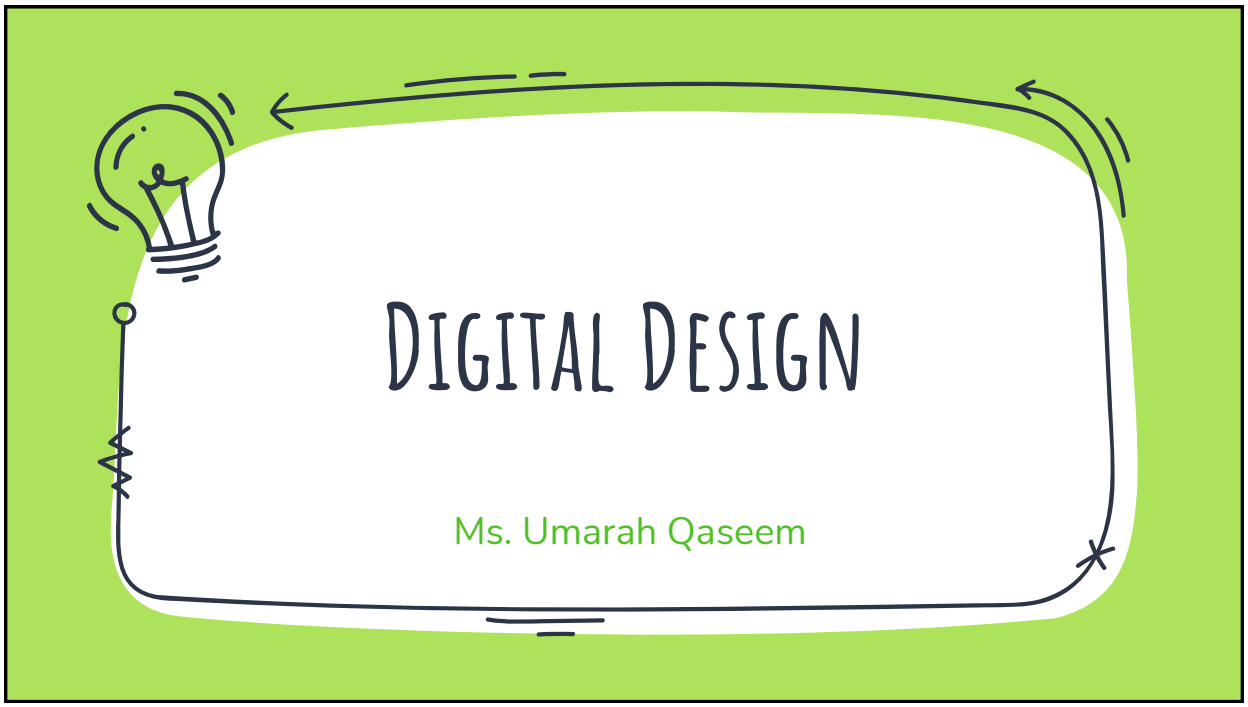
Digital Design
Ms. Umarah Qaseem

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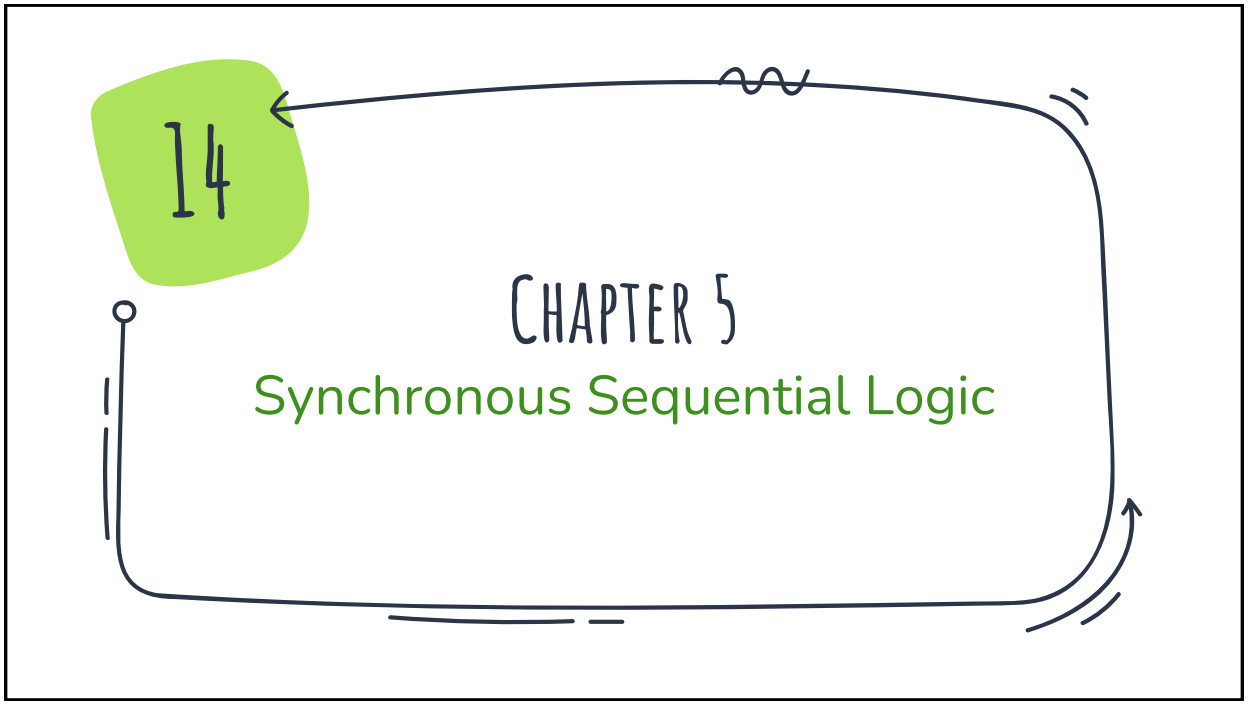
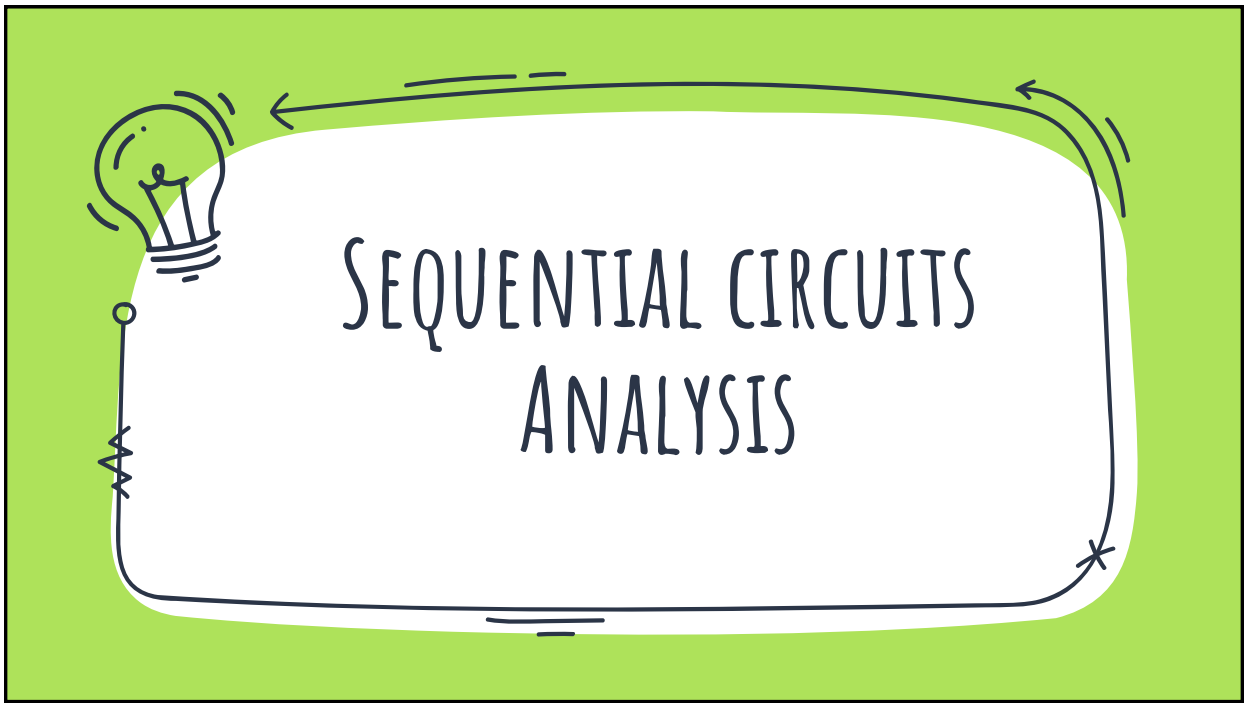

14
Chapter 5
Synchronous Sequential Logic

2

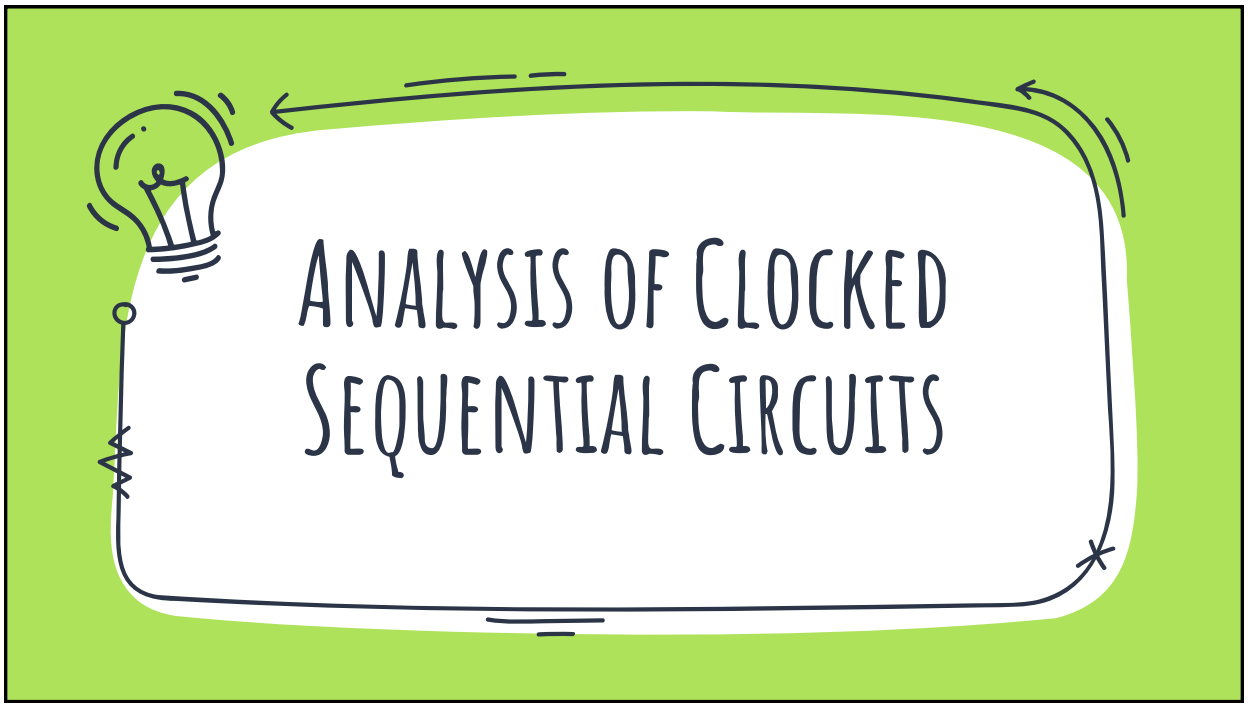


4

Analysis of Sequential Circuits

- How to design machines that go through a sequence of events
- Earlier we learned how to specify combinational circuits
  - Truth tables, Boolean equations, …
- Now extend to synchronous sequential circuits
  - Include time
  - Use ‘state tables’ and ‘state diagrams’

5



6

Analysis of Clocked Sequential Circuits

1. State/Output Equations (*transition/characteristic equation*)
   - Specifies the next state as a function of present state and input
2. State Table (*transition/characteristic table*)
   - Displays the relationship between various states in a table form
   - *Present State*, *Input*, *Next State*, *Output*
3. State Diagram
   - Graphic representation
   - States represented by circles
   - Lines represent transition

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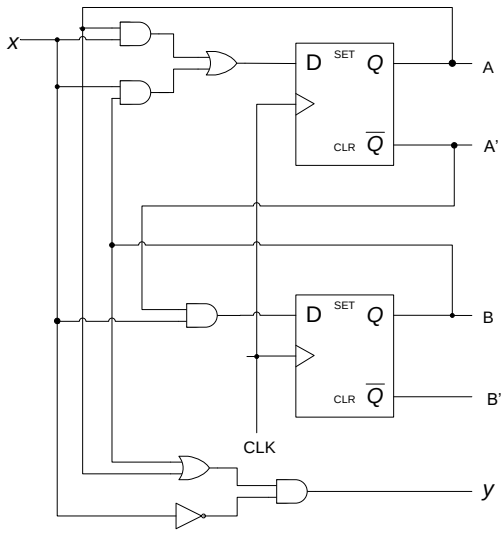
State Table

- State Table
- It is like truth table but with states added

8



Since A(t+1)=D,
D=Ax+Bx

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

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

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

And

$y(t) = [A(t) + B(t)]\, x'(t)$

$y = (A + B)x'$

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

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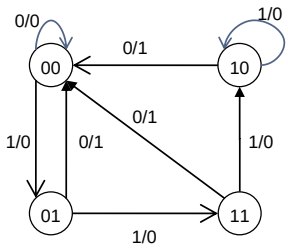

Since D input of the flip flop determines the next state, we can write a set of state equation as

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

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

And

$y(t) = [A(t) + B(t)]\, x'(t)$

$y = (A + B)x'$

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

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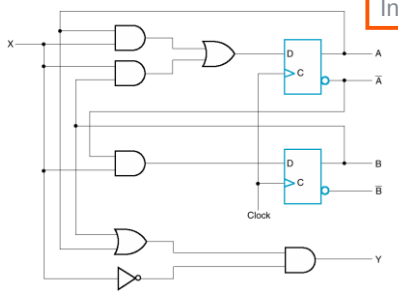
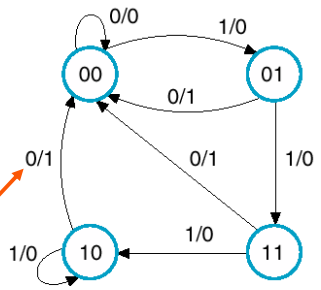
State Diagram – Mealy Model



Input/Output



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

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Analysis with D Flip Flop

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Analysis with D Flip Flop

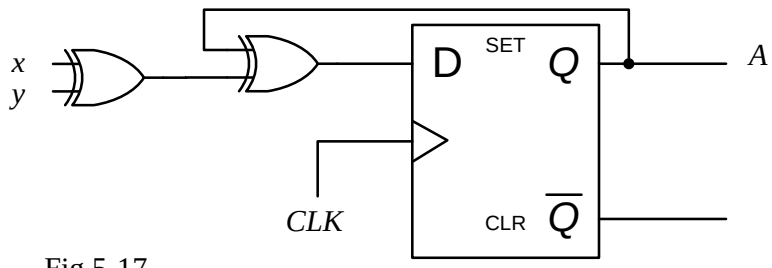

Fig 5-17

14

Analysis with D Flip Flop

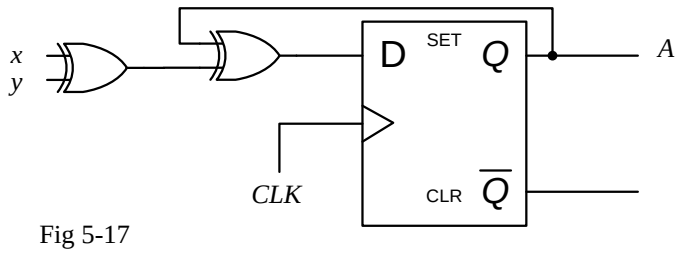

Fig 5-17

- $A(t+1) = D_A$
- $D_A = A \oplus x \oplus y$
- **$A(t+1) = A \oplus x \oplus y$**

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Analysis with D Flip Flop

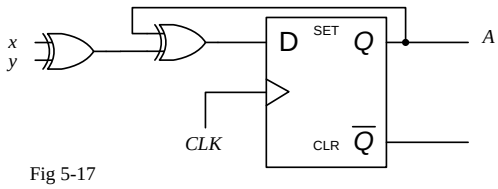

Fig 5-17

- **$A(t+1) = A \oplus x \oplus y$**

Present State	Input		Next State
A	x	y	A
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

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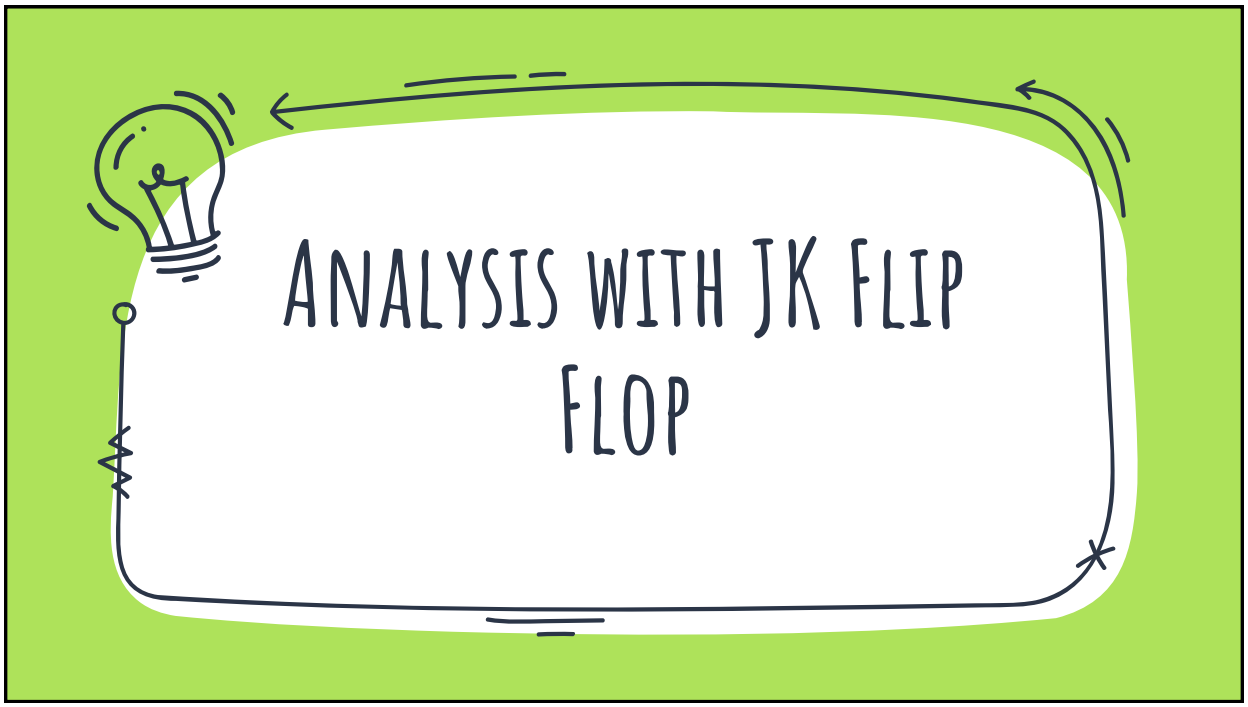

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Analysis procedure of Flip Flop

- The next-state value of a sequential circuit that uses flip-flops can be derived using the following procedure.
  1. determine the flip-flop input equation in terms of present state and input variable.
  2. List the binary values of each input equation
  3. Use the corresponding flip-flop characteristic table to determine the next values in the state table.

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Analysis with JK Flip Flop

$$Q(t+1) = JQ' + K'Q$$

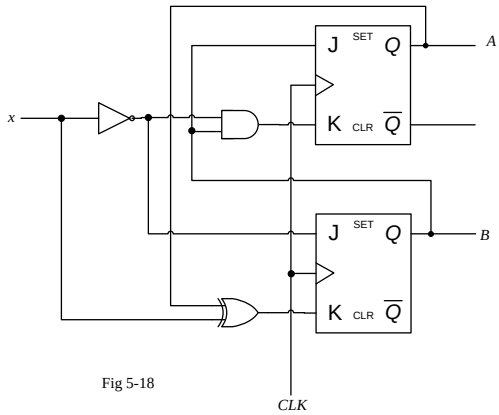

Fig 5-18

$J_A = B$ $\quad K_A = Bx'$

$J_B = x'$ $\quad K_B = A'x + Ax'$

$= A \oplus x$

$A(t+1) = J_A A' + K_A' A$

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

$= A'B + (B'+X)A$

$= A'B + AB' + Ax$

$B(t+1) = J_B B' + K_B' B$

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

$= B'x' + ABx + A'Bx'$

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Analysis with JK Flip Flop

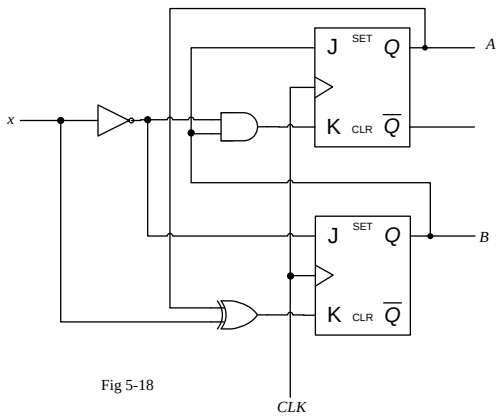

Fig 5-18

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

$A(t+1) = J_A A' + K_A' A$

$= A'B + AB' + Ax$

$B(t+1) = J_B B' + K_B' B$

$= B'x' + ABx + A'Bx'$

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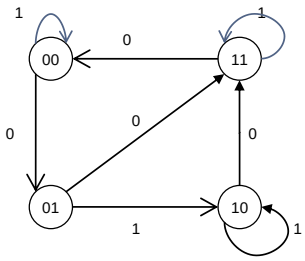
Analysis with JK Flip Flop



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

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Analysis with T Flip-Flops:

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Analysis with T Flip-Flops:

- Same procedure as J-K flip-flops.

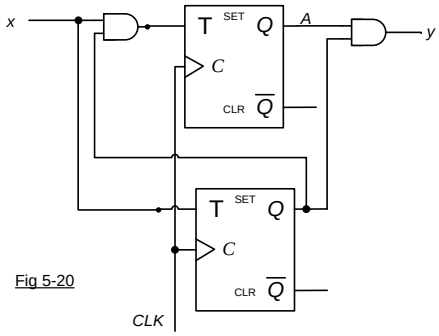

Fig 5-20

$$Q(t+1) = TQ' + T'Q$$

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Analysis with T Flip-Flops:

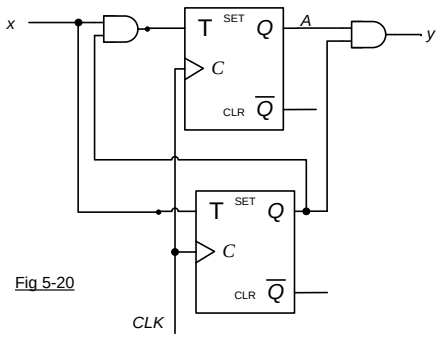

Fig 5-20

- $Q(t+1) = T'Q + TQ'$
- $A(t+1) = T_A 'A + T_A A'$
- $T_A = Bx,$
- $A(t+1) = (Bx)'A + (Bx)A'$
- $=(B'+x')A + (Bx)A'$
- $= AB' + Ax' + A'Bx$
- $T_B = X,$
- $B(t+1) = T_B 'B + T_B B' = T_B \oplus B$
- $= x \oplus B$
- $y=AB$

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Analysis with T Flip-Flops:

- Same procedure as J-K flip-flops.

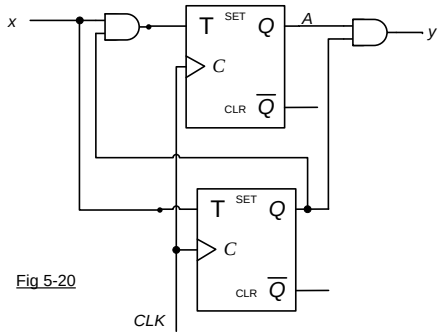

Fig 5-20

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

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Analysis with T Flip-Flops:

- Same procedure as J-K flip-flops.

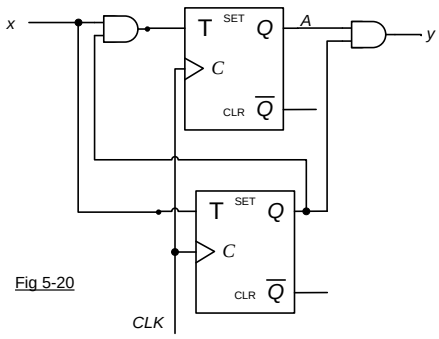

Fig 5-20

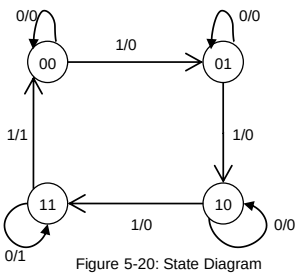

Figure 5-20: State Diagram

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References

- Chapter 5 and 6 – Digital Design Morris Mano
- Template is taken from slides carnival.

Slides Carnival

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