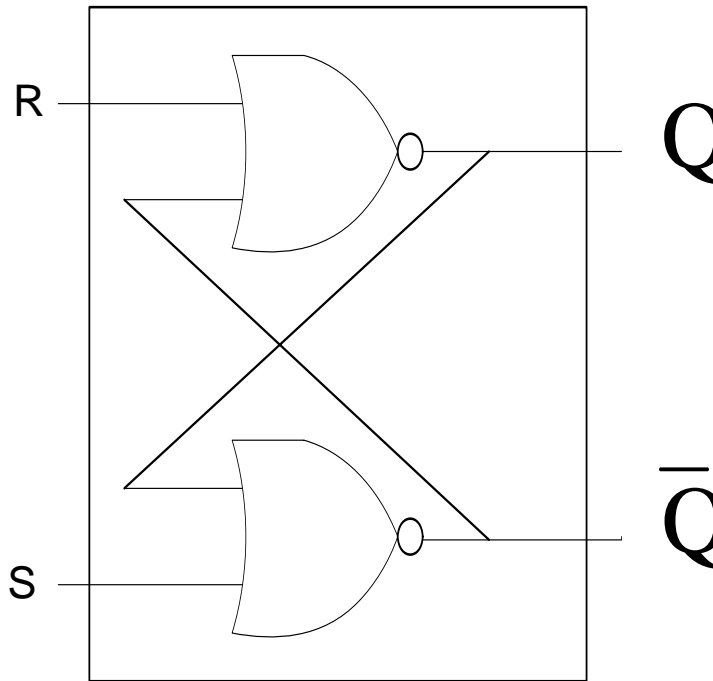


# RS Latch

$$Q_+ = S + R' Q$$

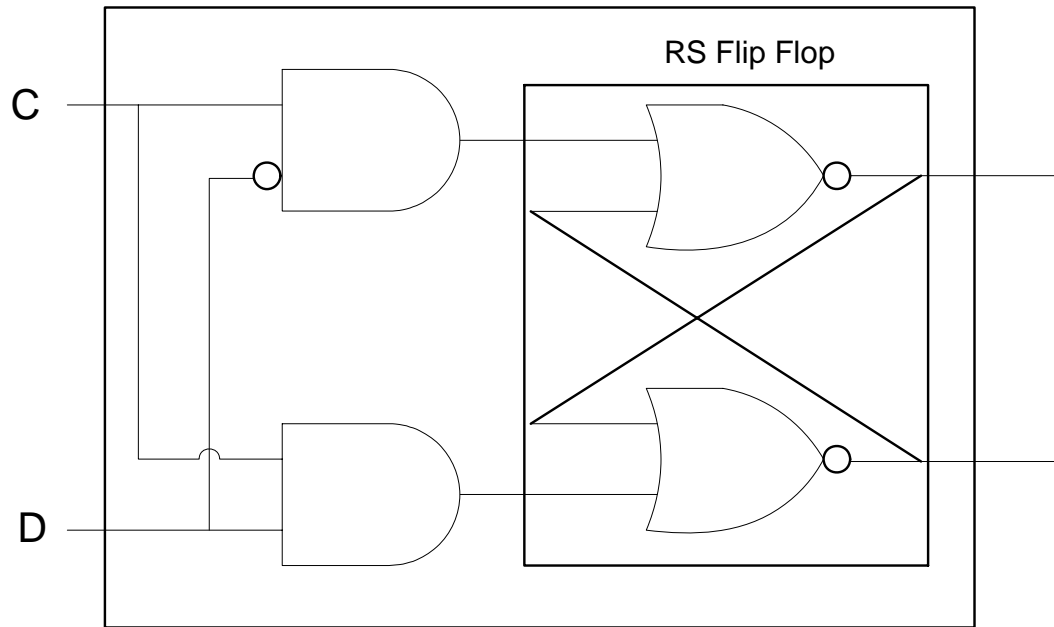


<b>R</b>	<b>S</b>	<b>Q<sub>t+1</sub></b>
0	0	$\bar{q}_t$
0	1	1
1	0	0
1	1	—

Two Problems:

R=S= 1 Not allowed, Data is transparent

# The D Latch

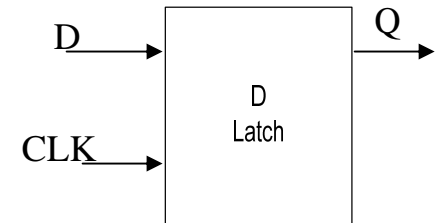
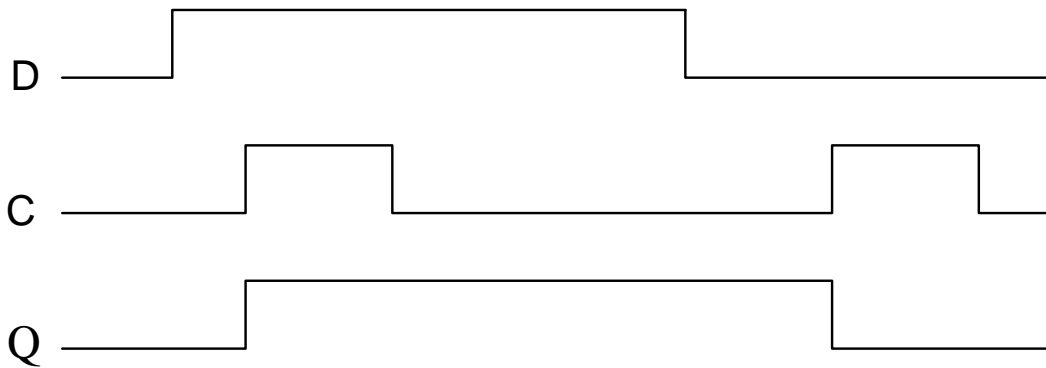


Q

$\bar{Q}$

D	Q <sup>+</sup>
0	0
1	1

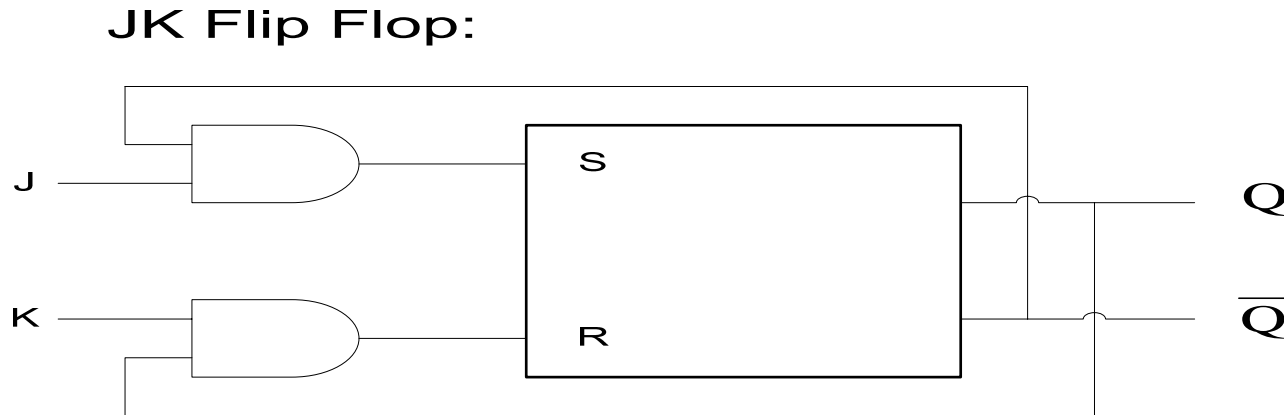
$$Q^+ = D$$



Problem: Level sensitive

# JK Latch : Universal, Level sensitive,

## Timing Constraints due to feed back.



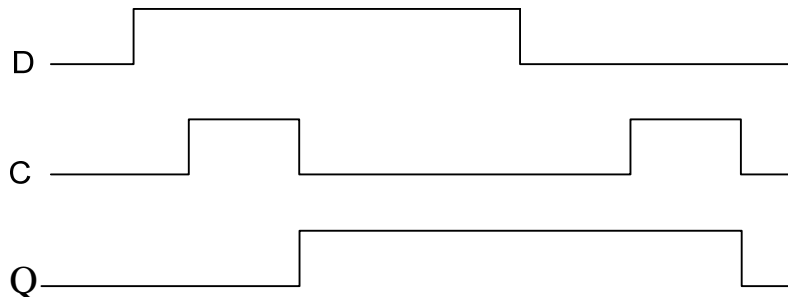
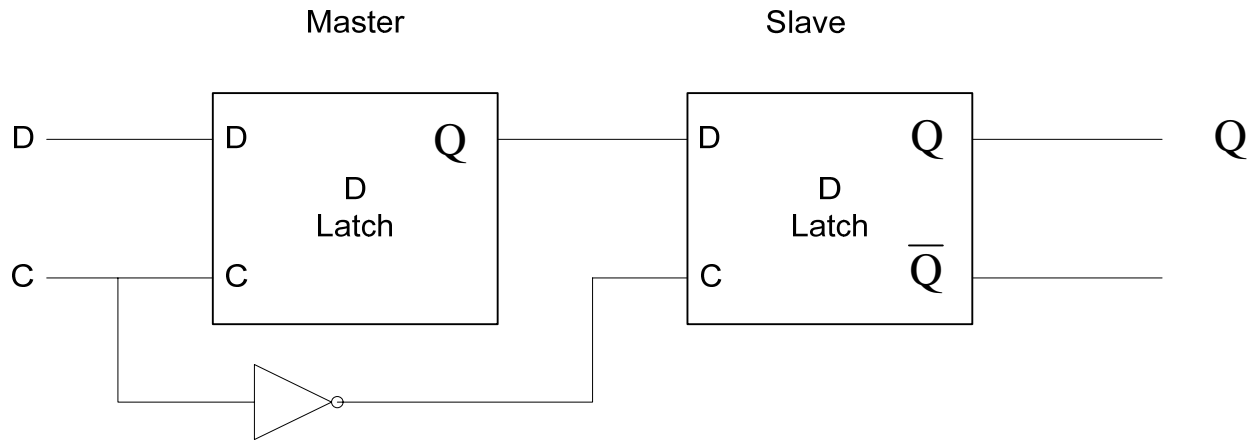
$$Q_{t+1} = J\bar{Q}_t + \bar{K}Q_t$$

# Master Slave Flip Flop

Edge sensitive, Set up and Hold time

## Master and Slave Flip Flop :

A D Flip Flop with a falling-edge trigger.



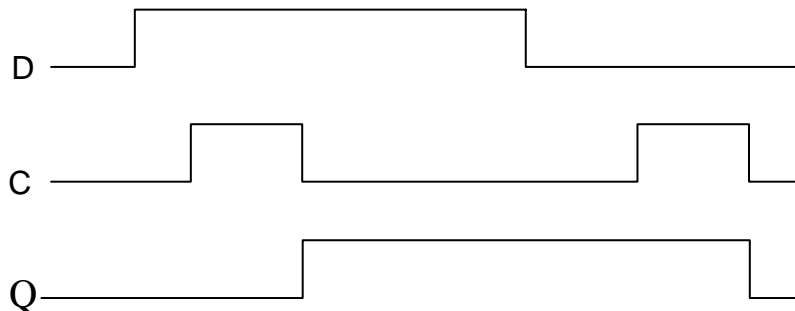
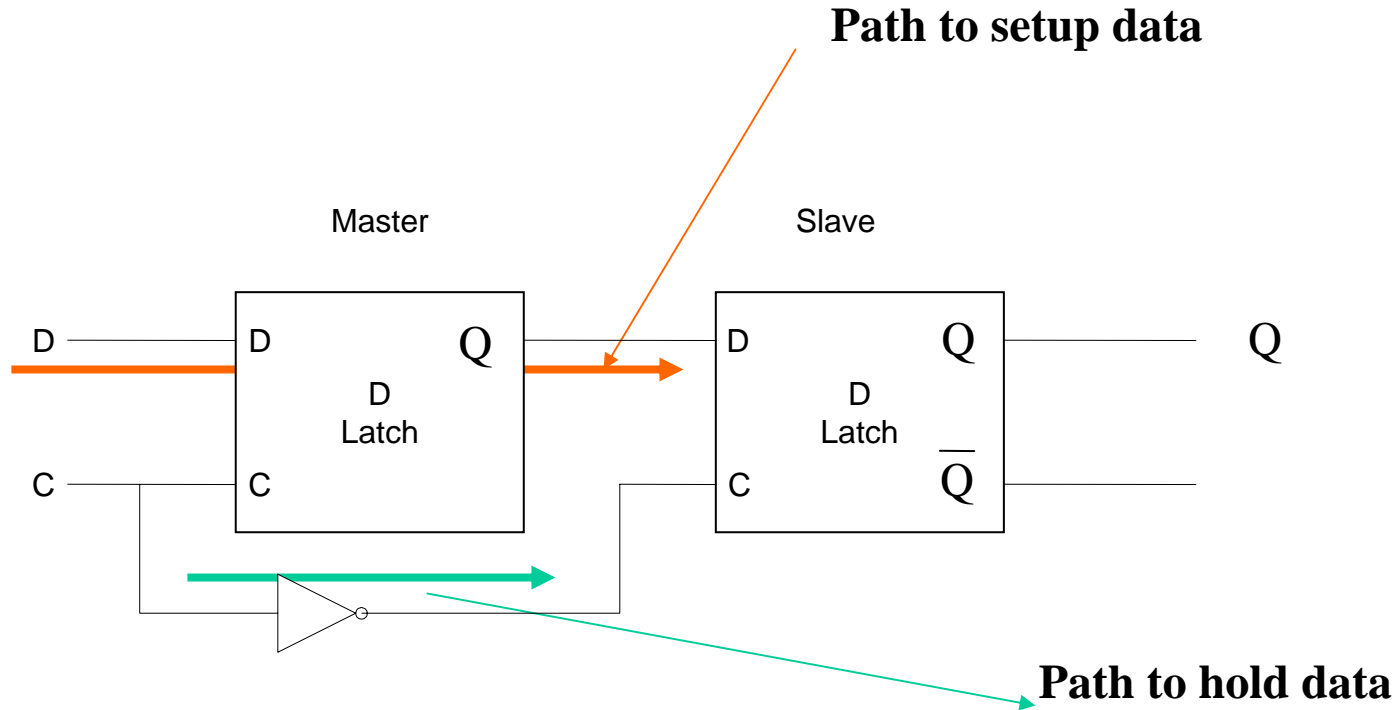
# Master Slave Flip Flop Edge sensitive,-Falling Edge

Set Up and Hold Time constraints

Concordia

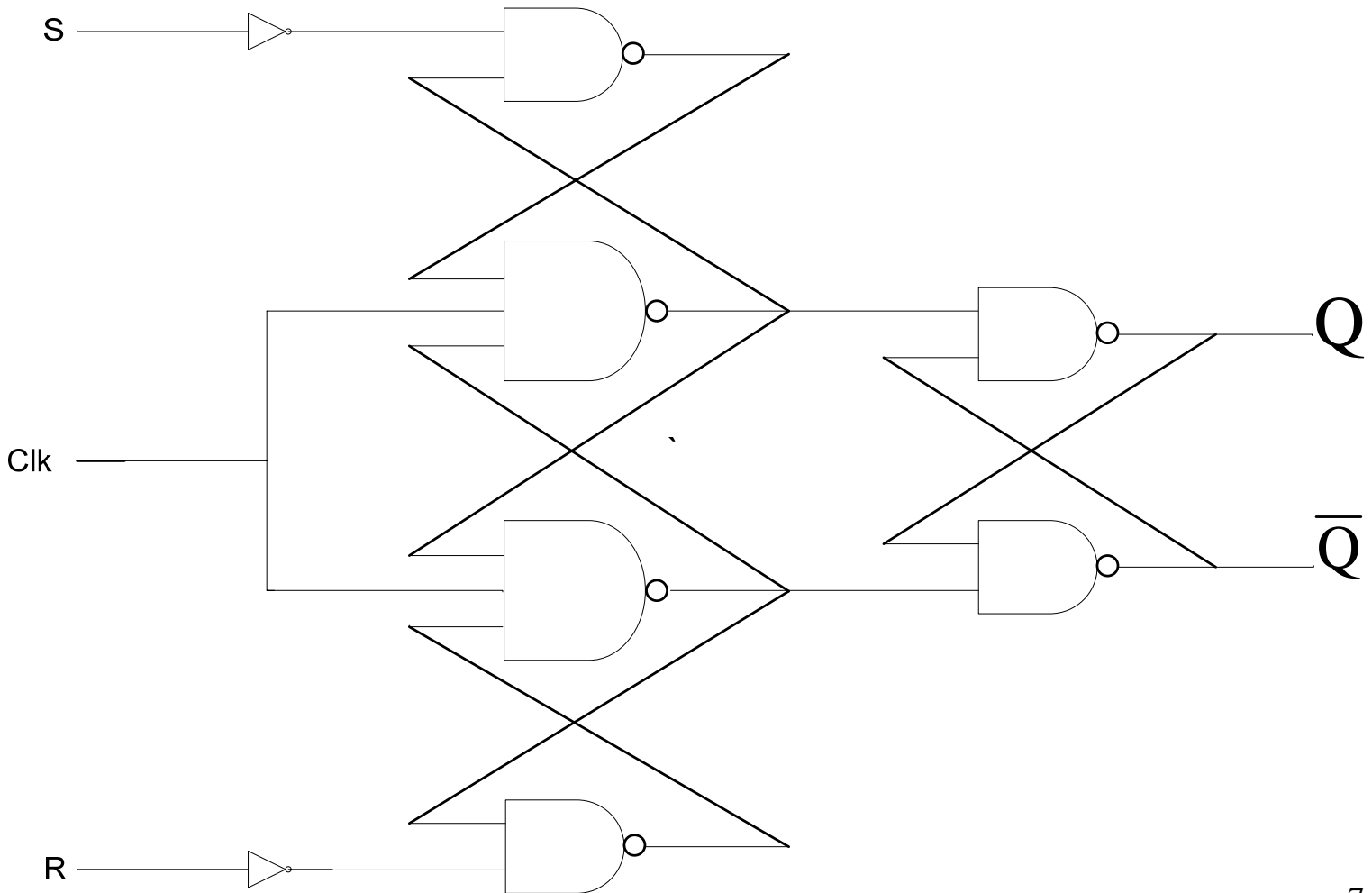


University



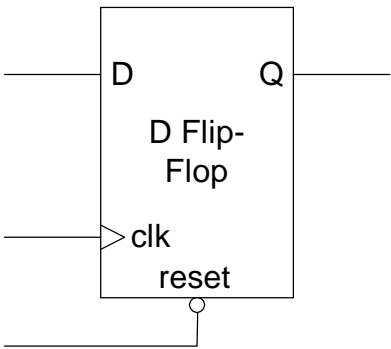
# Edge triggered Flip Flop:

## Set up and Hold time Constraints

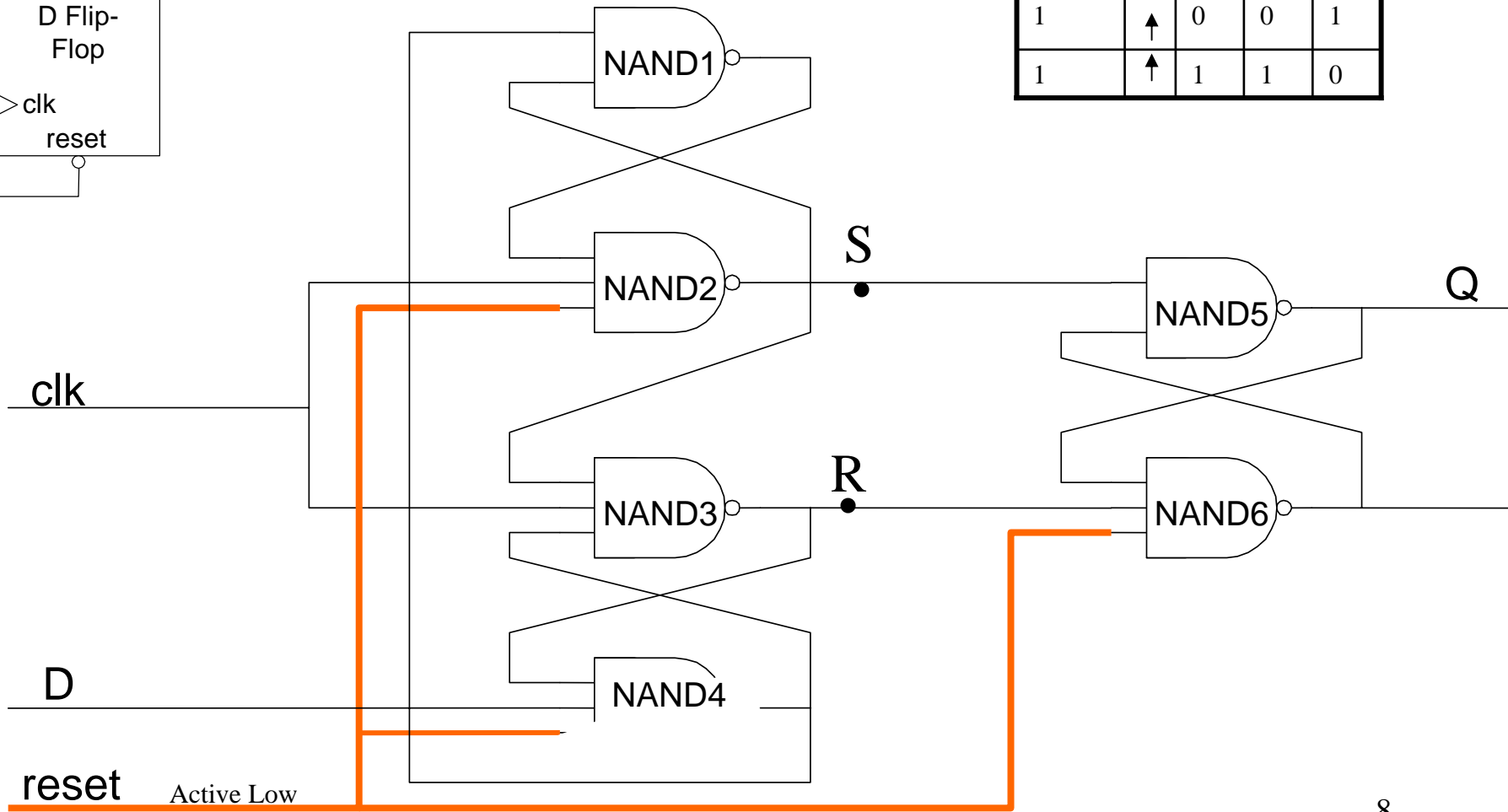


# Edge Triggered, D Flip Flop,

## With Reset



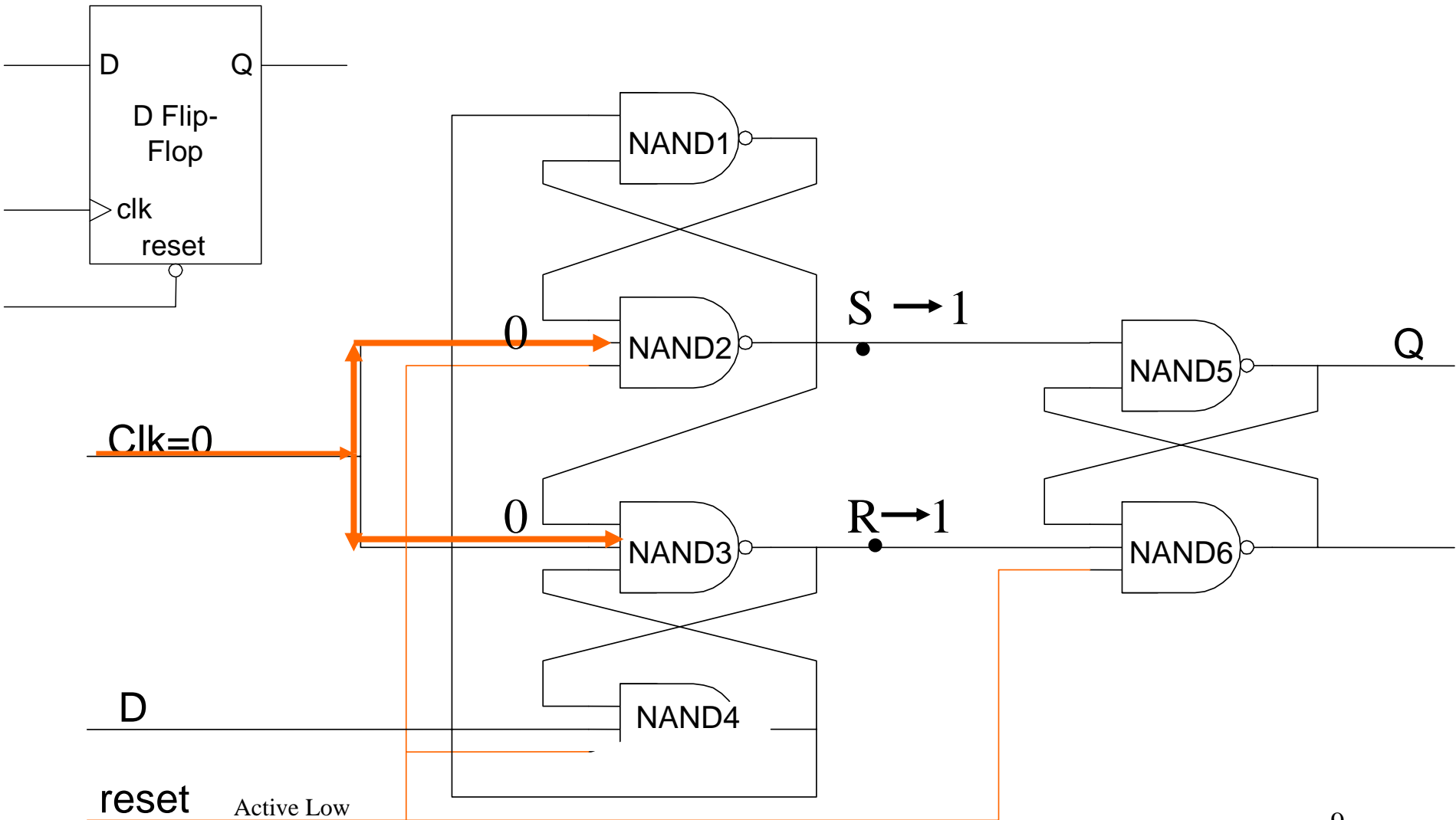
Reset	C	D	Q	Q'
0	X	X	0	1
1	↑	0	0	1
1	↑	1	1	0





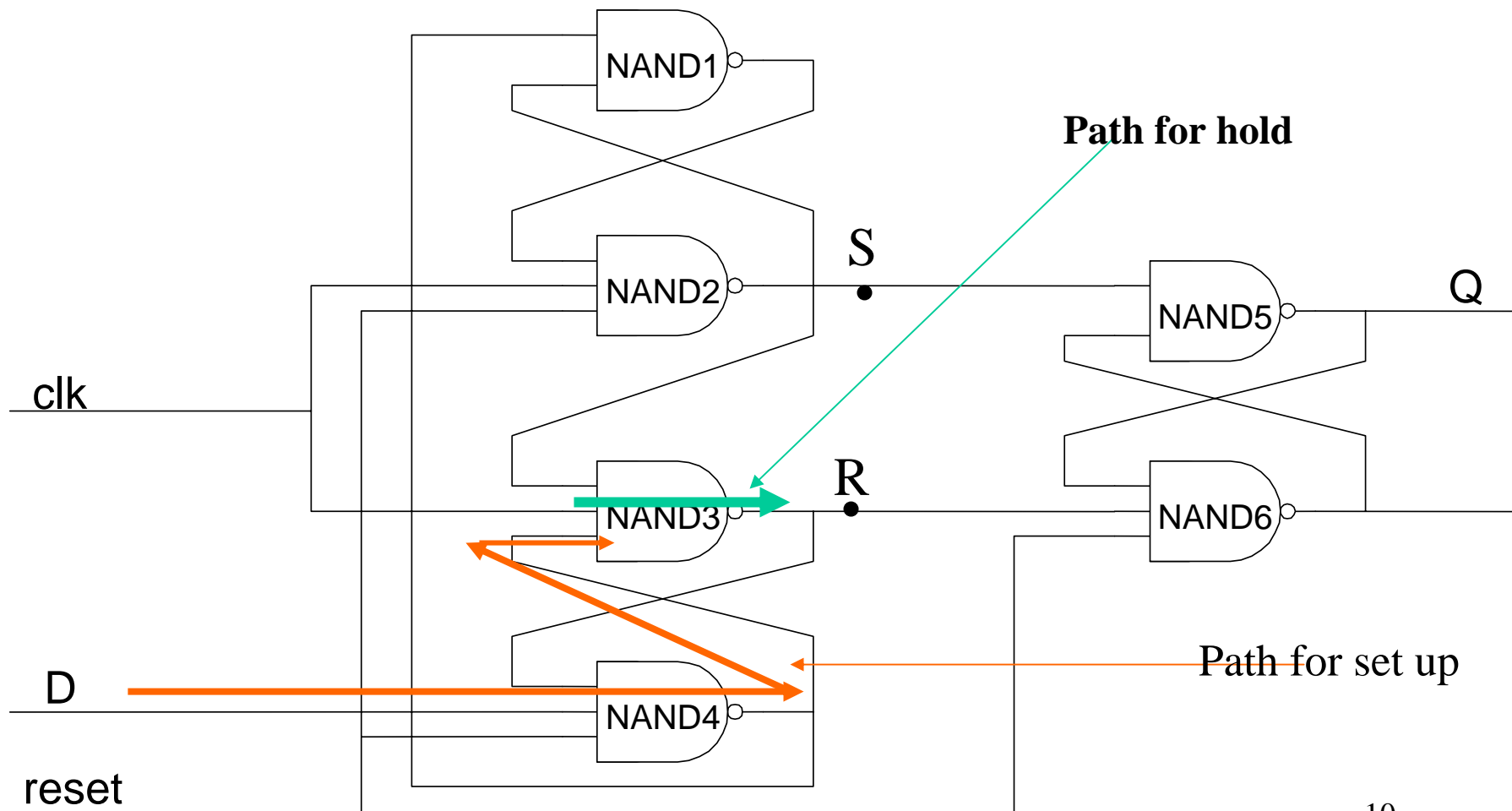
# Edge Triggered, D Flip Flop

When CLK=0



# When CLK changes from 0 to 1

Case1, D=0:  $t_{\text{setup}} = t_4$ ,  $t_{\text{hold}} = t_3$

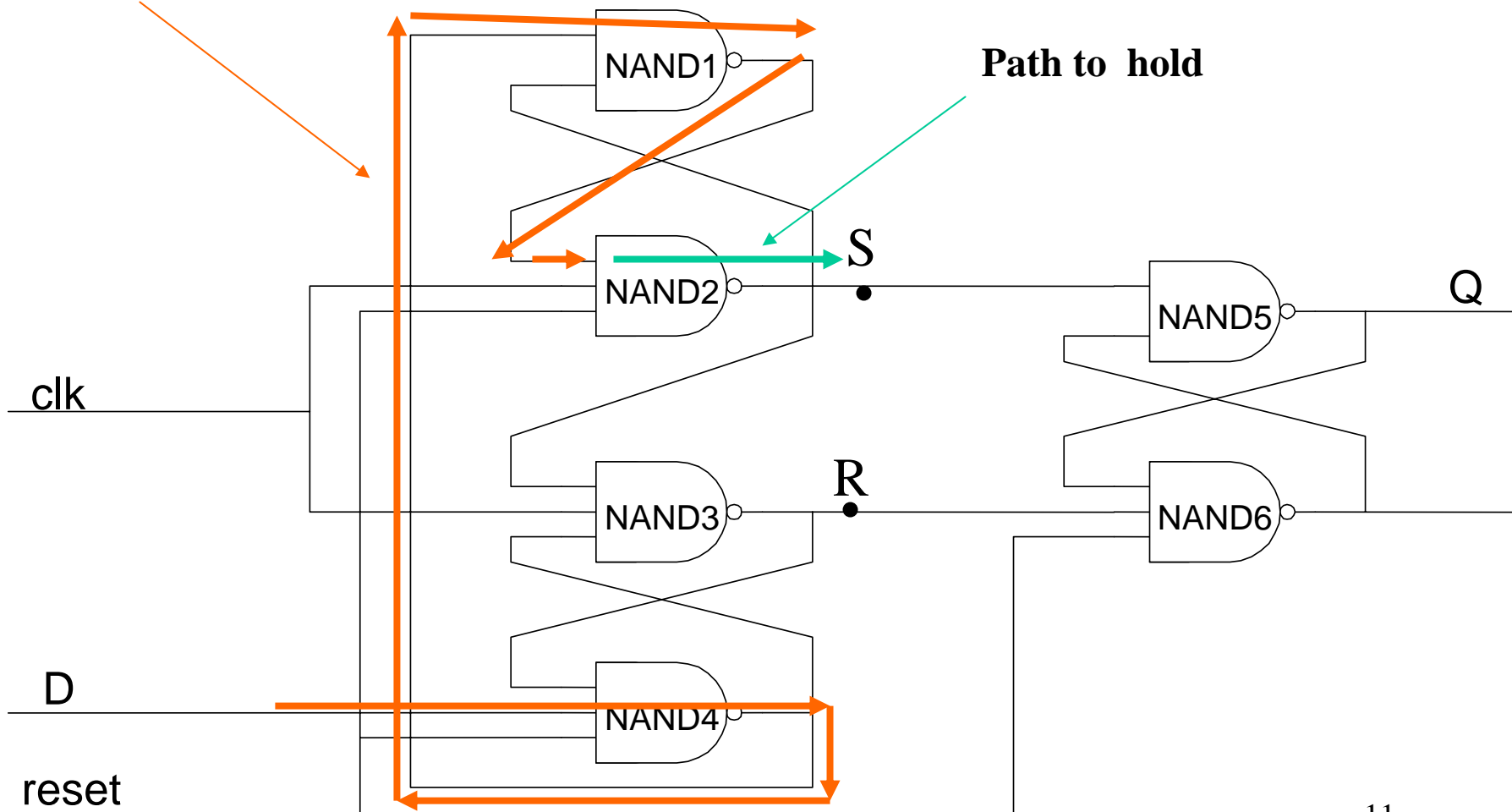


# When CLK changes from 0 to 1

Case2, D=1  $t_{\text{setup}} = t_4 + t_1$   $t_{\text{hold}} = t_2$

**Path to set up**

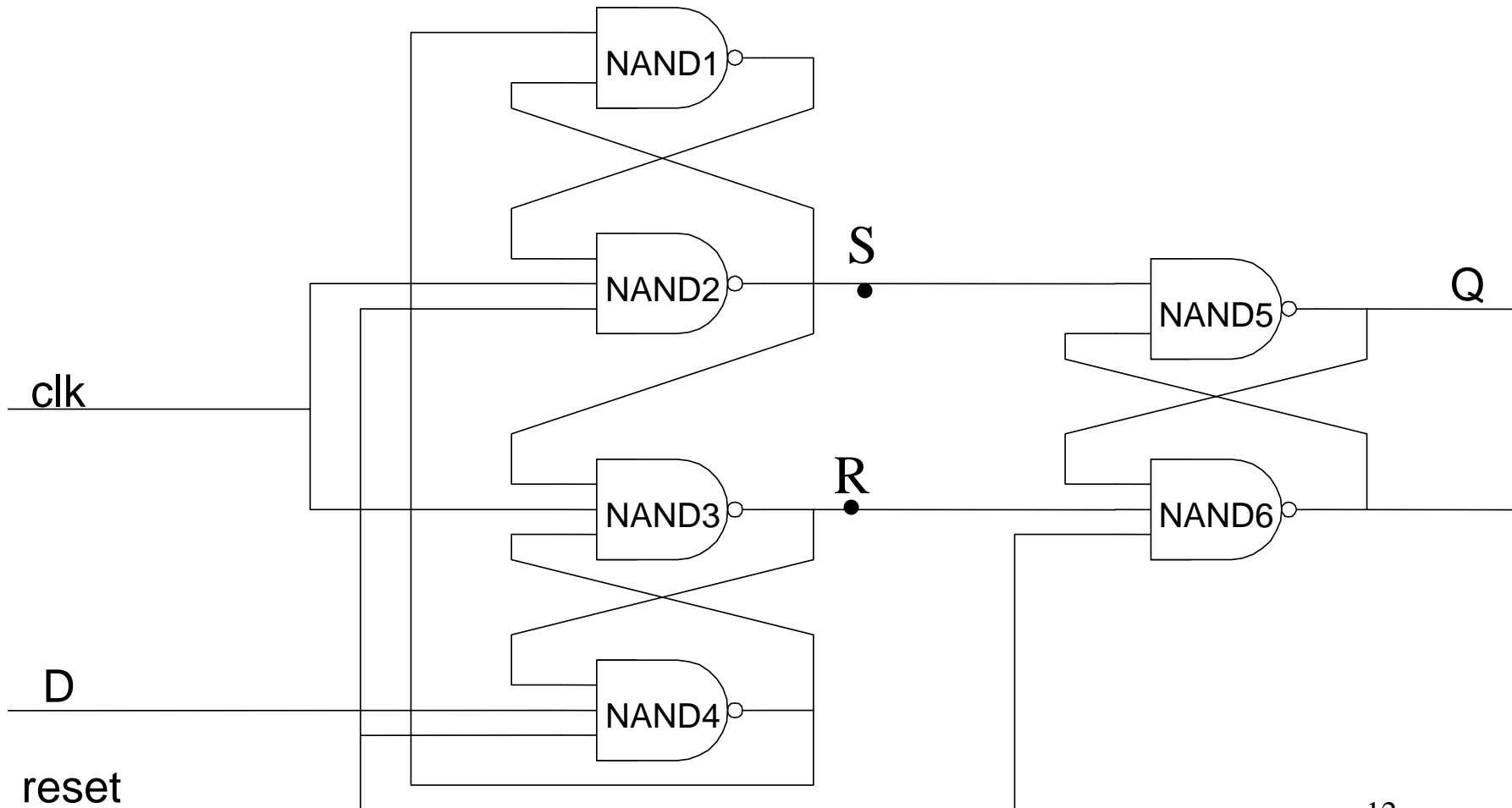
**Path to hold**



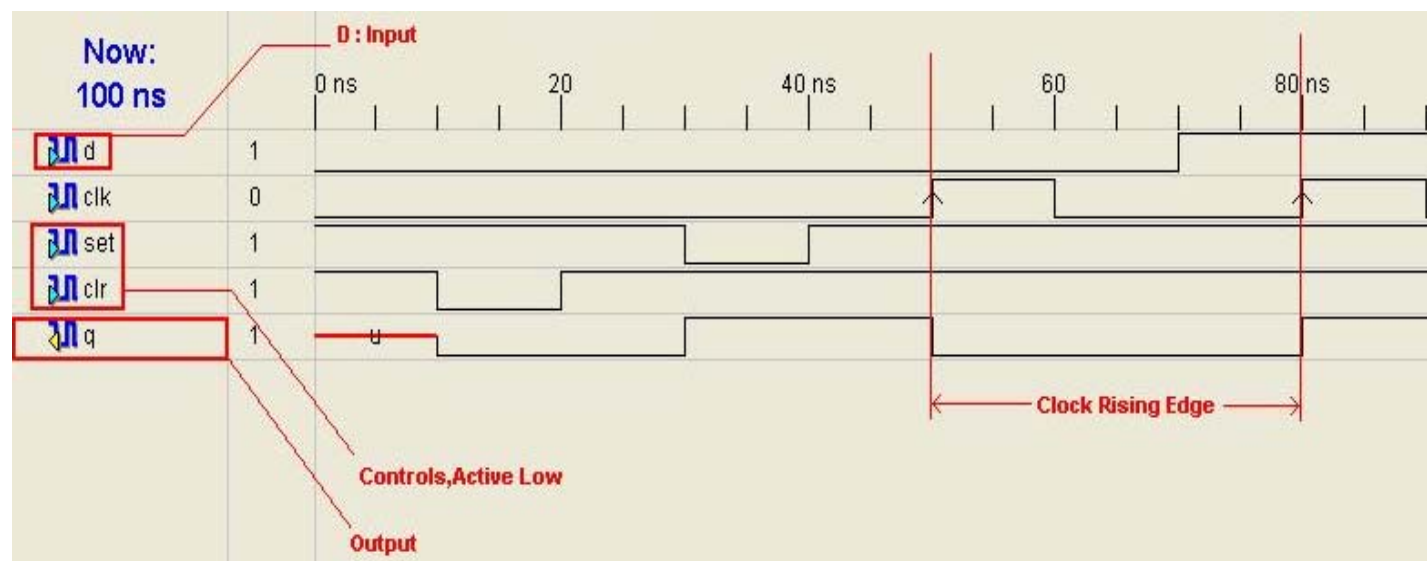
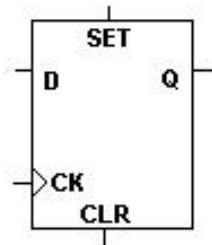
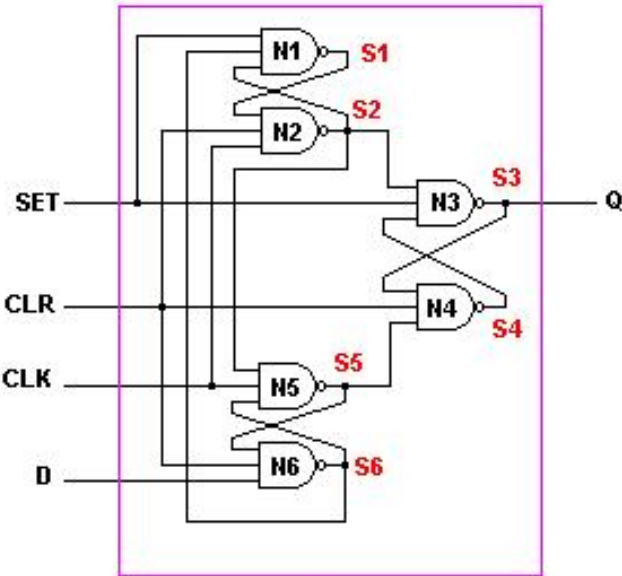
## When CLK changes from 0 to 1

Case1, D=0:  $t_{\text{setup}} = t_4$ ,  $t_{\text{hold}} = t_3$

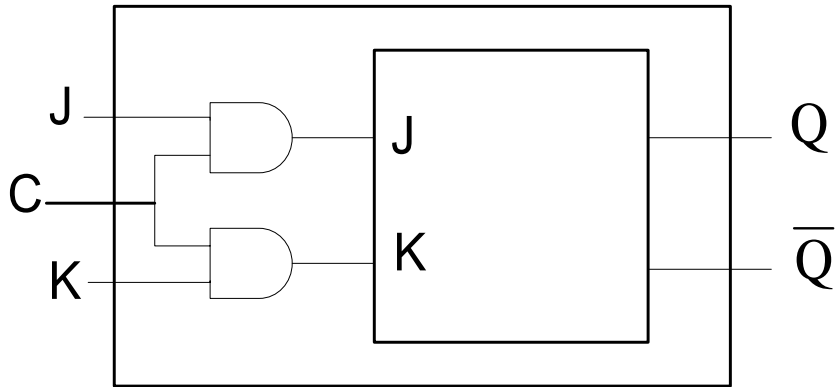
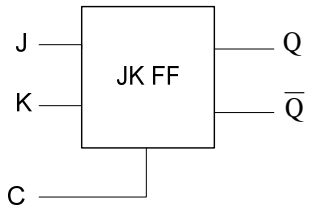
Case2, D=1  $t_{\text{setup}} = t_4 + t_1$   $t_{\text{hold}} = t_2$



# D Flip Flop

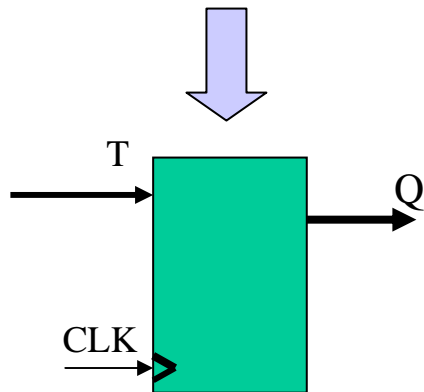
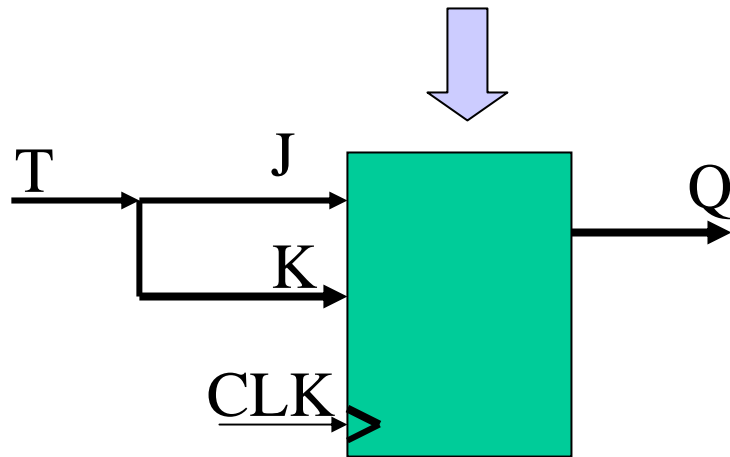
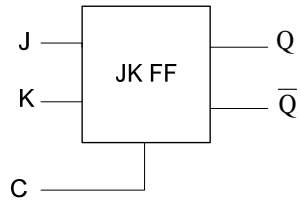


# JK Flip Flop with a rising-edge :



$$Q^+ = JQ' + K'Q$$

# T-Flip Flop



$$Q^+ = JQ' + K'Q$$

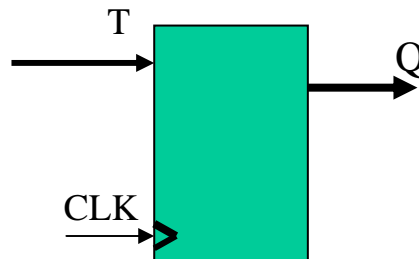
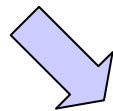
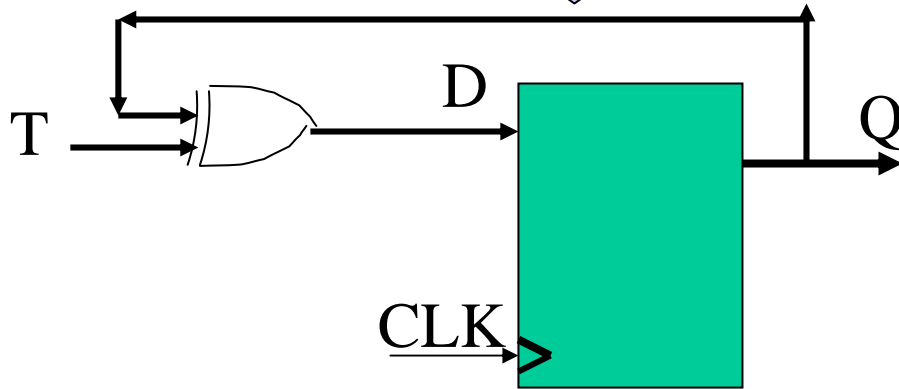
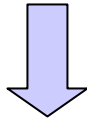
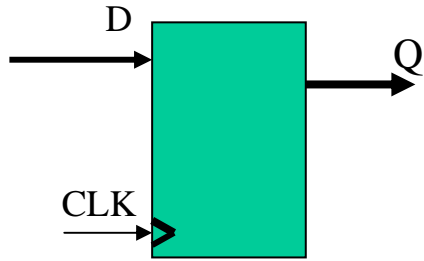
$$J=K=T$$

$$Q^+ = TQ' + T'Q$$

$$T=1 \quad Q^+ = Q'$$

$$T=0 \quad Q^+ = Q$$

# T-Flip Flop



$$Q^+ = JQ' + K'Q$$

$$J=K=T$$

$$Q^+ = TQ' + T'Q$$

$$T=1 \quad Q^+ = Q'$$

$$T=0 \quad Q^+ = Q$$