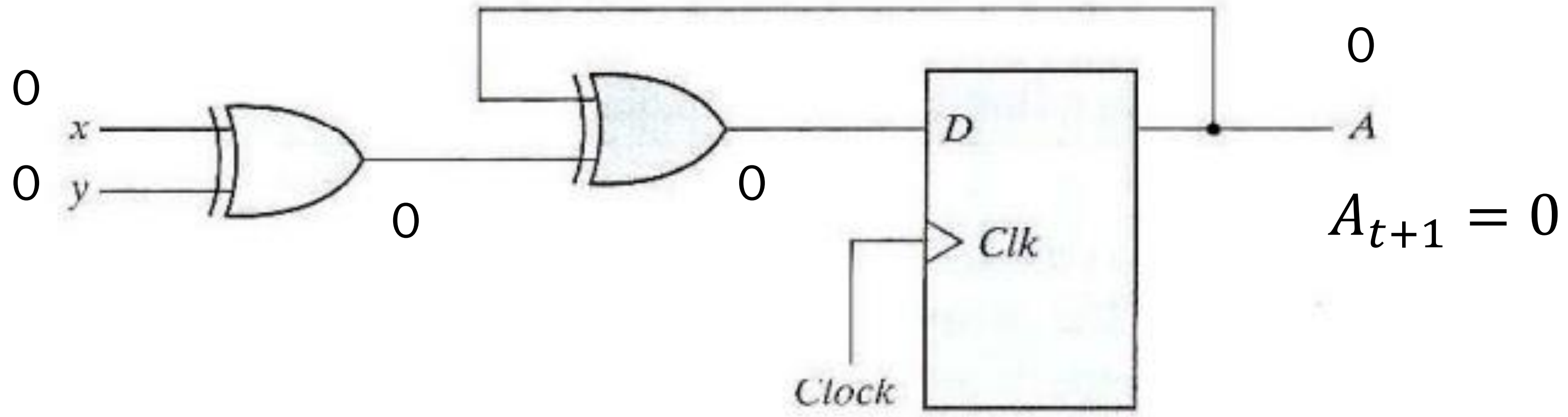
State table

Equation for next stage in D flip flop is $Q_{n+1} = D$

Example when present stage A = 0, x =0 and y=0, the output $A_{t+1} = 0$

Truth table XOR

A	B	Out
0	0	0
0	1	1
1	0	1
1	1	0



9.2 Circuit to State Diagram

Step 2. Make the state table

Because there is no output, therefore the state table does not need the output column

$$A_{t+1} = D$$
$$D = A\ \boldsymbol{XOR}\ (X\ \boldsymbol{XOR}\ Y)$$

State table

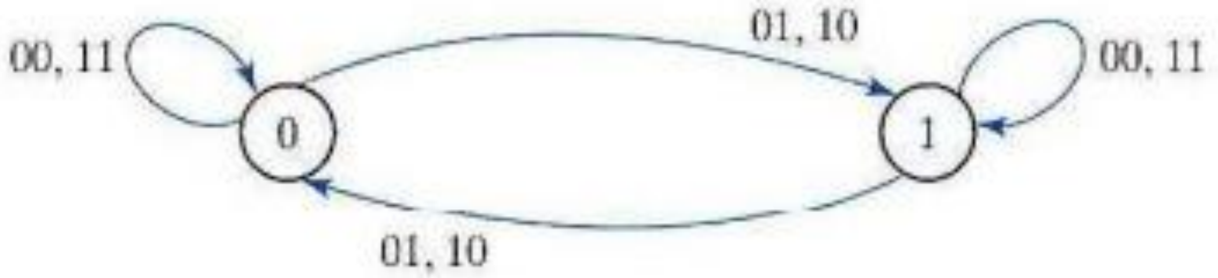
Present state	Inputs		Next state
A	x	y	A_{t+1}
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

9.2 Circuit to State Diagram

Step 3. Make the state diagram

There is 1 flip flop, therefore there are 2 state

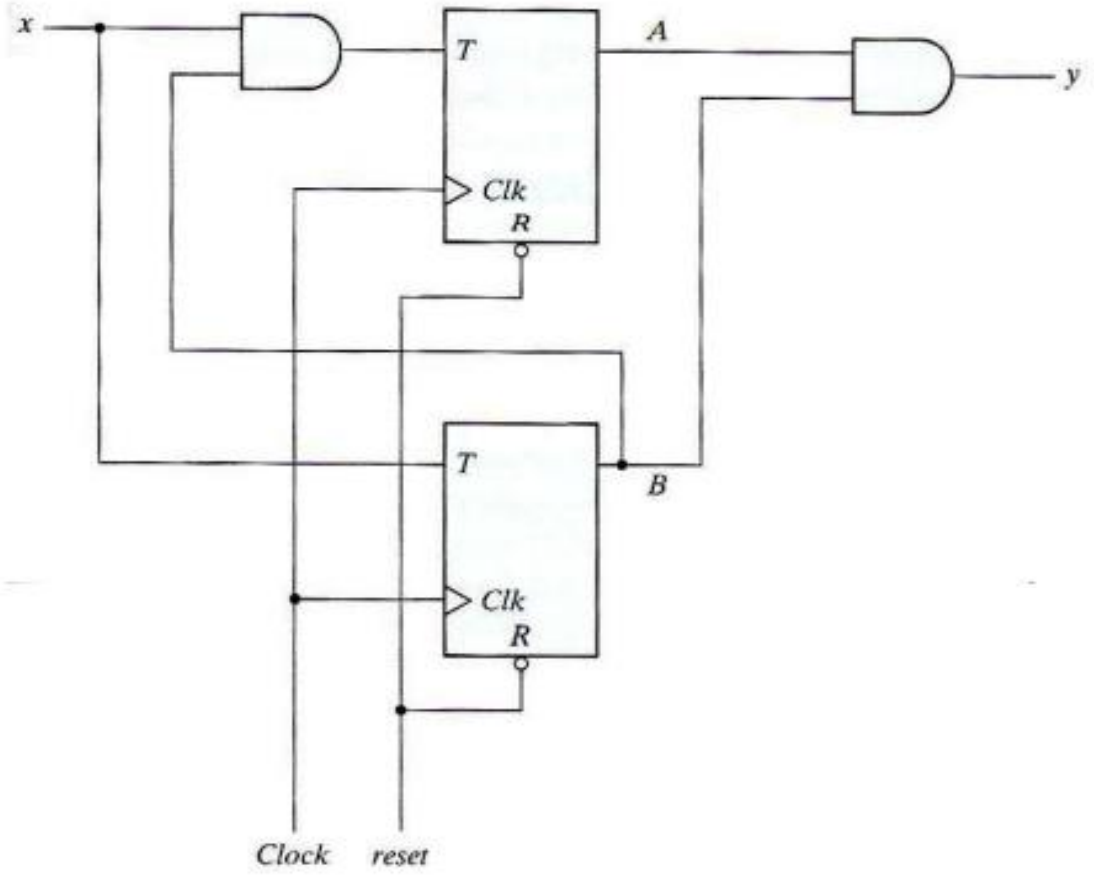
Present state	Inputs		Next state
A	x	y	A_{t+1}
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1



9.2 Circuit to State Diagram

Example.

Find the state table and state diagram for the given circuit



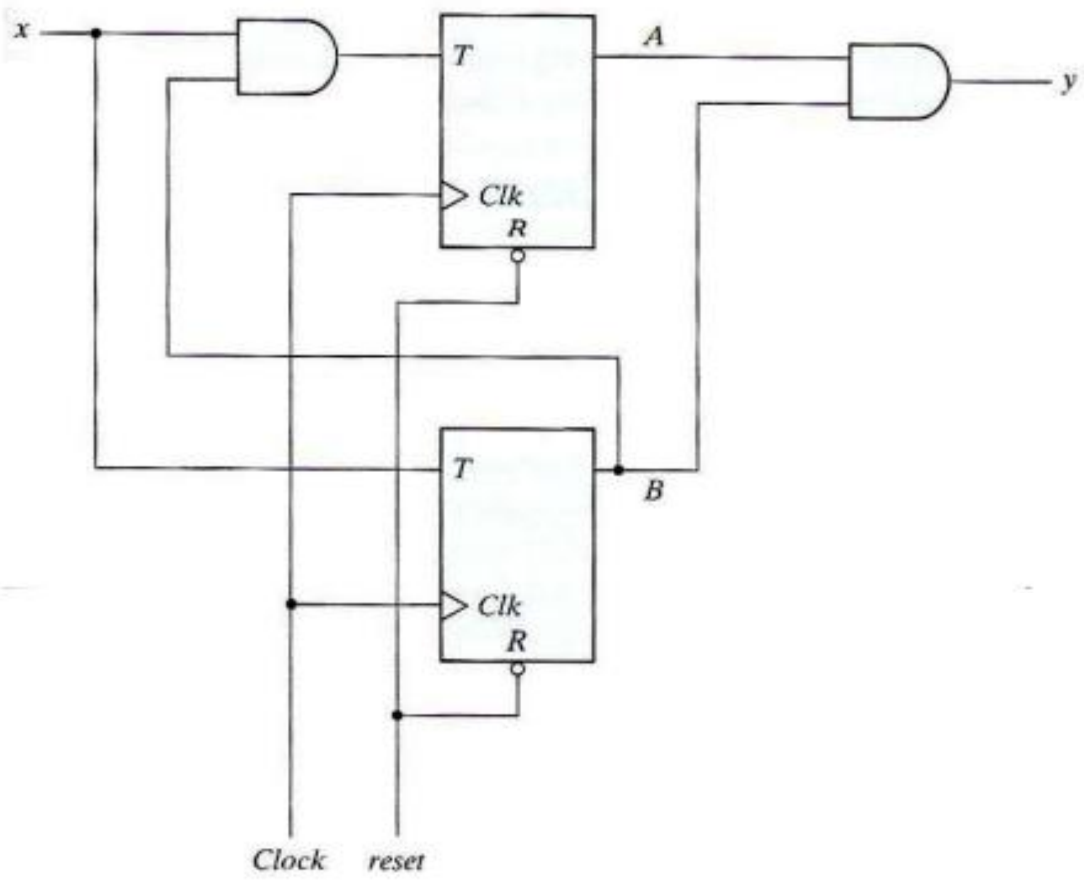
9.2 Circuit to State Diagram

Step 1. Find the input output equation

$Y = AB$

$T_A = XB$

$T_B = X$



9.2 Circuit to State Diagram

Step 2. Make the state table

There is 1 input, 1 output, 2 T flip flop

Input x		P.S		N.S		Ouput Y
0	1	A	B	A_{t+1}	B_{t+1}	

9.2 Circuit to State Diagram

$Y = AB$

$T_A = XB$

$T_B = X$

In T flip flop

$Q_{n+1} = Q_n \; XOR \; T$, therefore

$A_{t+1} = A \; XOR \; T_A = A \; XOR \; (XB)$

$B_{t+1} = B \; XOR \; T_B = \mathrm{B \; XOR \; X}$

Input	P.S		N.S		Output
	A	B	$\boldsymbol{A_{t+1}}$	$\boldsymbol{B_{t+1}}$	
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	1	0	0
0	1	1	1	1	1
1	0	0	0	1	0
1	0	1	1	0	0
1	1	0	1	1	0
1	1	1	0	0	1

9.2 Circuit to State Diagram

The state table can also be written as

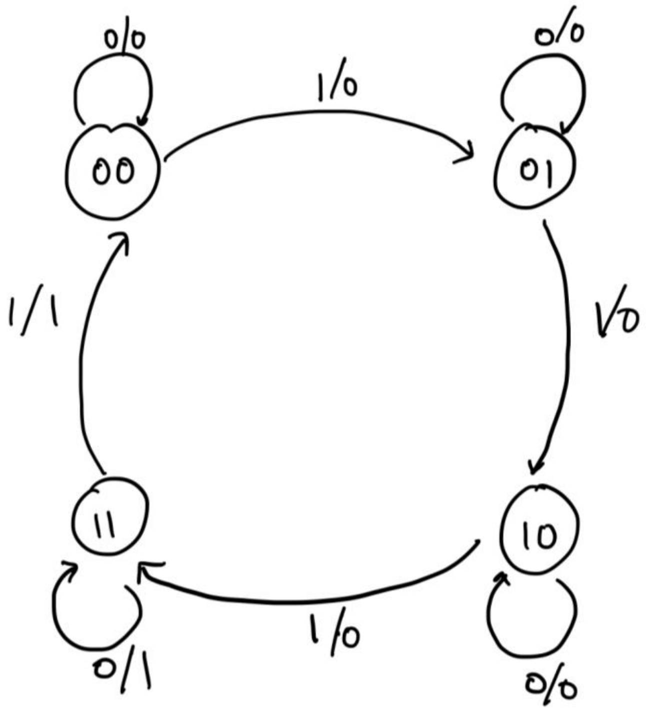
Present State		Next State				Output
		x = 0		x = 1		
A	B	A	B	A	B	y
		0	0	0	1	0
		0	1	1	0	0
		1	0	1	1	0
		1	1	0	0	1

9.2 Circuit to State Diagram

Step 3. Make the state diagram

There are 2 flip flop, therefore there are 4 state

Input	P.S		N.S		Output
	A	B	A_{t+1}	B_{t+1}	
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	1	0	0
0	1	1	1	1	1
1	0	0	0	1	0
1	0	1	1	0	0
1	1	0	1	1	0
1	1	1	0	0	1



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9.3 State Diagram to Circuit

9.3 State Diagram to Circuit

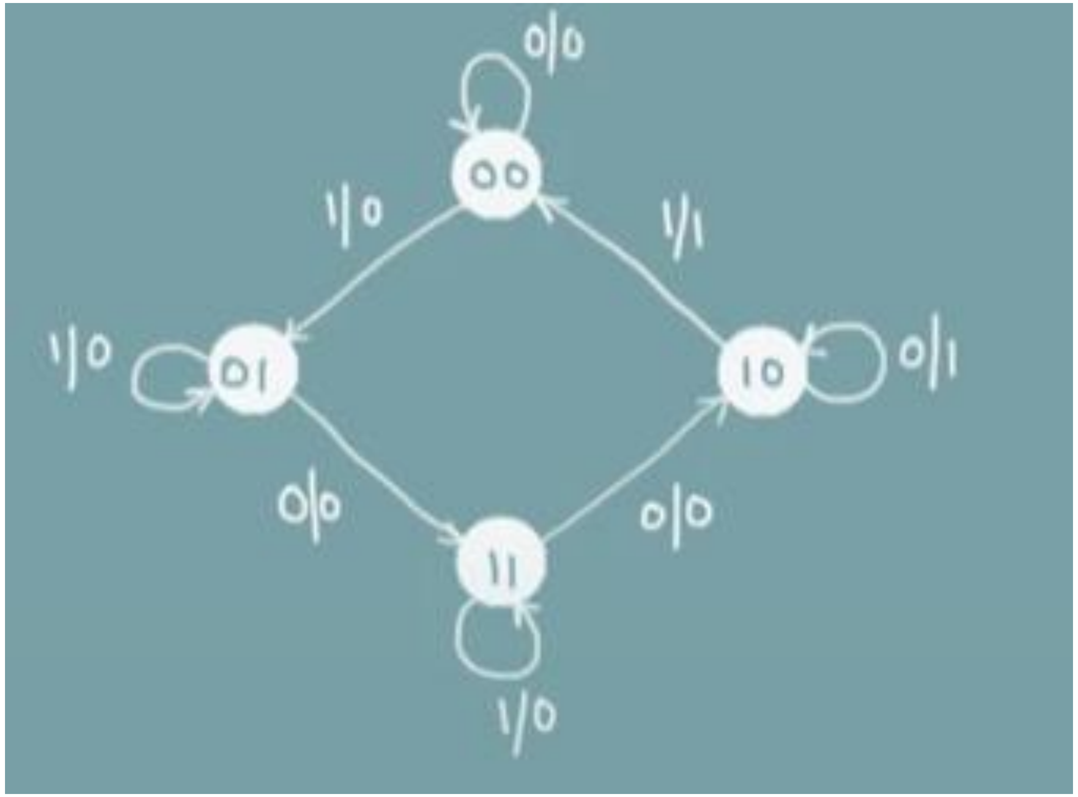
Step

1. Obtain the state table
2. Determine the number of flip flop required and assign letter number
3. Decide the type of flip flop
4. Derive the circuit excitation table from state table
5. Obtain the expression for circuit output and flip flop input
6. Implement the circuit

9.3 State Diagram to Circuit

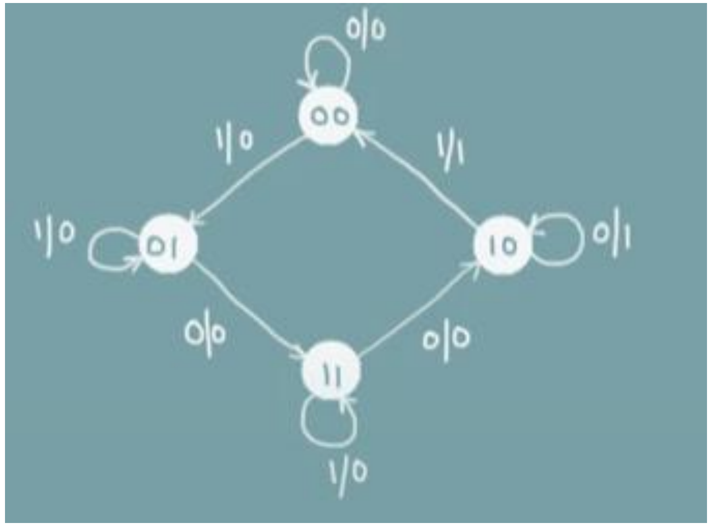
Example.

Find the circuit for the given state diagram



9.3 State Diagram to Circuit

Step 1. Obtain state table



P.S		N.S				Output	
Q_A	Q_B	X=0		X=1		X=0	X=1
		Q_{A+}	Q_{B+}	Q_{A+}	Q_{B+}		
0	0	0	0	0	1	0	0
0	1	1	1	0	1	0	0
1	0	1	0	0	0	1	1
1	1	1	0	1	1	0	0

9.3 State Diagram to Circuit

Step 2. Determine the number of flip flop required

There are 4 state → 2 flip flops (flip flop A and flip flop B)

Step 3. Decide the type of flip flop

For this example, we will be use T flip flop

9.3 State Diagram to Circuit

Step 4.

Derive the circuit excitation table from state table

Circuit excitation table

P.S			N.S		FF input		OUTPUT
Q_A	Q_B	X	Q_{A+}	Q_{A+}	T_A	T_B	Y
0	0	0	0	0			0
0	0	1	0	1			0
0	1	0	1	1			0
0	1	1	0	1			0
1	0	0	1	0			1
1	0	1	0	0			1
1	1	0	1	0			0
1	1	1	1	1			0

9.3 State Diagram to Circuit

Qn	Qn+1	T
0	0	0
0	1	1
1	0	1
1	1	0

Clk	T	Qn+1
0	X	Qn
1	0	Qn
1	1	$\overline{Qn}$

Circuit excitation table

P.S			N.S		FF input		OUTPUT
Q_A	Q_B	X	Q_{A+}	Q_{A+}	T_A	T_B	Y
0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	0
0	1	0	1	1	1	0	0
0	1	1	0	1	0	0	0
1	0	0	1	0	0	0	1
1	0	1	0	0	1	0	1
1	1	0	1	0	0	1	0
1	1	1	1	1	0	0	0

9.3 State Diagram to Circuit

Step 5. Obtain the expression for circuit output and flip flop input

Use the characteristic table, when the value of $\boldsymbol{T_A}$ $\boldsymbol{T_B}$, and Y are 1

P.S			N.S		FF input		OUTPUT
Q_A	Q_B	X	Q_{A+}	Q_{A+}	T_A	T_B	Y
0	0	1	0	1	0	1	0
0	1	0	1	1	1	0	0
1	0	1	0	0	1	0	1
1	1	0	1	0	0	1	0

$$T_A = \boldsymbol{Q_A{}'Q_BX' + Q_AQ_B'X}$$

$$T_B = \boldsymbol{Q_A{}'Q_B'X + Q_AQ_BX'}$$

We can also use K-MAP for this

9.3 State Diagram to Circuit

Step 5. Obtain the expression for circuit output and flip flop input

Use the characteristic table, when the value of $\boldsymbol{T_A}$ $\boldsymbol{T_B}$, and Y are 1

P.S			N.S		FF input		OUTPUT
$\boldsymbol{Q_A}$	$\boldsymbol{Q_B}$	X	$\boldsymbol{Q_{A+}}$	$\boldsymbol{Q_{A+}}$	$\boldsymbol{T_A}$	$\boldsymbol{T_B}$	Y
1	0	0	1	0	0	0	1
1	0	1	0	0	1	0	1

$$Y = \boldsymbol{Q_A Q_B' X' + Q_A Q_B' X = Q_A Q_B'(X + X') = Q_A Q_B'.}1 = \boldsymbol{Q_A Q_B'}$$

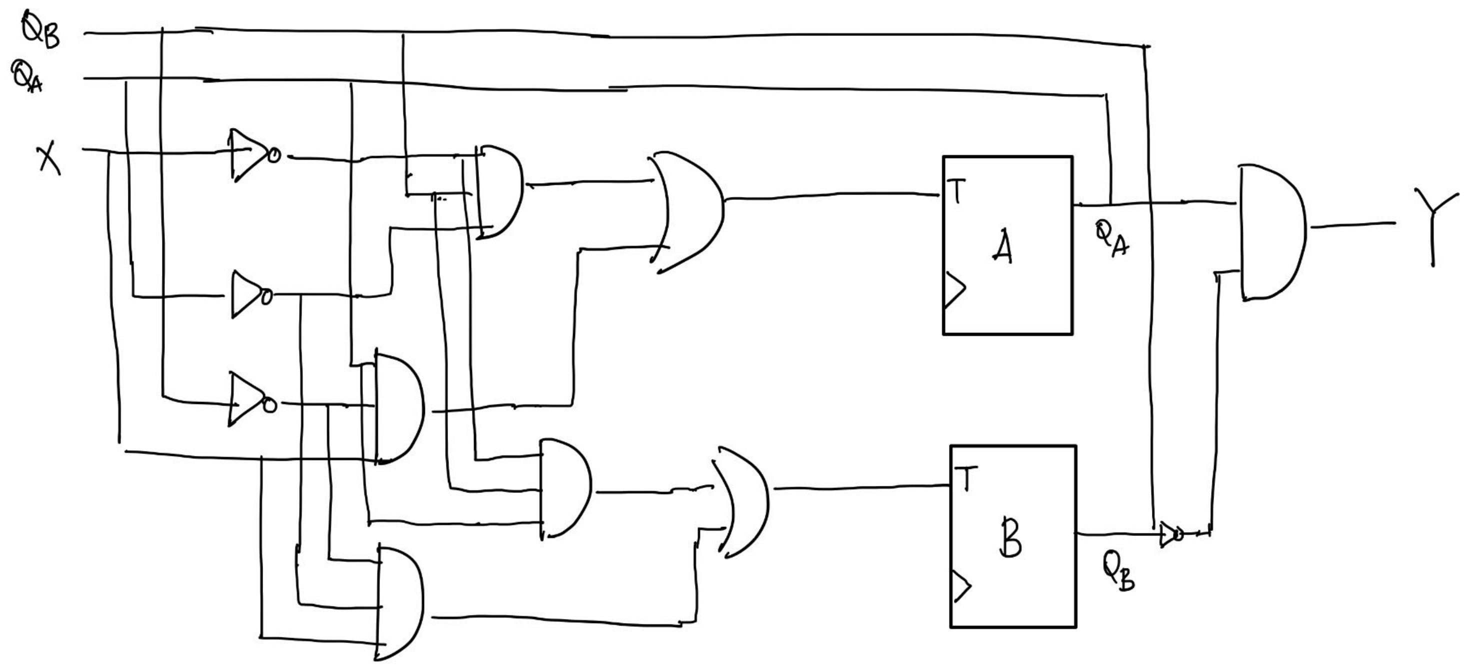
We can also use K-MAP for this

9.3 State Diagram to Circuit

Step 6. Implement the circuit

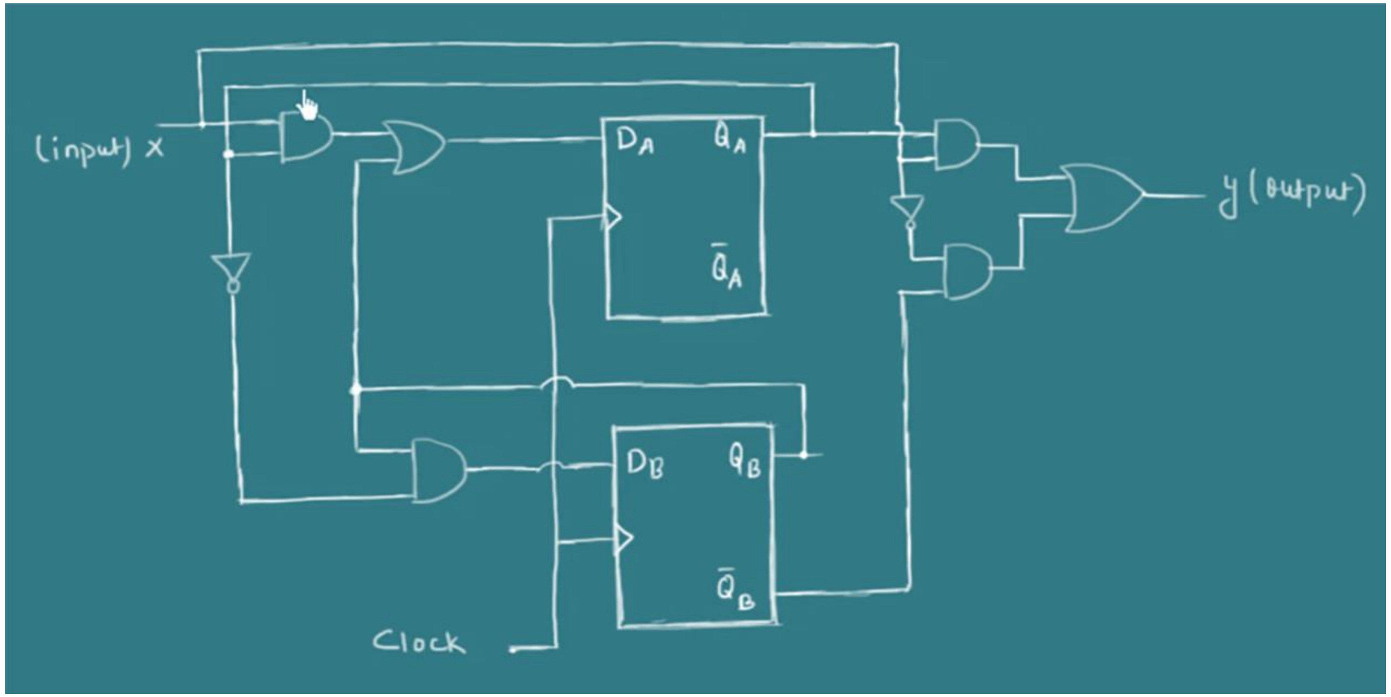
$$T_B = Q_A'Q_B'X + Q_AQ_BX' \qquad Y = Q_AQ_B'$$

$$T_A = Q_A'Q_BX' + Q_AQ_B'X$$



Assignment

Find the state diagram from the given circuit



Assignment

- Collect your answer to eLearning
- Your answer should be in 1 PDF file with file name : NIM(without zero)_Name_Assignment 8
- Deadline : Wednesday, April 13, 23.59 WIB

References

M. Morris Mano, Digital Design, 5th ed, Prentice Hall, 2012, **Chapter 5**

Next Topic : Simplification of Sequential Circuit