Other Flip Flops, Analysis of Sequential Circuits

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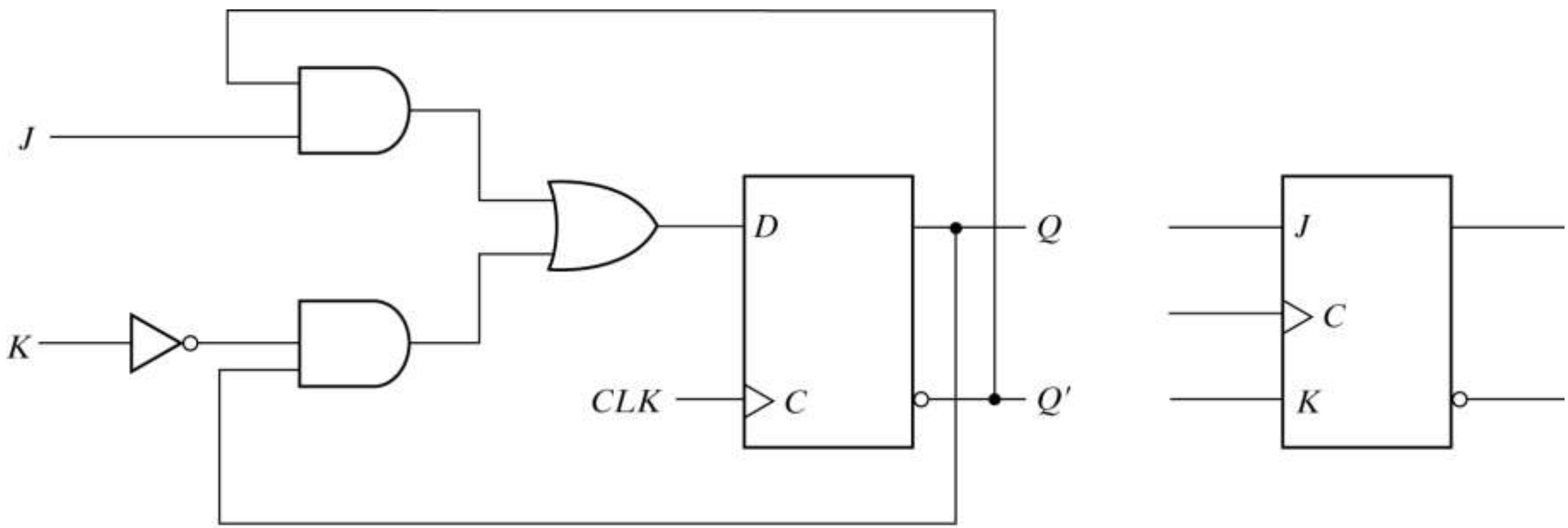
JK Flip Flop

- The JK flip flop performs three operations:
  - set it to 1
  - reset it to 0
  - complement the output
- 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.

JK Flip Flop Logic



(a) Circuit diagram

(b) Graphic symbol

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

JK Characteristic Table

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

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.
- 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

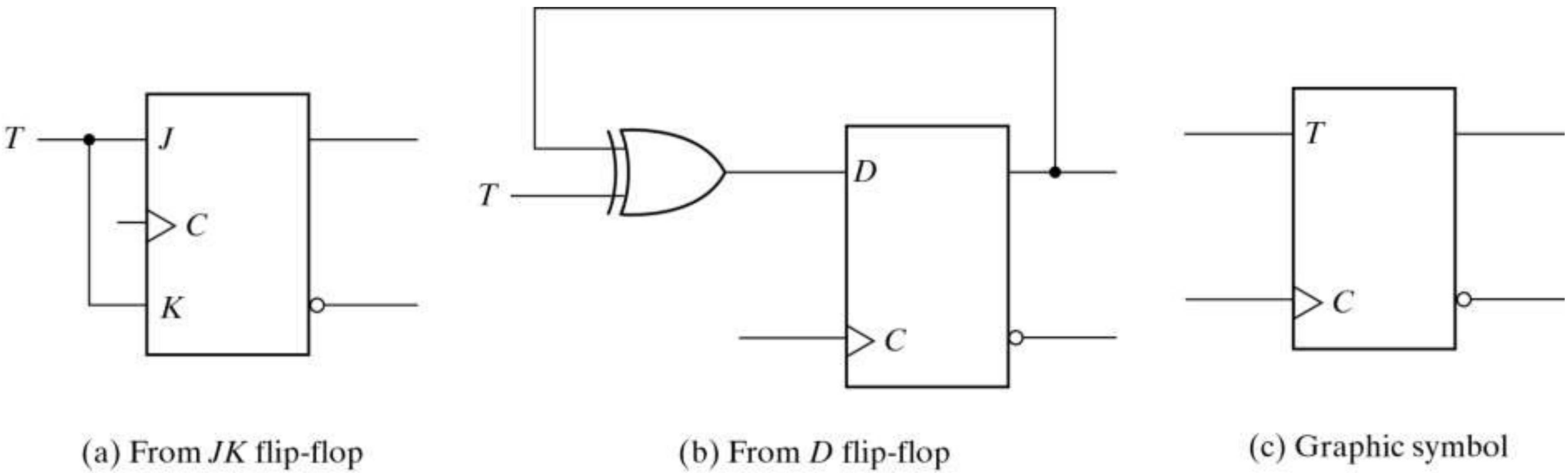


Fig. 5-13 T Flip-Flop

Characteristic Tables

- Characteristic tables define the logical properties of a flip flop by describing its operations in tabular form.
  - They define the next state as a function of the inputs and the present state.
  - Q(t) refers to the present state prior to the application of a clock edge.
  - Q(t + 1) refers to the next state one clock period later.
  - Clock edges are not listed as inputs but are implied by the transition from t to t + 1.

T Flip Flop Characteristic Table

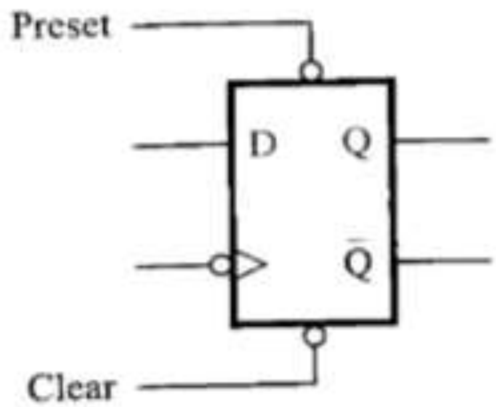
T Flip Flop		
T	**Q(t + 1)**	
0	Q(t)	No change
1	Q'(t)	Complement

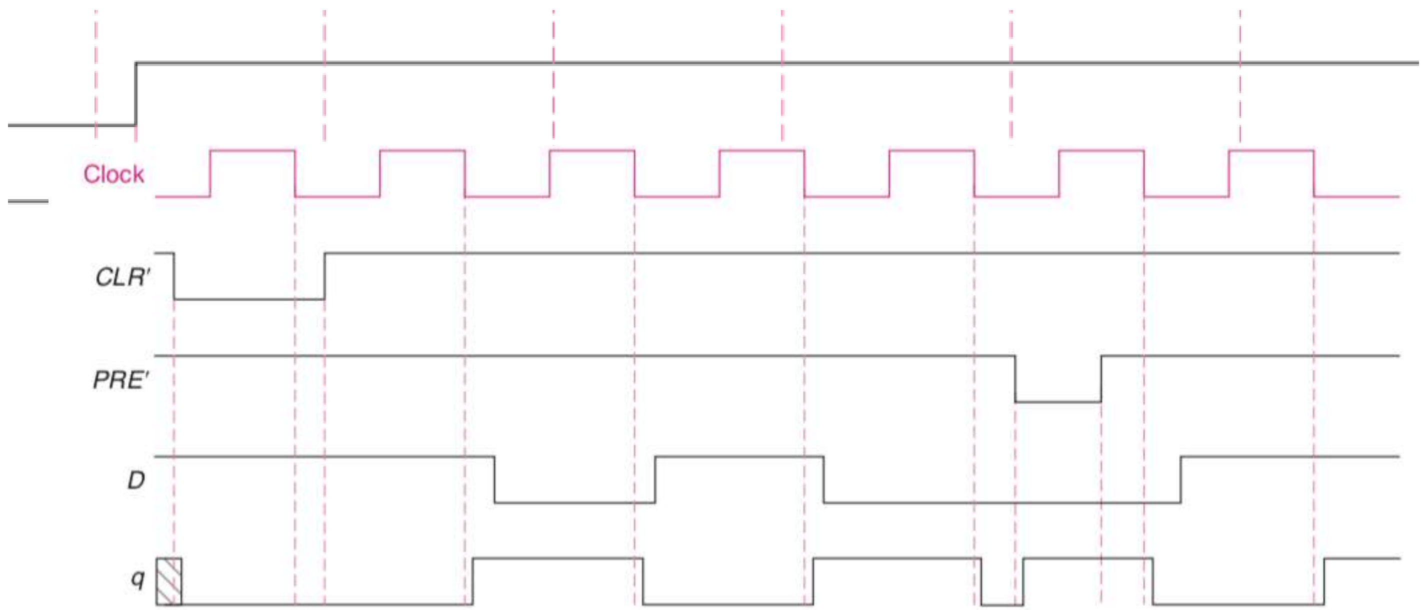
$Q(t + 1) = TQ' + T'Q$

Characteristic Equations

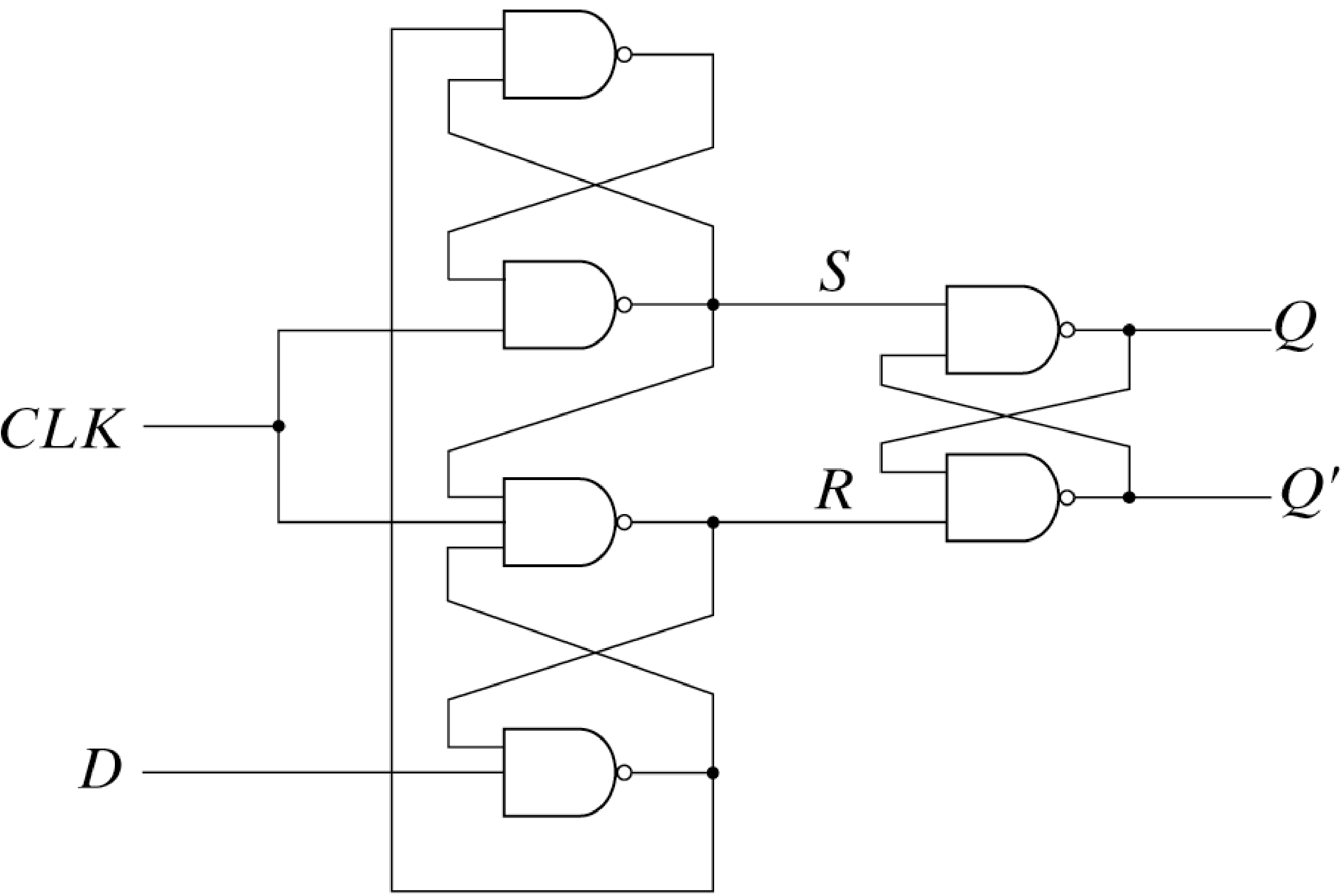
- The D flip flop can be expressed as:
  - $Q(t + 1) = D$
- The JK flip flop can be expressed as:
  - $Q(t + 1) = JQ' + K'Q$
- The T flip flop can be expressed as:
  - $Q(t + 1) = TQ' + T'Q$

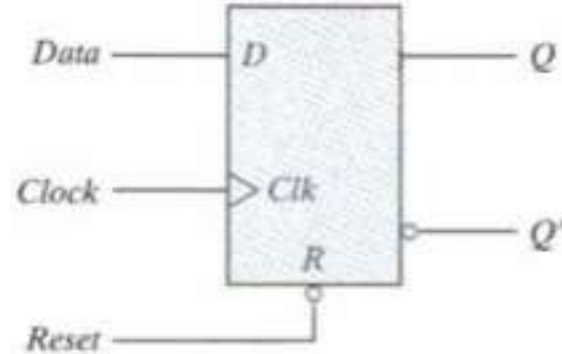
Direct Input to Flip Flops





D Flip Flop with Asynchronous Reset



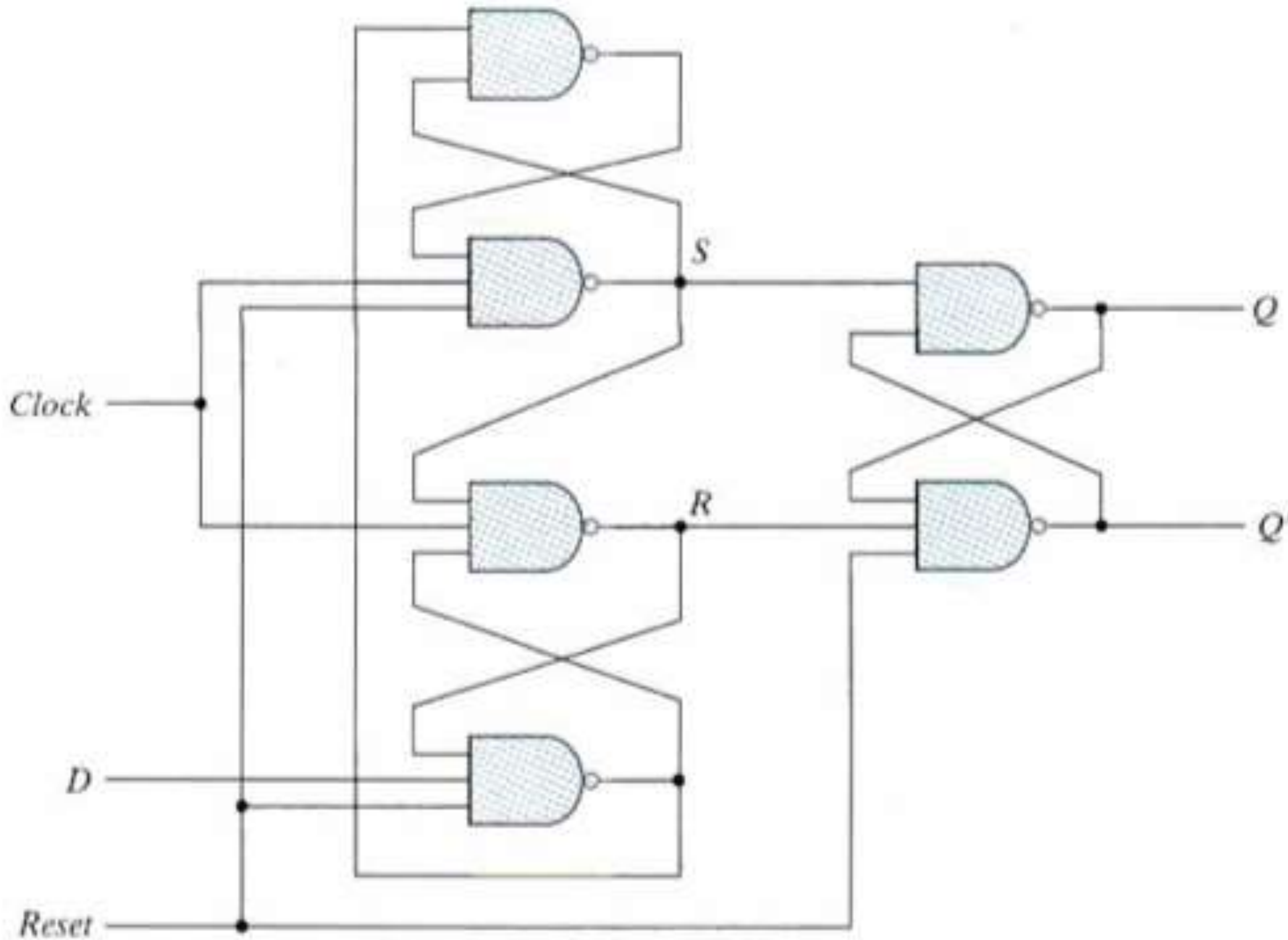


(b) Graphic symbol

R	Clk	D	Q	Q'
0	X	X	0	1
0	↑	0	0	1
0	↑	1	1	0

(b) Function table

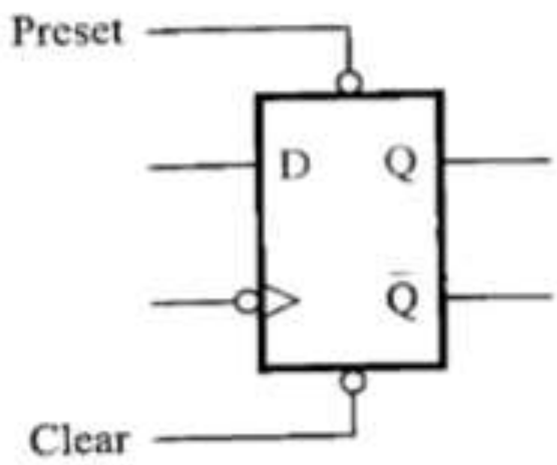
Solution



(a) Circuit diagram

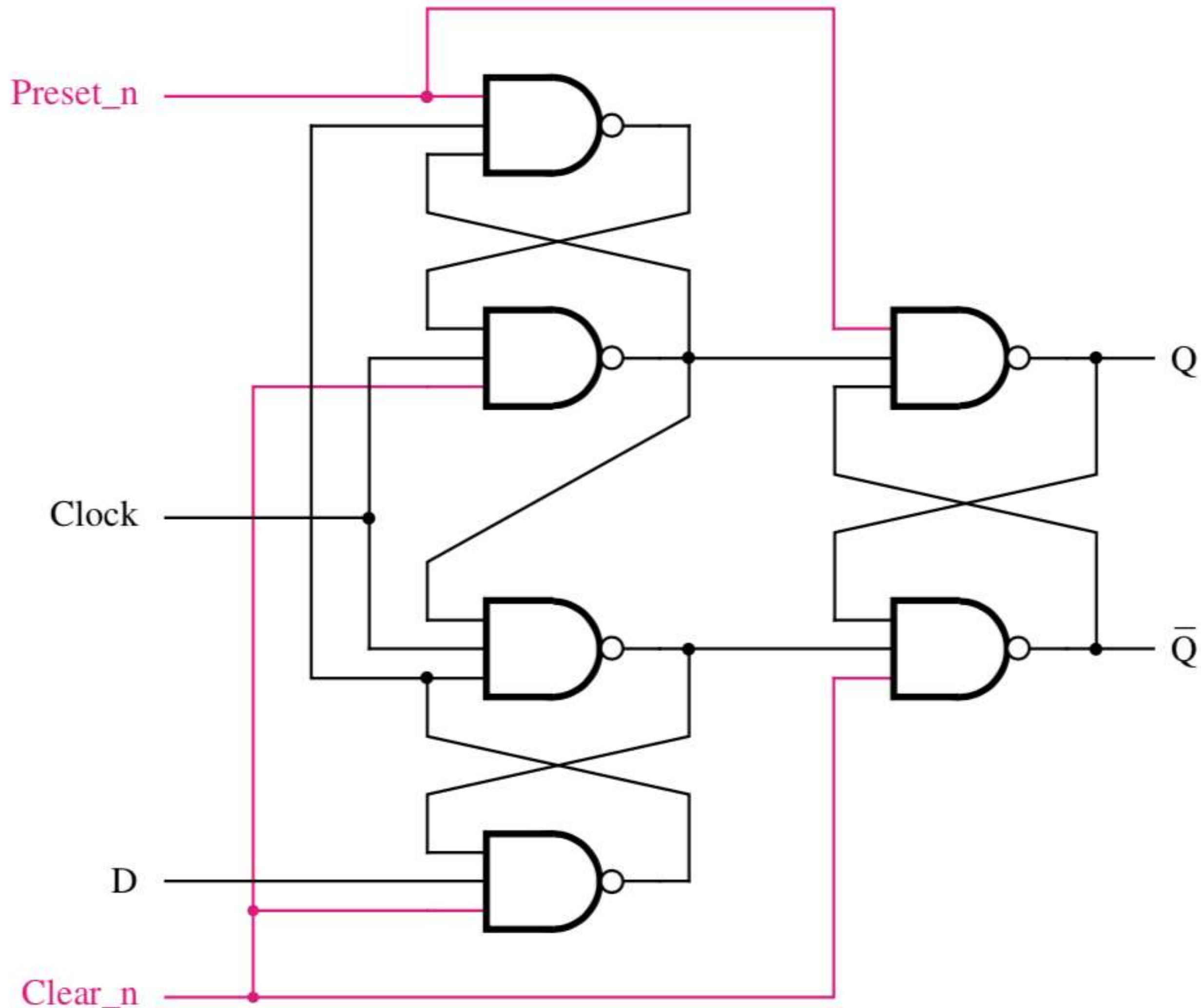
Practice Problem

- Make changes in circuits of Master-Slave D Flip Flop with NAND Gates into D flip flop with Clear and Preset inputs

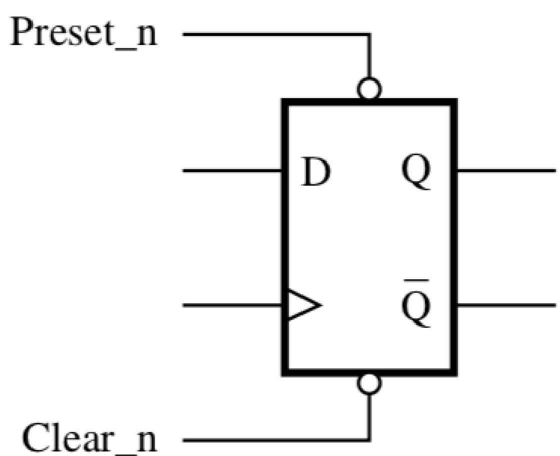


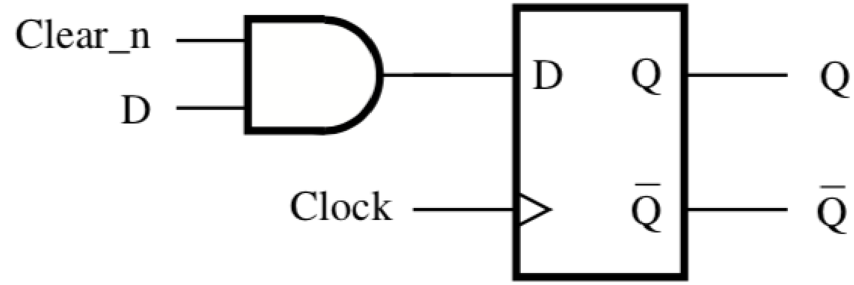
Solution

Positive-edge-triggered D flip-flop with *Clear* and *Preset*



Asynchronous Vs Synchronous Reset



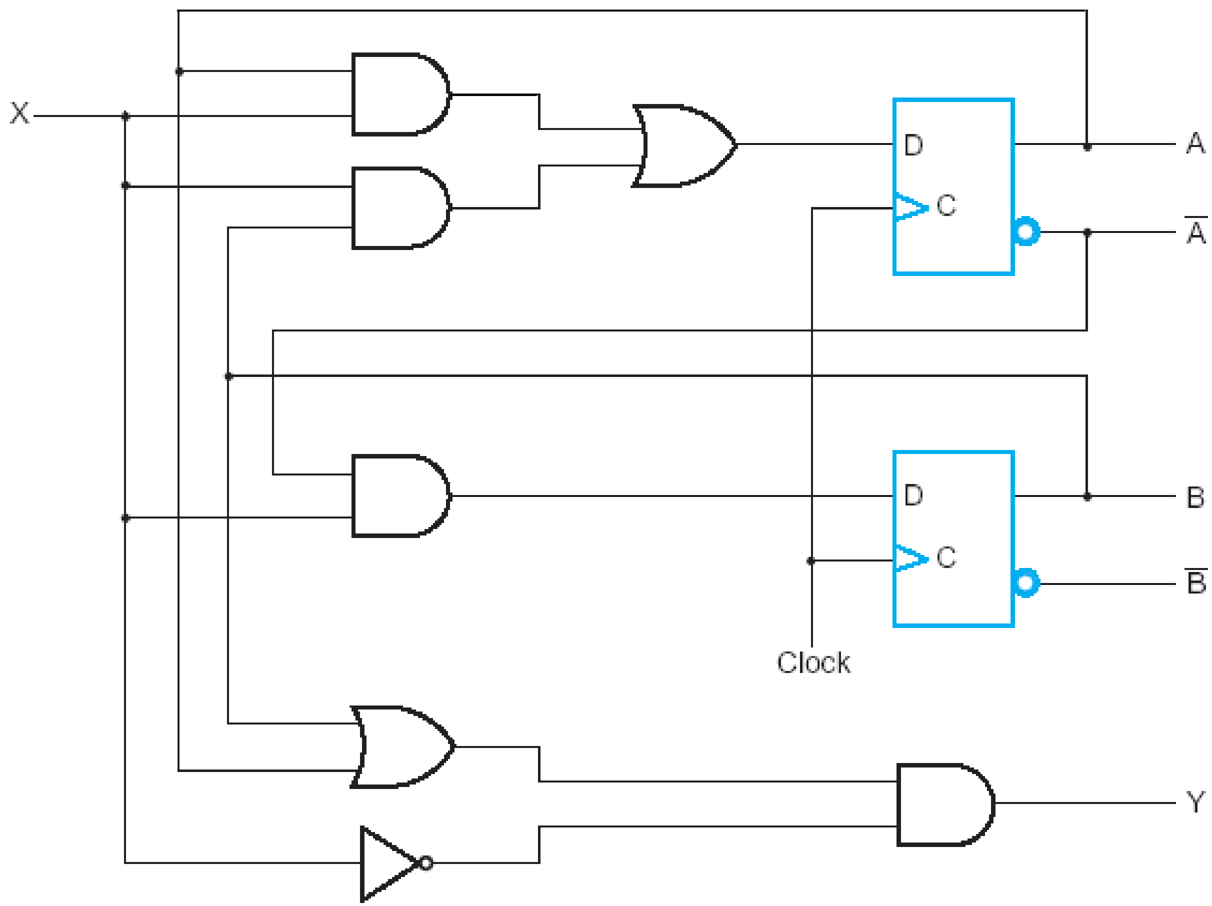


Overview

- D Flip Flop
    - Characteristic Table?
    - Characteristic Equation?
- JK Flip Flop
    - Characteristic Table?
    - Characteristic Equation?
- T Flip Flop
    - Characteristic Table?
    - Characteristic Equation?

- Analysis of Clocked Sequential Circuits
  - Circuit with D flip flops
  - Circuit with T or JK flop flops

Example Sequential Circuit



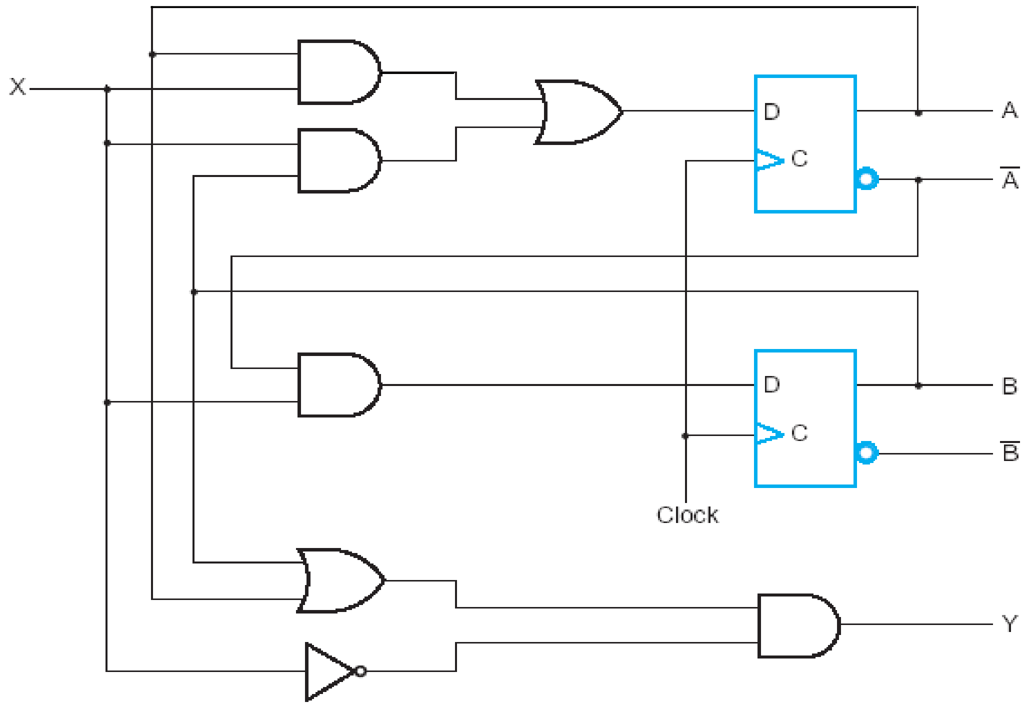
Analysis of Clocked Sequential Circuits

- The behavior of a clocked sequential circuit is determined from the inputs, the outputs, and the state of its flip flops.
  - The outputs and the next state are both a function of the inputs and the present state.
- Analysis consists of obtaining a table or a diagram for the time sequence of inputs, outputs, and internal states.
- It is also possible to write Boolean expressions that describe the behavior.

State Equations

- A state equation (transition equation) specifies the next state as a function of the present state and inputs.
  - It is an algebraic equation that specifies the condition for a flip flop state transition.

State Equations



- **Since the D input determines the next state:**
  - **A(t + 1) = A(t)x(t) + B(t)x(t) = Ax + Bx**
  - **B(t + 1) = A'(t)x(t) = A'x**
  - **y(t) = [A(t) + B(t)]x'(t) = (A + B)x'**

State Table

- The time sequence of inputs, outputs, and flip flop states can be enumerated in a state table (transition table).
  - The table consists of four sections
    - Present state shows the states of the flip flops at time t
    - Input gives input values for each possible present state
    - Next state shows the states of the flip flops one cycle later at t + 1
    - Output gives the value of other outputs at time t for each present state and input condition

Our Example

- The derivation of a state table requires listing all possible binary combinations of present state and inputs.
  - In our example, we have eight combinations from 000 to 111.
- The next state values are then determined from the logic diagram or from the state equations.

Example State Table

- $A(t + 1) = Ax + Bx$
- $B(t + 1) = A'x$
- $y(t) = (A + B)x'$

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

Generic Procedure

- A sequential circuit with m flip flops and n inputs needs 2^{m+n} rows in the state table.
- The numbers 0 through $2^{m+n} - 1$ are listed under the present state and input columns.
- The next state section has m columns, one for each flip flop.
  - Next state values are derived from the state equations.
- The output section has many columns as there are output values
  - Output values are derived from the circuit or the Boolean function in the same matter as a truth table.

Alternative 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

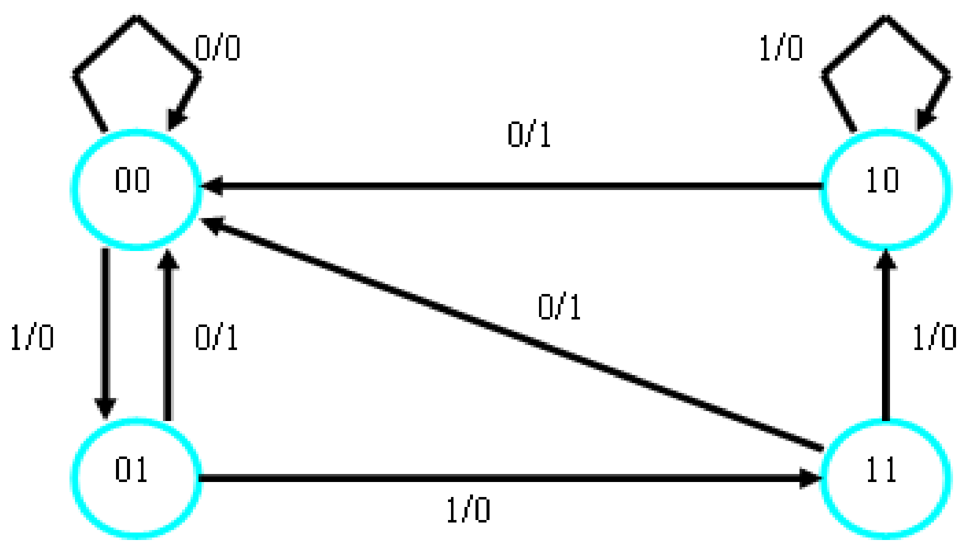
Present State		Next State			Output	
		x = 0	x = 1		x = 0	x = 1
AB		AB	AB			y
00		00	01		0	0
01		00	11		1	0
10		00	10		1	0
11		00	10		1	0

State Diagram

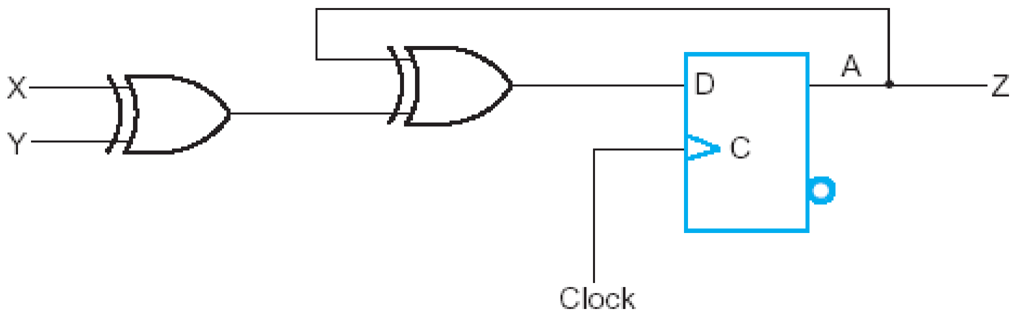
- Information in a state table can be represented graphically in the form of a state diagram.
- In a state diagram:
  - a state is represented by a circle
  - transitions between states are indicated by directed lines connecting the circles
  - Binary numbers inside the circles represent state of the flip flops
  - Directed lines are labeled with two binary numbers separated by a slash
    - The input value during the present state is labeled first
    - The second number gives the output after the present state with the given input

Example State Diagram

Present State		Next State			Output	
		x = 0	x = 1		x = 0	x = 1
AB		AB	AB			y
00		00	01		0	0
01		00	11		1	0
10		00	10		1	0
11		00	10		1	0

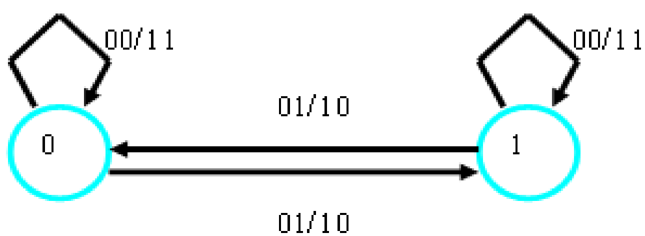


Example Analysis



Present state	Inputs		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

- $D_A = A \oplus x \oplus y$



End of Lecture