Chapter5-Synchronous Sequential Logic

Lecture3- Design JK and T Flip-Flops using D Flip-flops

Objectives

- Construct JK and T Flip-flops using D Flip-flops
- Derive Characteristic tables, Characteristic equations, and State equations

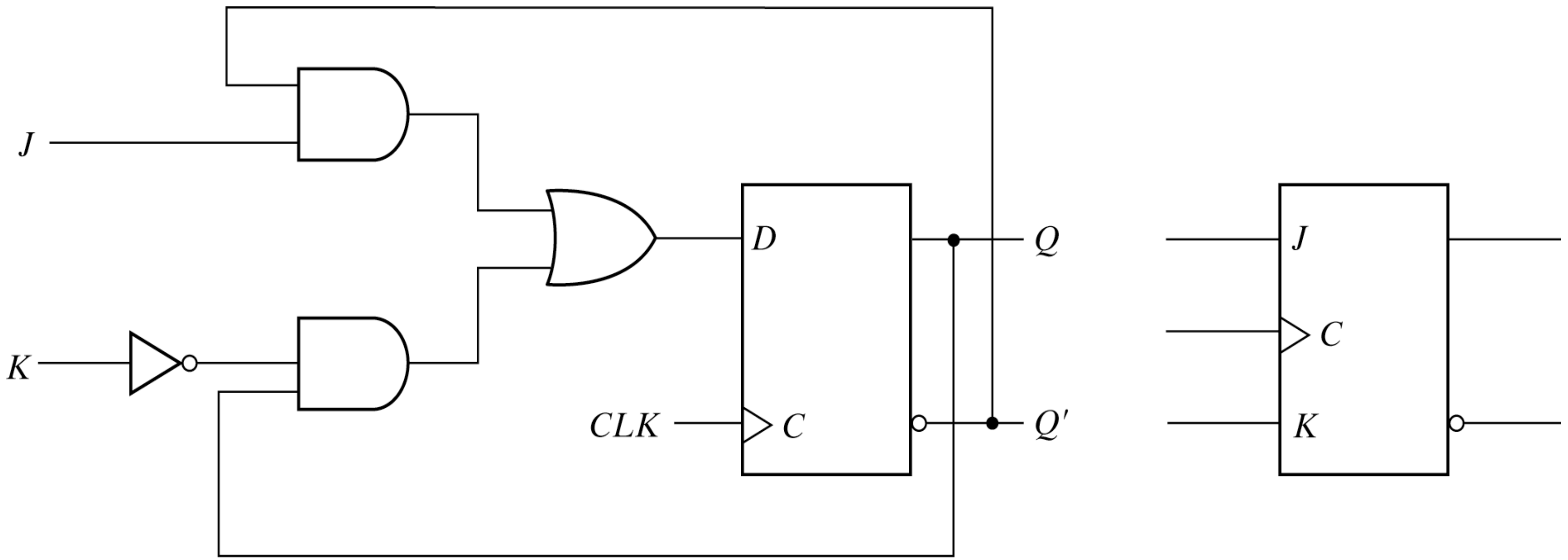
Other Flip Flops

- D flip-flop is the basic flip-flop and other types of flip flops can be constructed by using the D flip flop and external logic. The other most widely used flip-flops in the design of digital systems are:
  - JK flip flop
  - T (Toggle) flip flop
- There are three basic operations that can be performed with a flip-flop: Set it to 1, Reset it to 0, or complement its output.
- Synchronized with a clock signal, the JK flip performs all these three operations.

JK Flip Flop

- The JK flip flop has two inputs J and K, and two outputs Q and Q′. It performs four basic operations:
  - set it to 1 i.e Q=1
  - reset it to 0 i.e Q=0
  - complement the output i.e Q(t+1)=Q′(t)
  - No change i.e Q(t+1)=Q(t)
- The J input sets the flip flop to 1.
- The K input resets the flip flop to 0.
- When both J and K are enabled, the output is complemented.
- When J and K are both 0, the data most recently stored is held.

JK Flip Flop Logic



(a) Circuit diagram

(b) Graphic symbol

Fig. 5-12 *JK* Flip-Flop

Analysis of the JK Circuit

- The circuit applied to the D input is

$$D = JQ' + K'Q$$

  - If J = 1 and K = 0, $D = Q + Q' = 1$, set to 1
  - If J = 0 and K = 1, $D = 0$, reset to 0
  - If J = K = 1, $D = Q'$, complements the output
  - If J = K = 0, $D = Q$, leaving the output unchanged
- The characteristics table of the JK flip-flop is shown below

JK Flip-Flop			
J	K	Q(t+1)	
0	0	Q(t)	No change
0	1	0	Reset
1	0	1	Set
1	1	Q′(t)	Complement

- The characteristics table defines the next state Q(t+1) of a flip-flop in terms of its present state Q(t) and flip-flop inputs.
- The characteristics equation of the flip-flop is **$Q(t+1) = J(t)Q'(t) + K'(t)Q(t)$**

T Flip Flop

- The T (Toggle) flip flop is a complementing flip flop and can be obtained from a JK flip flop when inputs J and K are tied together.
- Because of its complementing property T flip-flop is extensively used in the design of counters.
- The T flip flop can be obtained from a D flip flop by using an XOR as the input for D.
    - ➢ The expression for D input is $D = T \oplus Q = TQ' + T'Q$
    - ➢ When $T = 0$, ($j = k = 0$) then $D = Q$ and there is no change in the output
    - ➢ When $T = 1$, ($j = k = 1$) then $D = Q'$ and the output complements

T Flip Flop Logic Diagram

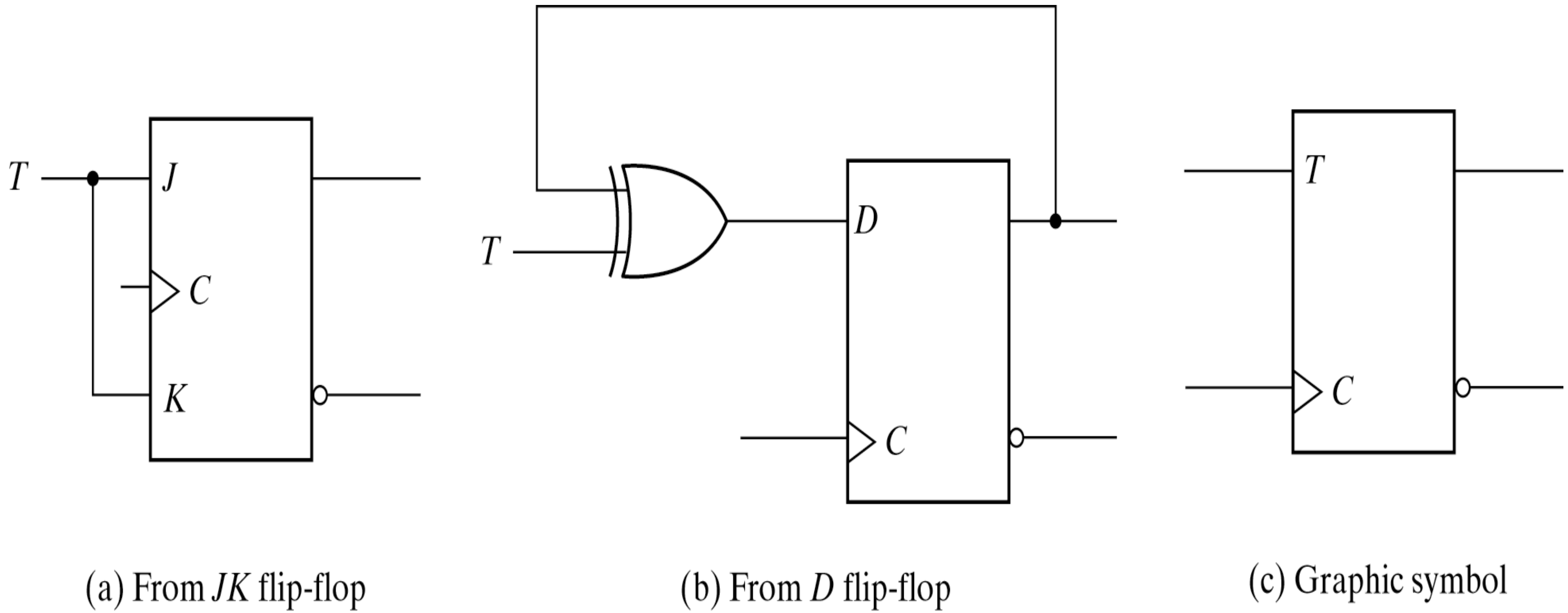


Fig. 5-13 T Flip-Flop

T Flip Flop Characteristic Table

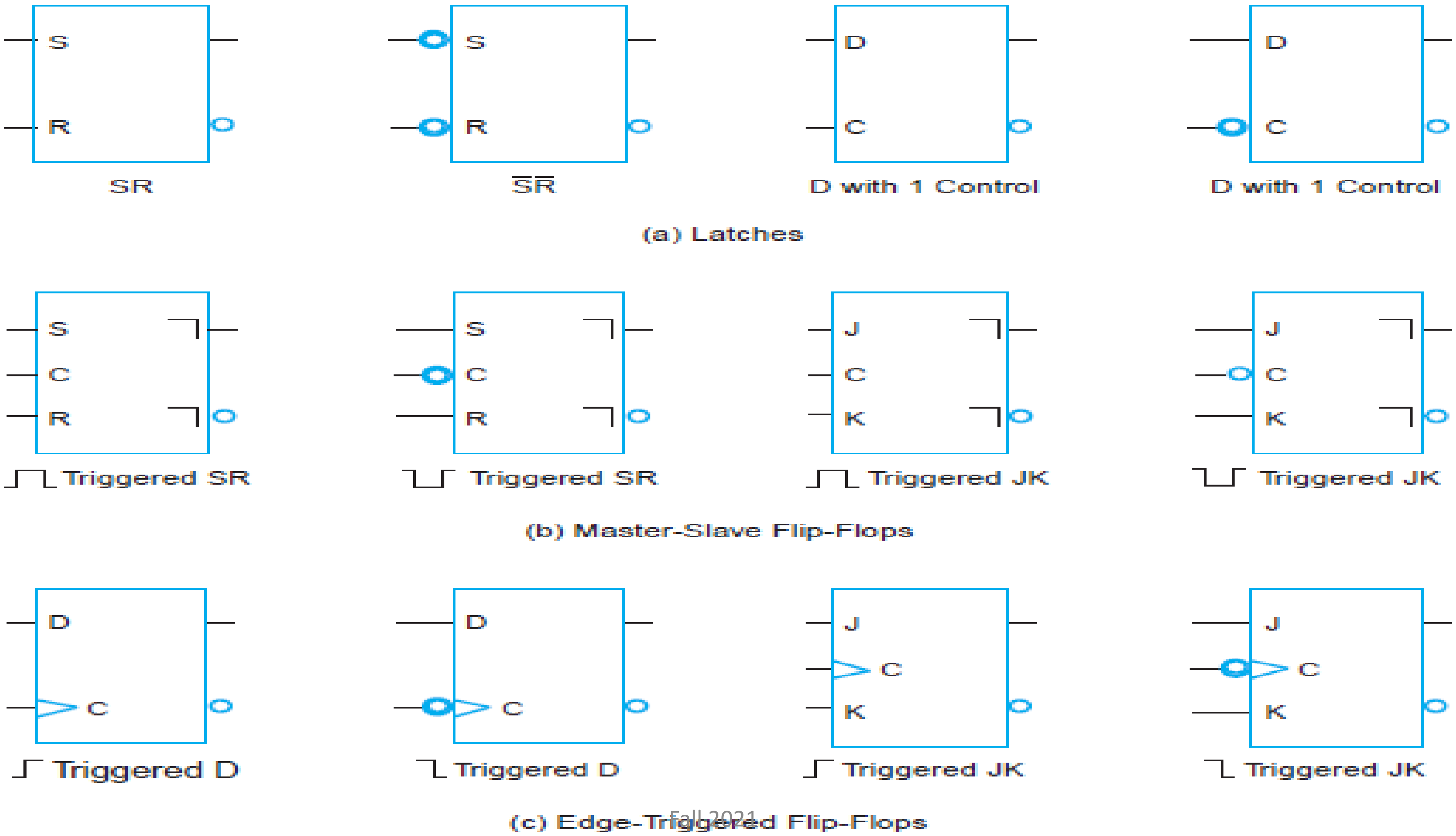
- The following characteristic table for T flip-flop shows:

  When T=0; the flip-flop preserves previously stored value i.e No Change

  When T=1; the flip-flop toggles

T Flip-Flop		
T	Q(t+1)	
0 1	Q(t) Q´(t)	No change Complement

Standard Graphic Symbols of Latches and Flip-Flops



Characteristic Tables of Flip-Flops

(a) *JK* Flip-Flop

J	K	Q (t 1 1)	Operation
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	$\overline{Q}(t)$	Complement

(b) *SR* Flip-Flop

S	R	Q (t 1 1)	Operation
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	?	Undefined

(c) *D* Flip-Flop

D	Q (t 1 1)	Operation
0	0	Reset
1	1	Set

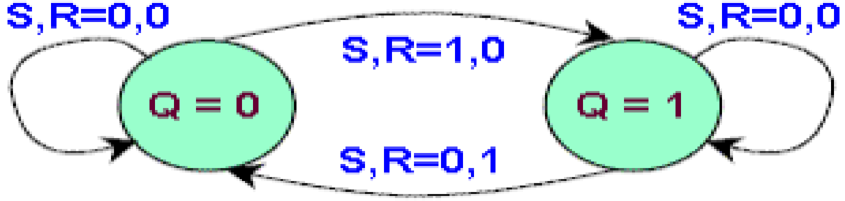
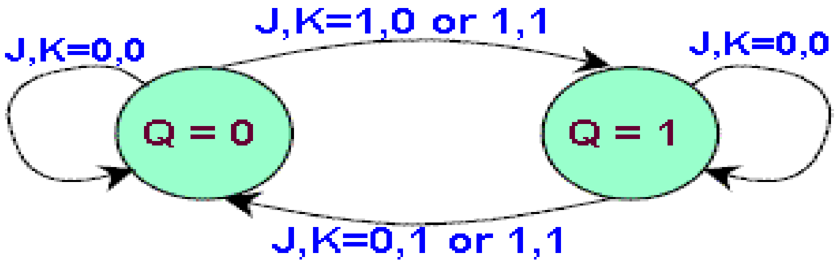
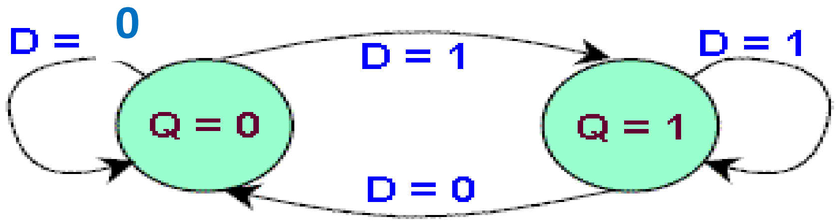
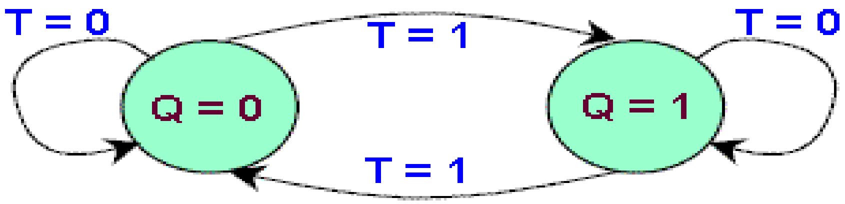
(d) *T* Flip-Flop

T	Q (t 1 1)	Operation
0	$Q(t)$	No change
1	$\overline{Q}(t)$	Complement

Characteristic Equations of Flip-Flops

- The D flip flop can be expressed as:
  - $Q(t + 1) = D$
- The JK flip flop can be expressed as:
  - $Q(t + 1) = JQ' + K'Q$
- The T flip flop can be expressed as:
  - $Q(t + 1) = TQ' + T'Q$
- The SR flip flop can be expressed as:
  - $Q(t + 1) = S+R'Q$

State Diagrams of All Flip-Flops

NAME	STATE DIAGRAM
SR	
JK	
D	
T	

Flip-Flop Excitation Tables

(a) *JK* Flip-Flop

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

(b) *SR* Flip-Flop

$Q(t)$	$Q(t+1)$	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

(c) *D* Flip-Flop

$Q(t)$	$Q(t+1)$	D
0	0	0
0	1	1
1	0	0
1	1	1

(d) *T* Flip-Flop

$Q(t)$	$Q(t+1)$	T
0	0	0
0	1	1
1	0	1
1	1	0

The End