

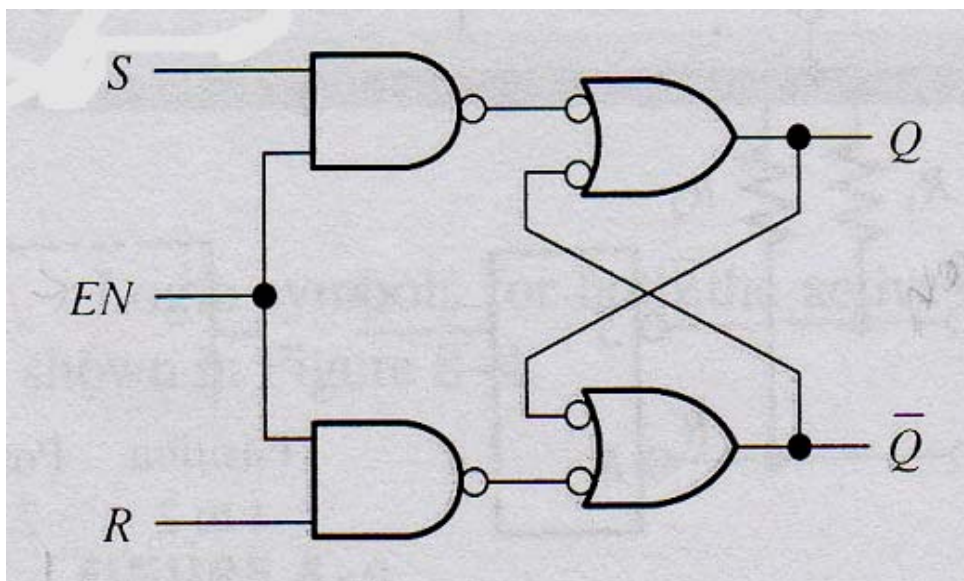
Flip-Flop:

The storage elements employed in clocked sequential circuits are called flip-flops. A flip-flop is a binary cell capable of storing one bit of information. It has two outputs, one for the normal value and one for the complement value of the bit stored in it.

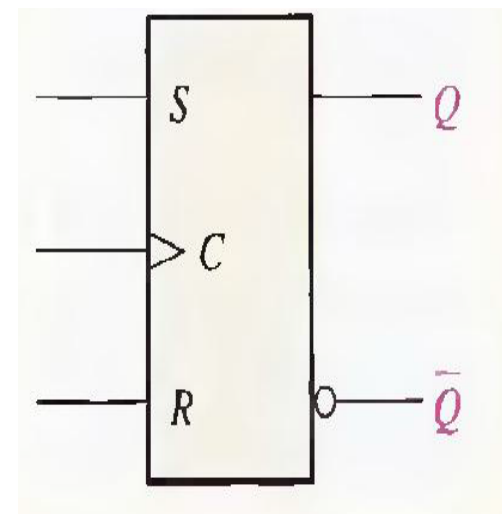
Type of flip-flops:

- 1- SR flip-flops.
- 2- D flip-flops.
- 3- JK flip-flops.
- 4- T flip-flops.

1- SR FLIP-FLOPS:



Logic diagram



Logic symbol

Figure (1) SR flip-flop

Inputs			Outputs		
S	R	CLK	Q	\bar{Q}	Comments
0	0	↑	Q0	$\bar{Q}0$	No change
0	1	↑	0	1	Reset
1	0	↑	1	0	Set
1	1	↑	?	?	Invalid

Truth table for SR flip-flop

2- D FLIP-FLOPS:

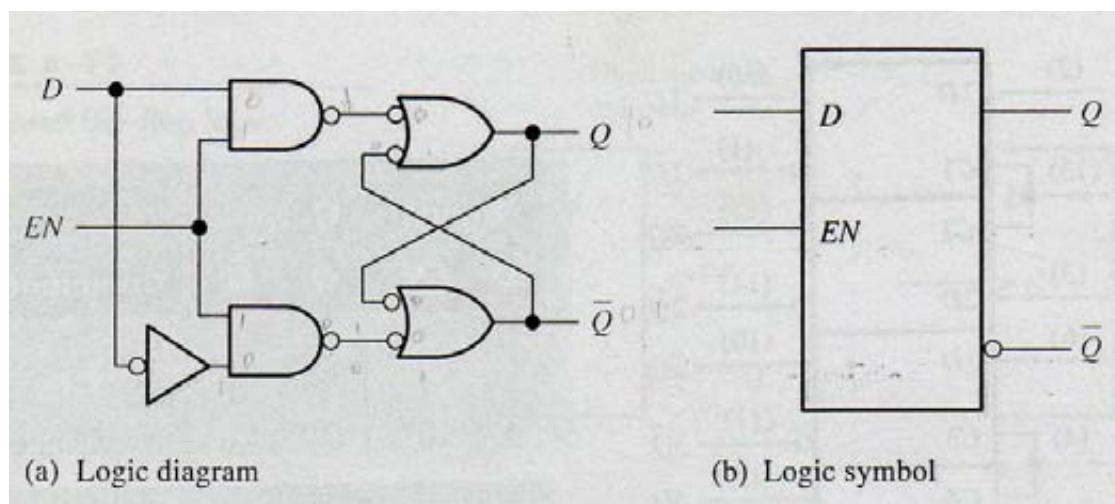
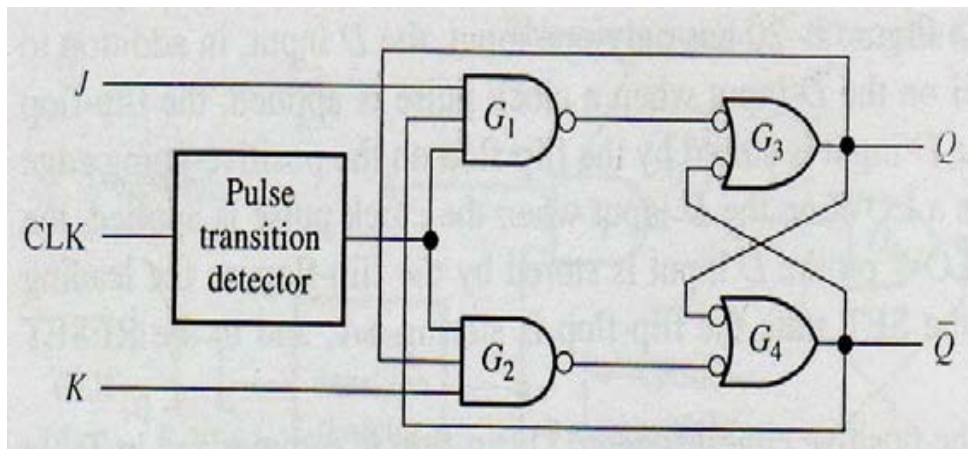


FIGURE (2) D Flip-flop

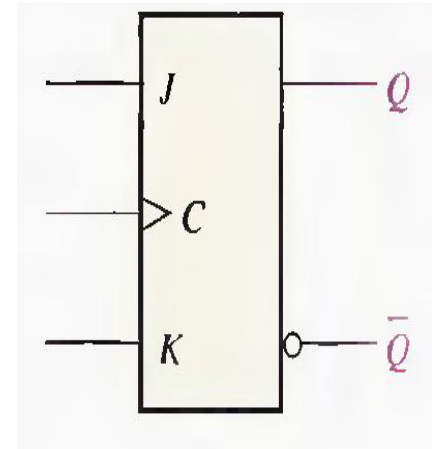
Inputs		Outputs		
D	CLK	Q	\bar{Q}	Comments
1	↑	1	0	Set(stor1)
0	↑	0	1	Reset(stor0)

Truth table for D flip-flop

3- J K FLIP-FLOPS:



Logic diagram



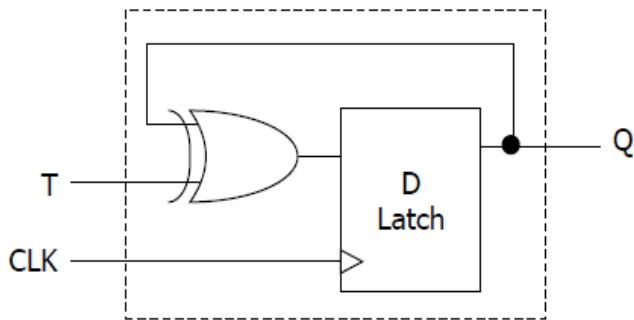
Logic symbol

Figure (3) JK Flip-flop

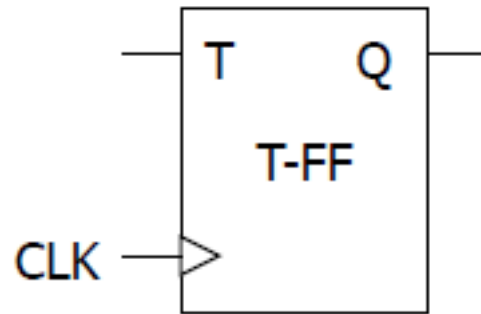
Inputs			Outputs		
J	K	CLK	Q	\bar{Q}	Comments
0	0	\uparrow	Q_0	\bar{Q}_0	No change
0	1	\uparrow	0	1	Reset
1	0	\uparrow	1	0	Set
1	1	\uparrow	\bar{Q}_0	Q_0	Toggle

Truth table for JK flip-flop

4- T FLIP-FLOPS:



Logic diagram



Logic symbol

FIGURE (4) D Flip-flop

T	Q	Q_{next}	Q_{next}'
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

CLK	T	Q
0	X	No change
1	0	No change
1	1	Toggle

Truth table for T flip-flop

State Diagram

A *state diagram* is a graph that shows the flip-flop's operations in terms of how it transitions from one state to another. The nodes are labeled with the states and the directed arcs are labeled with the input signals that cause the transition to go from one state to the next. Figure 5 shows the state diagram for the SR flip-flop. For example, to go from state $Q = 0$ to the state $Q = 1$, the two inputs S and R have to be 1 and 0 respectively. Similarly, if the current state is $Q = 0$ and we want to remain in that state, then SR need to be 00 or 01.

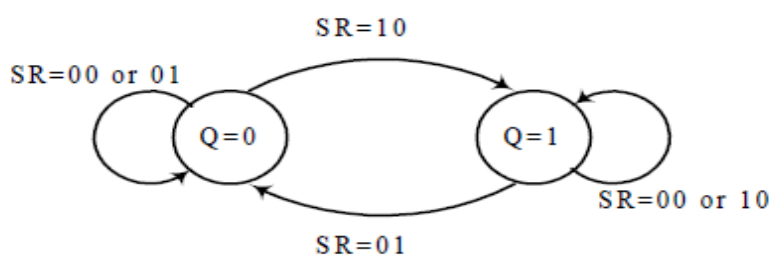
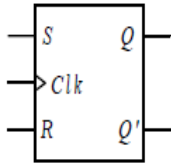
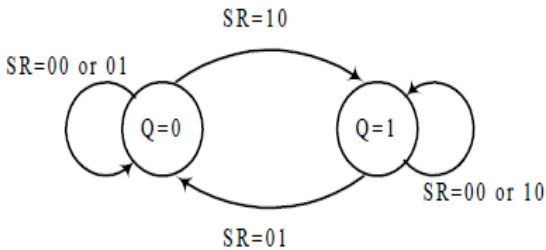
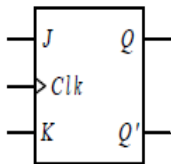
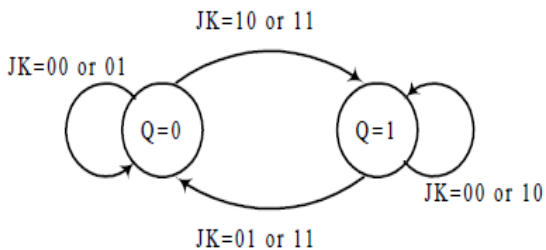
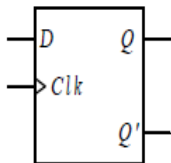
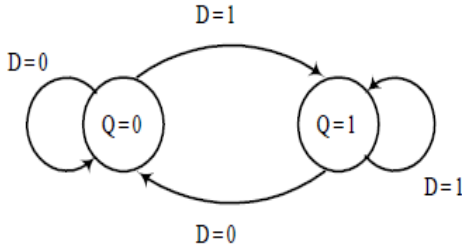
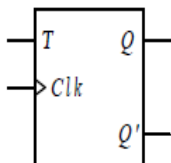
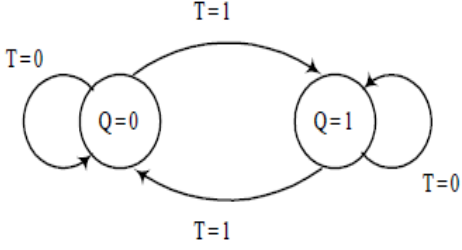
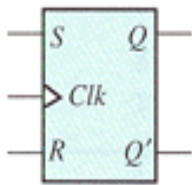
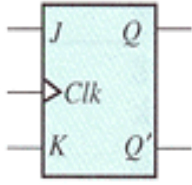
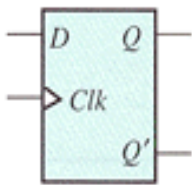
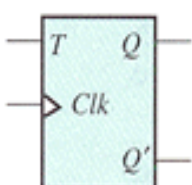


Figure 5. State diagram for the SR flip-flop.

Name / Symbol	Characteristic (Truth) Table	State Diagram / Characteristic Equations	Excitation Table																																																								
<div>SR</div> <div></div>	<table><tr><th>S</th><th>R</th><th>Q</th><th>Q_{next}</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td><td>×</td></tr><tr><td>1</td><td>1</td><td>1</td><td>×</td></tr></table>	S	R	Q	Q _{next}	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	0	1	0	0	1	1	0	1	1	1	1	0	×	1	1	1	×	<div></div> <div>$Q_{next} = S + R'Q$$SR = 0$</div>	<table><tr><th>Q</th><th>Q_{next}</th><th>S</th><th>R</th></tr><tr><td>0</td><td>0</td><td>0</td><td>×</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>×</td><td>0</td></tr></table>	Q	Q _{next}	S	R	0	0	0	×	0	1	1	0	1	0	0	1	1	1	×	0
S	R	Q	Q _{next}																																																								
0	0	0	0																																																								
0	0	1	1																																																								
0	1	0	0																																																								
0	1	1	0																																																								
1	0	0	1																																																								
1	0	1	1																																																								
1	1	0	×																																																								
1	1	1	×																																																								
Q	Q _{next}	S	R																																																								
0	0	0	×																																																								
0	1	1	0																																																								
1	0	0	1																																																								
1	1	×	0																																																								
<div>JK</div> <div></div>	<table><tr><th>J</th><th>K</th><th>Q</th><th>Q_{next}</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td><td>0</td></tr></table>	J	K	Q	Q _{next}	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	0	1	0	0	1	1	0	1	1	1	1	0	1	1	1	1	0	<div></div> <div>$Q_{next} = J'K'Q + JK' + JKQ'$$= J'K'Q + JK'Q + JK'Q' + JKQ'$$= K'Q(J' + J) + JQ'(K' + K)$$= K'Q + JQ'$</div>	<table><tr><th>Q</th><th>Q_{next}</th><th>J</th><th>K</th></tr><tr><td>0</td><td>0</td><td>0</td><td>×</td></tr><tr><td>0</td><td>1</td><td>1</td><td>×</td></tr><tr><td>1</td><td>0</td><td>×</td><td>1</td></tr><tr><td>1</td><td>1</td><td>×</td><td>0</td></tr></table>	Q	Q _{next}	J	K	0	0	0	×	0	1	1	×	1	0	×	1	1	1	×	0
J	K	Q	Q _{next}																																																								
0	0	0	0																																																								
0	0	1	1																																																								
0	1	0	0																																																								
0	1	1	0																																																								
1	0	0	1																																																								
1	0	1	1																																																								
1	1	0	1																																																								
1	1	1	0																																																								
Q	Q _{next}	J	K																																																								
0	0	0	×																																																								
0	1	1	×																																																								
1	0	×	1																																																								
1	1	×	0																																																								
<div>D</div> <div></div>	<table><tr><th>D</th><th>Q</th><th>Q_{next}</th></tr><tr><td>0</td><td>×</td><td>0</td></tr><tr><td>1</td><td>×</td><td>1</td></tr></table>	D	Q	Q _{next}	0	×	0	1	×	1	<div></div> <div>$Q_{next} = D$</div>	<table><tr><th>Q</th><th>Q_{next}</th><th>D</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>	Q	Q _{next}	D	0	0	0	0	1	1	1	0	0	1	1	1																																
D	Q	Q _{next}																																																									
0	×	0																																																									
1	×	1																																																									
Q	Q _{next}	D																																																									
0	0	0																																																									
0	1	1																																																									
1	0	0																																																									
1	1	1																																																									
<div>T</div> <div></div>	<table><tr><th>T</th><th>Q</th><th>Q_{next}</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table>	T	Q	Q _{next}	0	0	0	0	1	1	1	0	1	1	1	0	<div></div> <div>$Q_{next} = TQ' + T'Q = T \oplus Q$</div>	<table><tr><th>Q</th><th>Q_{next}</th><th>T</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table>	Q	Q _{next}	T	0	0	0	0	1	1	1	0	1	1	1	0																										
T	Q	Q _{next}																																																									
0	0	0																																																									
0	1	1																																																									
1	0	1																																																									
1	1	0																																																									
Q	Q _{next}	T																																																									
0	0	0																																																									
0	1	1																																																									
1	0	1																																																									
1	1	0																																																									

FLIP-FLOP NAME	FLIP-FLOP SYMBOL	CHARACTERISTIC TABLE	CHARACTERISTIC EQUATION	EXCITATION TABLE																																			
SR		<table><tr><th>S</th><th>R</th><th>Q(next)</th></tr><tr><td>0</td><td>0</td><td>Q</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>NA</td></tr></table>	S	R	Q(next)	0	0	Q	0	1	0	1	0	1	1	1	NA	$Q(next) = S + R'Q$ $SR = 0$	<table><tr><th>Q</th><th>Q(next)</th><th>S</th><th>R</th></tr><tr><td>0</td><td>0</td><td>0</td><td>X</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>X</td><td>0</td></tr></table>	Q	Q(next)	S	R	0	0	0	X	0	1	1	0	1	0	0	1	1	1	X	0
S	R	Q(next)																																					
0	0	Q																																					
0	1	0																																					
1	0	1																																					
1	1	NA																																					
Q	Q(next)	S	R																																				
0	0	0	X																																				
0	1	1	0																																				
1	0	0	1																																				
1	1	X	0																																				
JK		<table><tr><th>J</th><th>K</th><th>Q(next)</th></tr><tr><td>0</td><td>0</td><td>Q</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>Q'</td></tr></table>	J	K	Q(next)	0	0	Q	0	1	0	1	0	1	1	1	Q'	$Q(next) = JQ' + K'Q$	<table><tr><th>Q</th><th>Q(next)</th><th>J</th><th>K</th></tr><tr><td>0</td><td>0</td><td>0</td><td>X</td></tr><tr><td>0</td><td>1</td><td>1</td><td>X</td></tr><tr><td>1</td><td>0</td><td>X</td><td>1</td></tr><tr><td>1</td><td>1</td><td>X</td><td>0</td></tr></table>	Q	Q(next)	J	K	0	0	0	X	0	1	1	X	1	0	X	1	1	1	X	0
J	K	Q(next)																																					
0	0	Q																																					
0	1	0																																					
1	0	1																																					
1	1	Q'																																					
Q	Q(next)	J	K																																				
0	0	0	X																																				
0	1	1	X																																				
1	0	X	1																																				
1	1	X	0																																				
D		<table><tr><th>D</th><th>Q(next)</th></tr><tr><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td></tr></table>	D	Q(next)	0	0	1	1	$Q(next) = D$	<table><tr><th>Q</th><th>Q(next)</th><th>D</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>	Q	Q(next)	D	0	0	0	0	1	1	1	0	0	1	1	1														
D	Q(next)																																						
0	0																																						
1	1																																						
Q	Q(next)	D																																					
0	0	0																																					
0	1	1																																					
1	0	0																																					
1	1	1																																					
T		<table><tr><th>T</th><th>Q(next)</th></tr><tr><td>0</td><td>Q</td></tr><tr><td>1</td><td>Q'</td></tr></table>	T	Q(next)	0	Q	1	Q'	$Q(next) = TQ' + T'Q$	<table><tr><th>Q</th><th>Q(next)</th><th>T</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table>	Q	Q(next)	T	0	0	0	0	1	1	1	0	1	1	1	0														
T	Q(next)																																						
0	Q																																						
1	Q'																																						
Q	Q(next)	T																																					
0	0	0																																					
0	1	1																																					
1	0	1																																					
1	1	0																																					