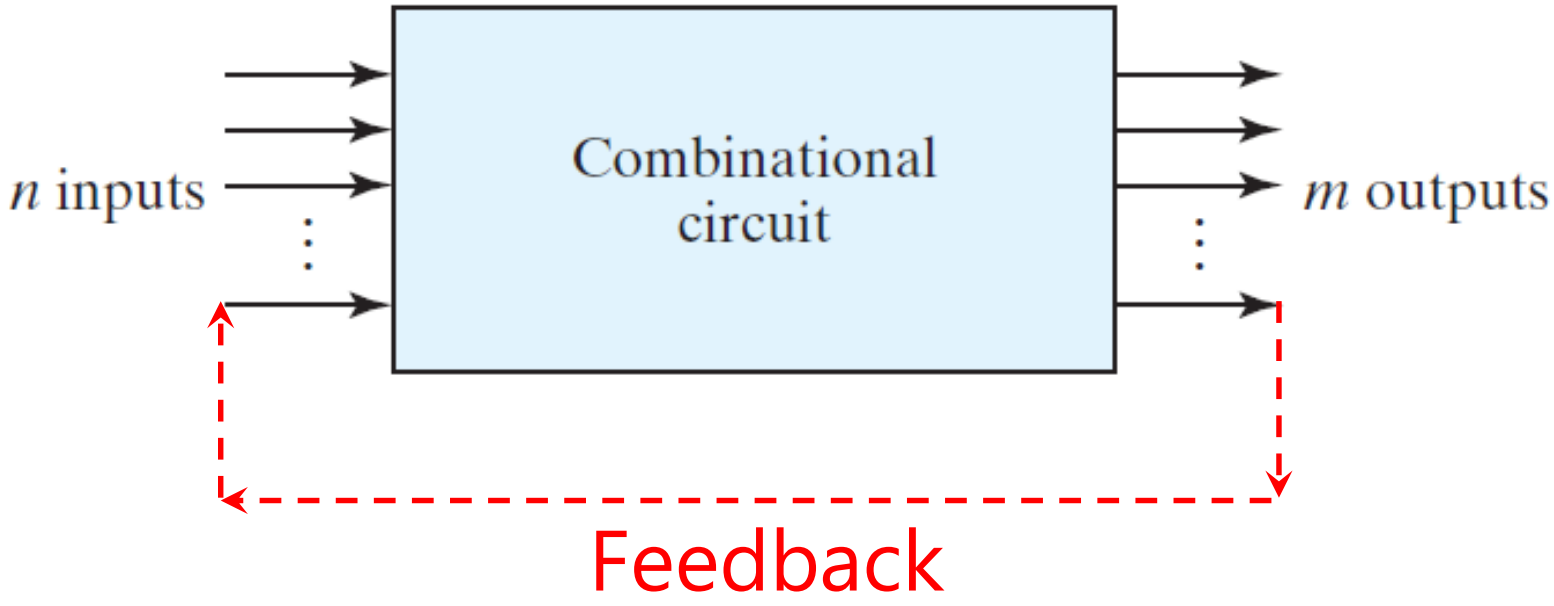
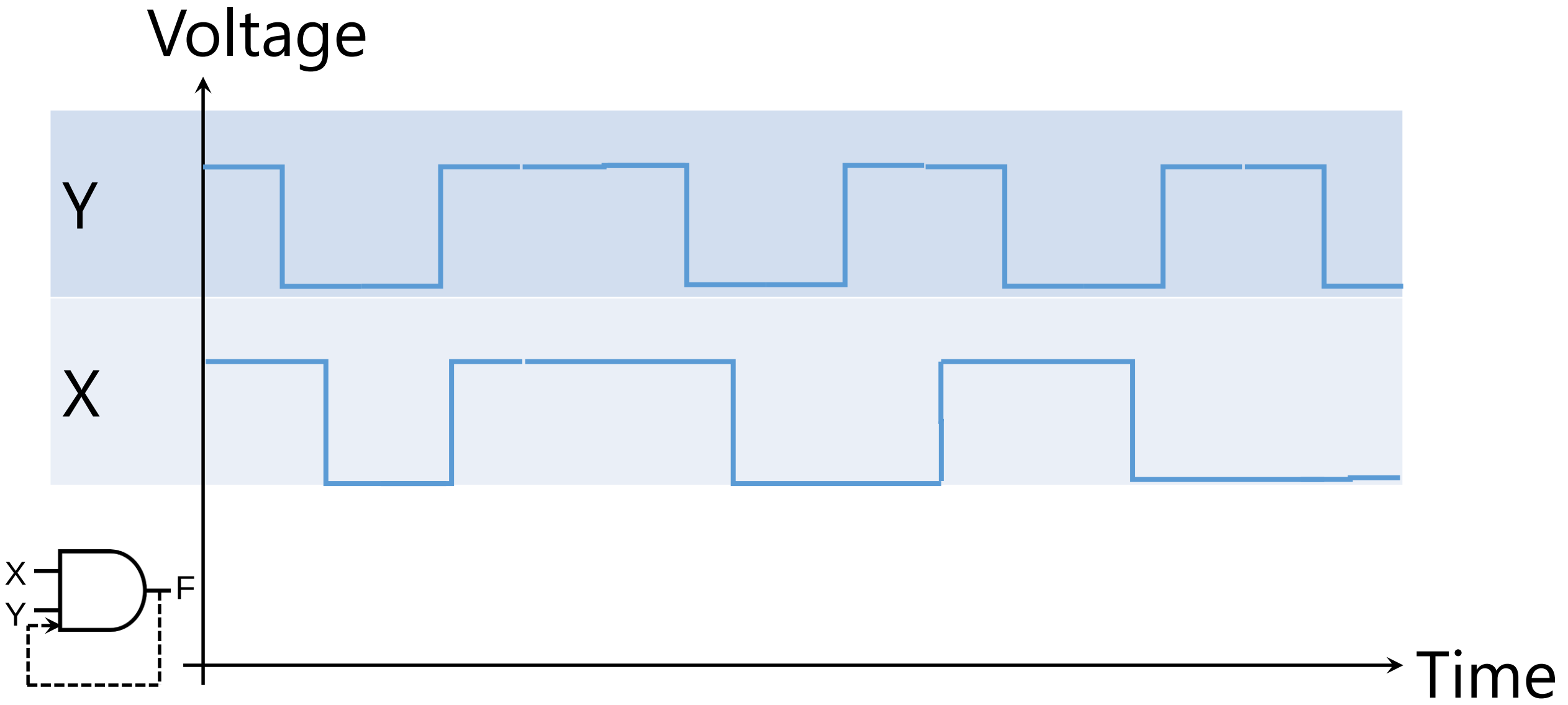
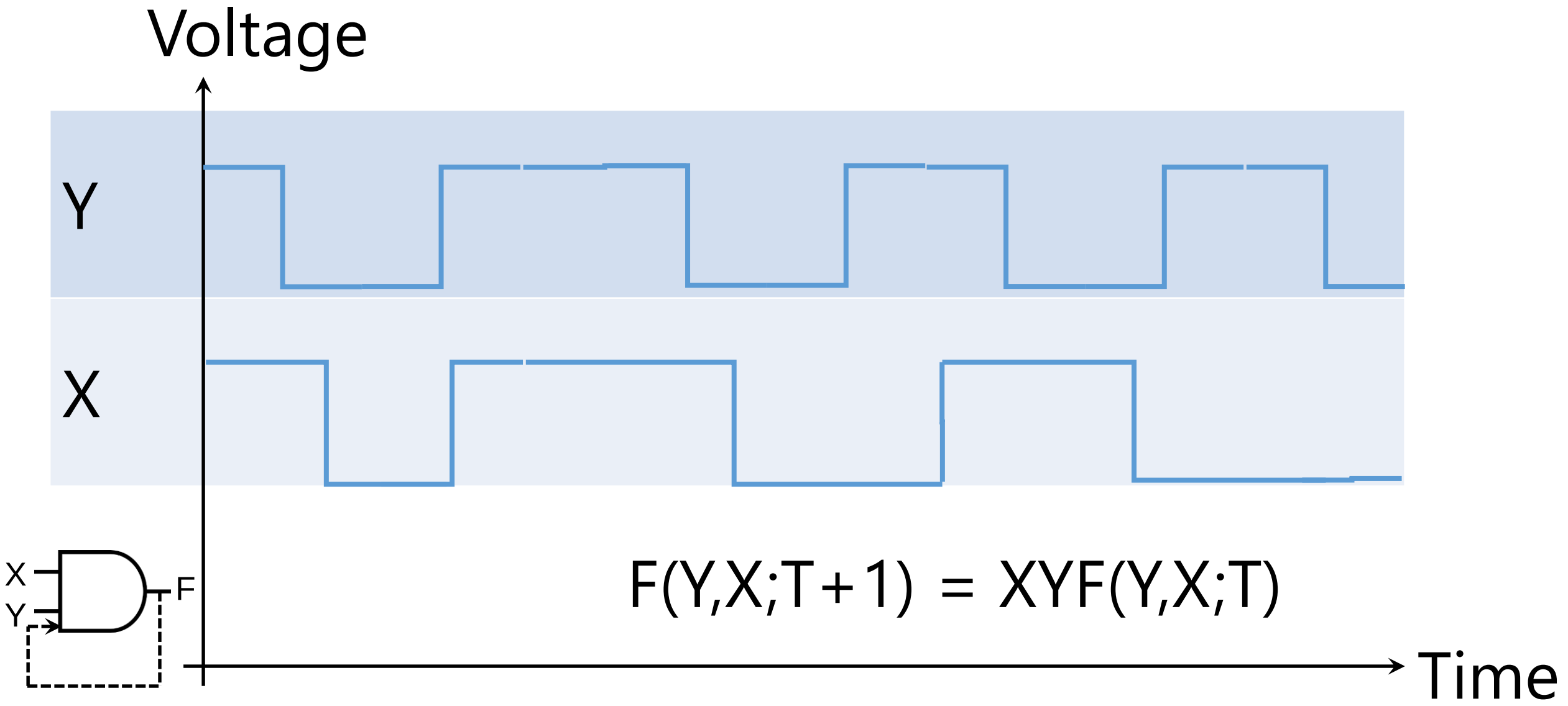
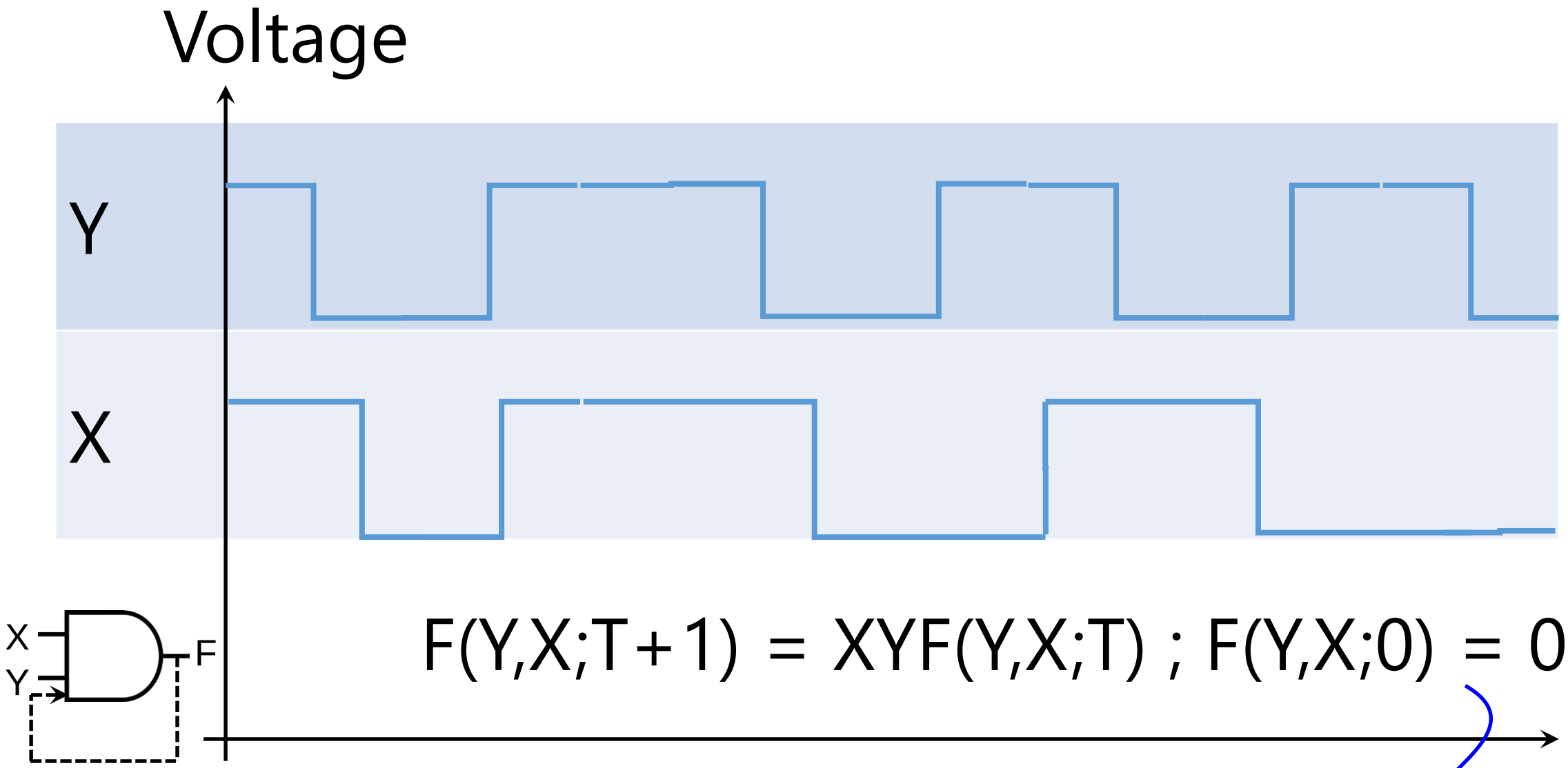
Sequential Logic

Sequential Logic



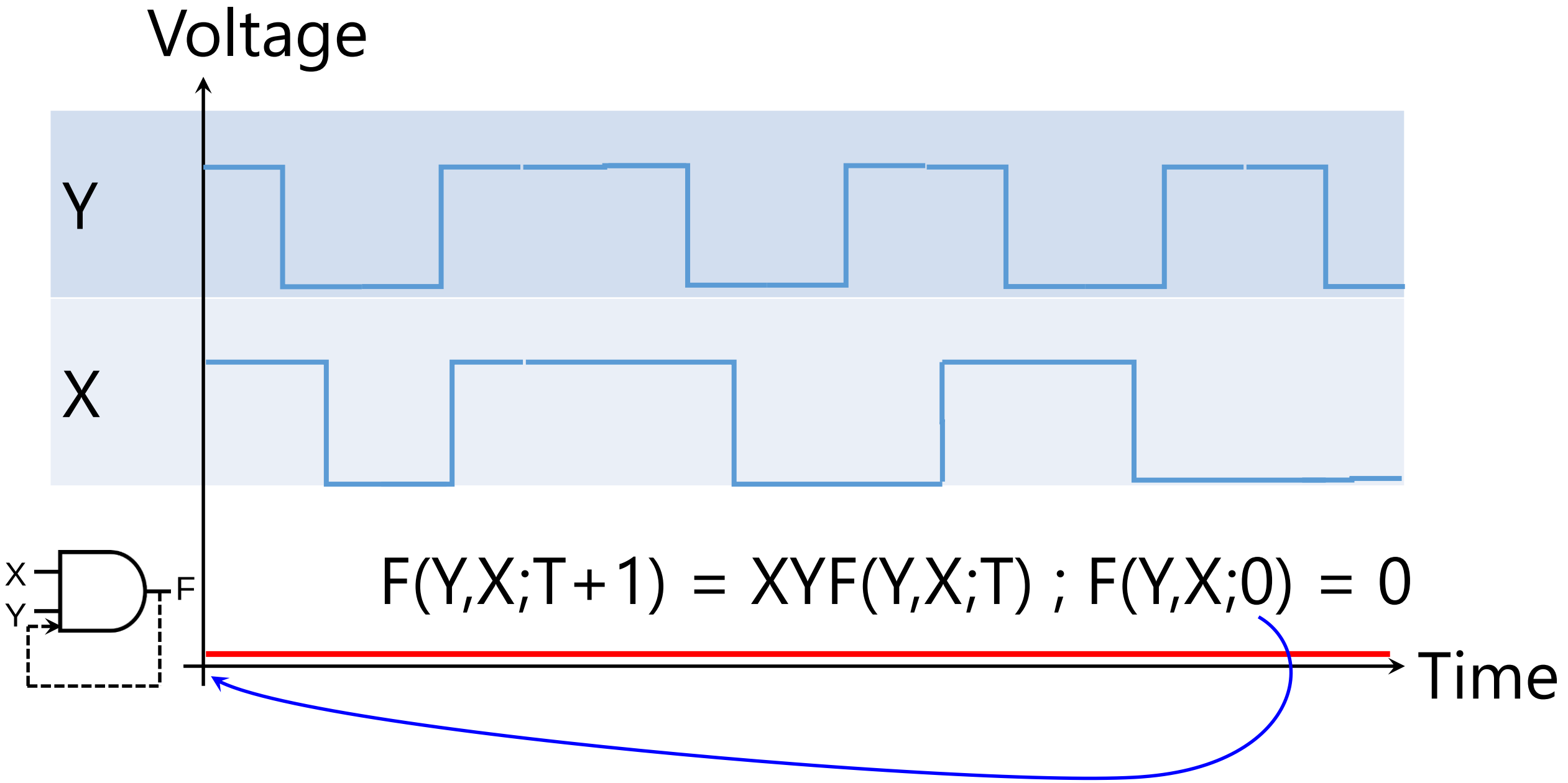

Voltage
Y
X
X
Y
F
Time

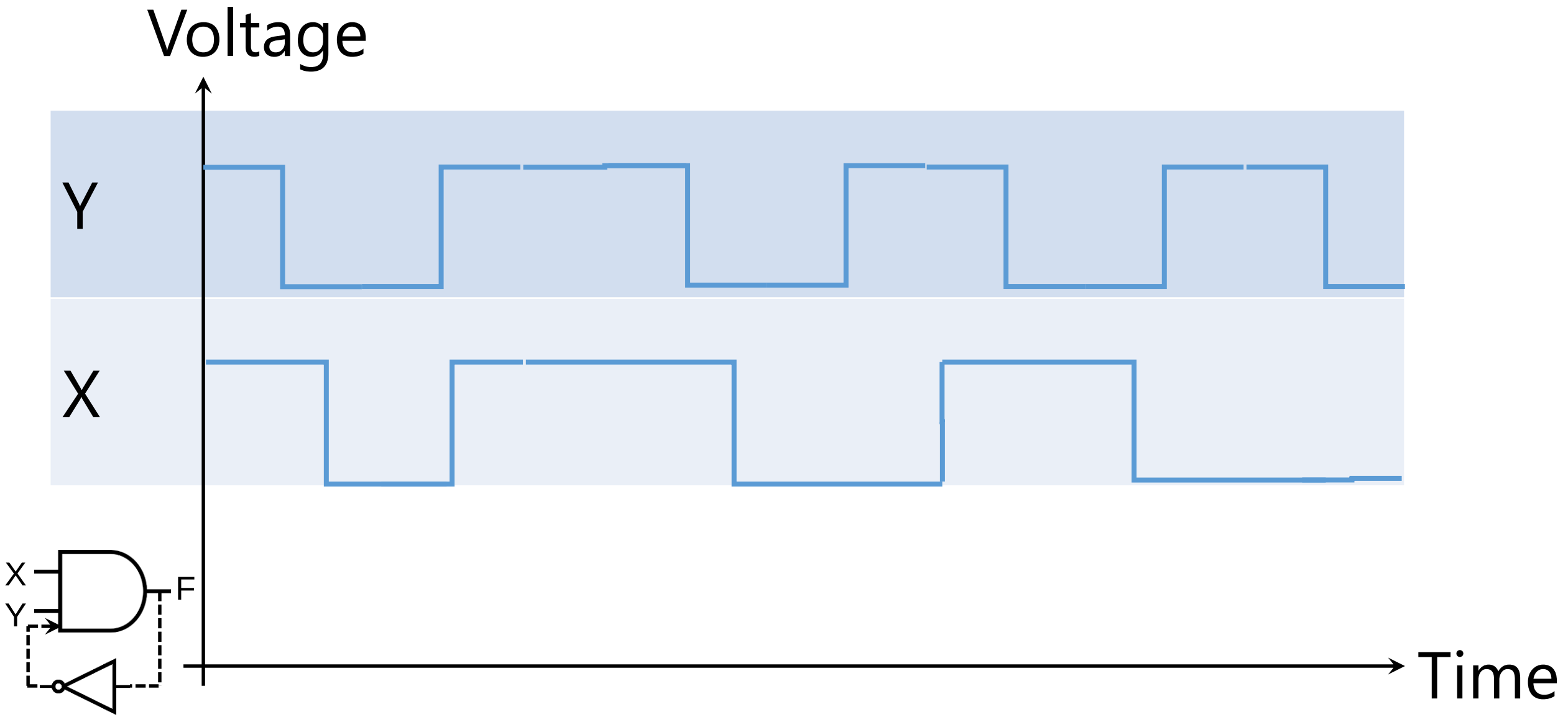

Voltage
Y
X
X
Y
F
F(Y,X;T+1) = XYF(Y,X;T)
Time



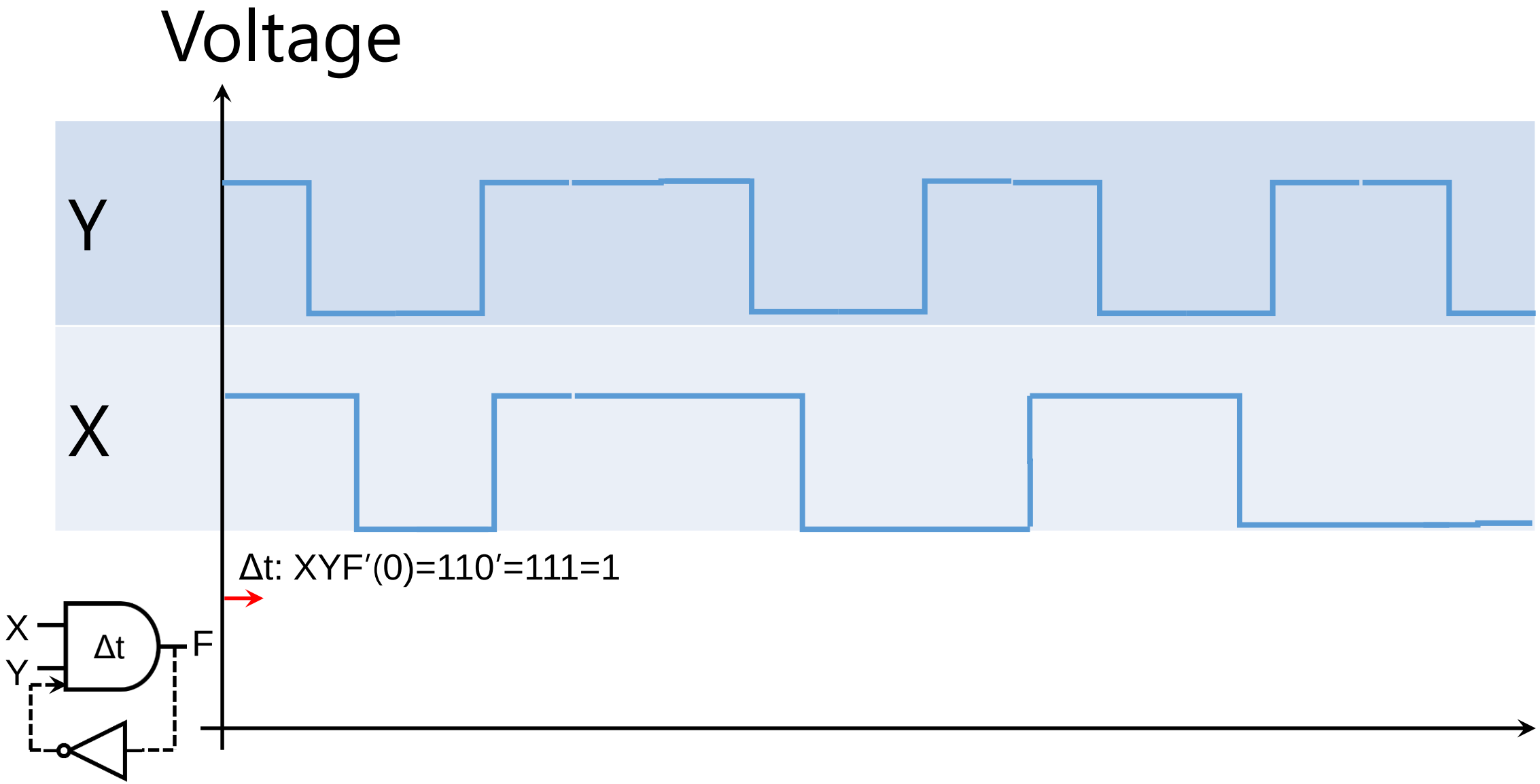
$$F(Y,X;T+1) = XYF(Y,X;T)\ ;\ F(Y,X;0) = 0$$

by default in positive logic

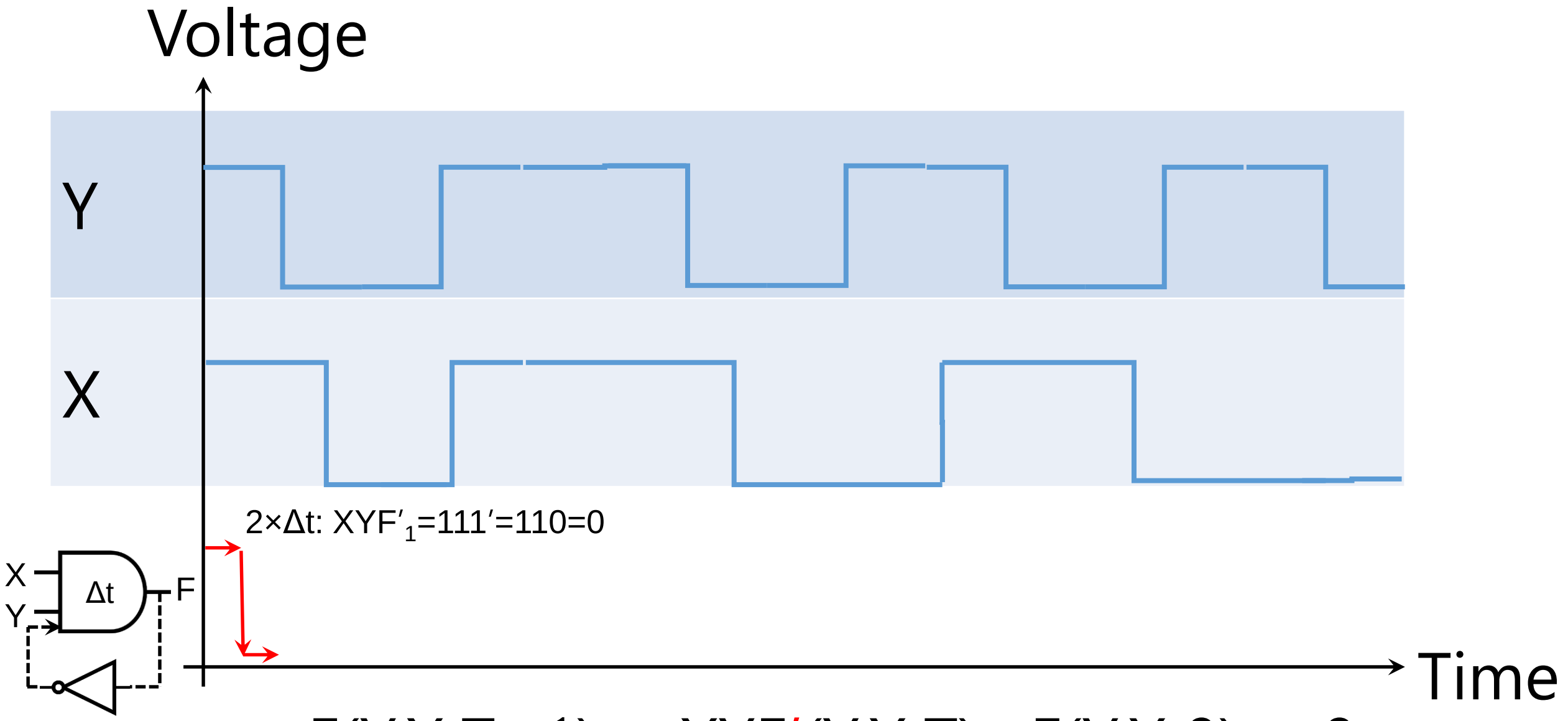

Voltage
Y
X
X
Y
F
F(Y,X;T+1) = XYF(Y,X;T) ; F(Y,X;0) = 0
Time



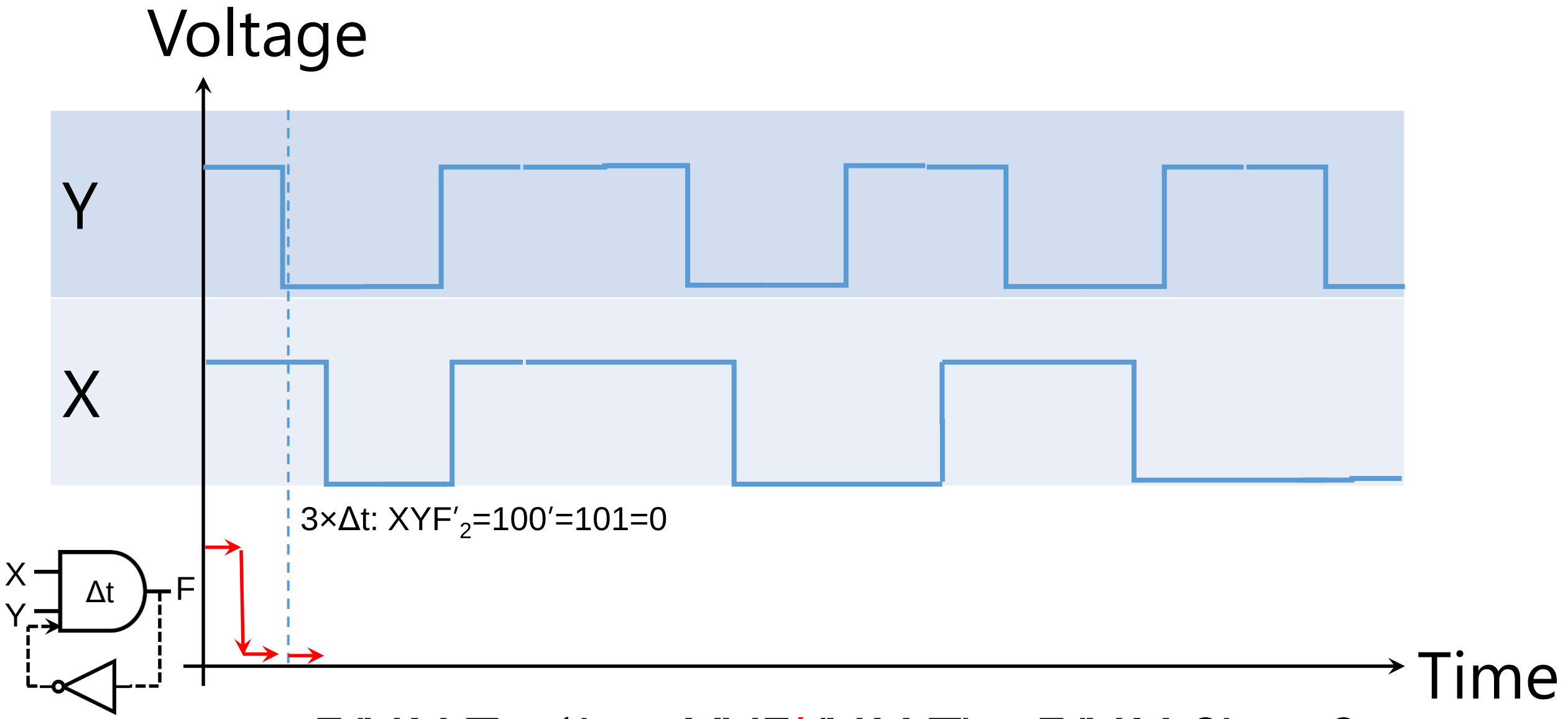
$$F(Y,X;T+1) = XYF'(Y,X;T) \; ; \; F(Y,X;0) = 0$$



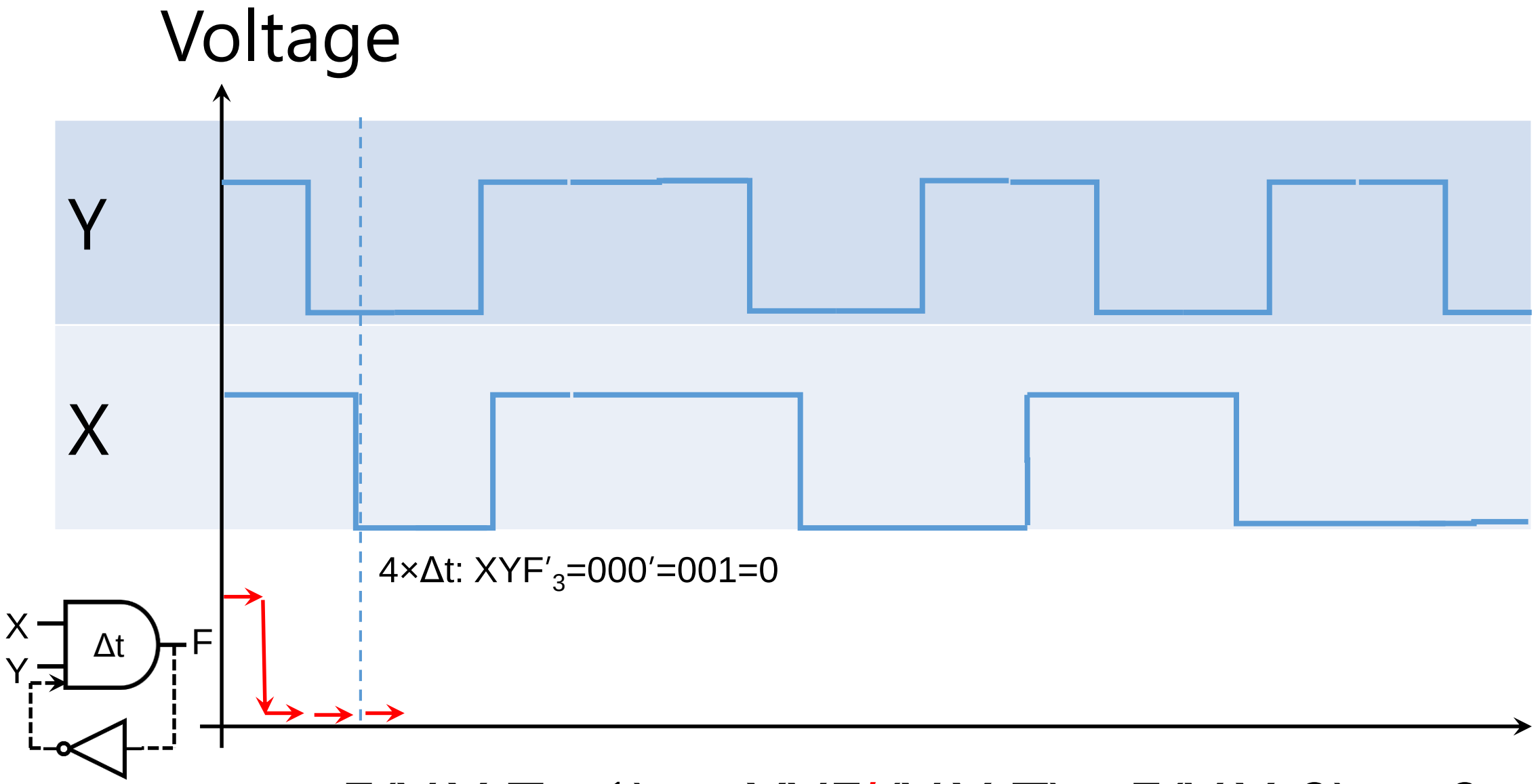
$$F(Y,X;T+1) = XYF'(Y,X;T)\ ;\ F(Y,X;0) = 0$$



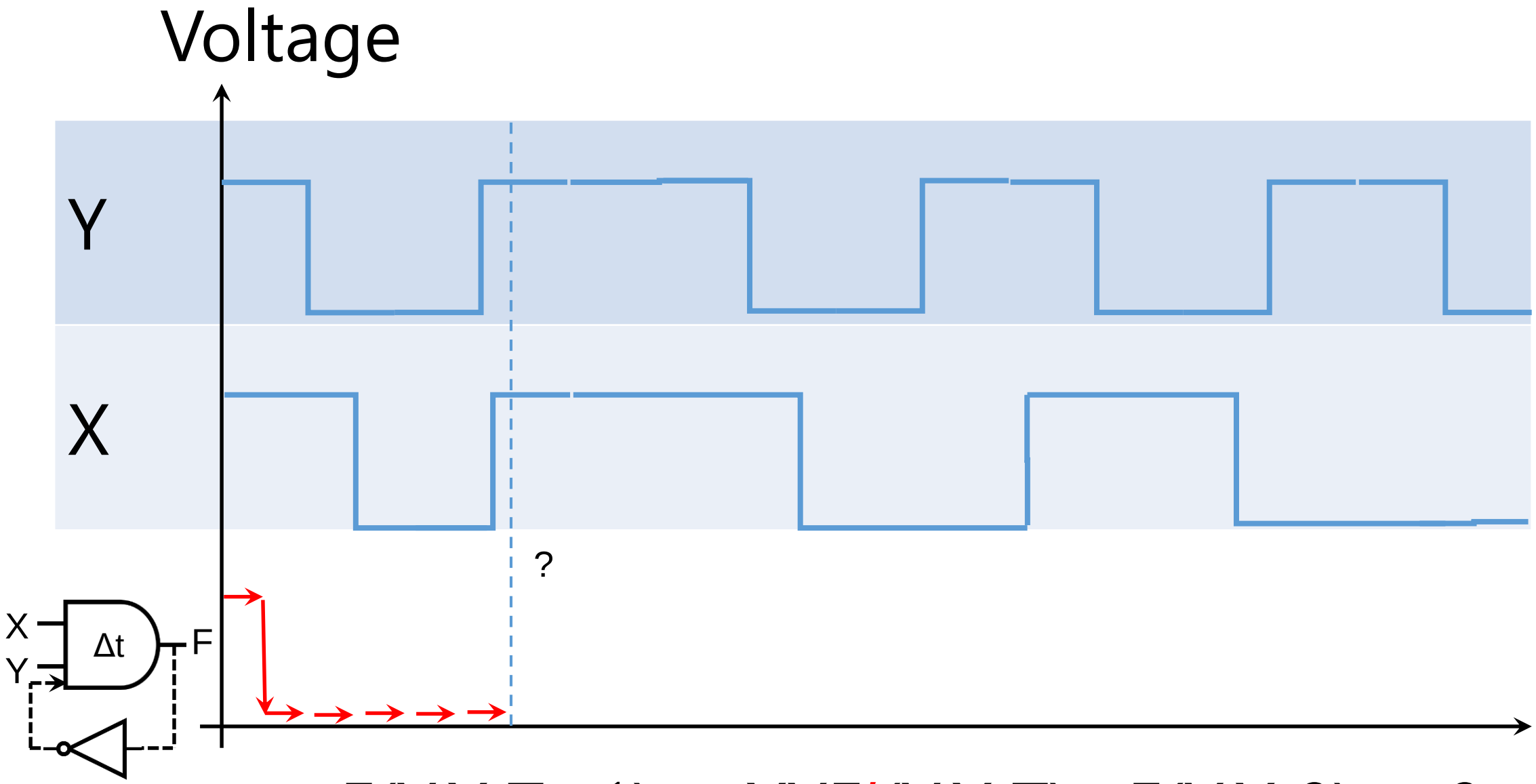
$$F(Y,X;T+1) = XYF'(Y,X;T)\ ;\ F(Y,X;0) = 0$$



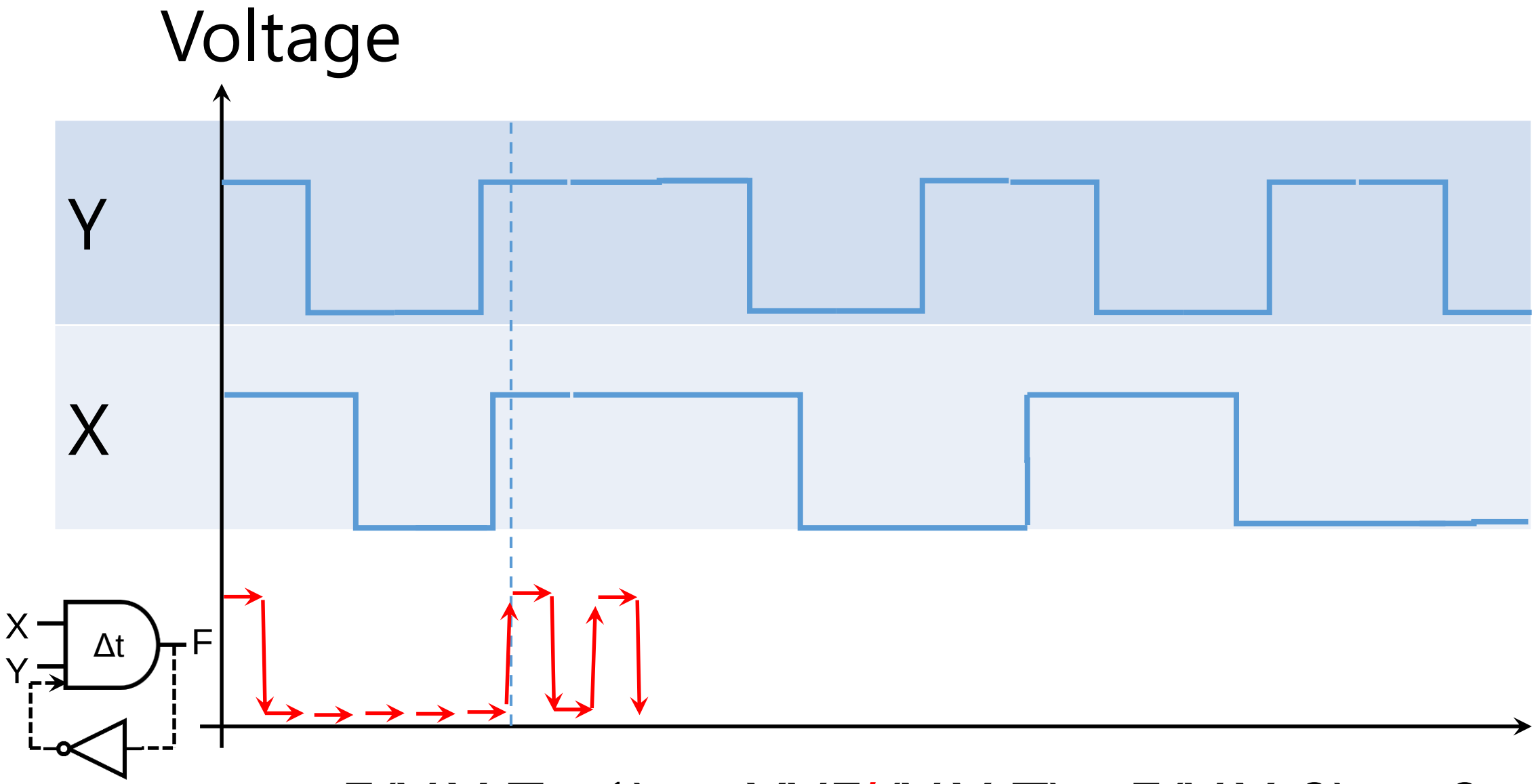
$$F(Y,X;T+1) = XYF'(Y,X;T)\ ;\ F(Y,X;0) = 0$$



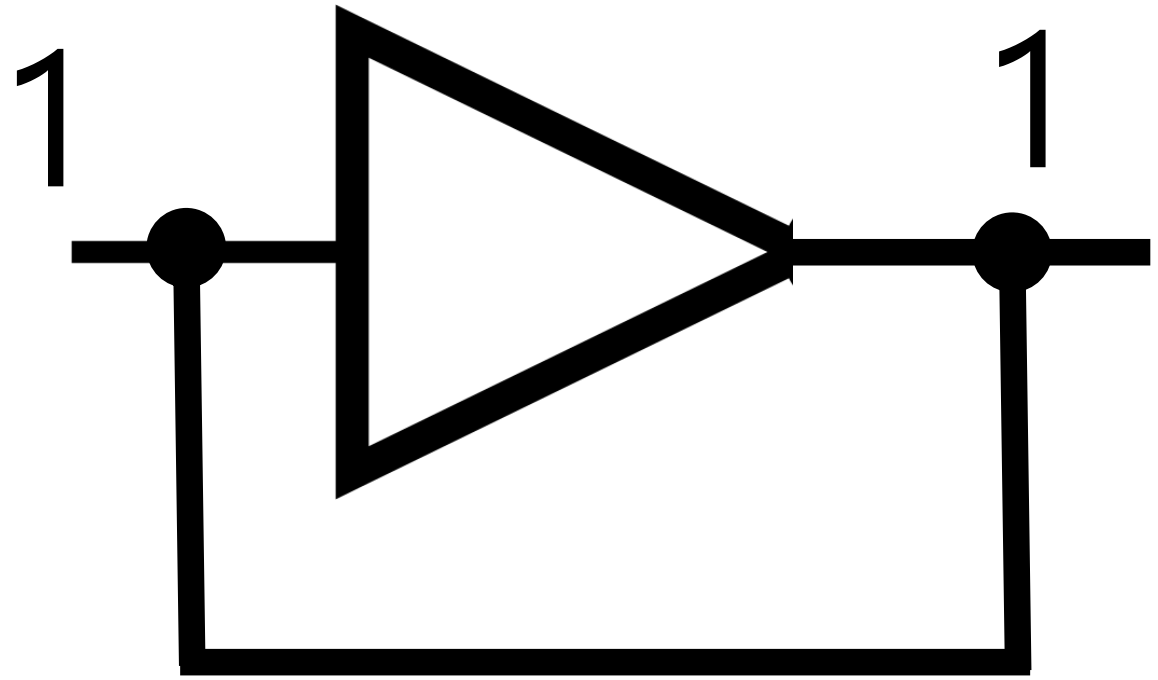
$$F(Y,X;T+1) = XYF'(Y,X;T)\ ;\ F(Y,X;0) = 0$$



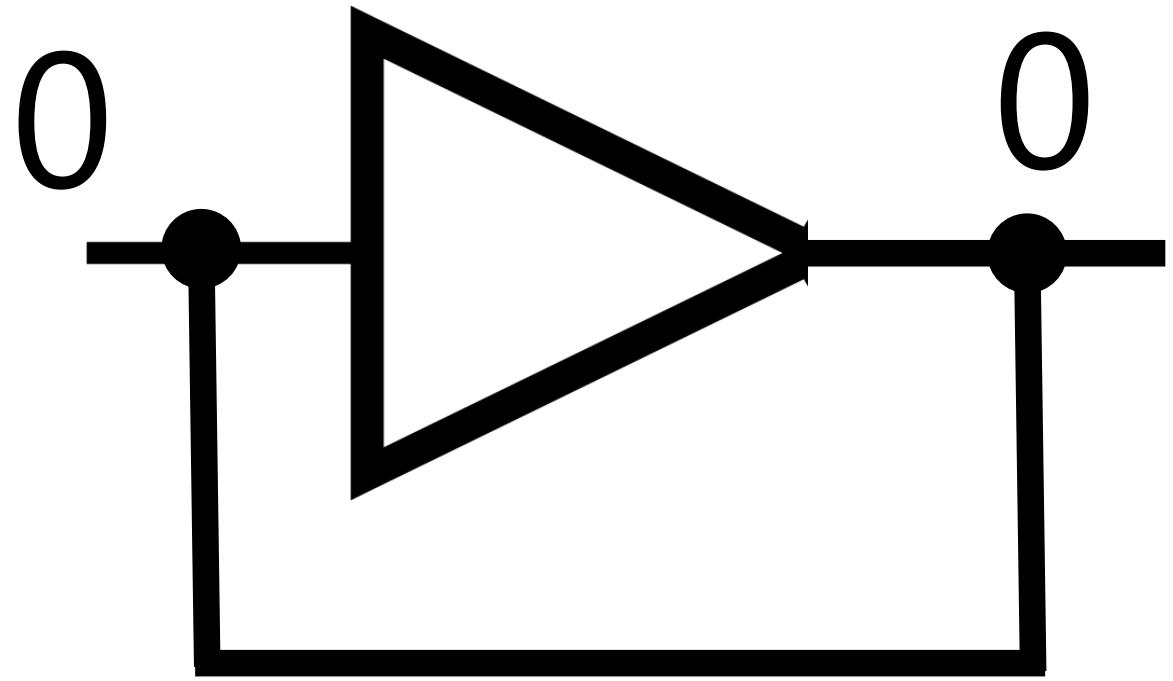
$$F(Y,X;T+1) = XYF'(Y,X;T)\ ;\ F(Y,X;0) = 0$$



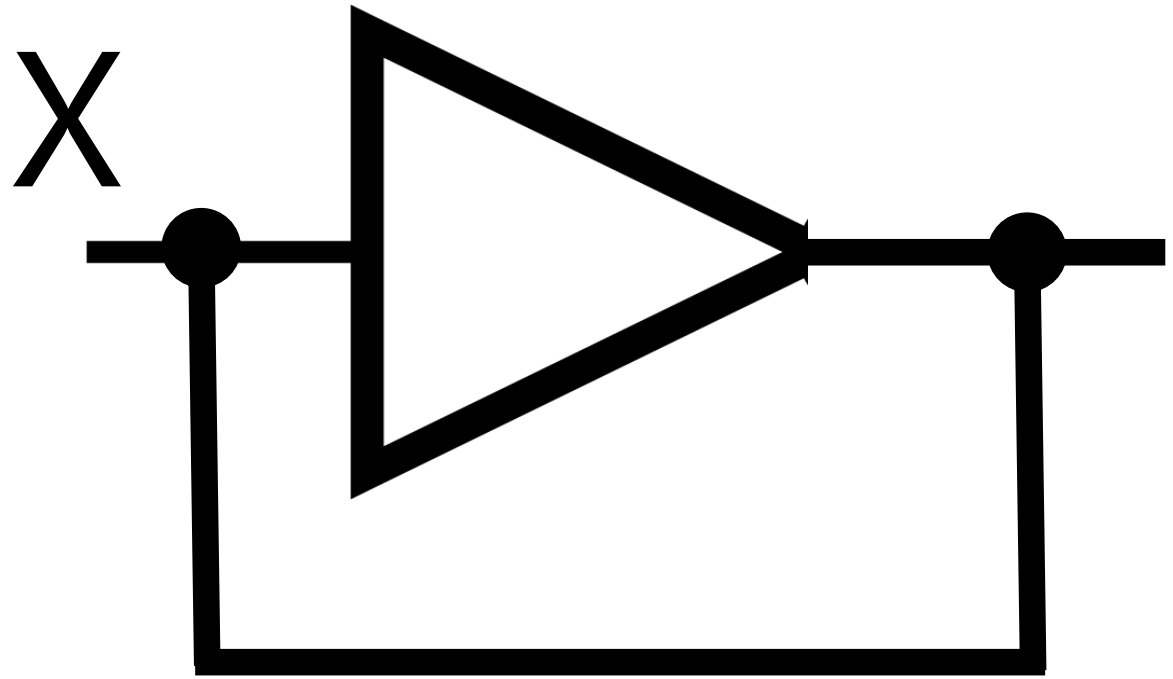
$$F(Y,X;T+1) = XYF'(Y,X;T)\ ;\ F(Y,X;0) = 0$$



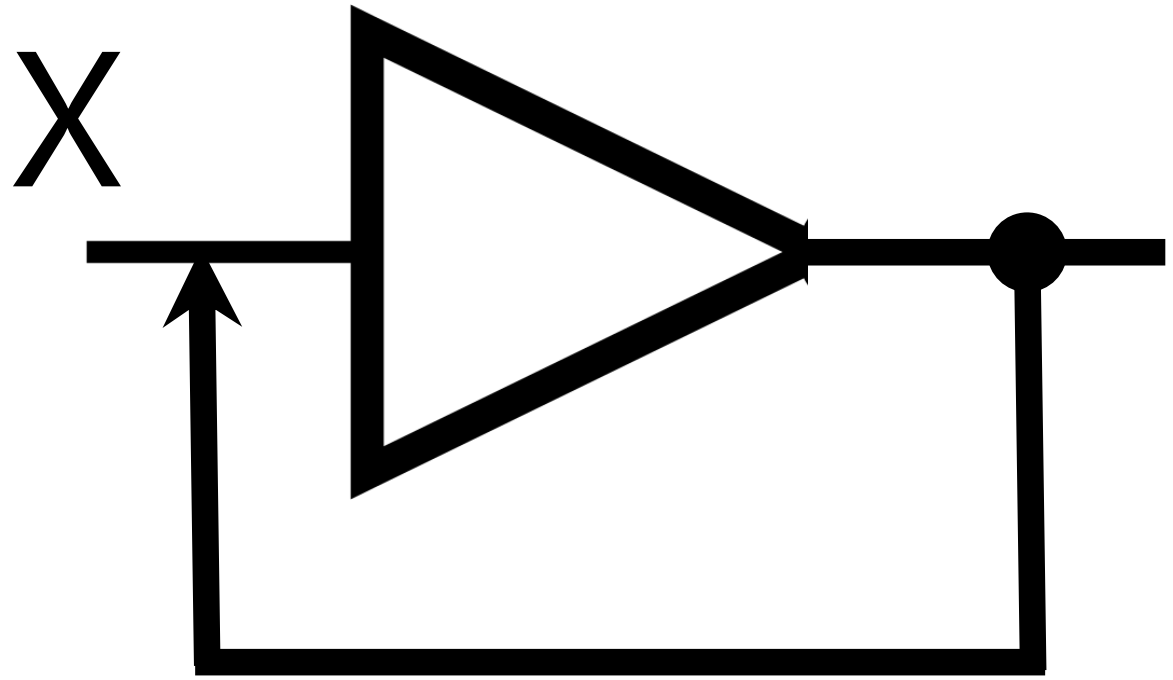
By feedback we can memorize 1



By feedback we can memorize 0



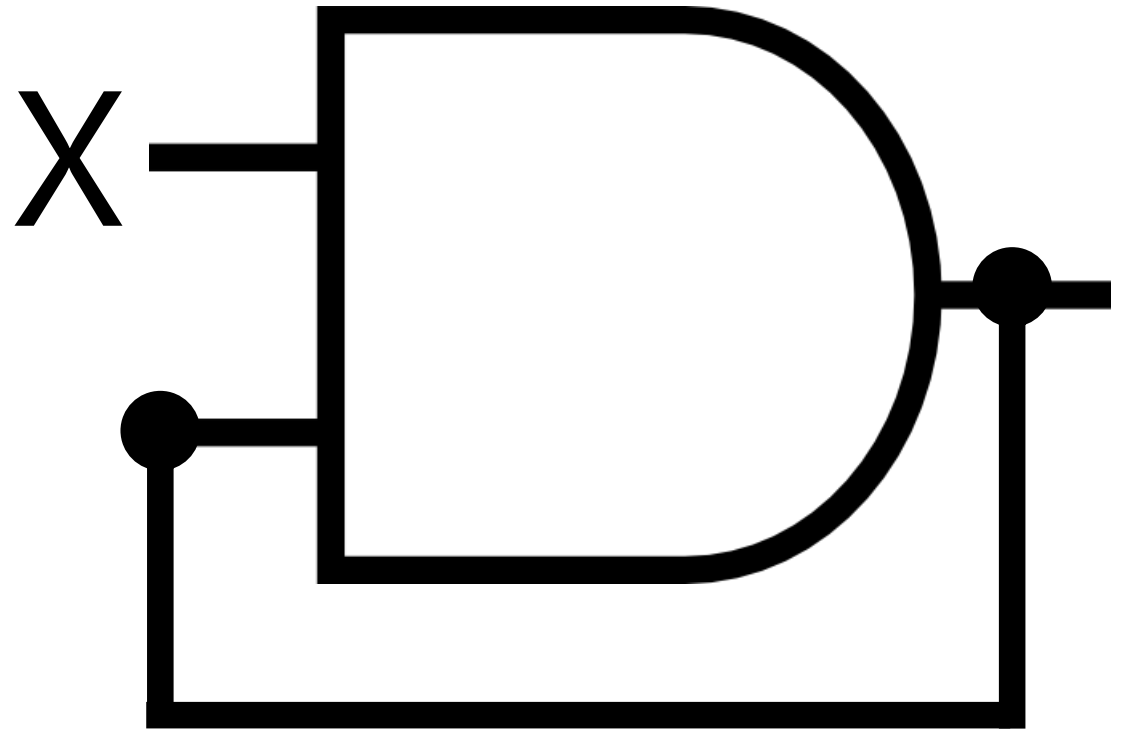
This design is logically incorrect! Why?



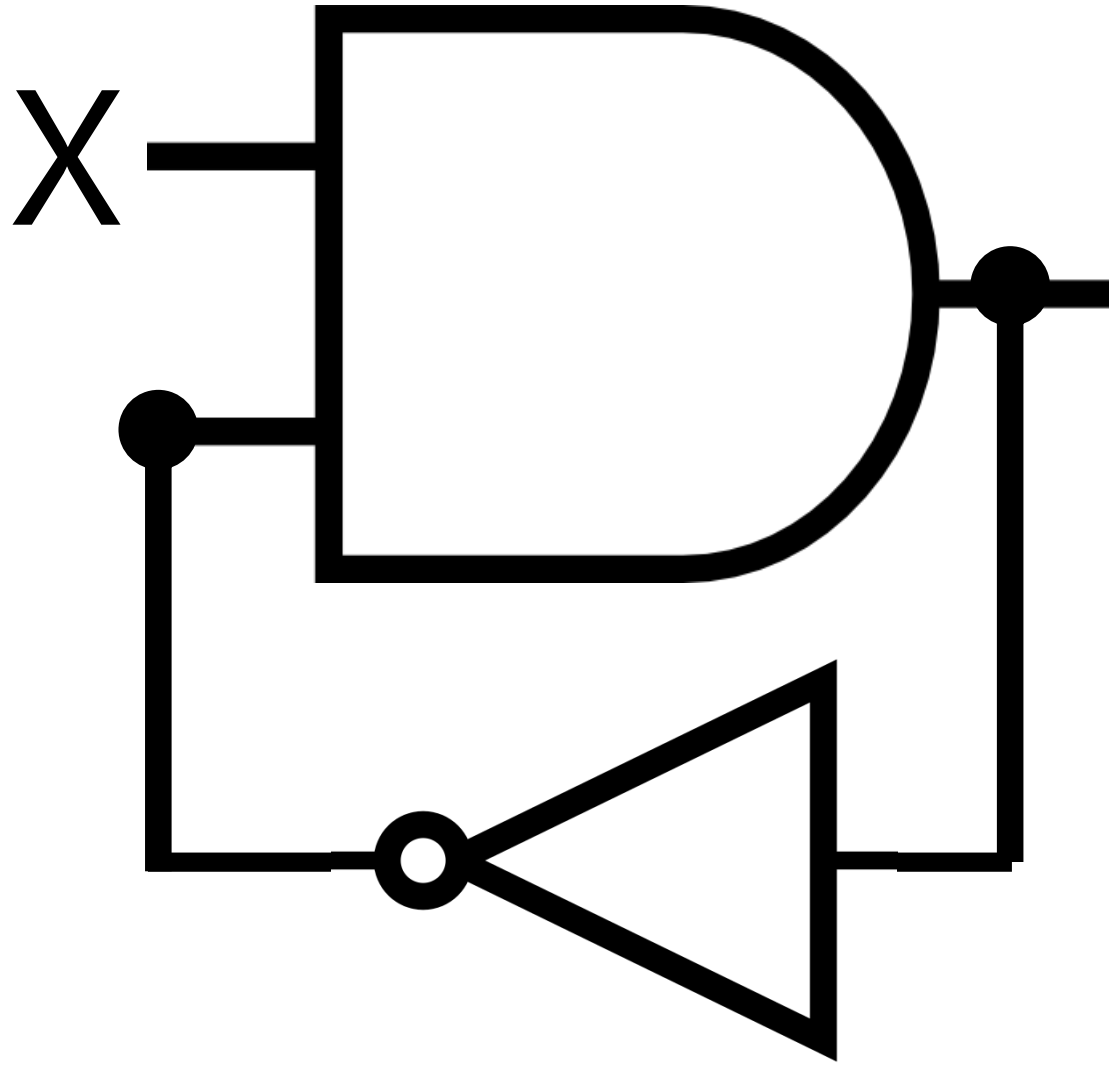
This design is logically incorrect! Why?

Buffer gate accepts one input.

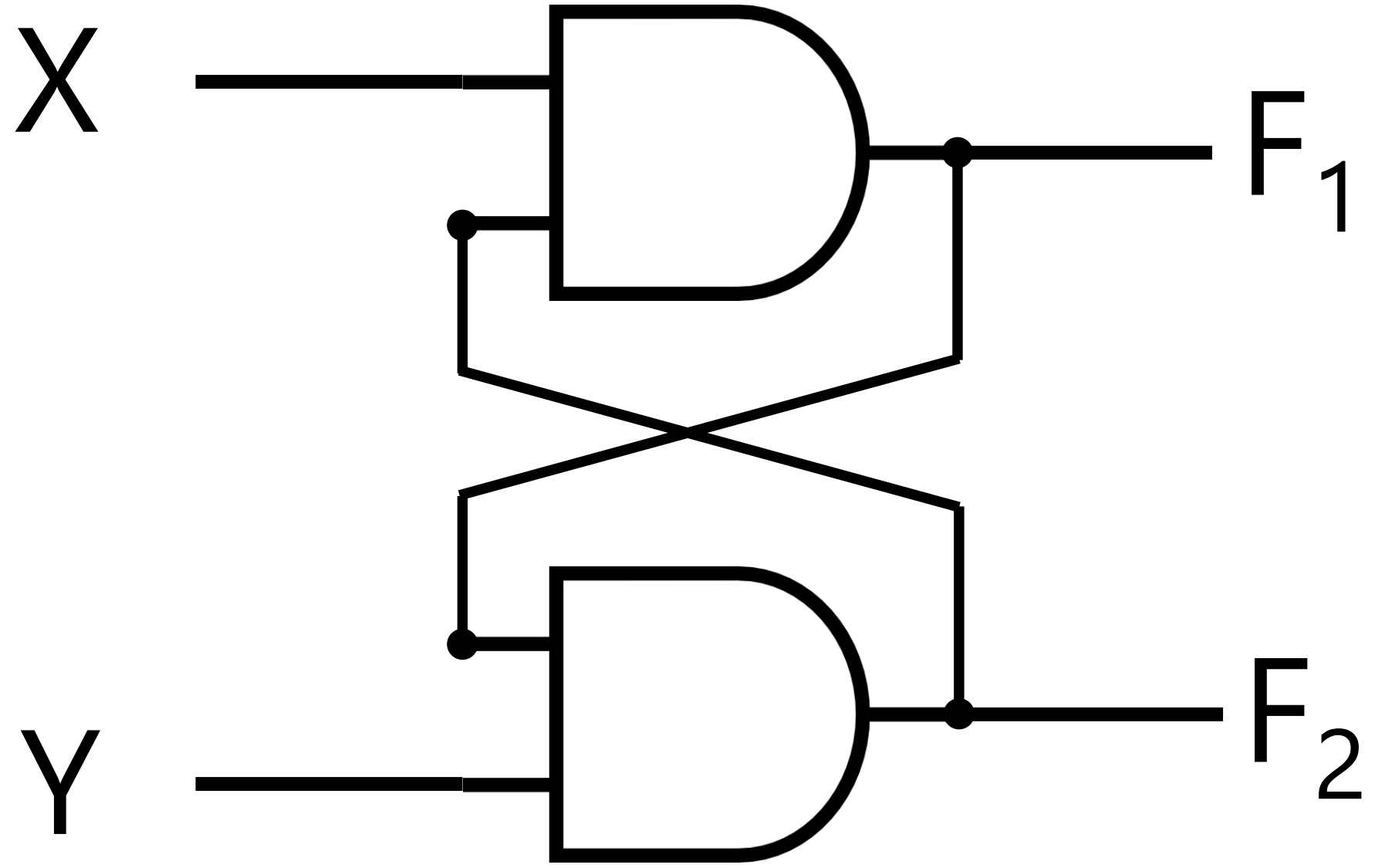
We have two inputs: X and X_{T-1}

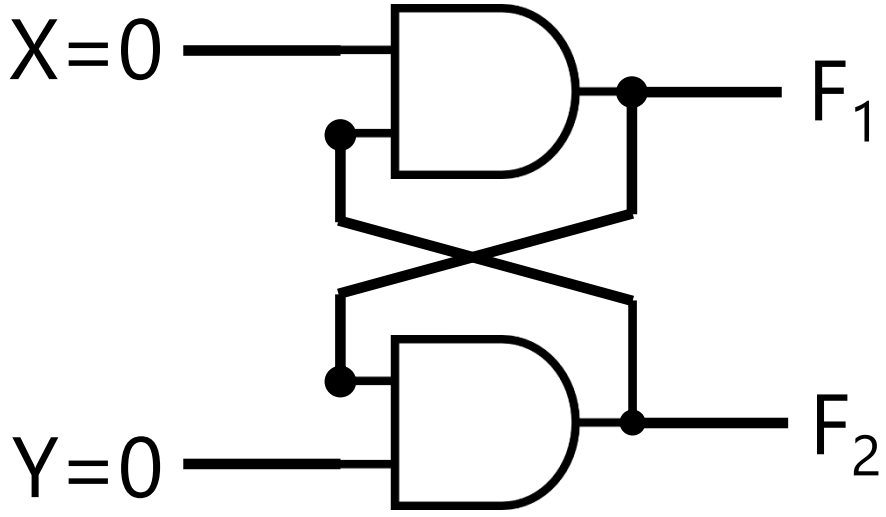


This design is logically correct!
But what’s the problem?

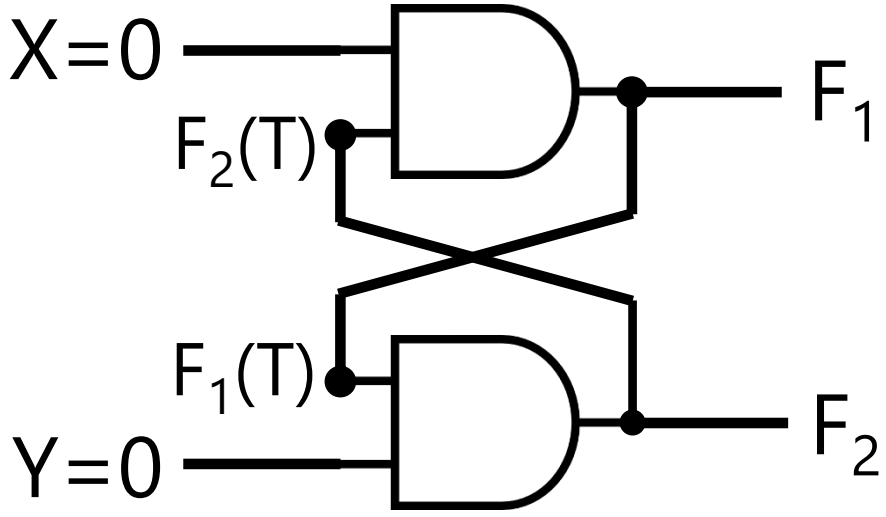


This design is also logically correct!
But what’s the problem?

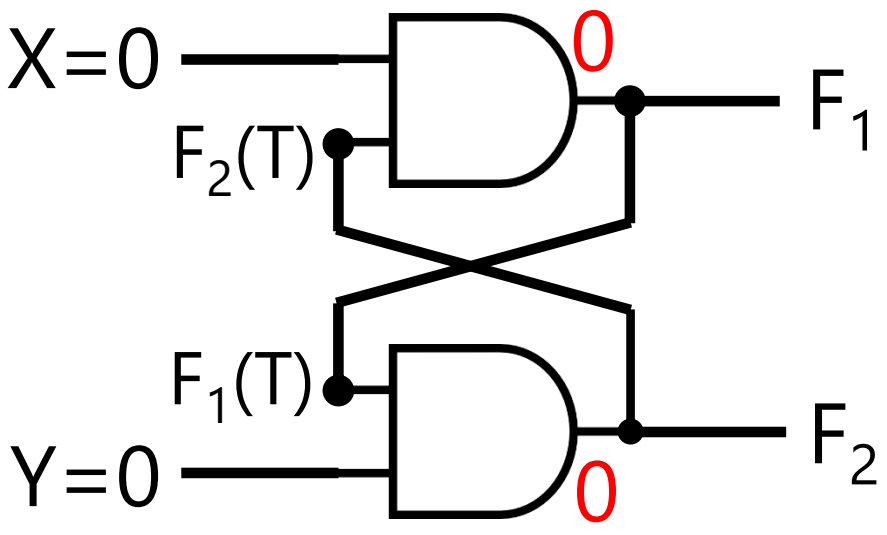

X
Y
F1
F2



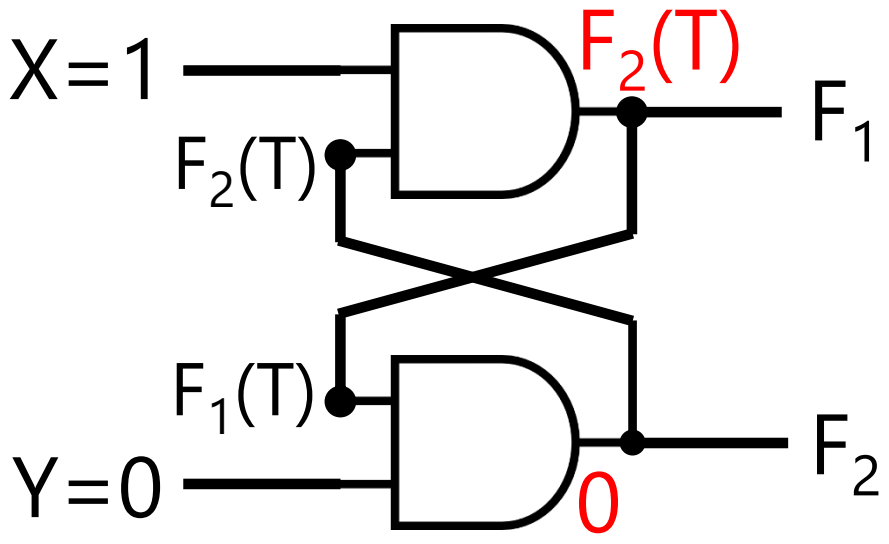
Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0		



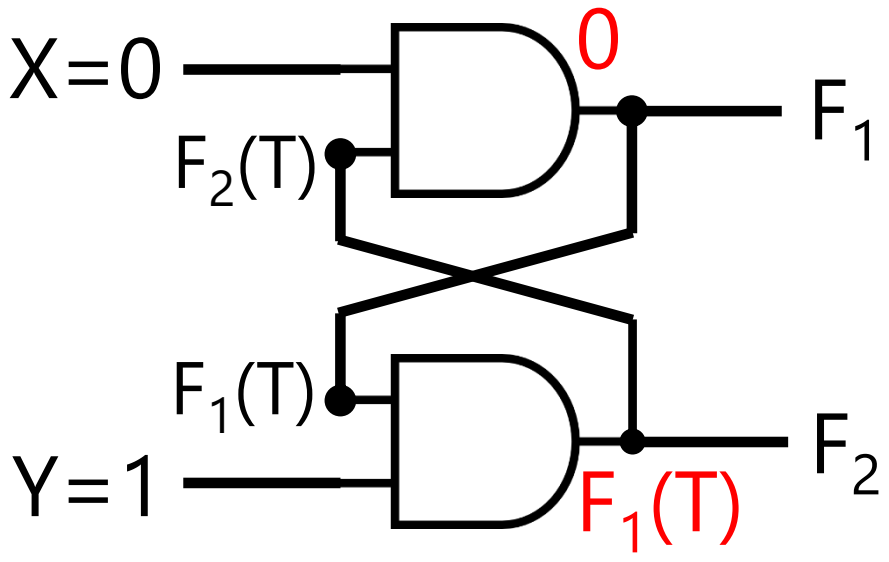
Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0		



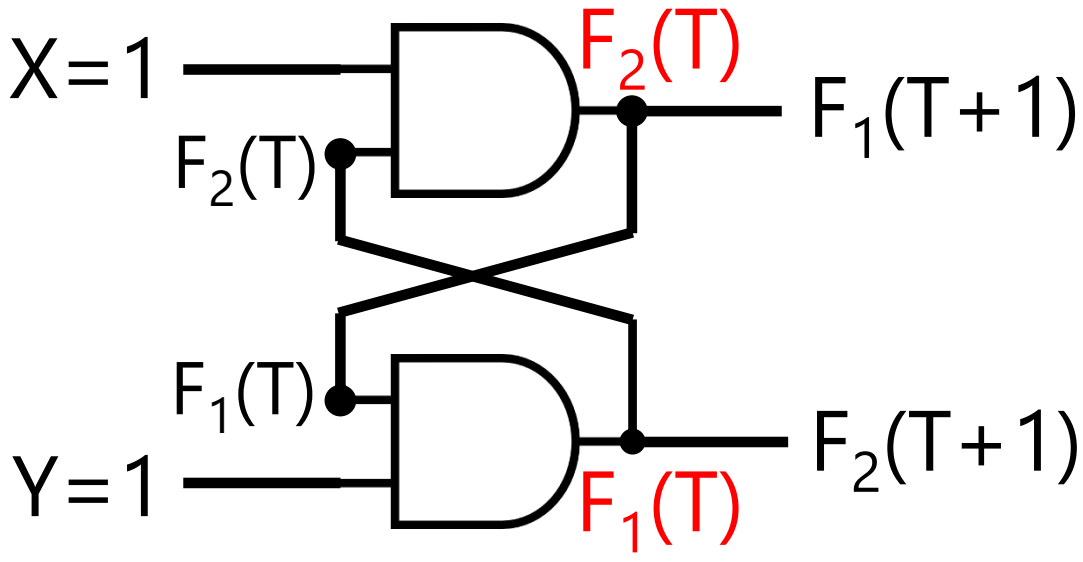
Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0



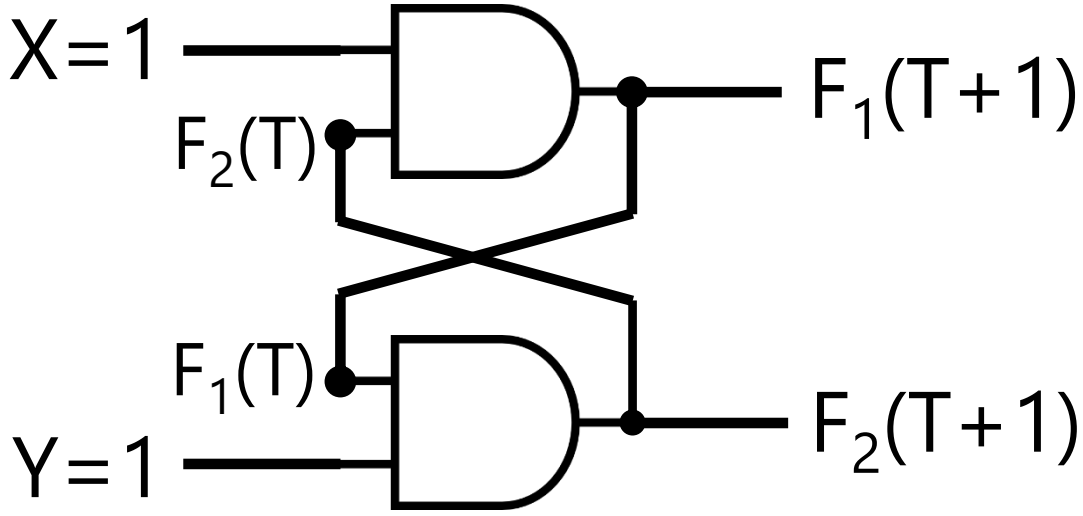
Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0
0	1	$F_2(T)$	0



Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0
0	1	$F_2(T)$	0
1	0	0	$F_1(T)$

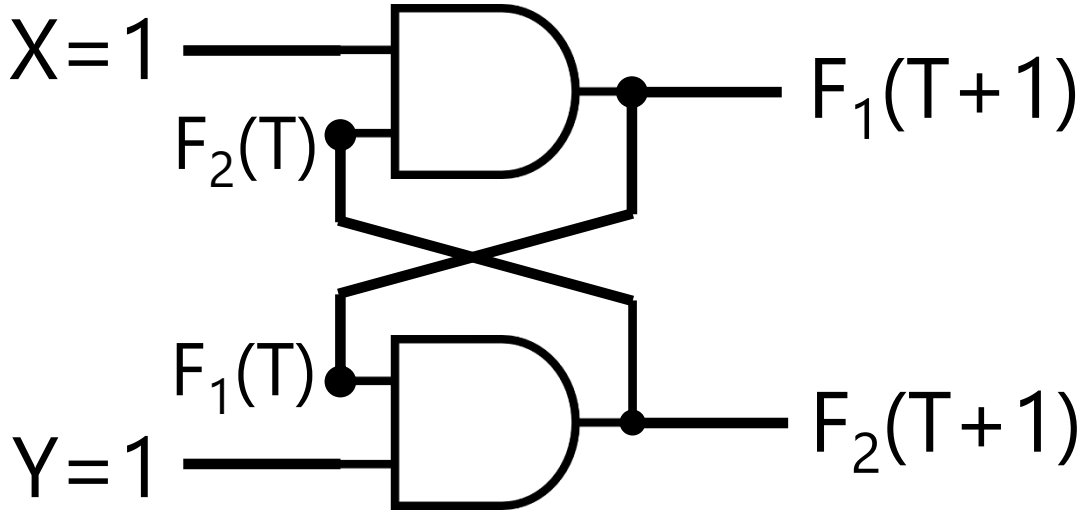


Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0
0	1	$F_2(T)$	0
1	0	0	$F_1(T)$
1	1	$F_2(T)$	$F_1(T)$



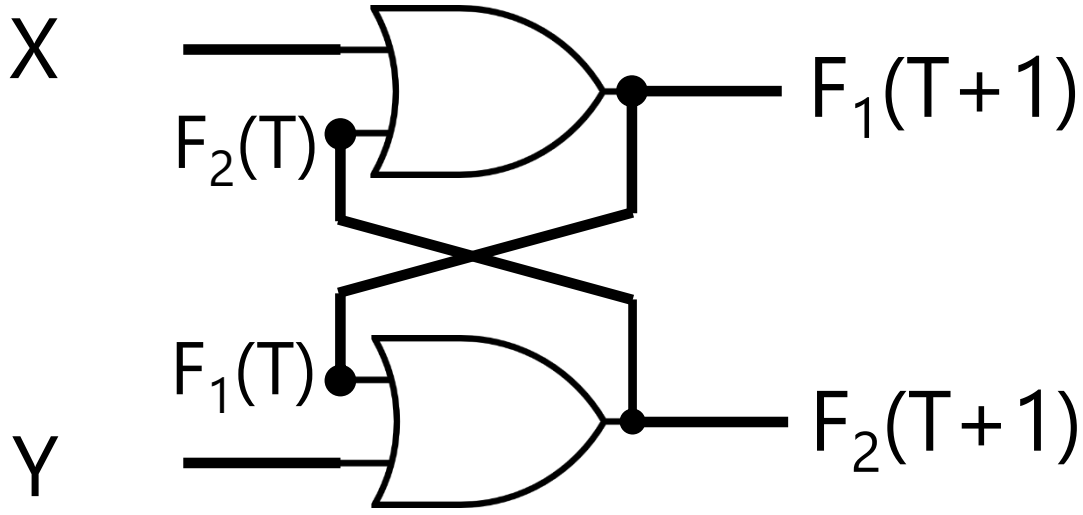
When it goes to 00 state, never recover to 1!

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0
0	1	$F_2(T)$	0
1	0	0	$F_1(T)$
1	1	$F_2(T)$	$F_1(T)$



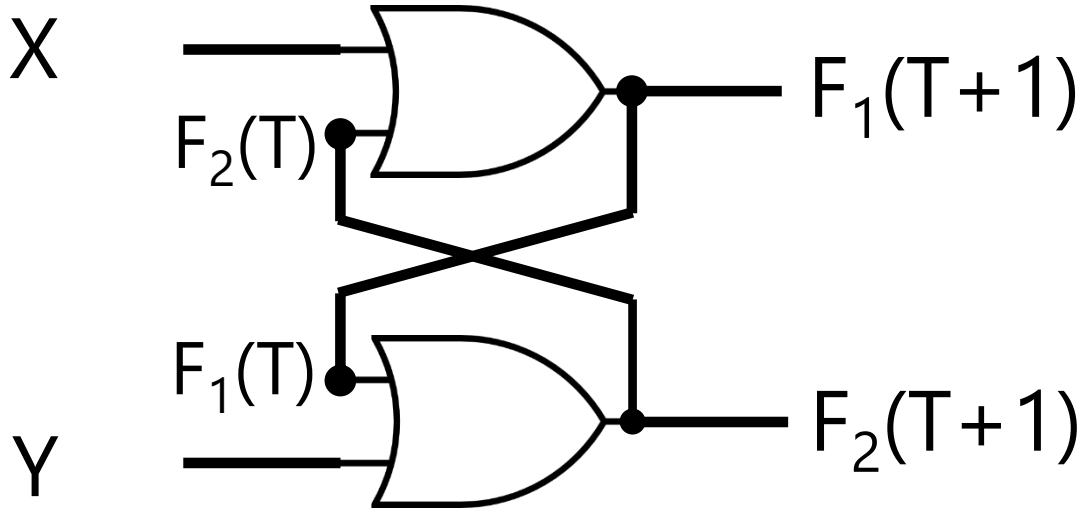
When it goes to 00 state, never recover to 1!

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0
0	1	0	0
1	0	0	0
1	1	0	0



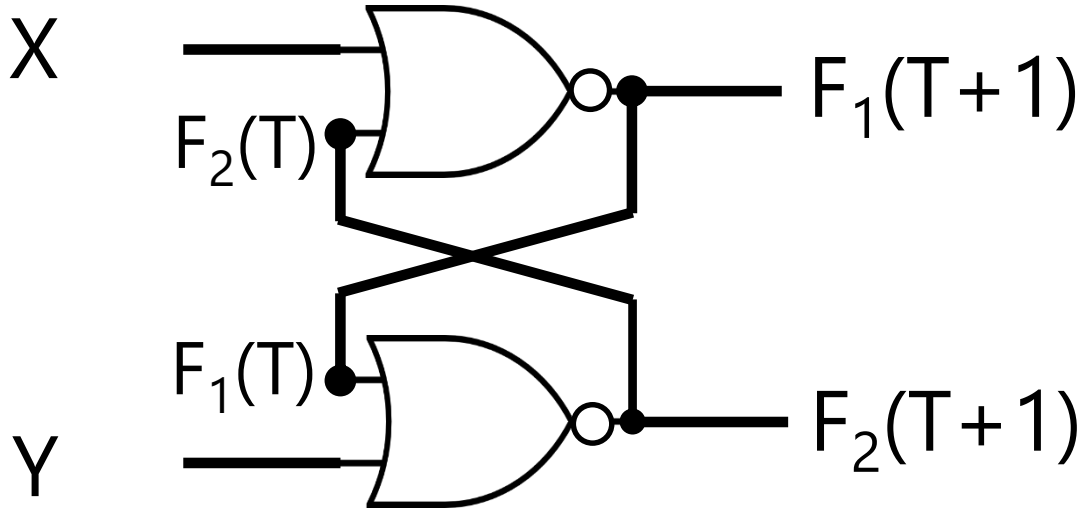
How about OR gates? Do they solve the problem?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0		
0	1		
1	0		
1	1		



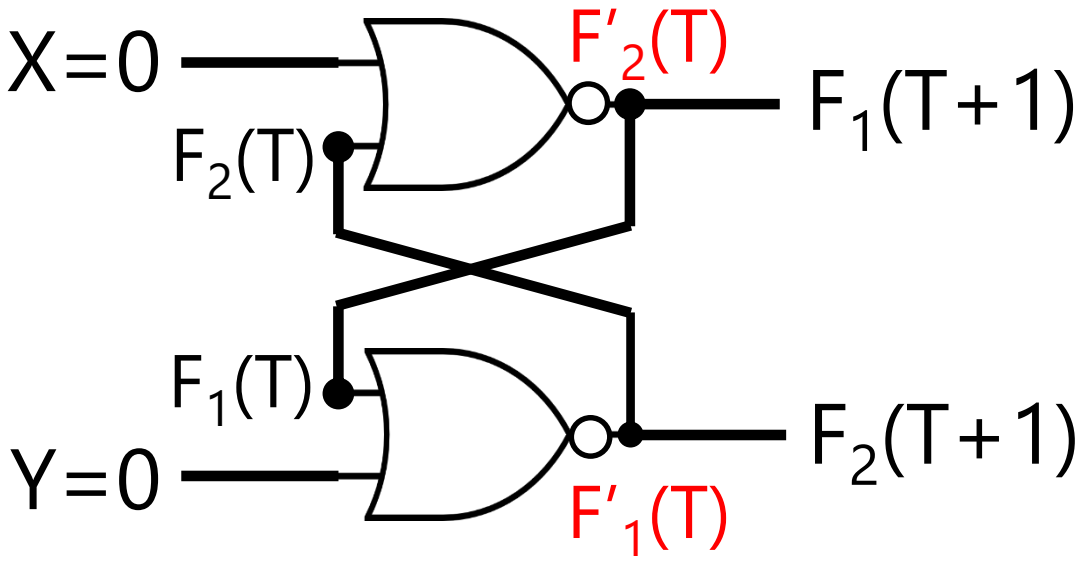
How about OR gates? Do they solve the problem? No! Why?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0		
0	1		
1	0		
1	1		



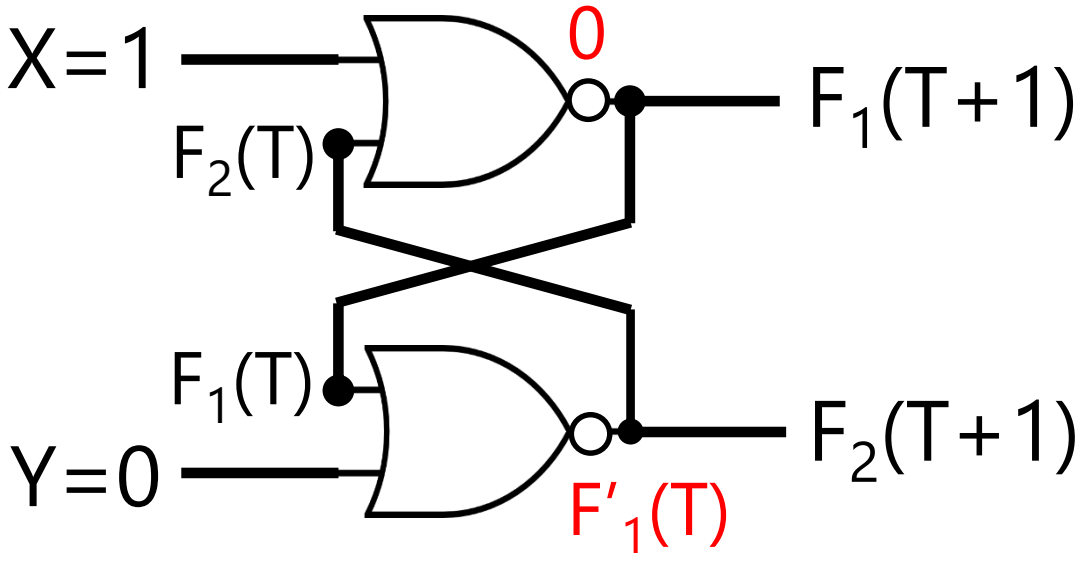
How about NOR gates? Do they solve the problem?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0		
0	1		
1	0		
1	1		



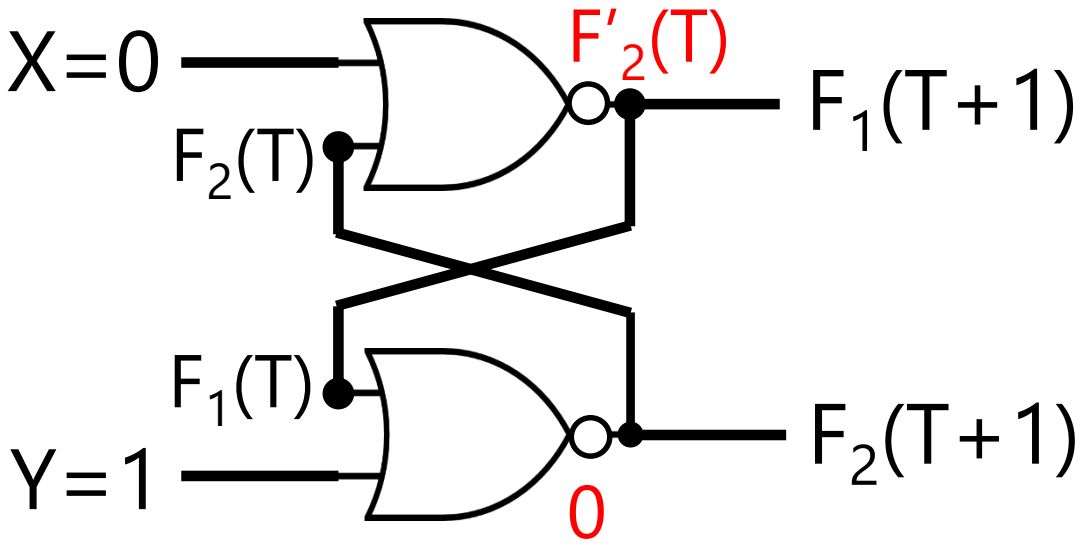
How about NOR gates? Do they solve the problem?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	$F'_2(T)$	$F'_1(T)$
0	1		
1	0		
1	1		



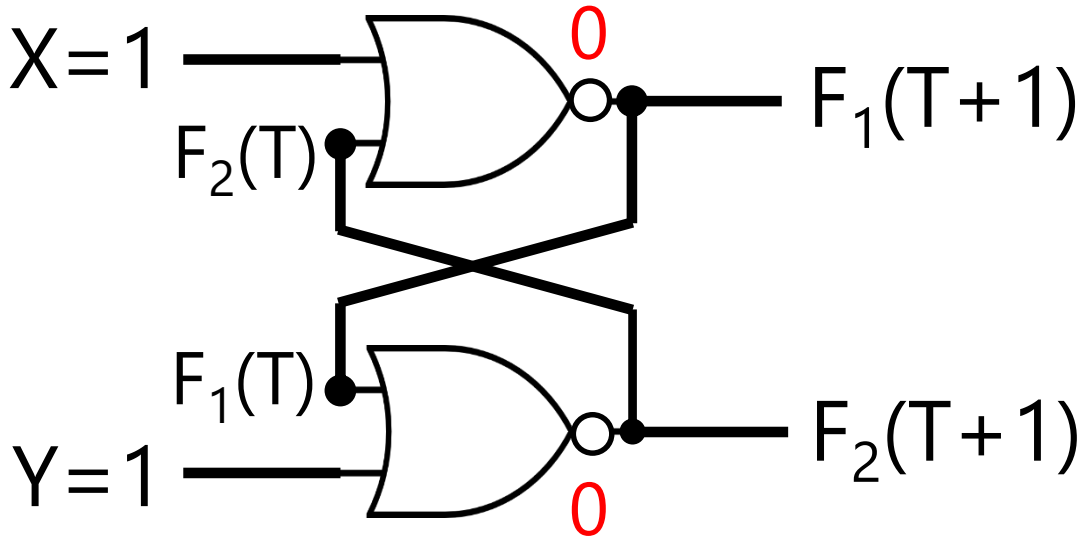
How about NOR gates? Do they solve the problem?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	$F'_2(T)$	$F'_1(T)$
0	1	0	$F'_1(T)$
1	0		
1	1		



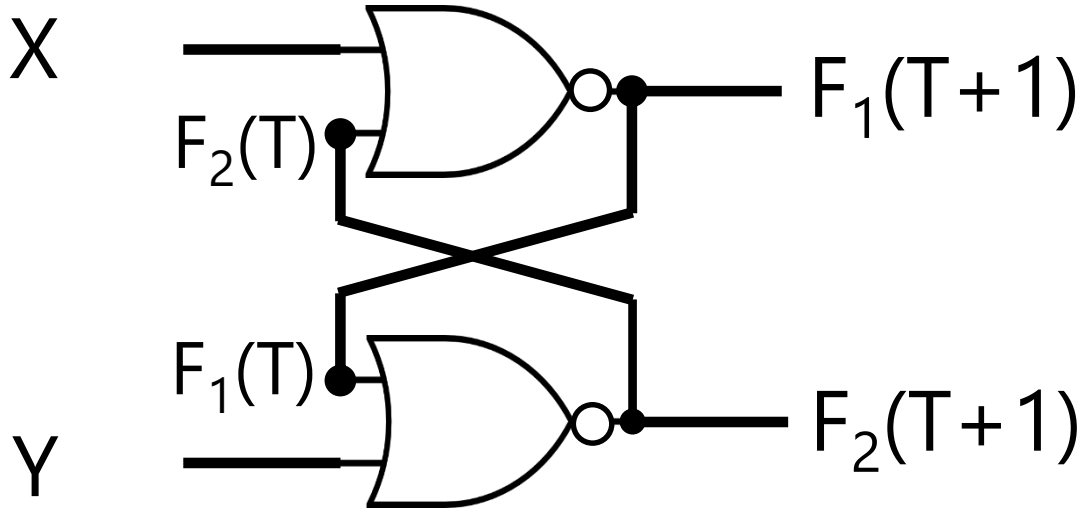
How about NOR gates? Do they solve the problem?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	$F'_2(T)$	$F'_1(T)$
0	1	0	$F'_1(T)$
1	0	$F'_2(T)$	0
1	1		



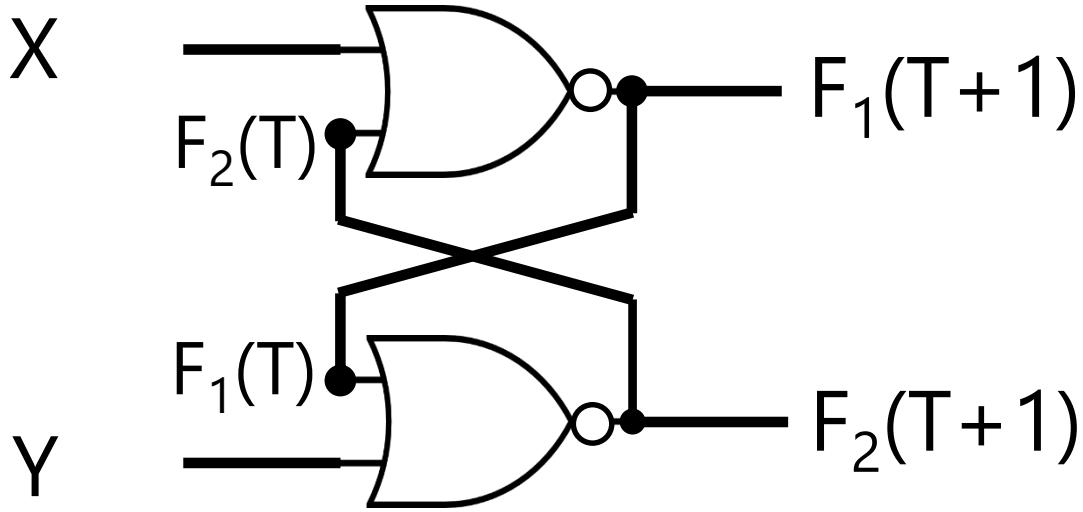
How about NOR gates? Do they solve the problem?

Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	$F'_2(T)$	$F'_1(T)$
0	1	0	$F'_1(T)$
1	0	$F'_2(T)$	0
1	1	0	0

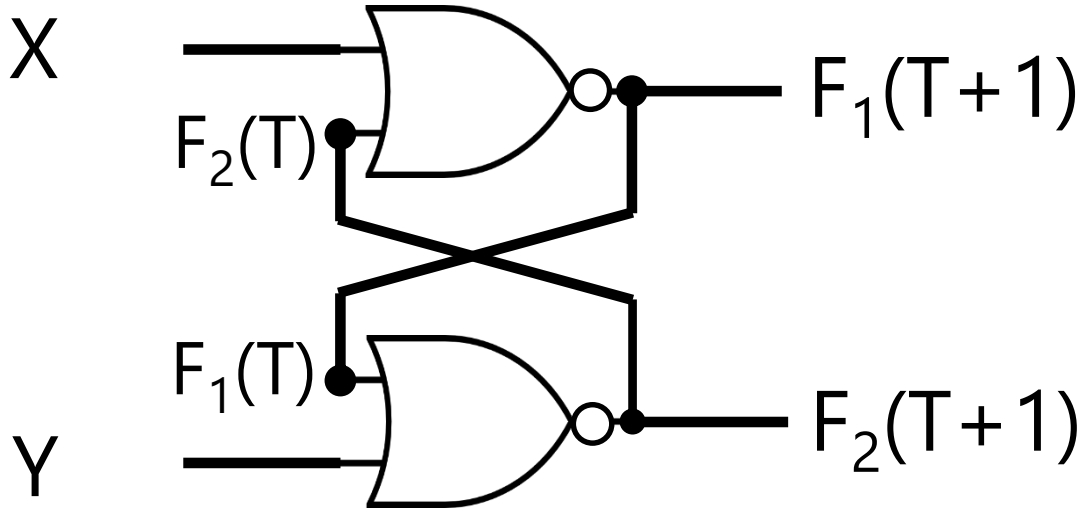


Seems working. But we have to check all possible current states?

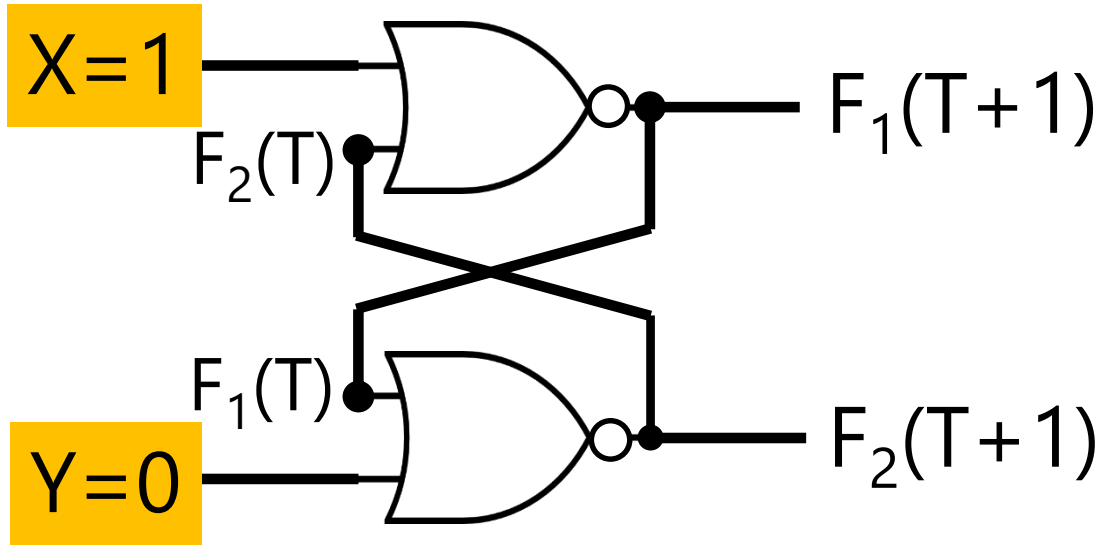
Y	X	$F_1(T+1)$	$F_2(T+1)$
0	0	$F'_2(T)$	$F'_1(T)$
0	1	0	$F'_1(T)$
1	0	$F'_2(T)$	0
1	1	0	0



		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0	$F'_2(T)$	$F'_1(T)$
0	1			0	$F'_1(T)$
1	0			$F'_2(T)$	0
1	1			0	0



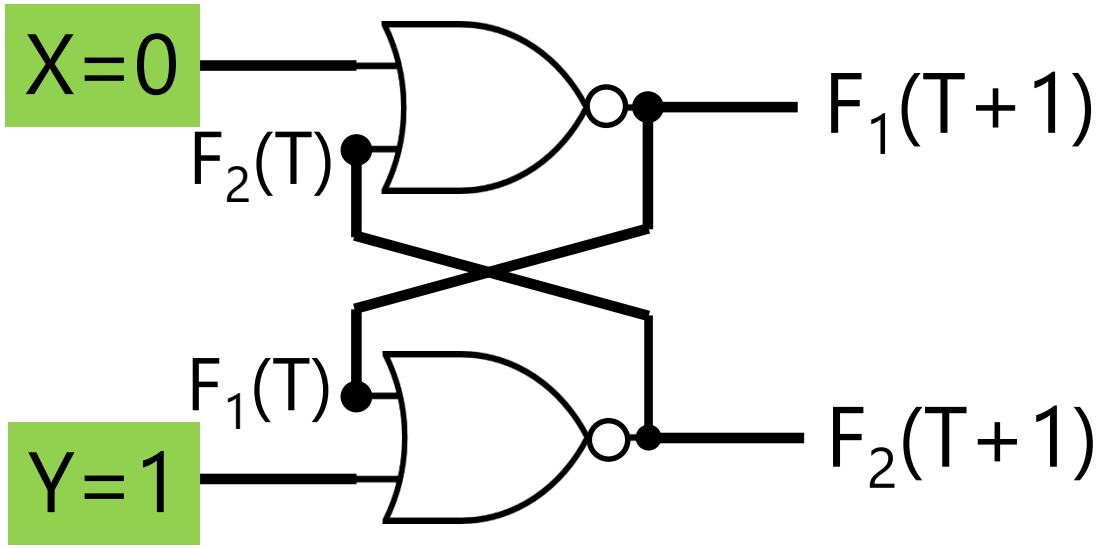
		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0	1	1
0	1			0	1
1	0			1	0
1	1			0	0



Reset Action

Reset State

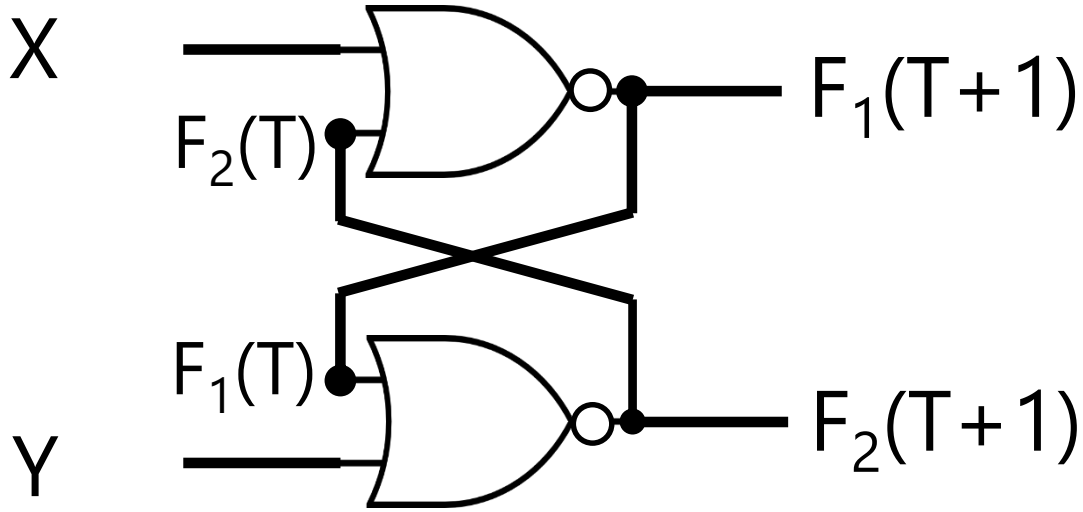
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0	1	1
0	1			0	1
1	0			1	0
1	1			0	0



Set Action

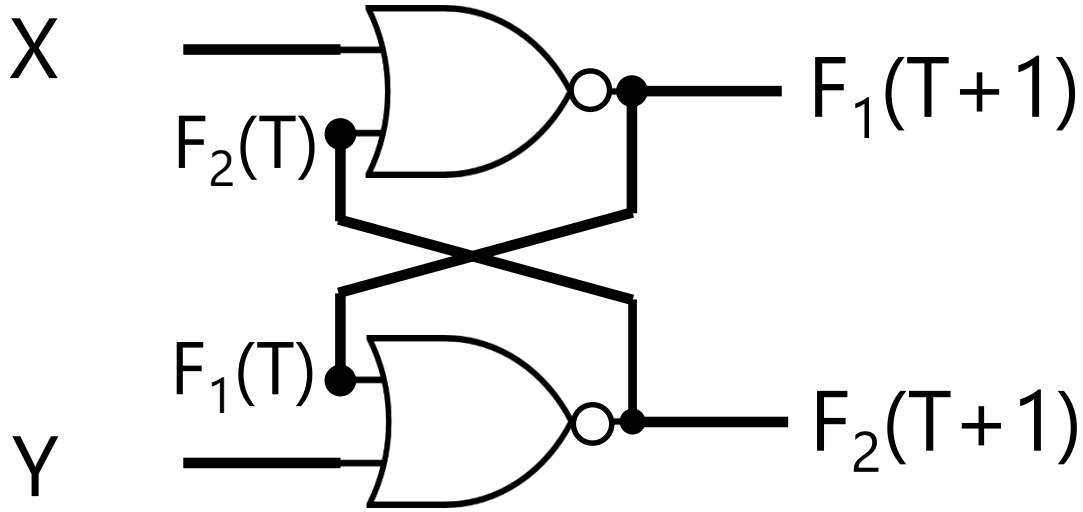
Set State

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0	1	1
0	1			0	1
1	0			1	0
1	1			0	0

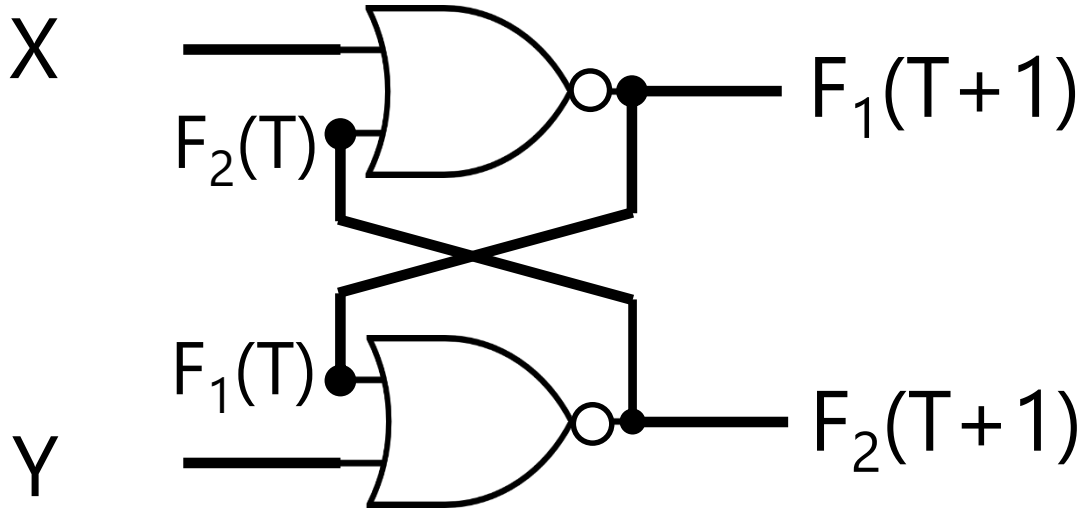


$F_1 = F'_2$

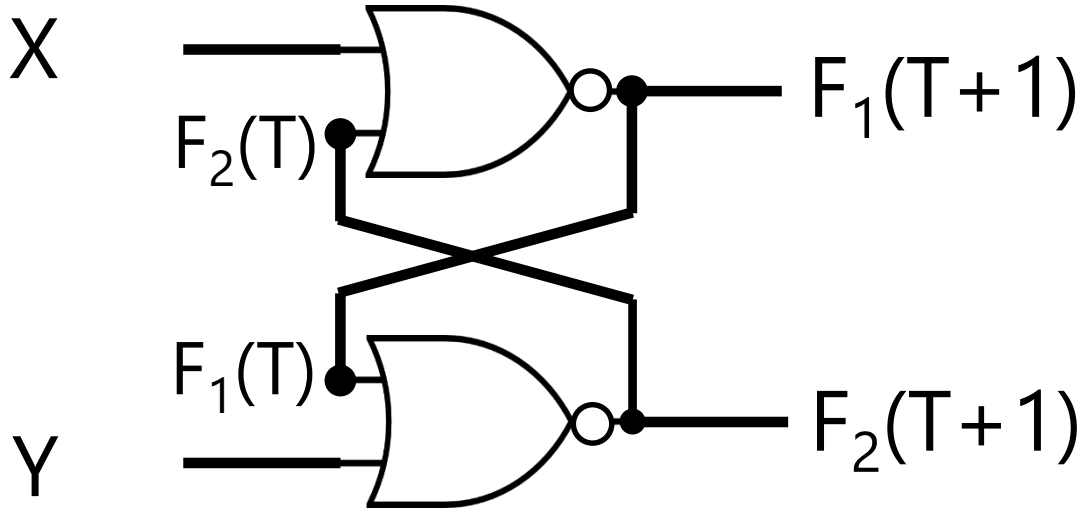
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0	1	1
0	1			0	1
1	0			1	0
1	1			0	0



		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	1	$F'_2(T)$	$F'_1(T)$
0	1			0	$F'_1(T)$
1	0			$F'_2(T)$	0
1	1			0	0

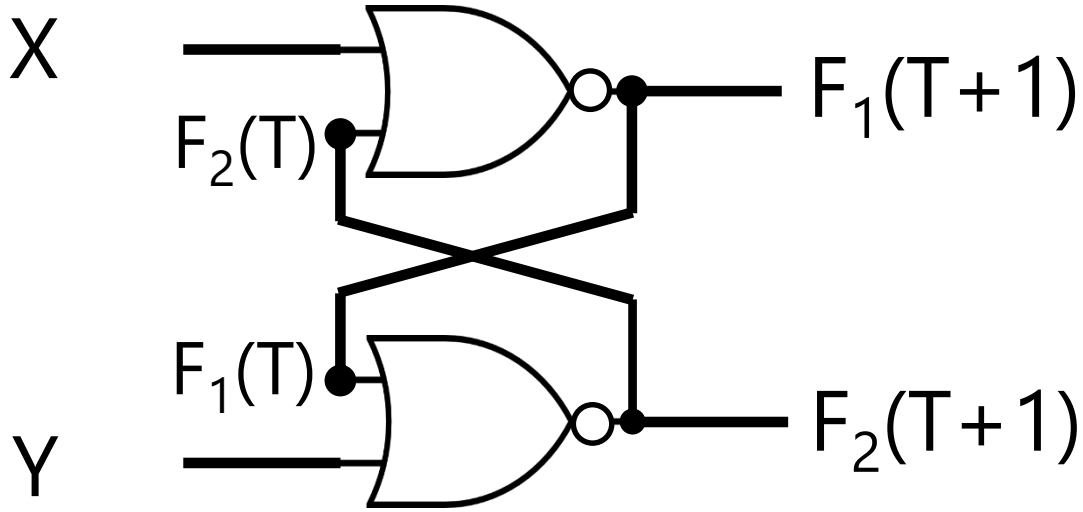


		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	1	0	0
0	1			0	0
1	0			0	0
1	1			0	0

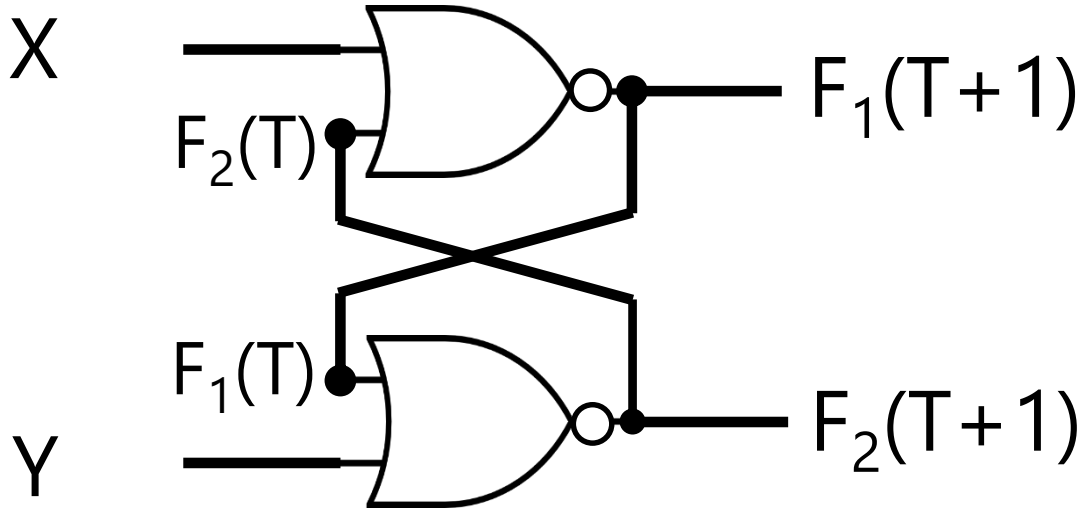


Default State

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	1	0	0
0	1				
1	0				
1	1				

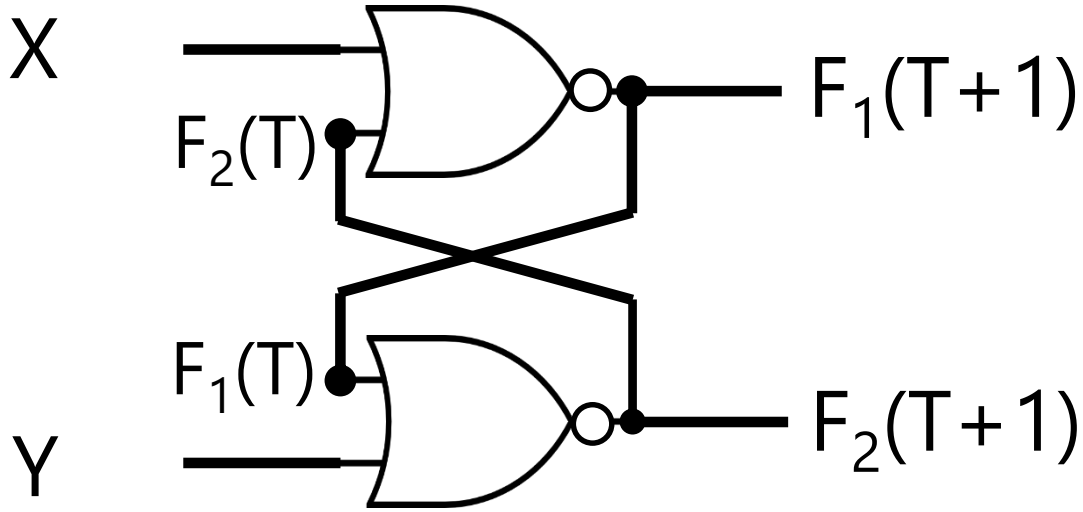


		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	0	$F'_2(T)$	$F'_1(T)$
0	1			0	$F'_1(T)$
1	0			$F'_2(T)$	0
1	1			0	0

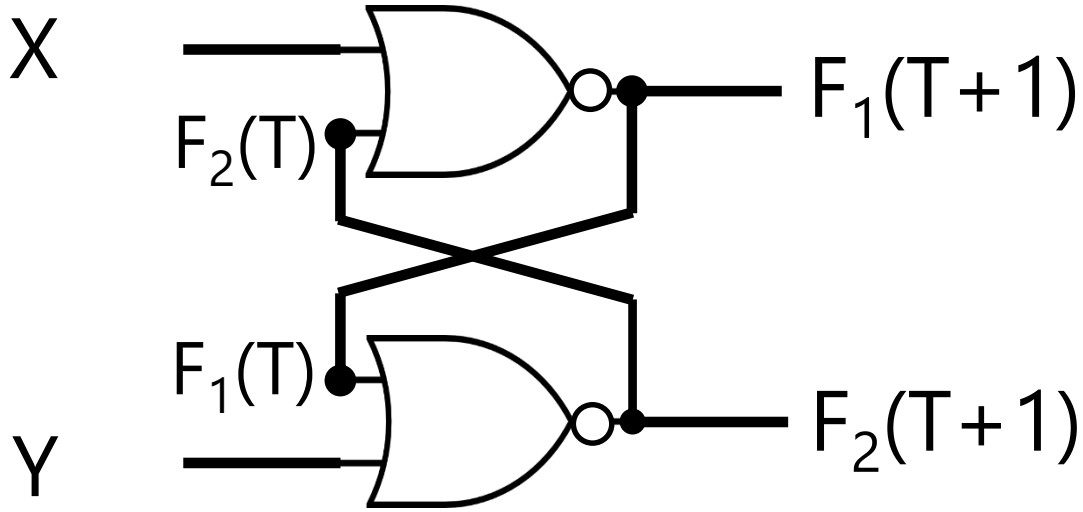


Set State

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	0	$F'_2(T)$	$F'_1(T)$
0	1			0	$F'_1(T)$
1	0			$F'_2(T)$	0
1	1			0	0

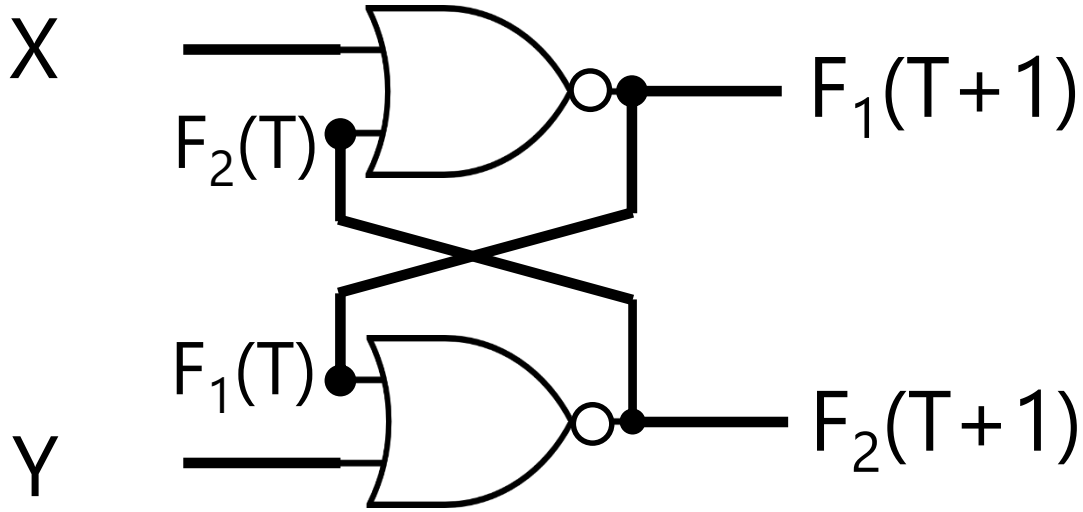


		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	0	1	0
0	1			0	0
1	0			1	0
1	1			0	0



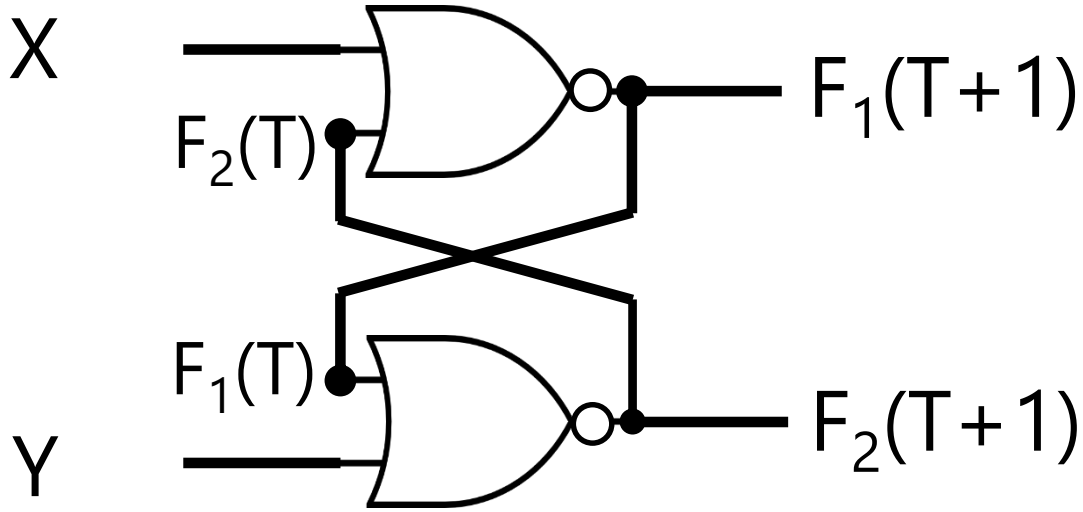
Store/Hold

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	0	1	0
0	1			0	0
1	0			1	0
1	1			0	0



Set Action

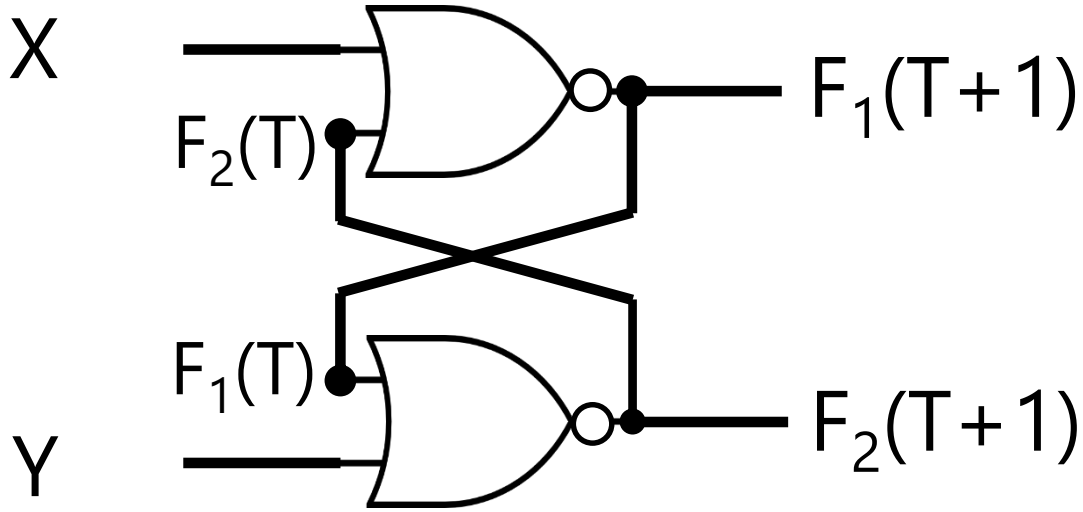
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	0	1	0
0	1			0	0
1	0			1	0
1	1			0	0



Reset Action

$F_1 \neq F'_2$

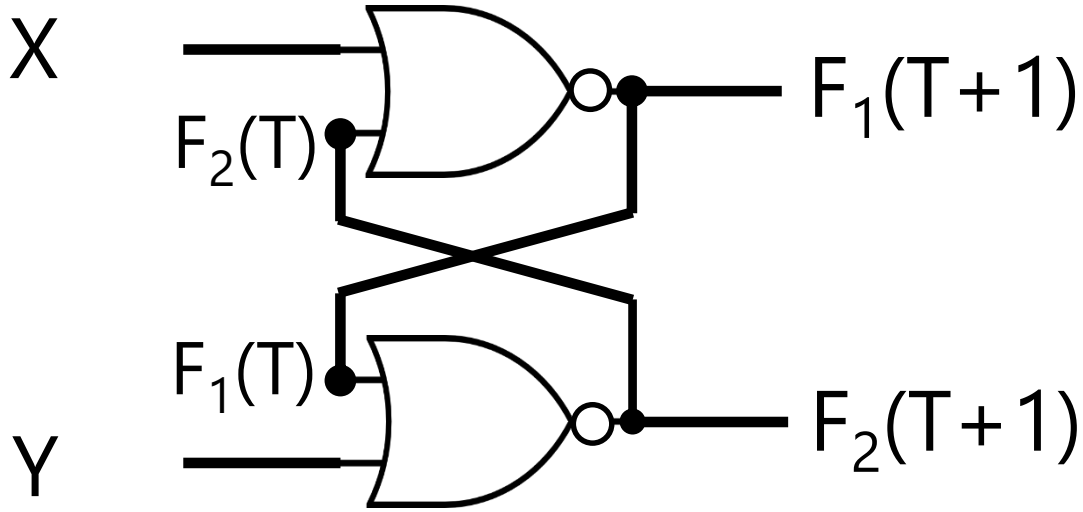
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	0	1	0
0	1			0	0
1	0			1	0
1	1			0	0



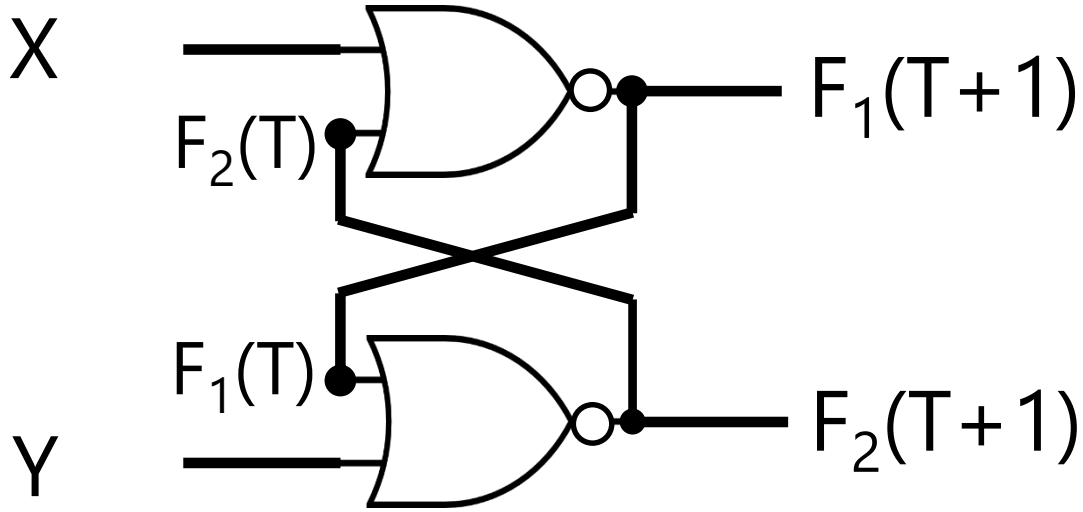
Reset Action

$F_1 = F'_2$

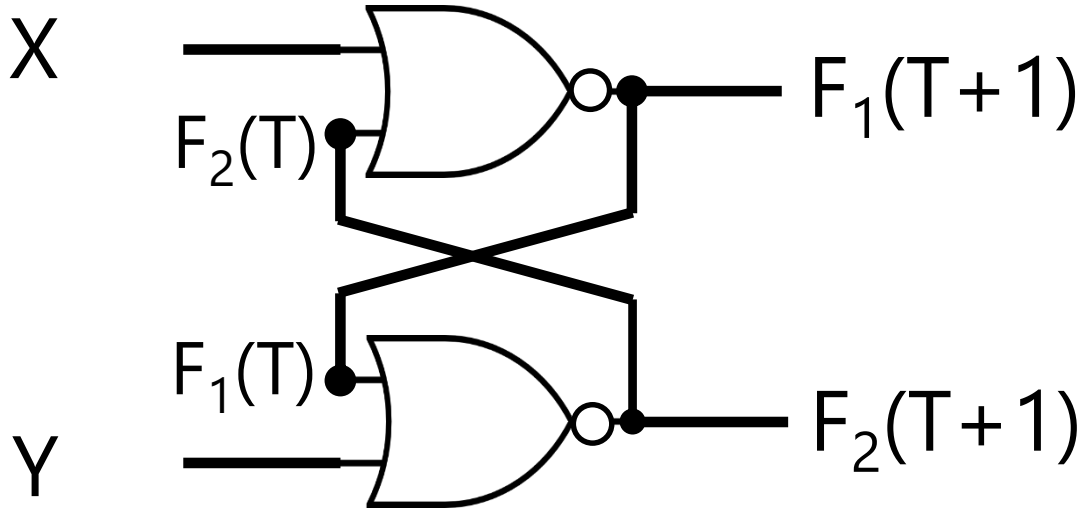
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$	$F_1(T+2)$	$F_2(T+2)$
0	0	1	0	1	0	1	0
0	1			0	0	0	1
1	0			1	0	1	0
1	1			0	0	0	0



		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+2)$	$F_2(T+2)$
0	0	1	0	1	0
0	1			0	1
1	0			1	0
1	1			0	0

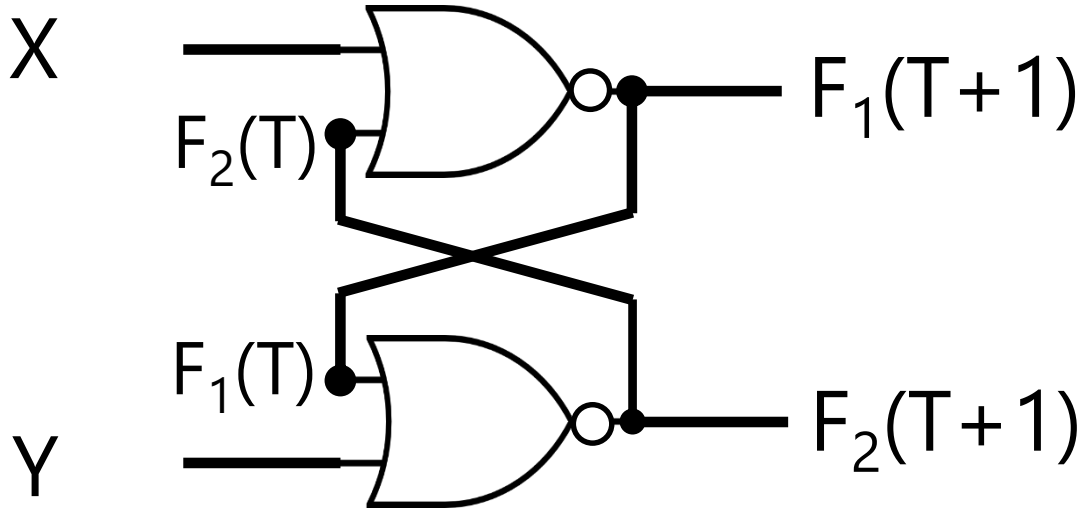


		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	1	$F'_2(T)$	$F'_1(T)$
0	1			0	$F'_1(T)$
1	0			$F'_2(T)$	0
1	1			0	0



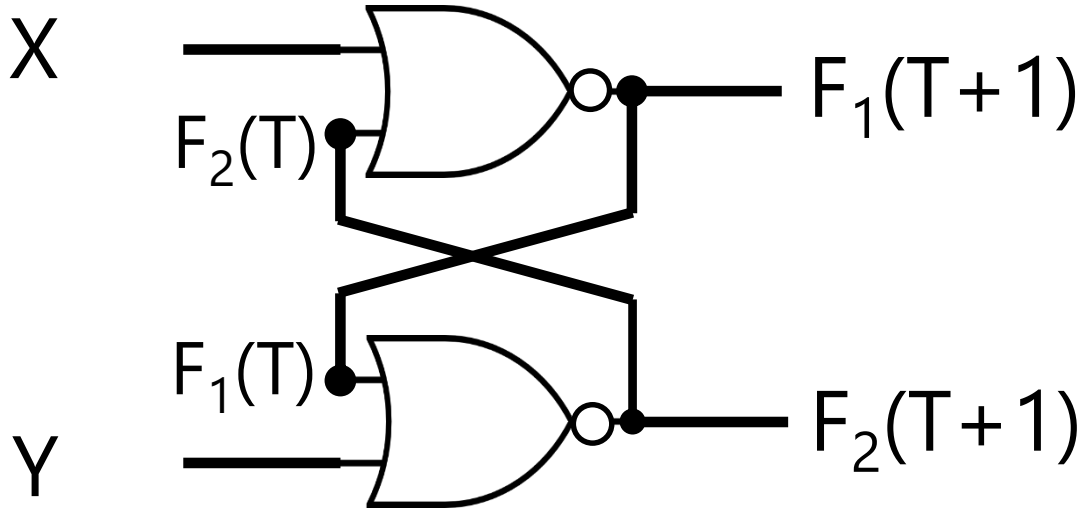
Reset State

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	1	$F'_2(T)$	$F'_1(T)$
0	1			0	$F'_1(T)$
1	0			$F'_2(T)$	0
1	1			0	0



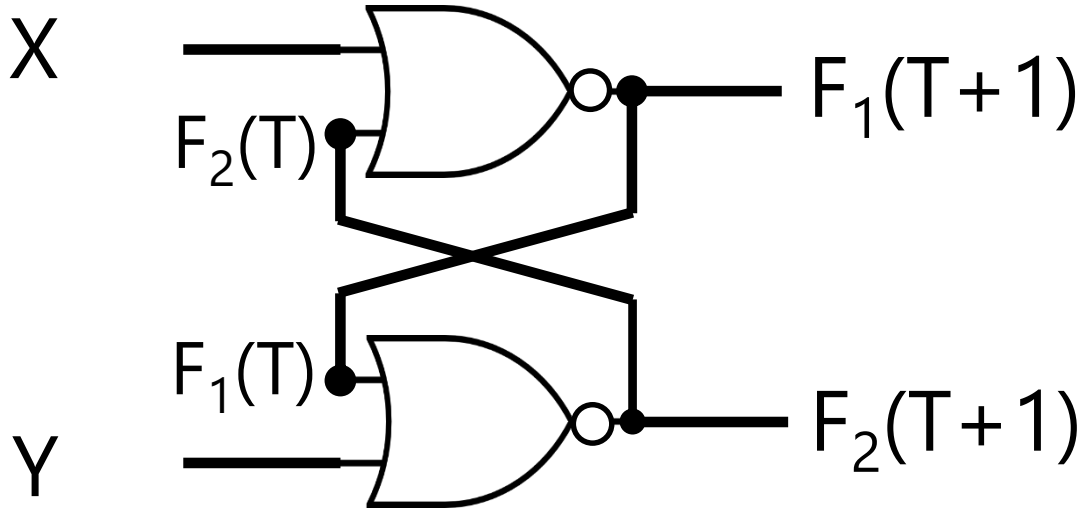
Store/Hold

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	1	0	1
0	1			0	1
1	0			0	0
1	1			0	0



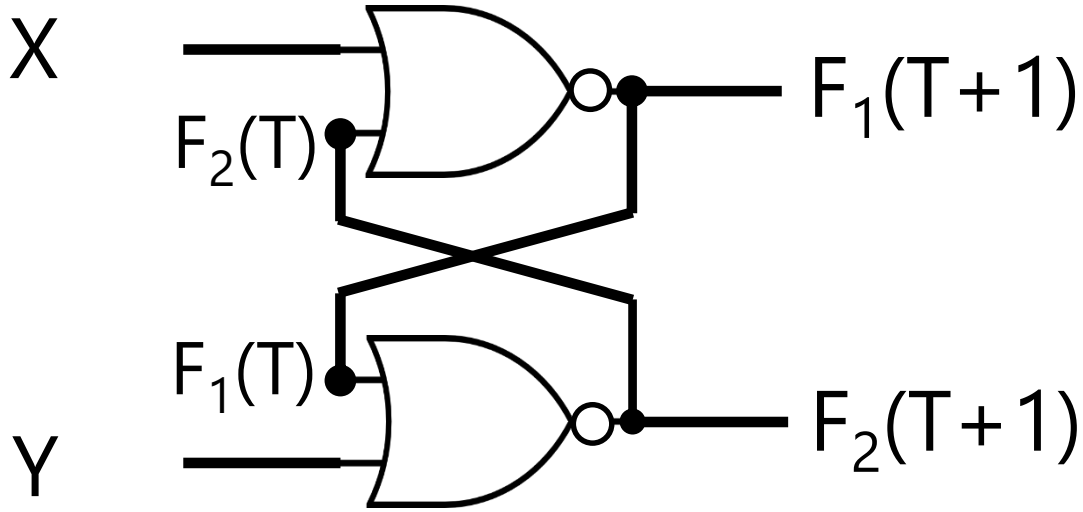
Reset Action

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	1	0	1
0	1			0	1
1	0			0	0
1	1			0	0



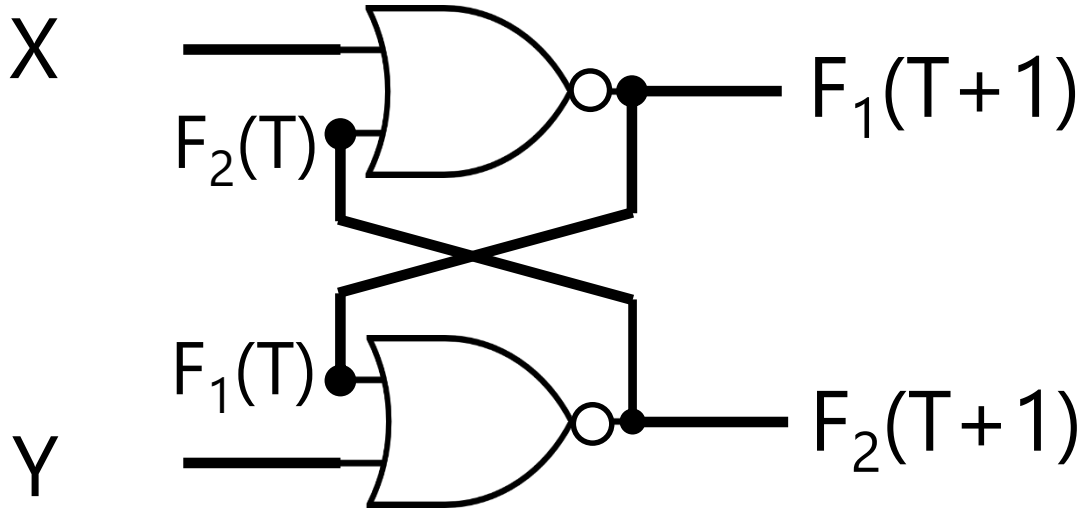
Set Action

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	1	0	1
0	1			0	1
1	0			0	0
1	1			0	0



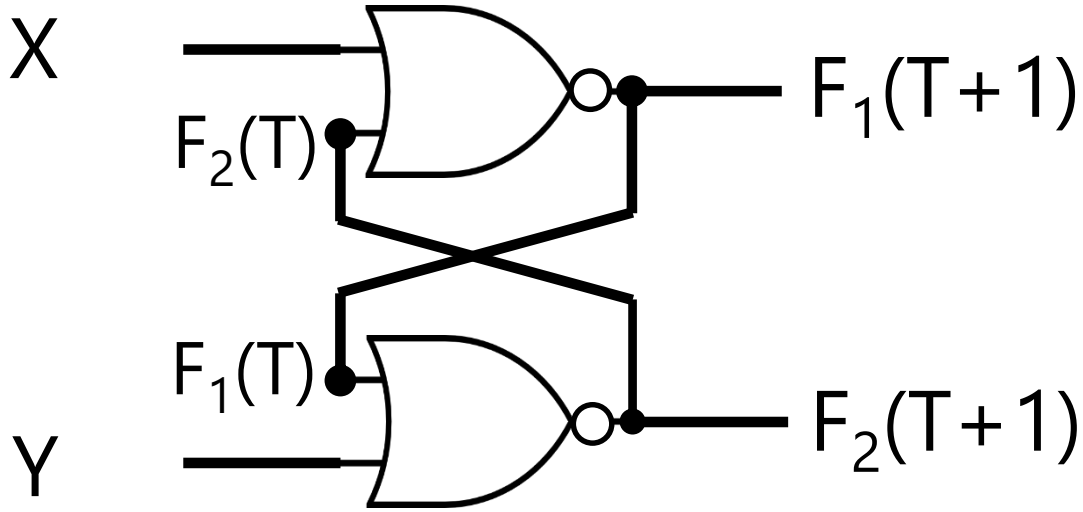
Set Action

Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$	$F_1(T+2)$	$F_2(T+2)$
0	0	0	1	0	1	0	1
0	1			0	1	0	1
1	0			0	0	1	0
1	1			0	0	0	0

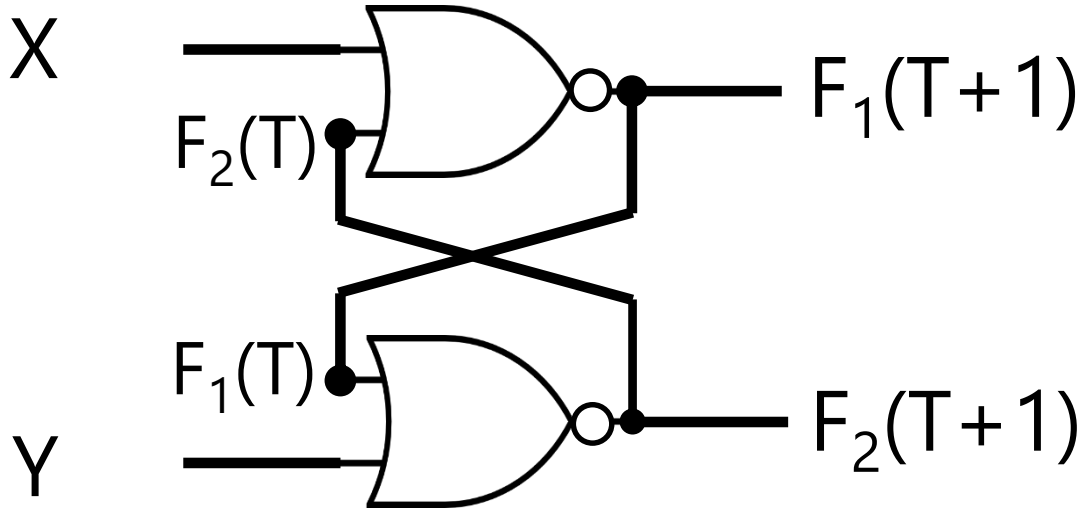


		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+2)$	$F_2(T+2)$
0	0	0	1	0	1
0	1	0	1	0	1
1	0	0	1	1	0
1	1	0	1	0	0

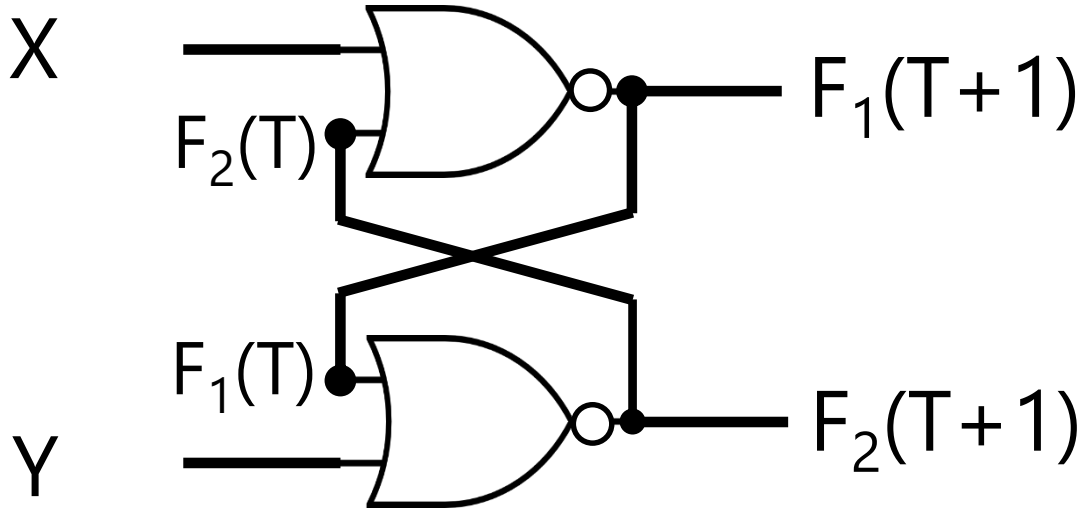
Recap



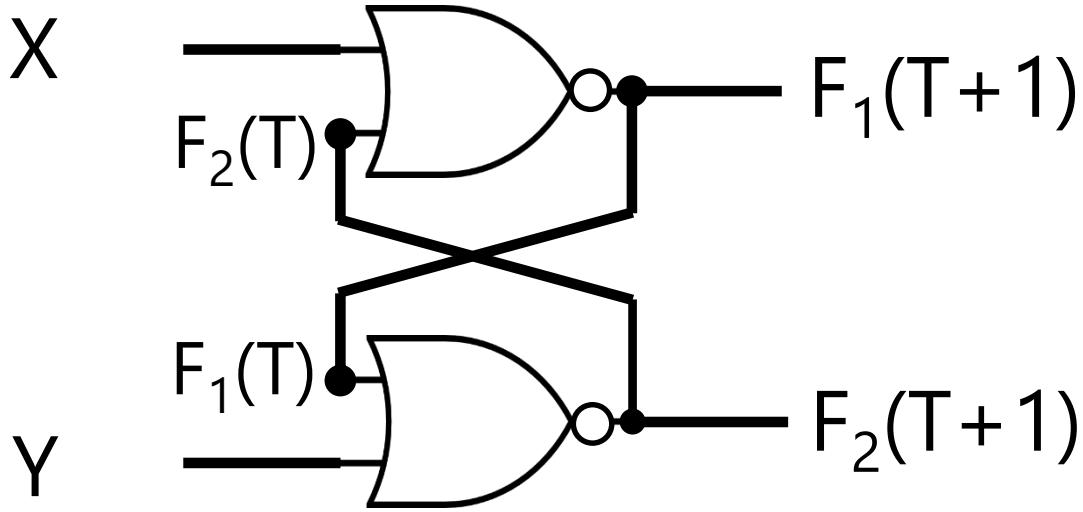
		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	0	0	1	1
0	1			0	1
1	0			1	0
1	1			0	0



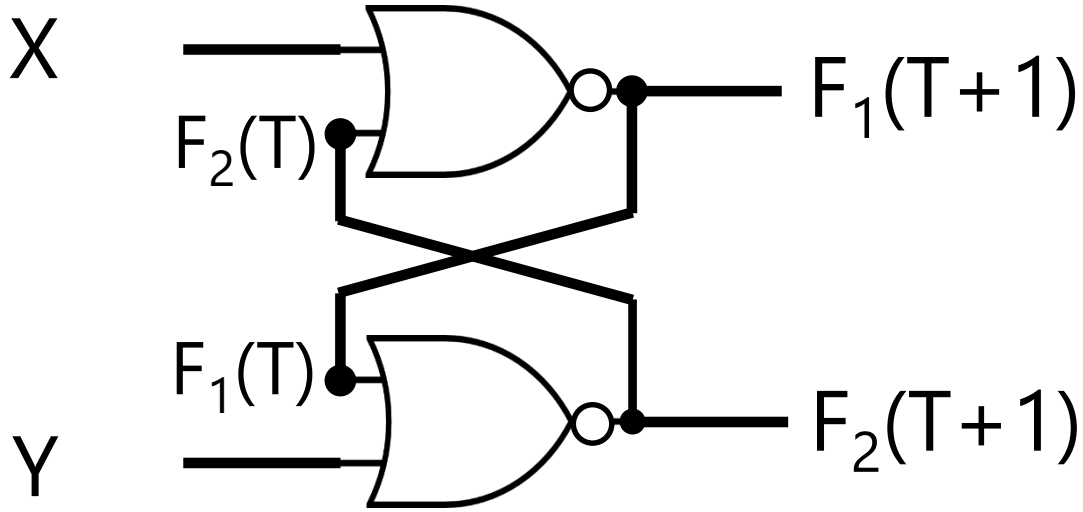
		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$
0	0	1	1	0	0
0	1			0	0
1	0			0	0
1	1			0	0



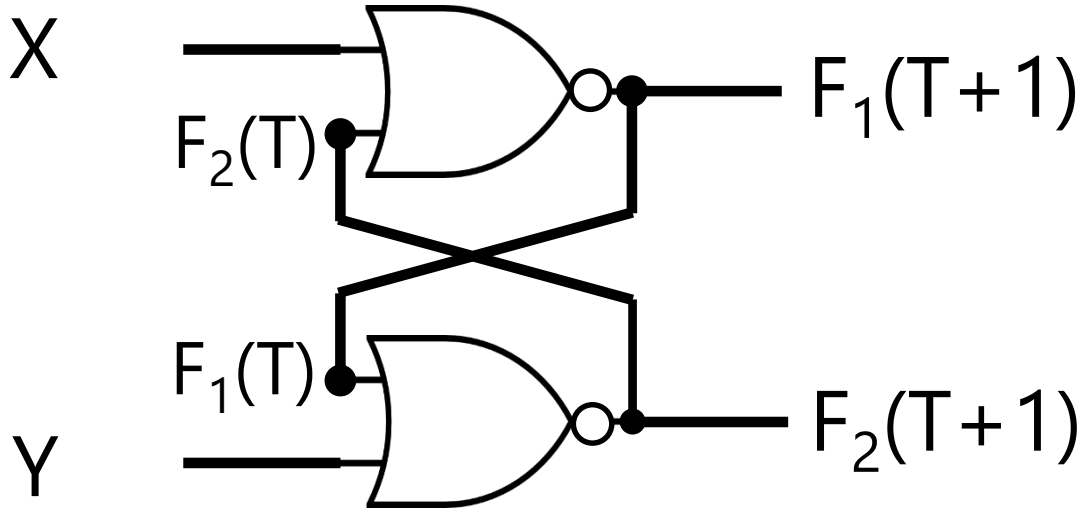
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+1)$	$F_2(T+1)$	$F_1(T+2)$	$F_2(T+2)$
0	0	1	1	0	0	1	1
0	1					0	1
1	0					1	0
1	1					0	0



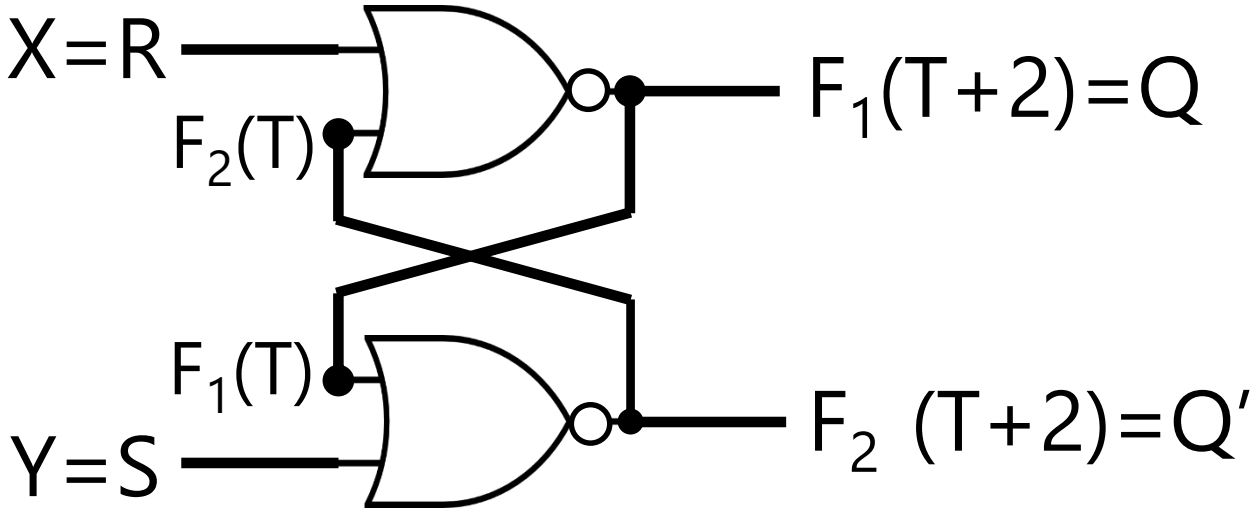
		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+2)$	$F_2(T+2)$
0	0	1	0	1	0
0	1			0	1
1	0			1	0
1	1			0	0



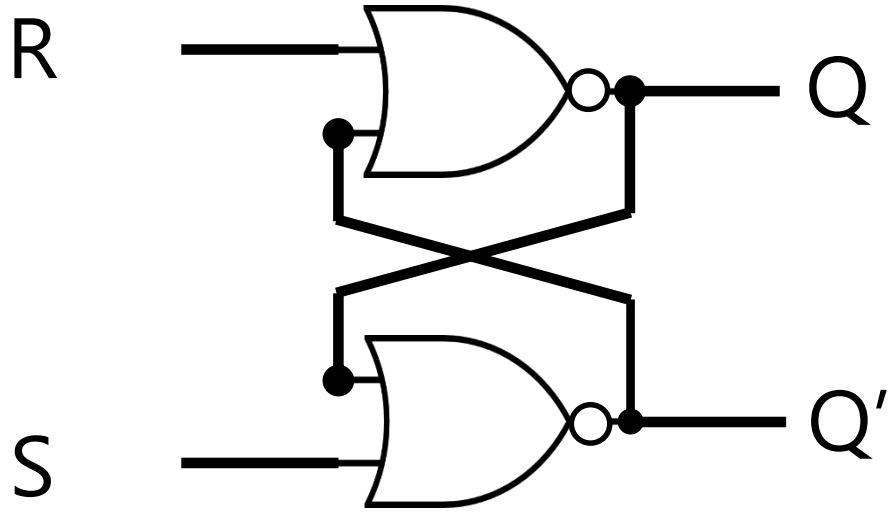
		Current State		Next State	
Y	X	$F_1(T)$	$F_2(T)$	$F_1(T+2)$	$F_2(T+2)$
0	0	0	1	0	1
0	1			0	1
1	0			1	0
1	1			0	0



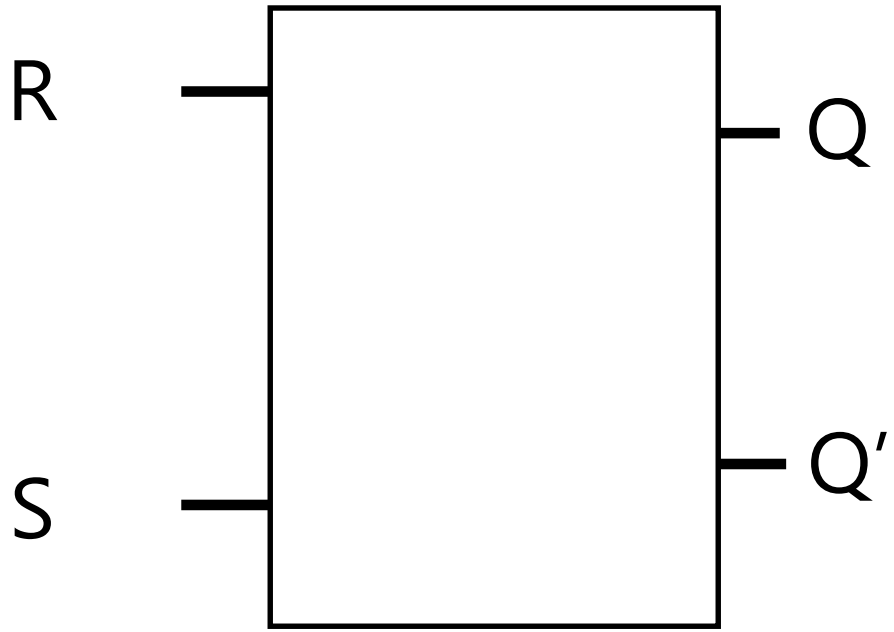
Y	X	$F_1(T+2)$	$F_2(T+2)$
0	0	$F_1(T)$	$F_2(T)$
0	1	0	1
1	0	1	0
1	1	X	X



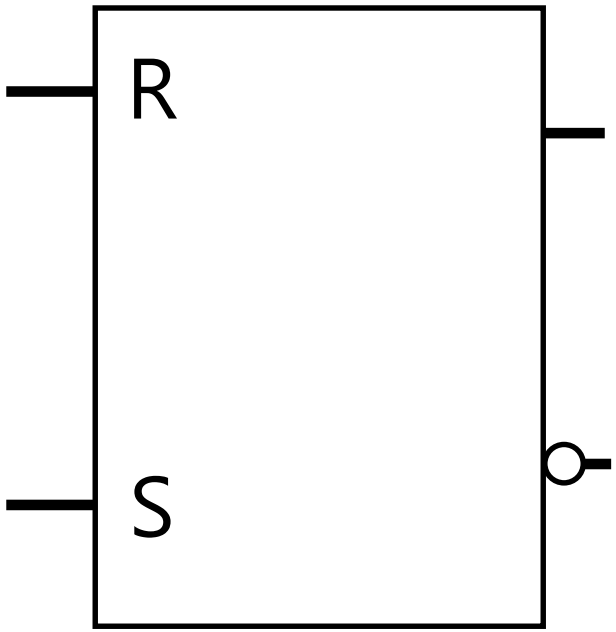
Y=S	X=R	$F_1(T+2)=Q$	$F_2(T+2)=Q'$
0	0	Q_t	Q'_t
0	1	0	1
1	0	1	0
1	1	X	X



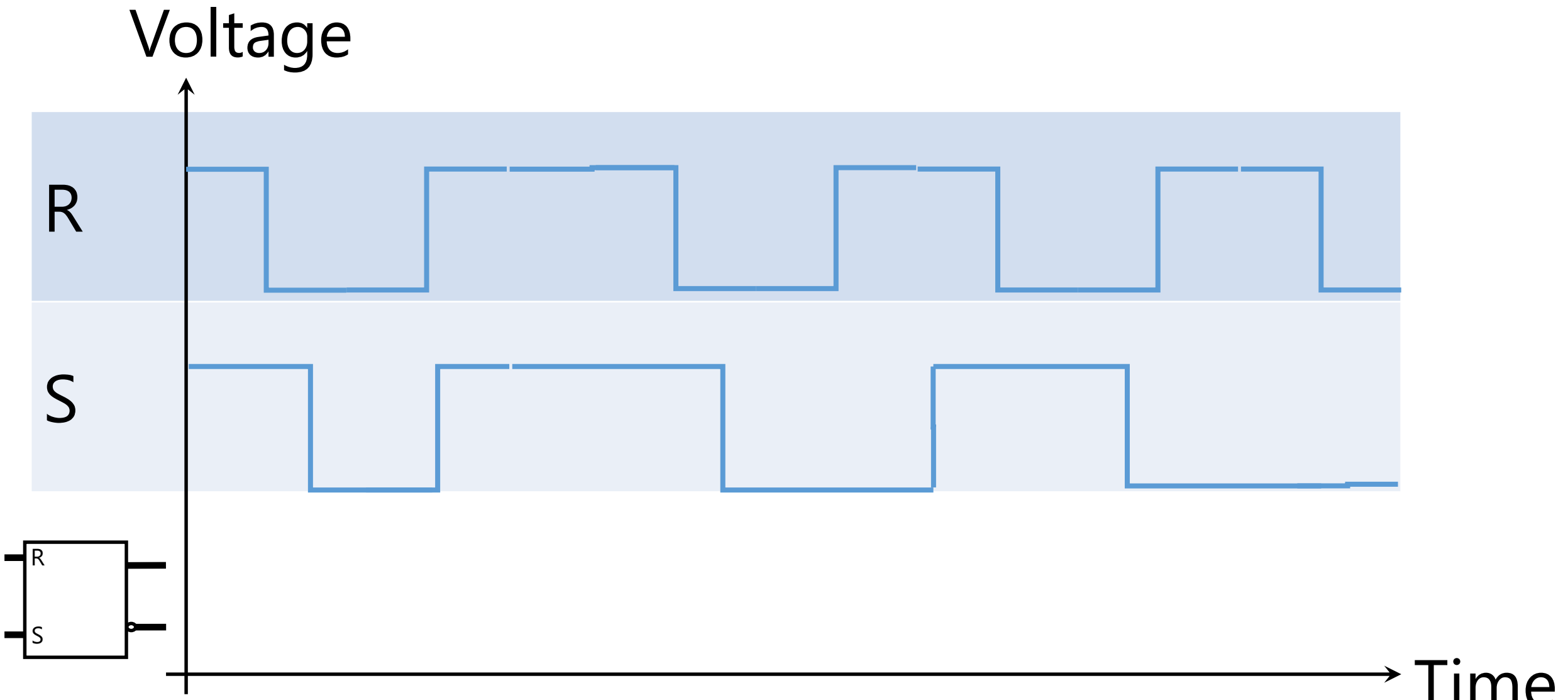
S	R	Q	Q′
0	0	Q_t	Q'_t
0	1	0	1
1	0	1	0
1	1	X	X

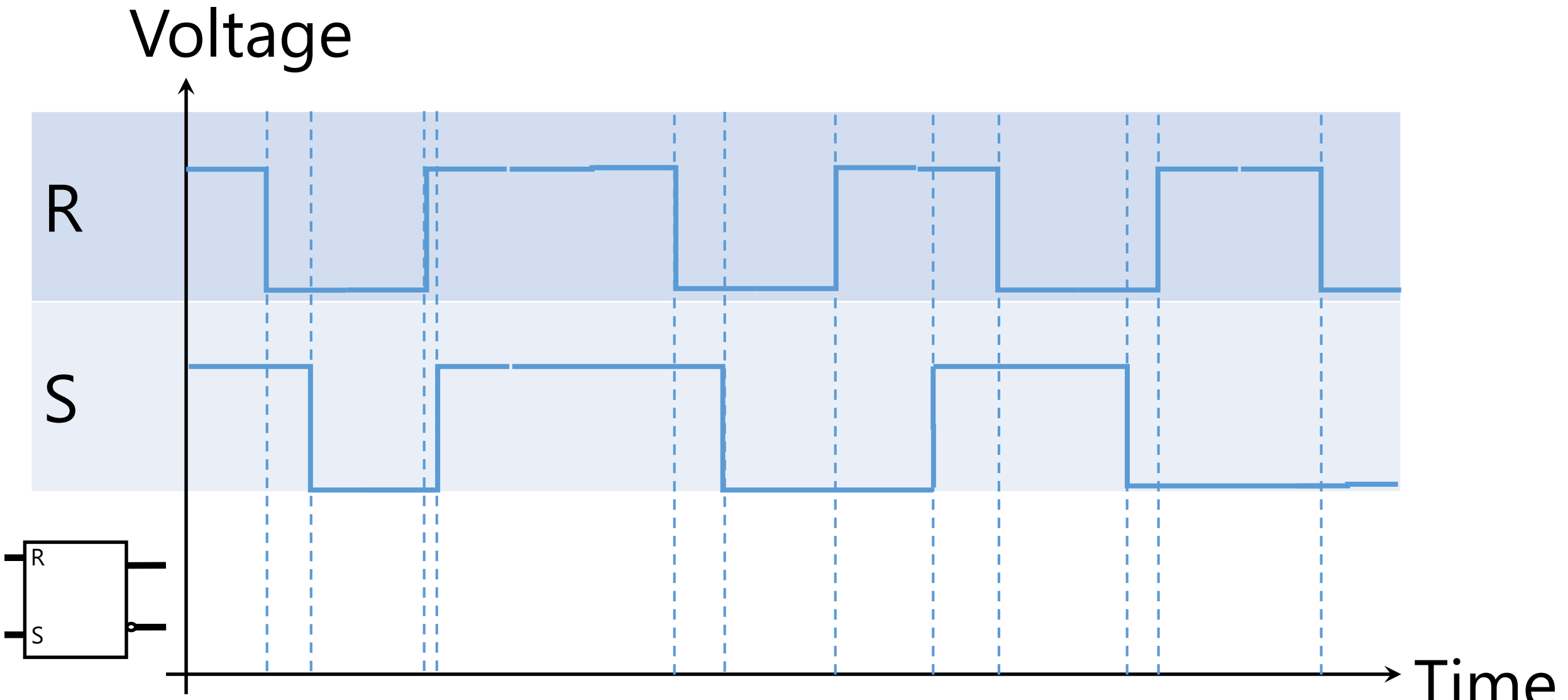


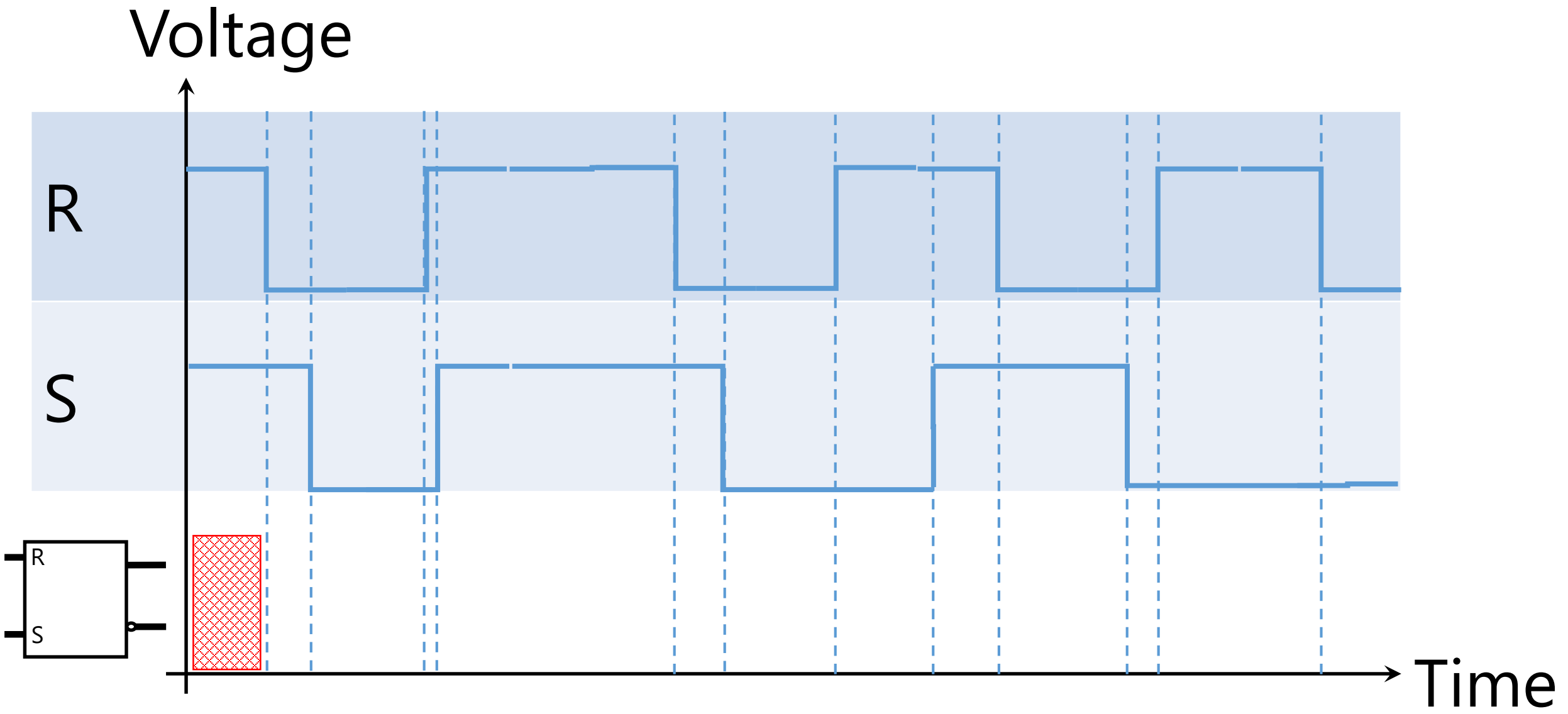
S	R	Q	Q′
0	0	Q_t	Q'_t
0	1	0	1
1	0	1	0
1	1	X	X

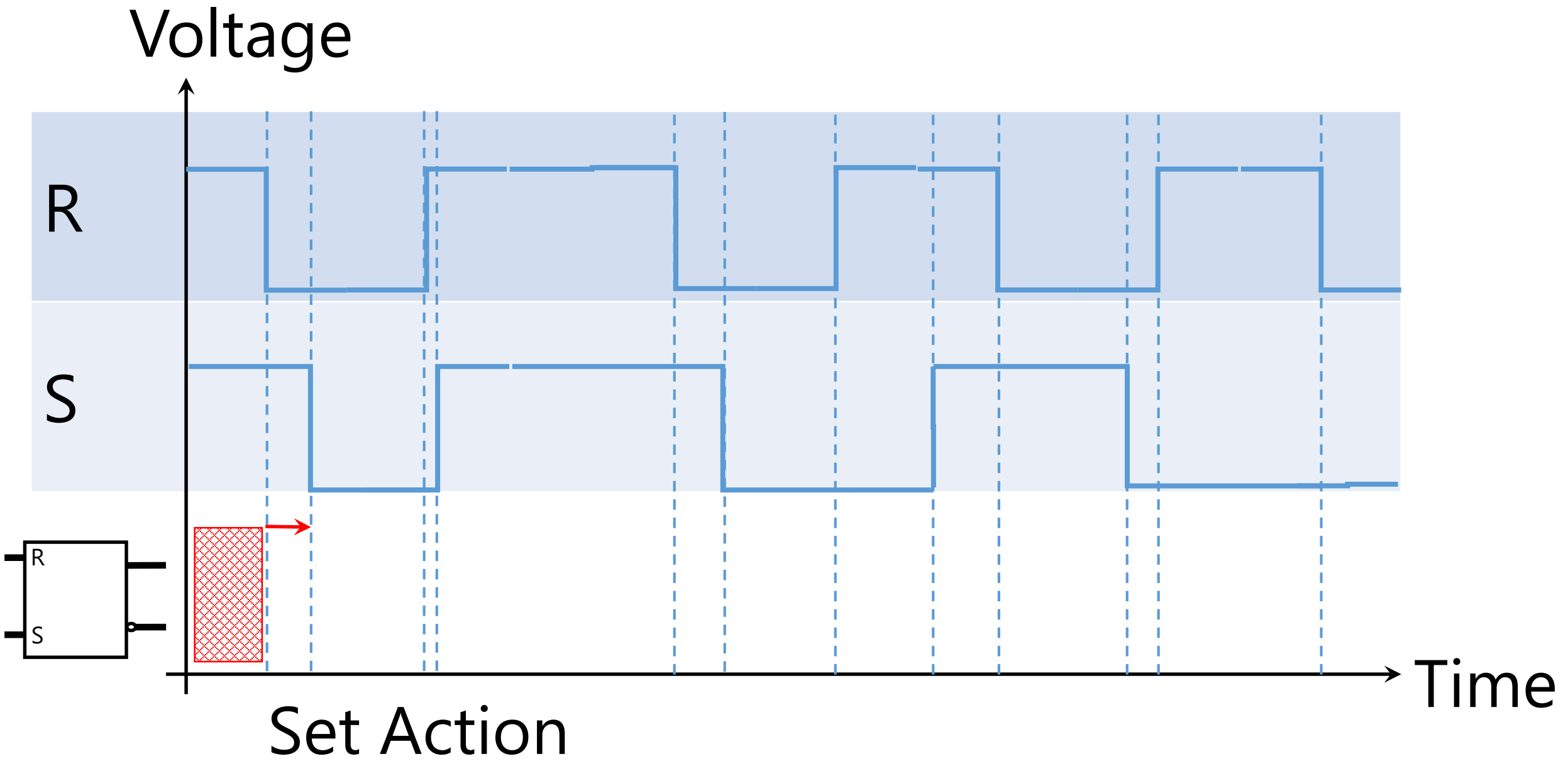


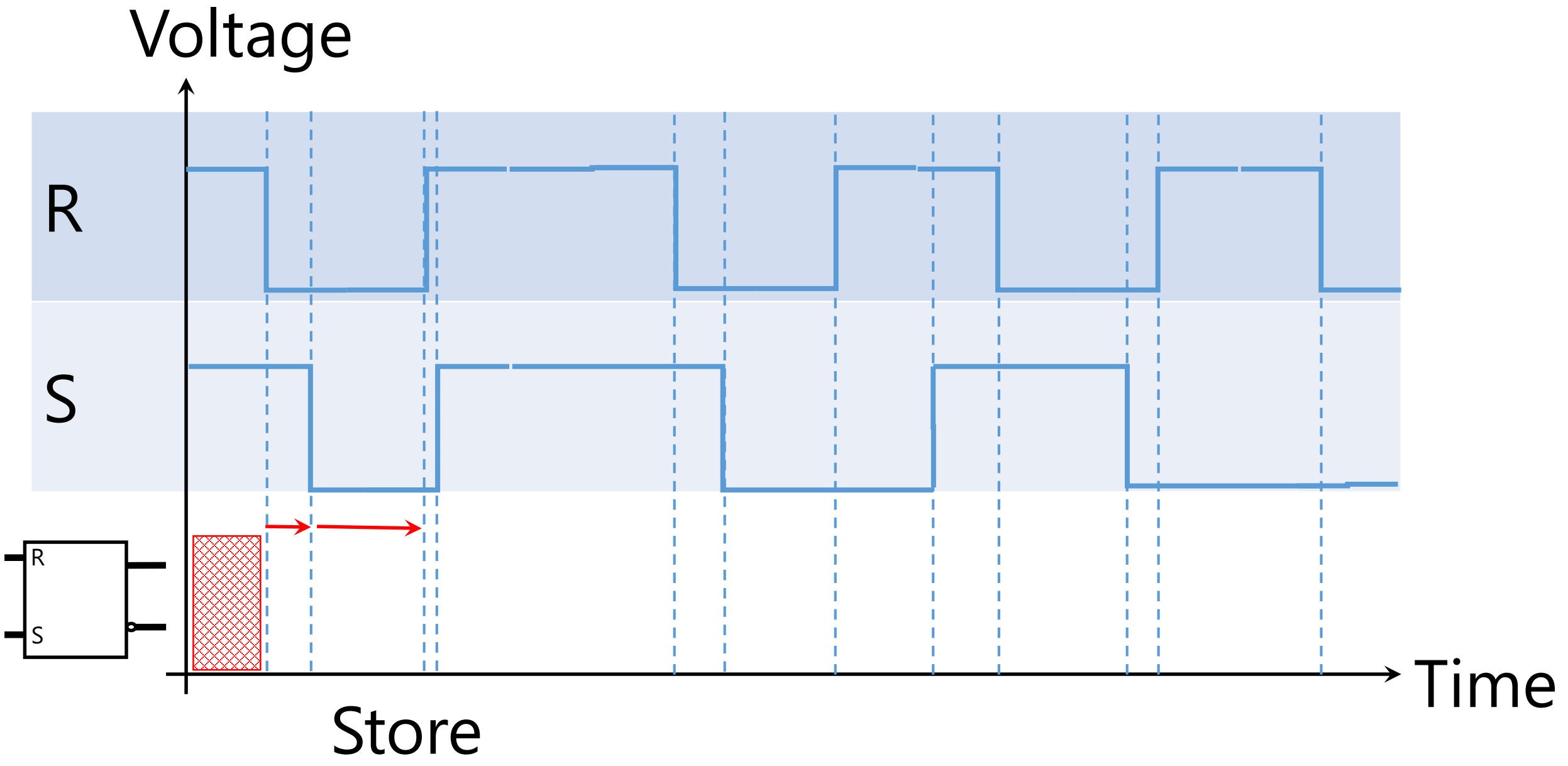
S	R	Q	Q′
0	0	Q_t	Q'_t
0	1	0	1
1	0	1	0
1	1	X	X

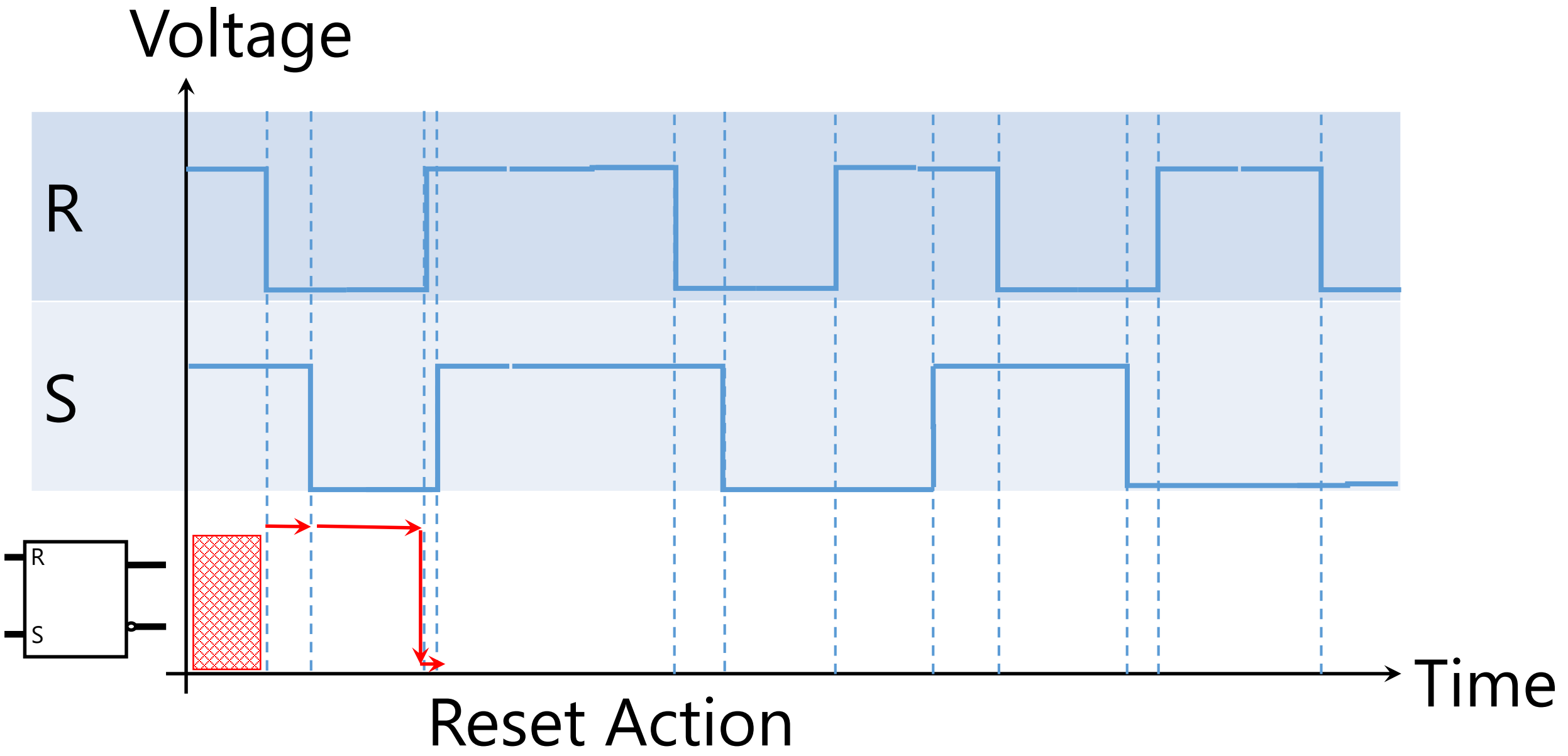

Voltage
R
S
R
S
Time

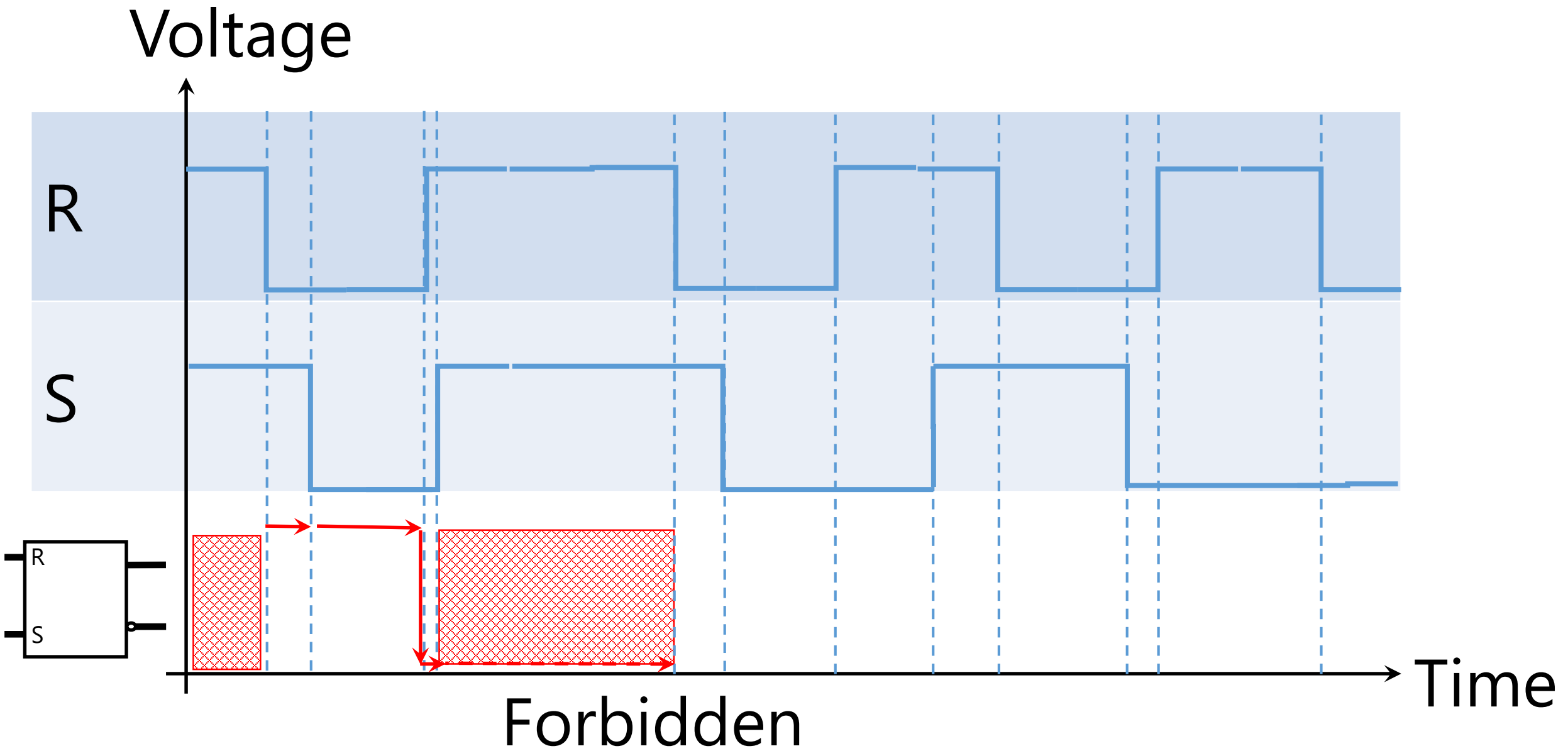

Voltage
R
S
R
S
Time

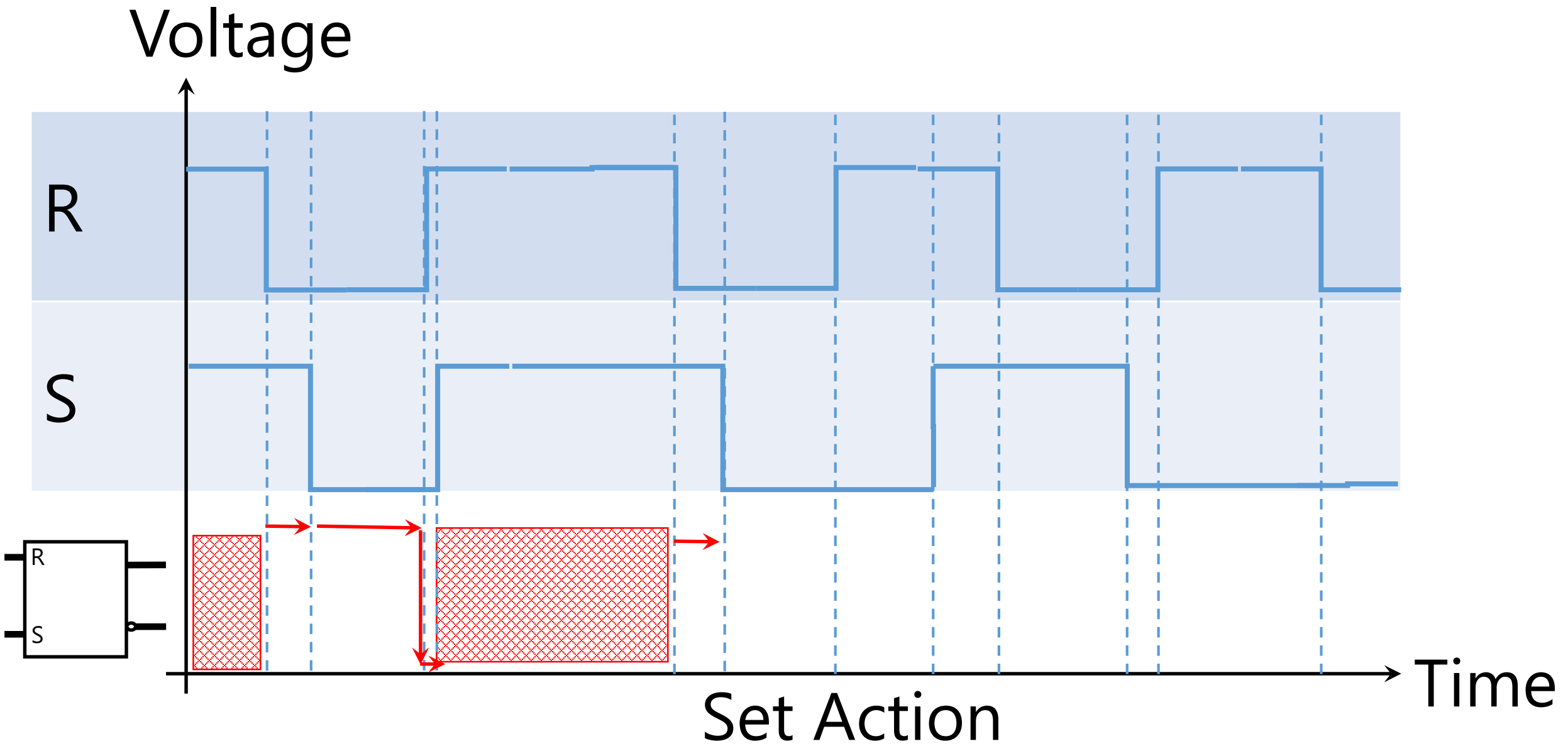

Voltage
R
S
R
S
Time

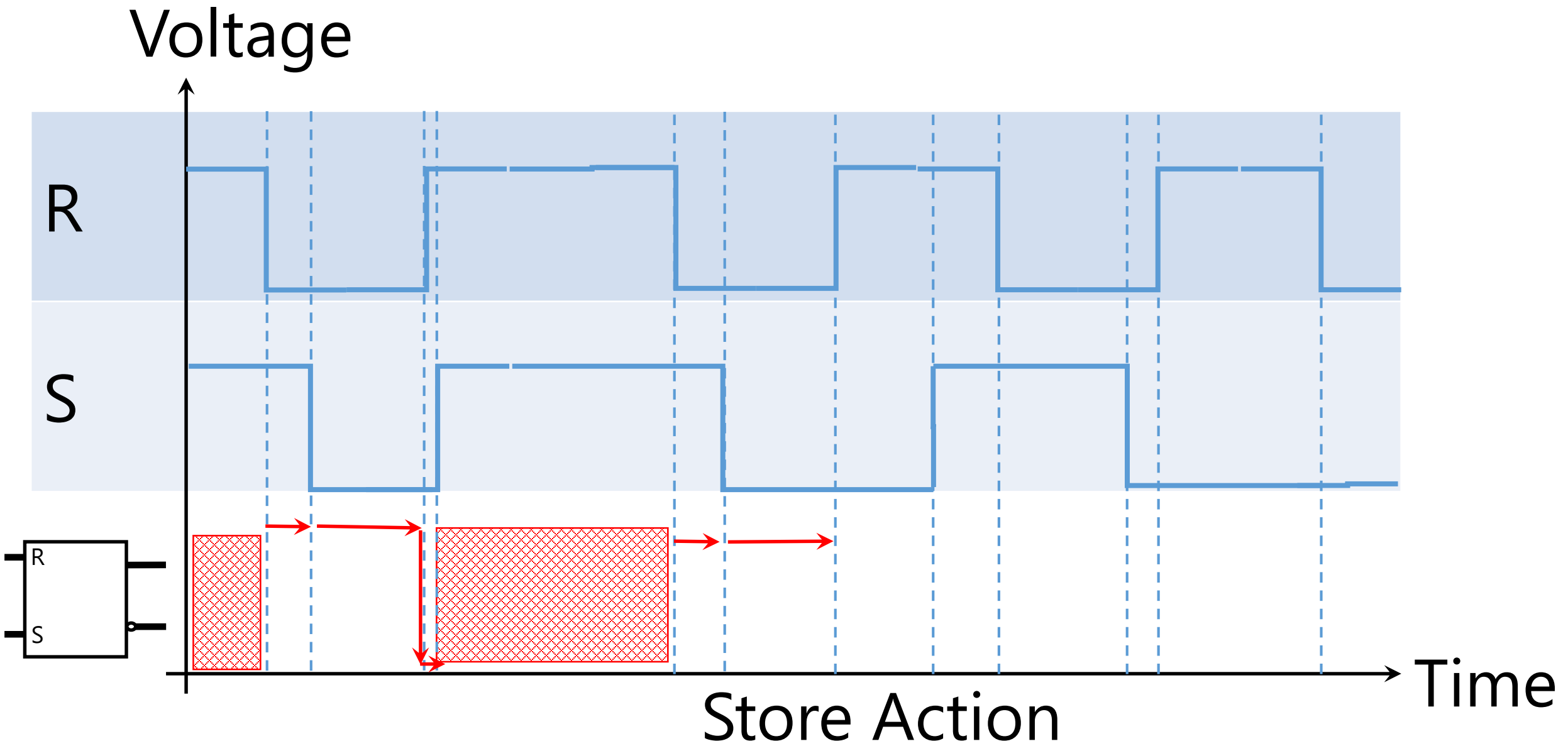

Voltage
R
S
R
S
Time
Set Action

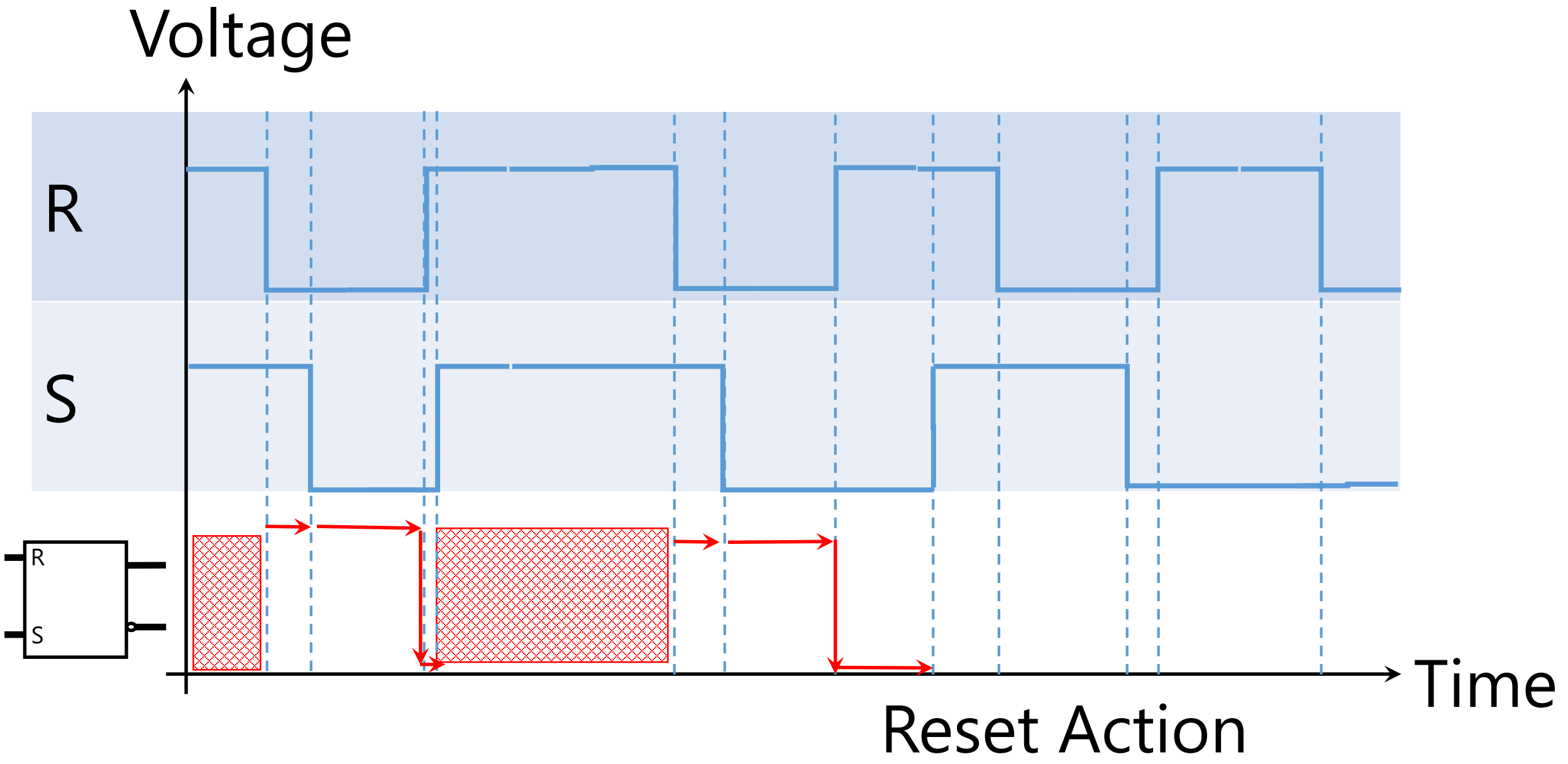

Voltage
R
S
R
S
Time
Store

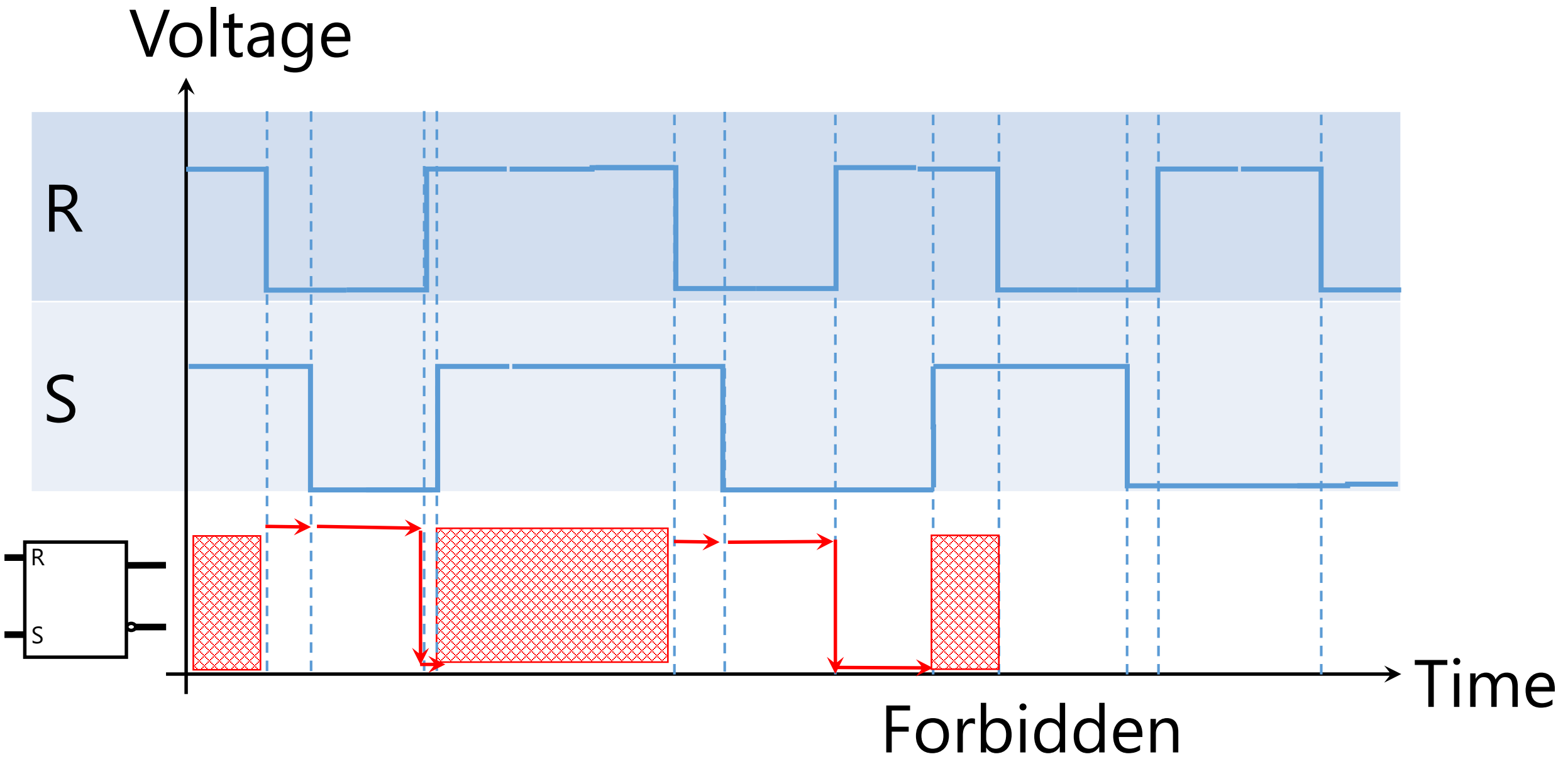

Voltage
R
S
R
S
Time
Reset Action

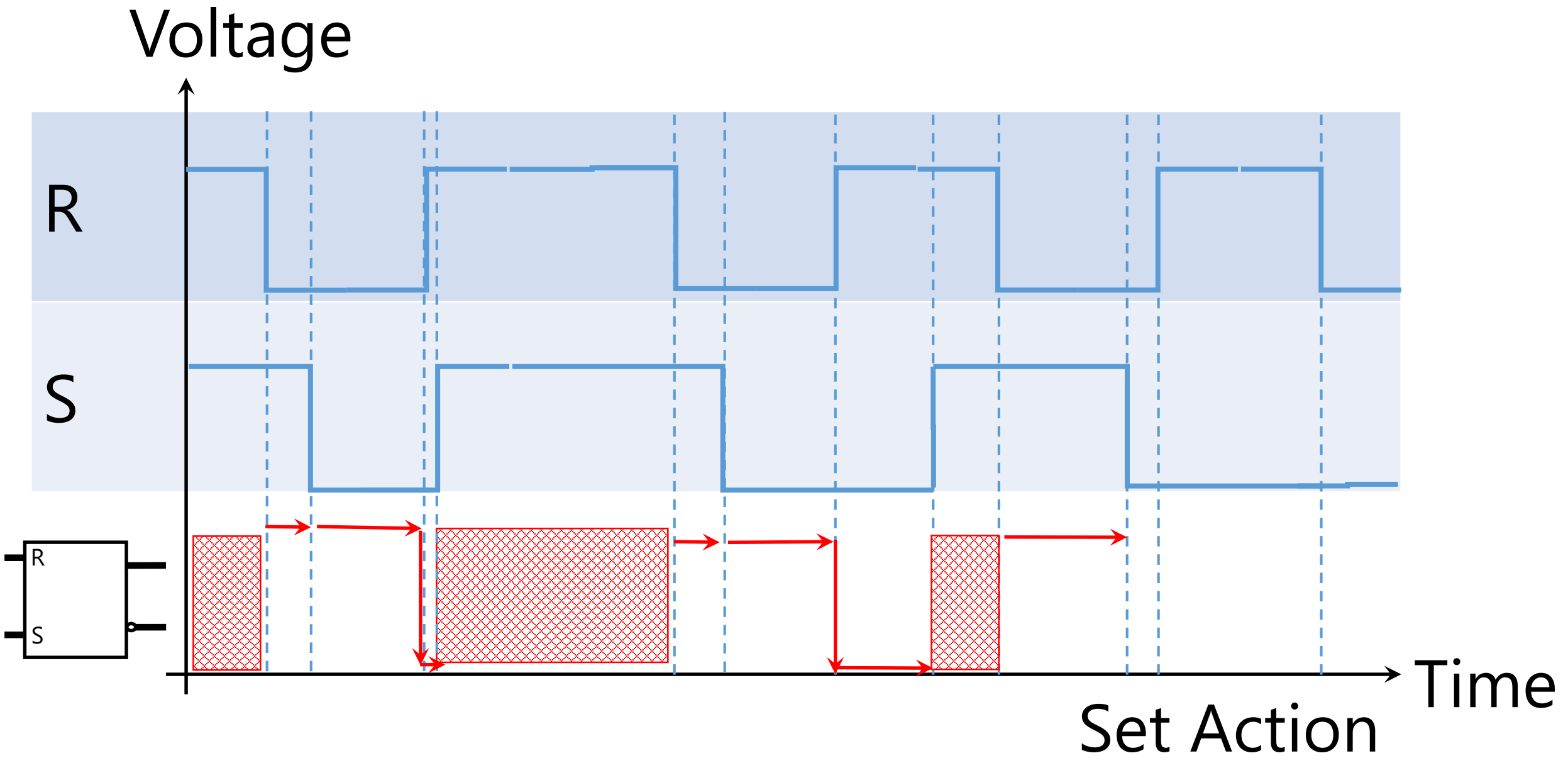

Voltage
R
S
R
S
Time
Forbidden

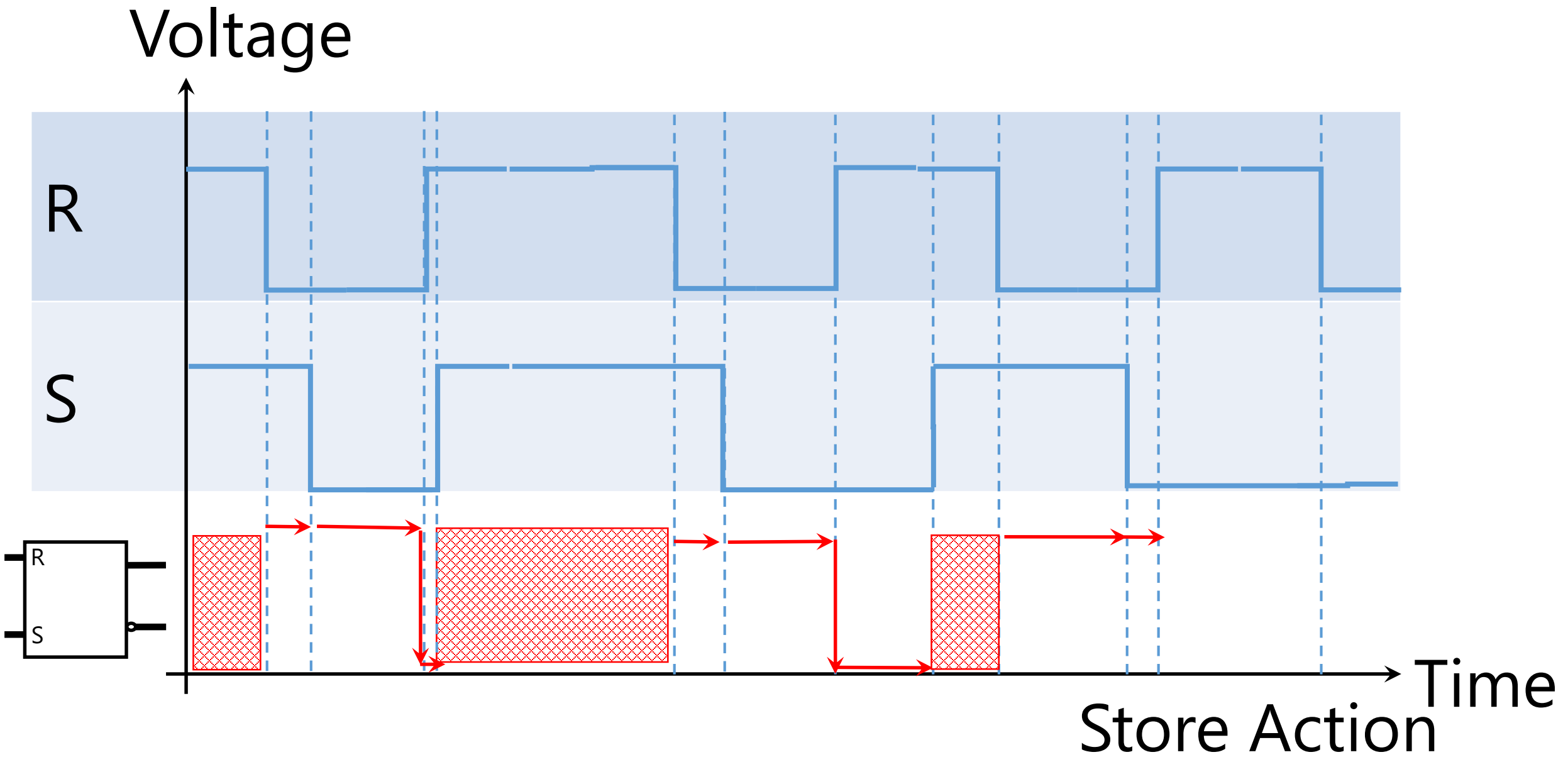

Voltage
R
S
R
S
Time
Set Action

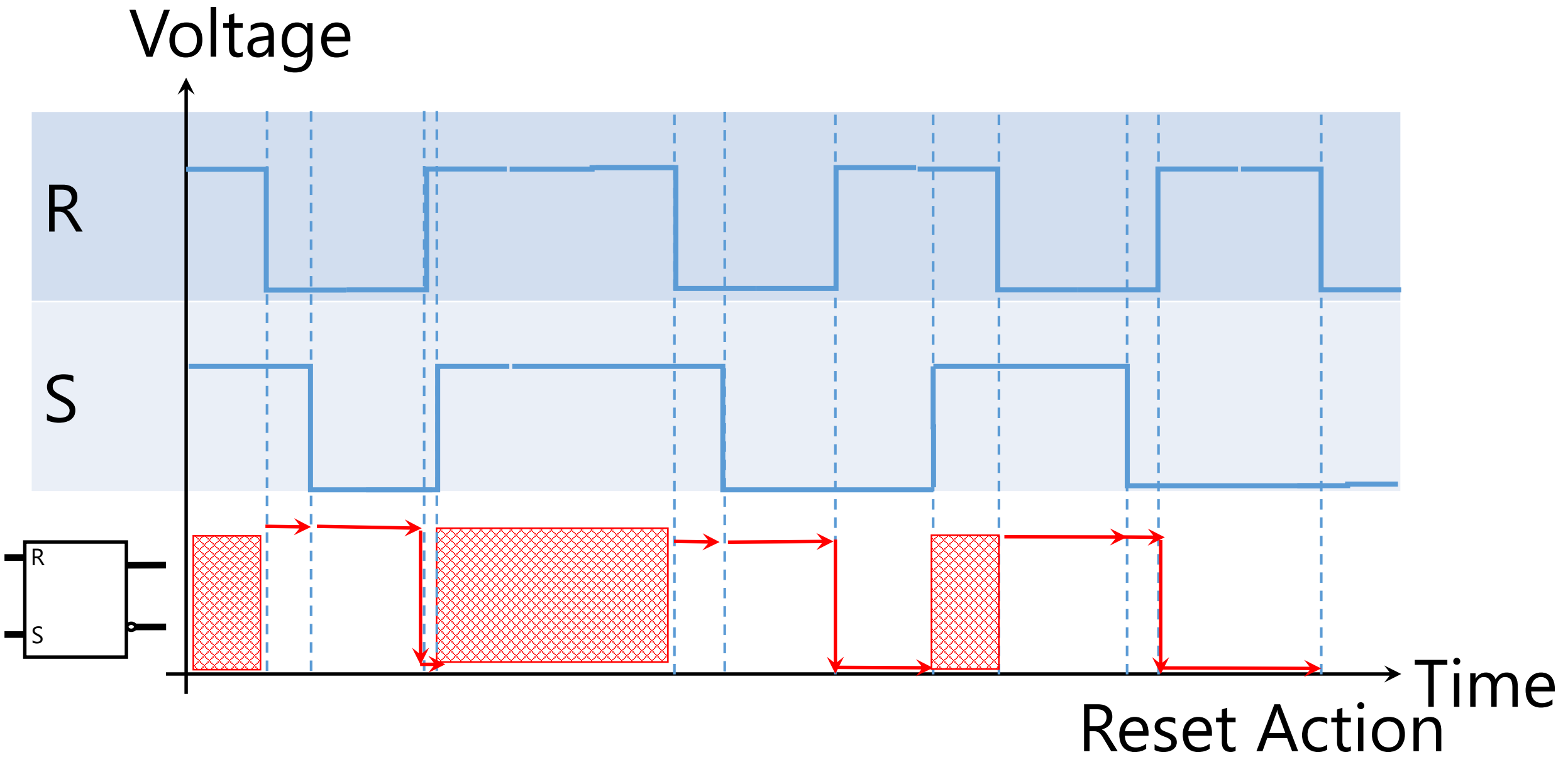

Voltage
R
S
R
S
Time
Store Action

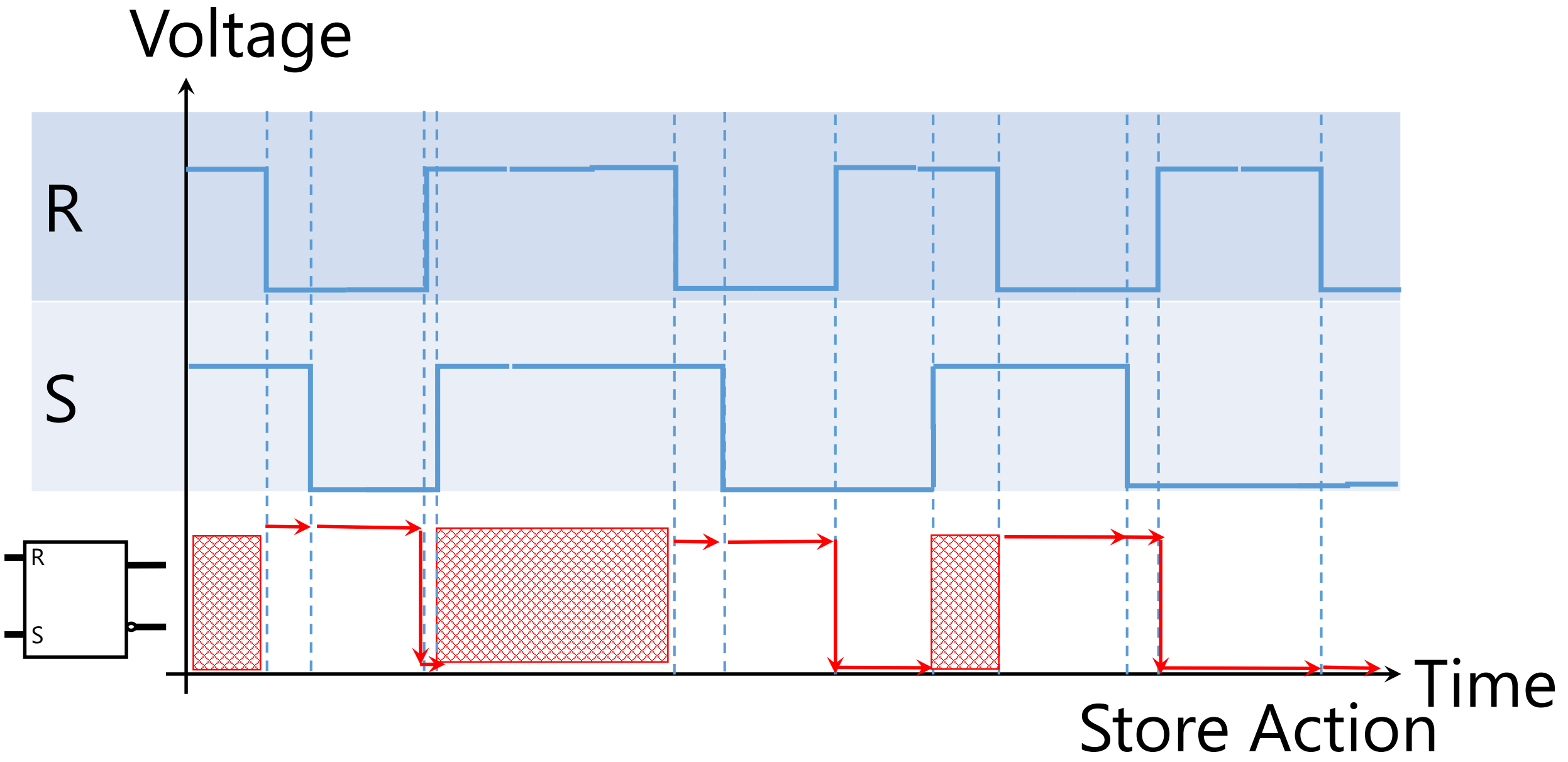

Voltage
R
S
R
S
Time
Reset Action


Voltage
R
S
R
S
Time
Forbidden


Voltage
R
S
R
S
Time
Set Action


Voltage
R
S
R
S
Time
Store Action


Voltage
R
S
R
S
Time
Reset Action


Voltage
R
S
R
S
Time
Store Action