数字电路与逻辑设计B

第十三讲

南京邮电大学

电子与光学工程学院

臧裕斌

4.3钟控触发器

一、钟控SRFF

1. 电路结构

2. 工作原理

3. 功能描述

二、钟控DFF

三、钟控触发器的空翻

4.4边沿触发器

一、维持阻塞型DFF

1. 电路结构
2. 工作原理
3. 功能描述

二、边沿JKFF

三、TFF和T′FF

1. TFF
2. T′FF

4.5触发器应用举例

1.消抖动开关

2.单脉冲发生器

3.分频器

4.6 Verilog描述触发器

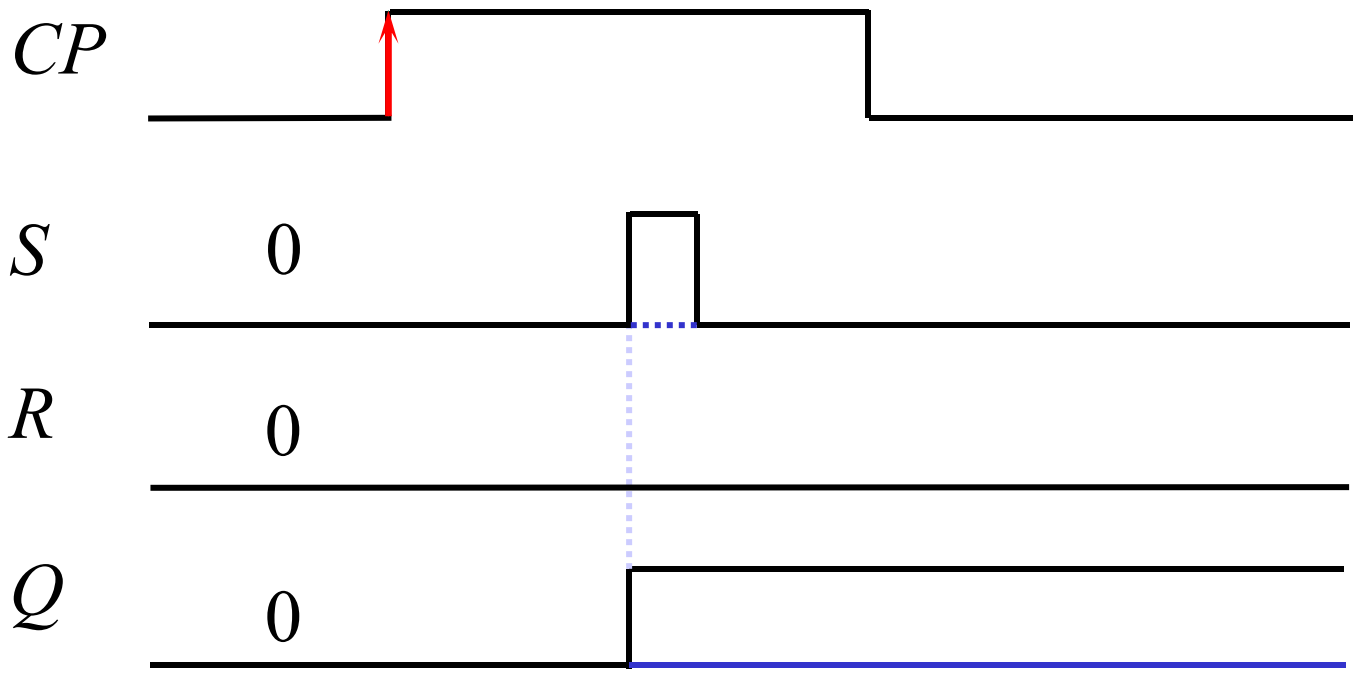
一、行为建模描述DFF

1. 没有异步清零端DFF

2. 有异步清零端DFF

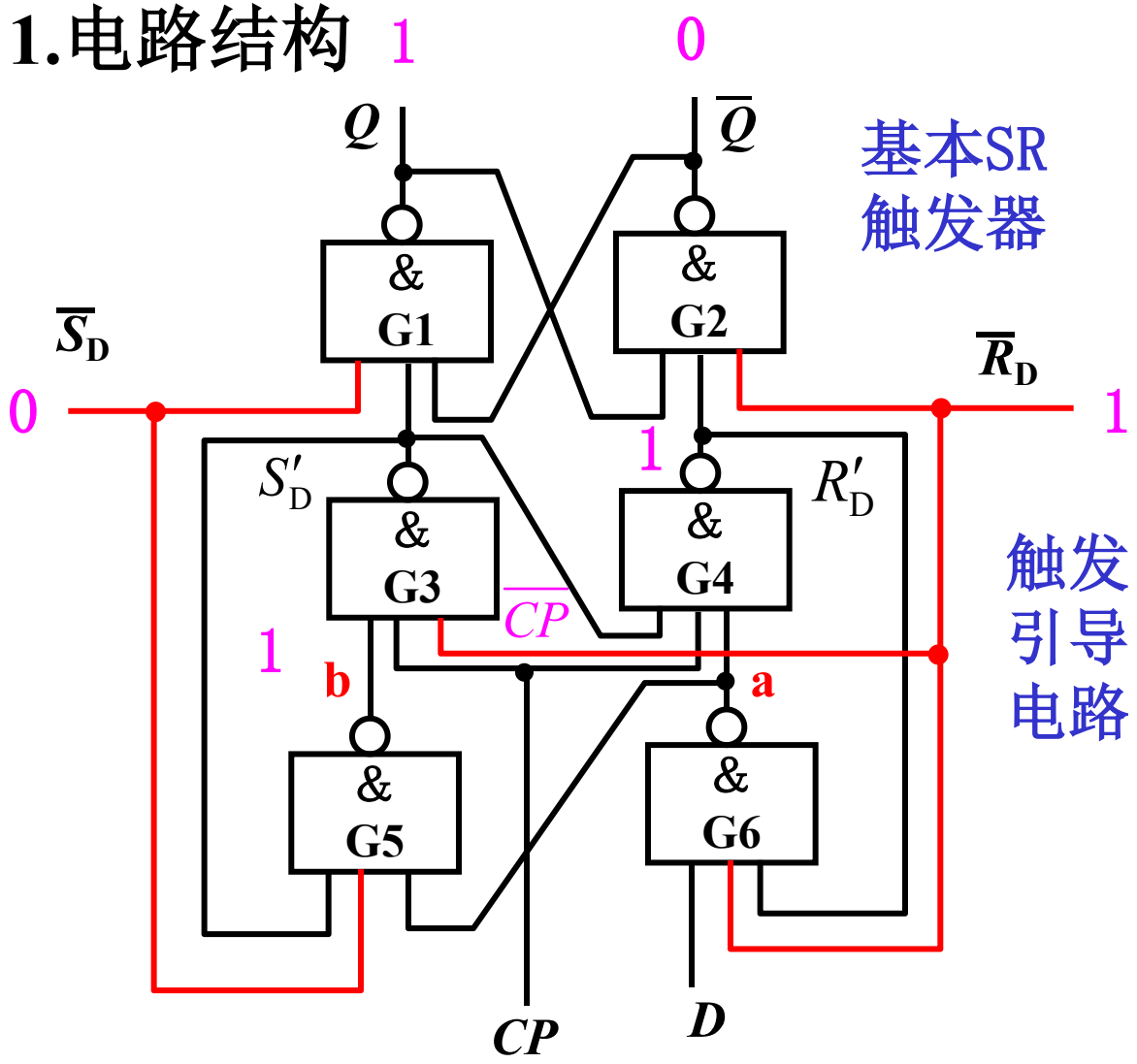
3. 有异步清零、置位端DFF

4. 4边沿触发器



一、维持阻塞型DFF

1.电路结构



控制信号 $\overline{S}_D$、$\overline{R}_D$

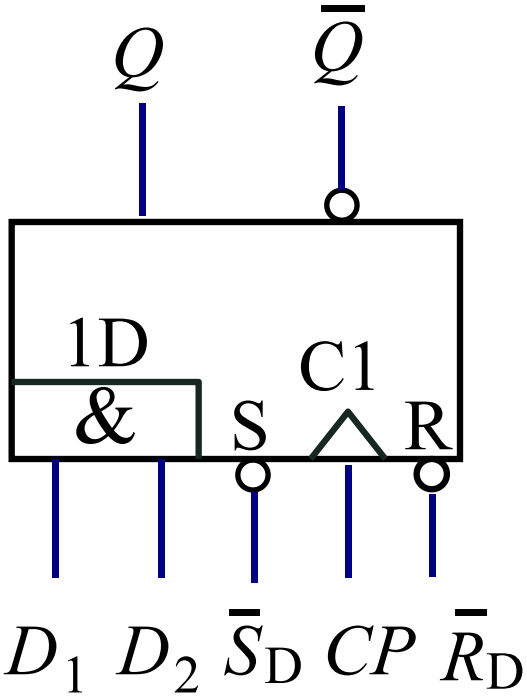
直接置1(置0)

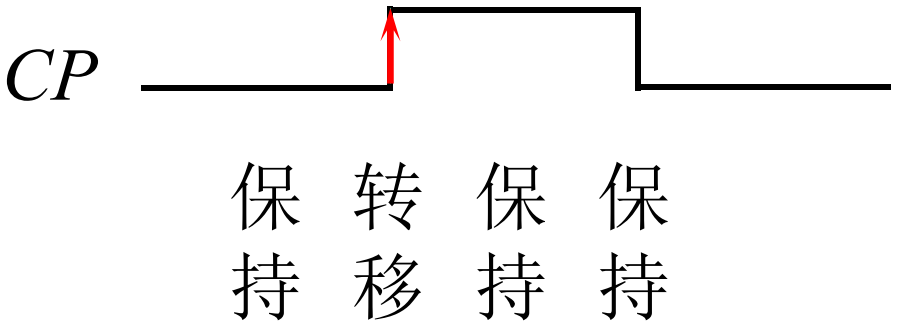
时钟信号 *CP*

何时转移

激励信号 *D*

转移何处





(b) 逻辑符号

图 4.4.1维阻DFF

2.工作原理

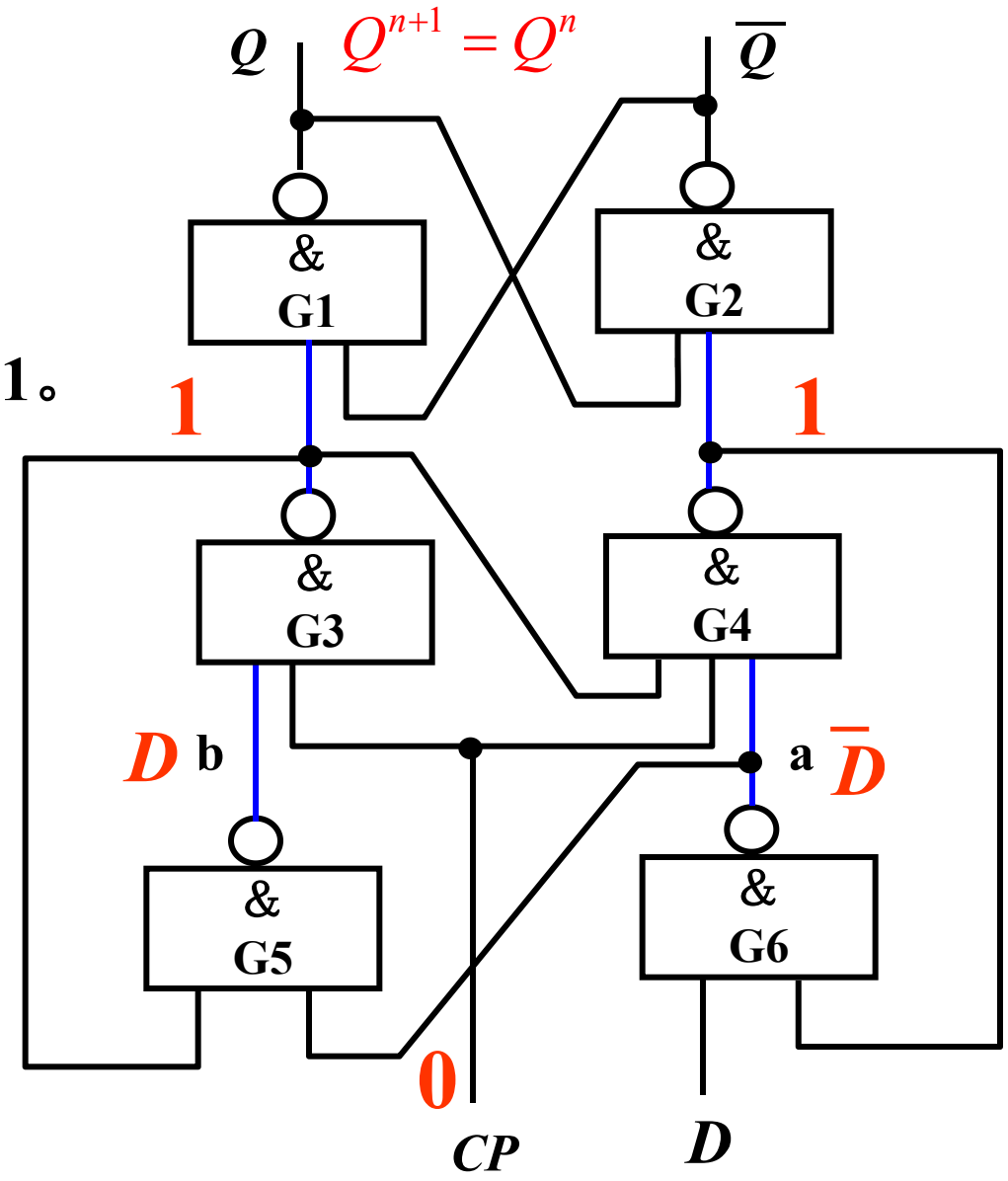
CP=0期间

(1) G3、G4被锁，输出均为1。

输出保持原状态不变

$Q^{n+1}=Q^n$　保持

(2) a= $\overline{D}$, b=*D*。



2.工作原理

$CP\uparrow$到达时

G_3、G_4开启，使

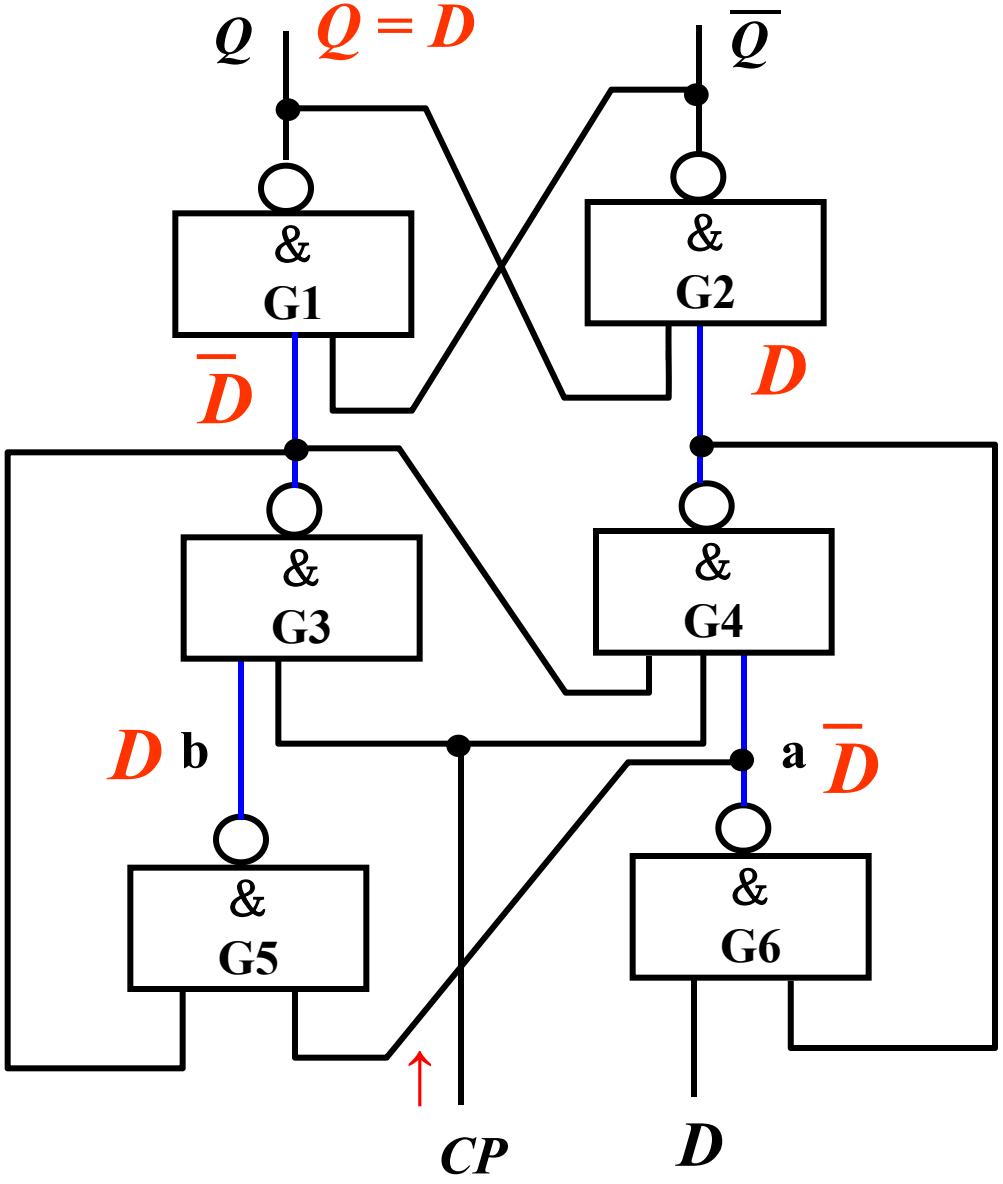
$$S'_{\mathrm{D}} = \overline{D} \quad R'_{\mathrm{D}} = D$$

因此

$$Q^{n+1} = \overline{S}'_{\mathrm{D}} + R_{\mathrm{D}} Q^n$$

$$= D + DQ^n = D$$

$$Q^{n+1} = D \quad \text{触发}$$



2.工作原理

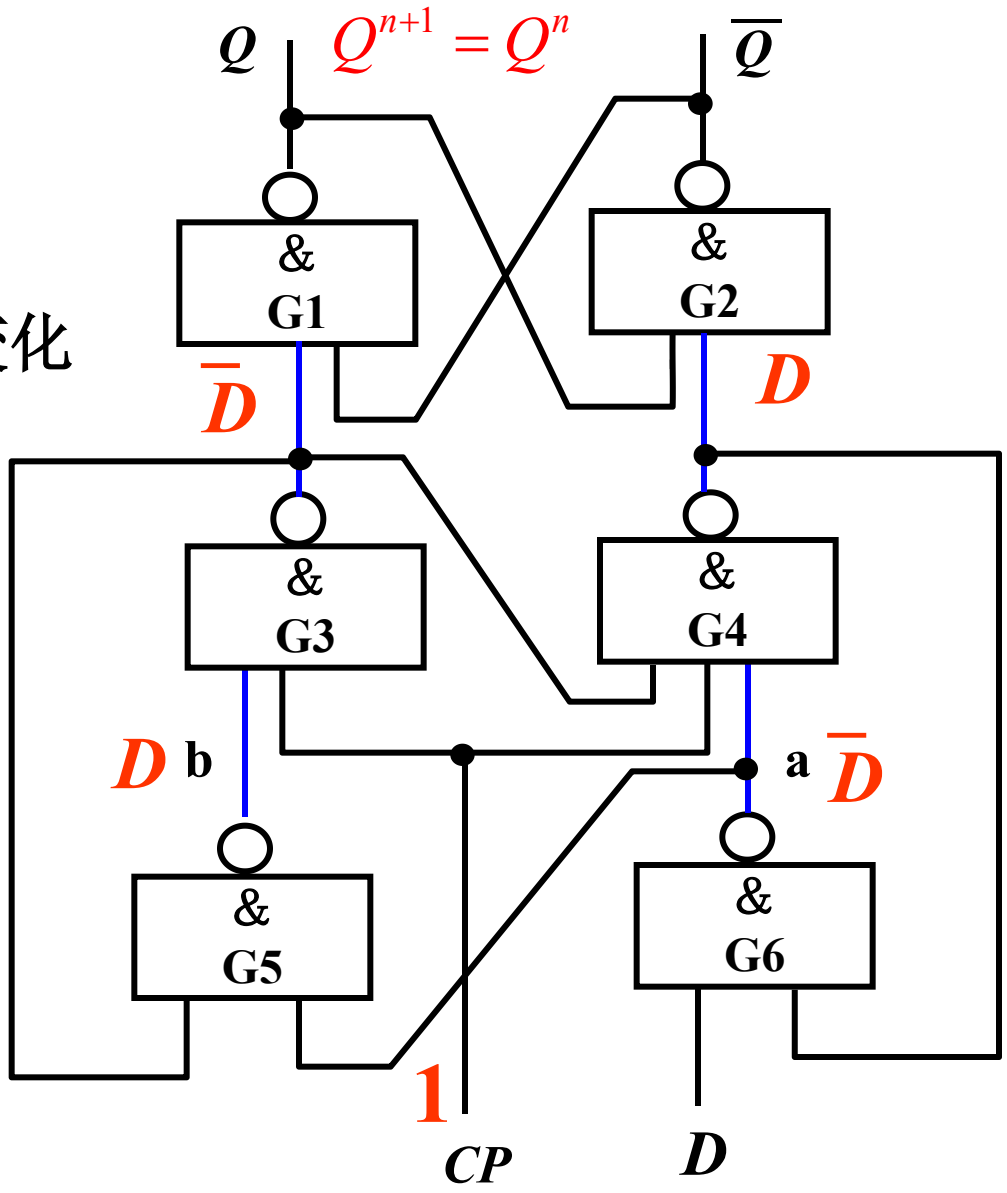
CP=1期间

G_3、G_4开启，无论D是否变化

$S'_D = \overline{D}$　$R'_D = D$　不变

因此

$Q^{n+1} = Q^n$　保持



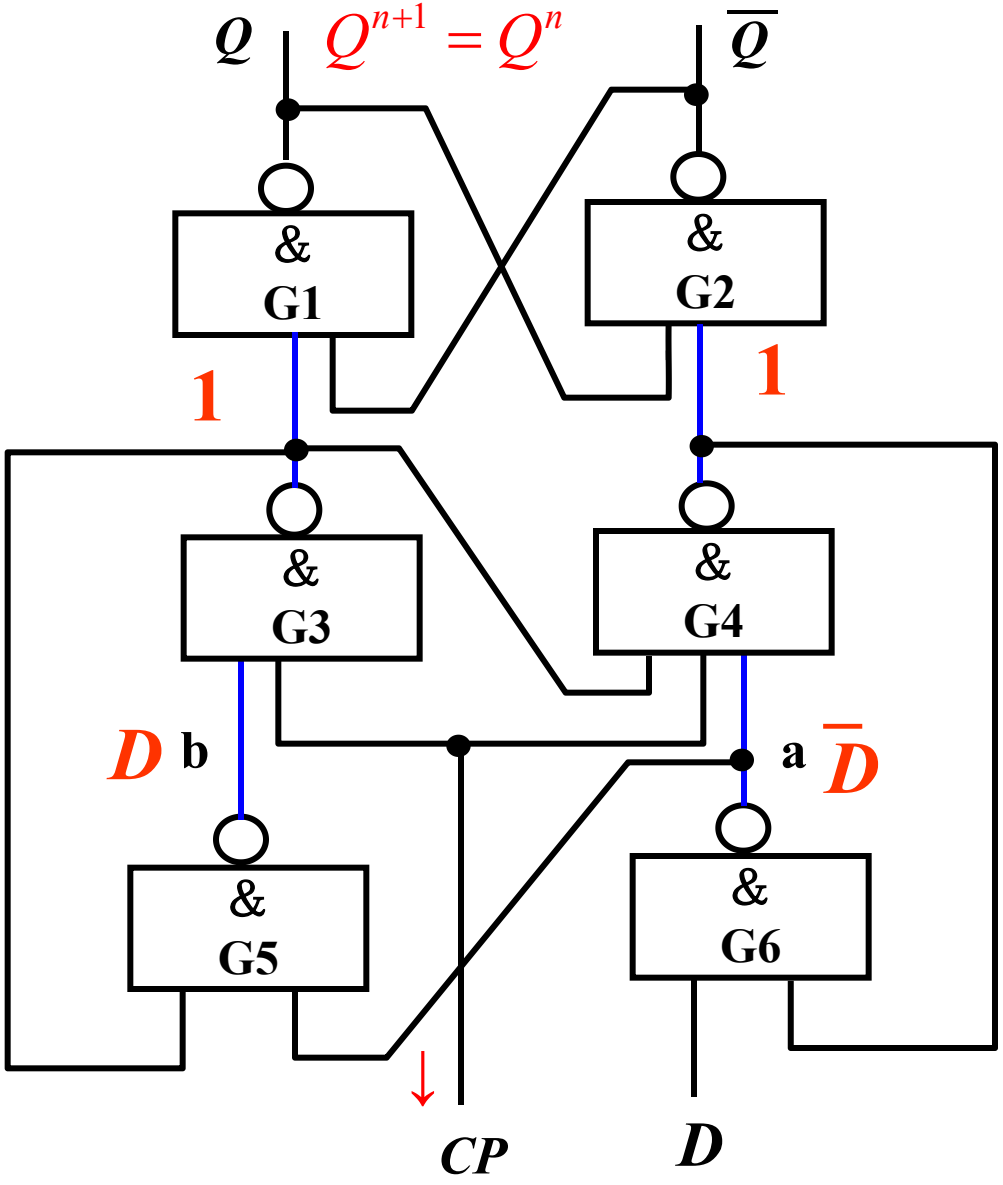
2.工作原理

CP↓到达时

G_3、G_4被锁，输出为1

输出保持原状态不变

$Q^{n+1}=Q^n$ 保持



3.功能描述

(1)次态方程：$Q^{n+1}=[D]\cdot CP\uparrow$

(2)功能表

表4.4.1 维阻DFF功能表

$\overline{S}_D$	$\overline{R}_D$	D	CP	Q^{n+1}	功能名称
1	1	0	↑	0	同步置0
1	1	1	↑	1	同步置1
0	1	ϕ	ϕ	1	异步置1
1	0	ϕ	ϕ	0	异步置0
1	1	ϕ	0	Q^n	保持

(3)激励表

表4.4.2 维阻DFF激励表

$Q^n \longrightarrow$	Q^{n+1}	D
0	0	0
0	1	1
1	0	0
1	1	1

(4)波形图

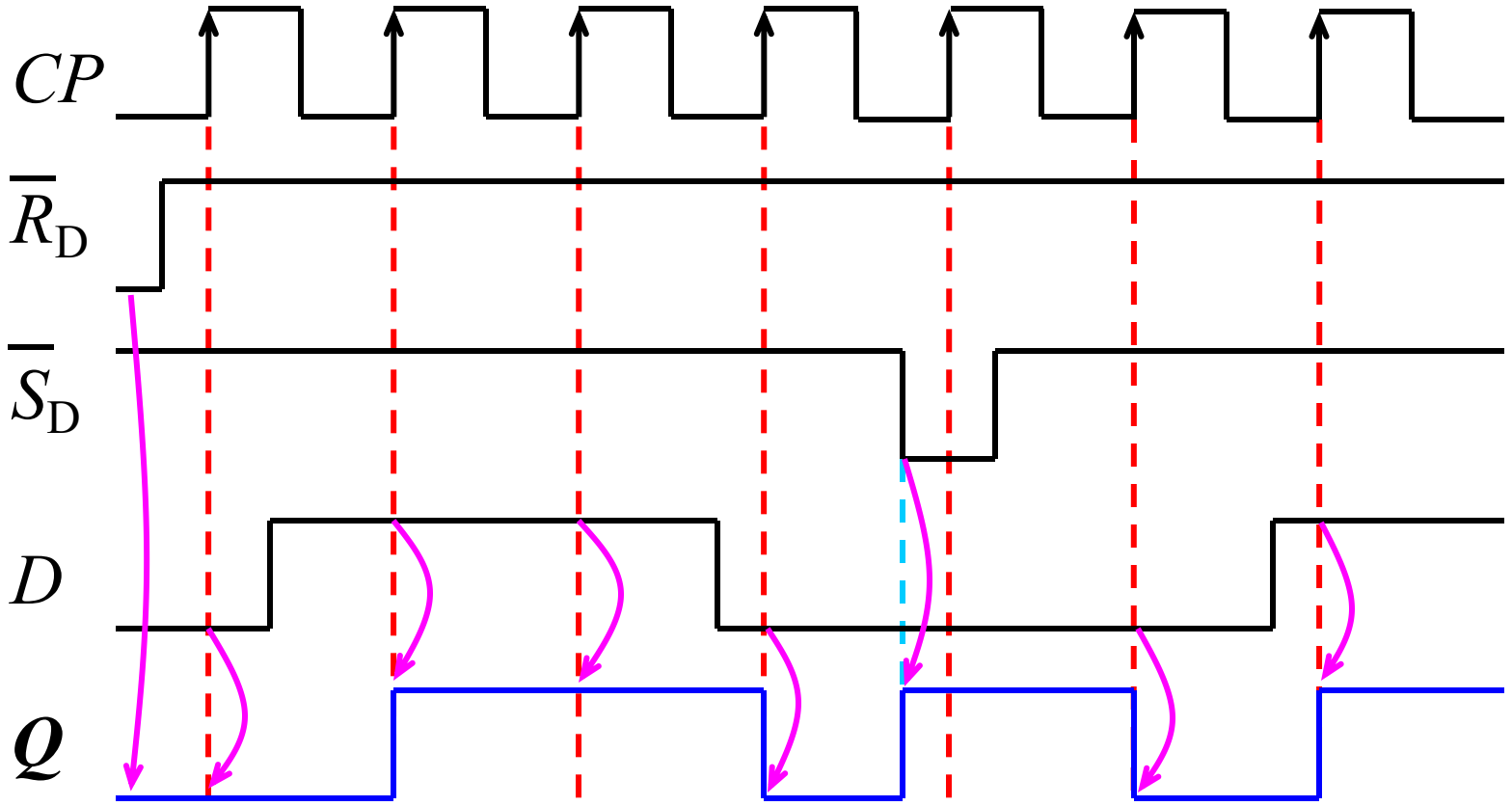


图 4.4.2 DFF的波形图

单选题 2分

设置

1. 同步转移时决定边沿DFF“转移至何状态”的是___。

A 控制信号

B 时钟信号

C 激励信号

提交

单选题 2分

设置

2. 边沿DFF中，控制优先权最高的是_____。

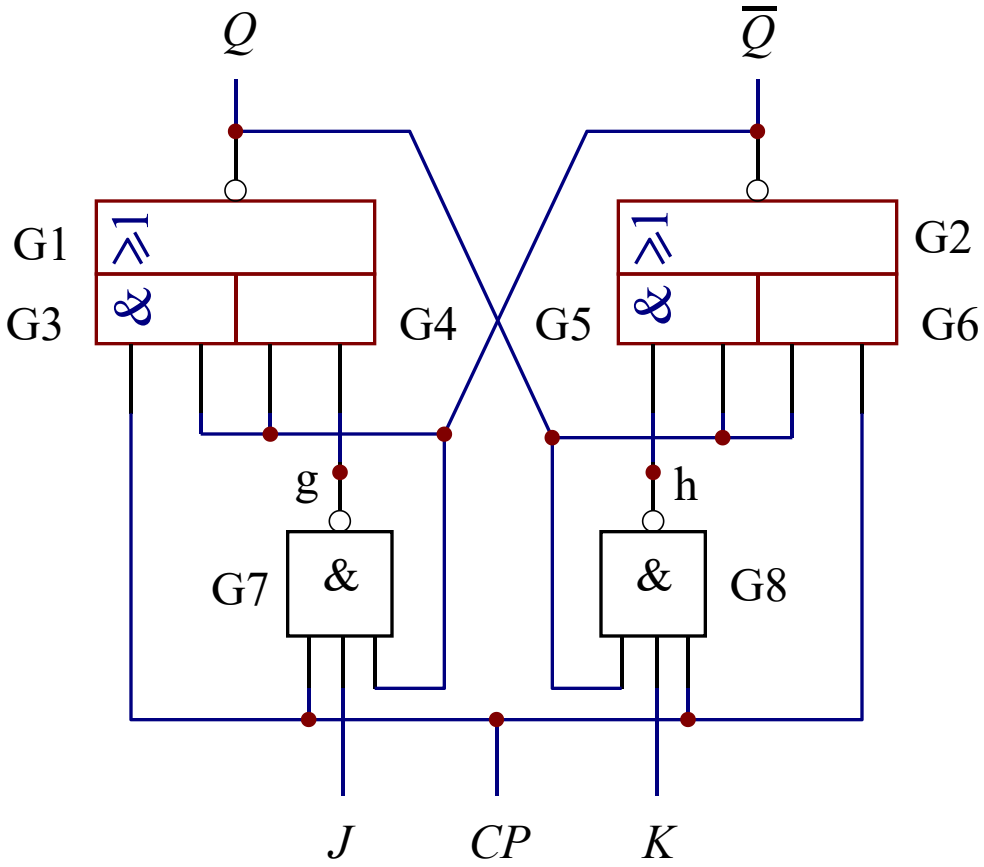
A 控制信号

B 时钟信号

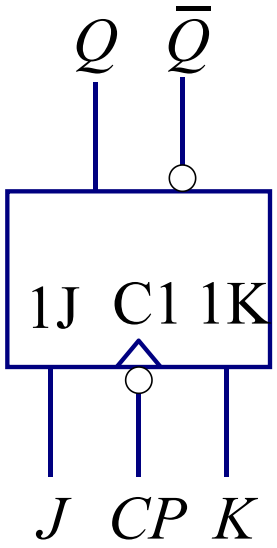
C 激励信号

提交

二、边沿JKFF



(a) 逻辑图



(b) 逻辑符号

(1)次态方程 $Q^{n+1}=[J\overline{Q}^n+\overline{K}Q^n]\cdot CP\downarrow$

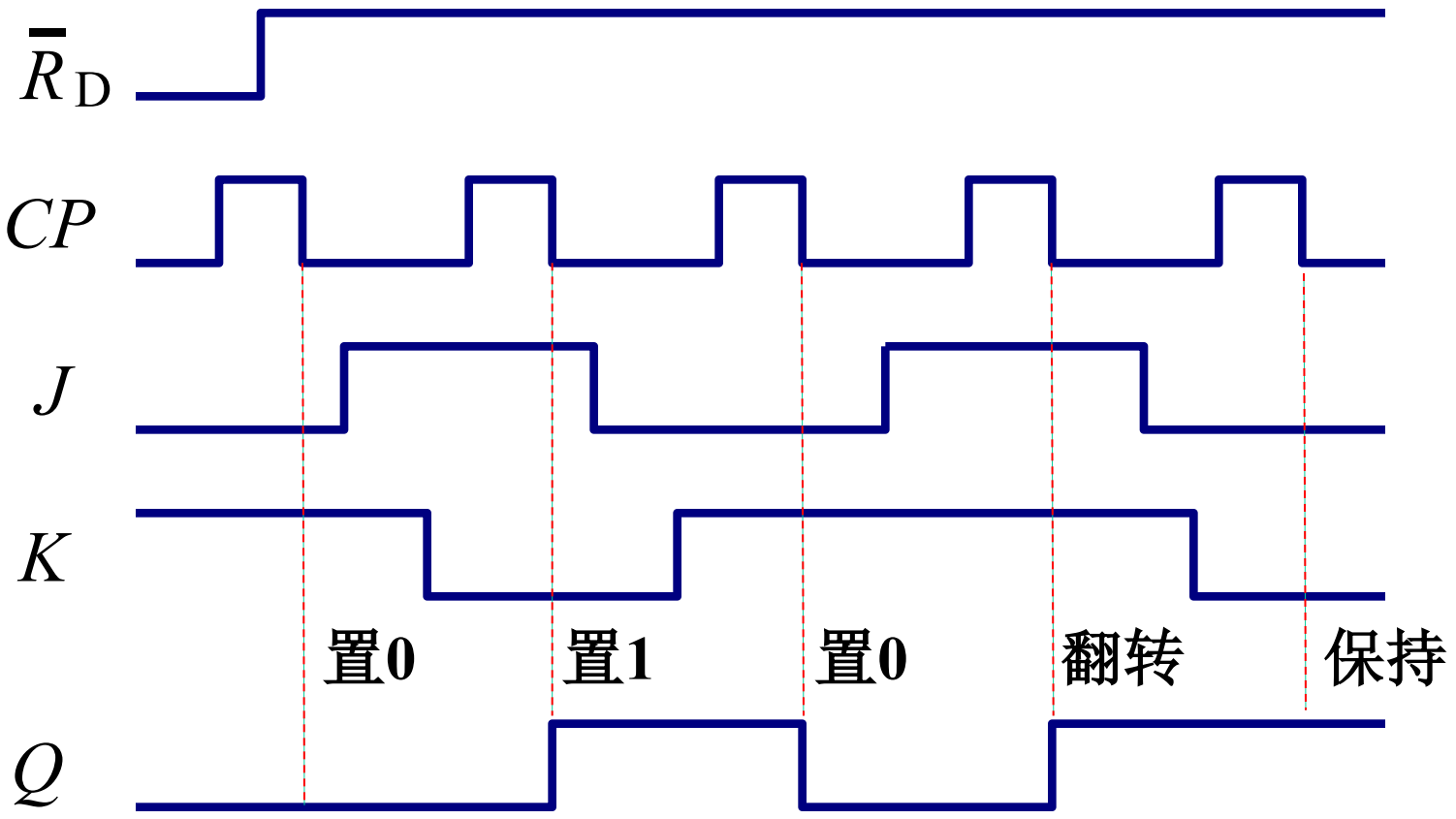
(2)功能表

$\overline{S}_D$	$\overline{R}_D$	J	K	CP	Q^{n+1}	$\overline{Q}^{n+1}$	功能名称
0	0	ф	ф	ф	1	1	不允许
1	0	ф	ф	ф	0	1	异步置0
0	1	ф	ф	ф	1	0	异步置1
1	1	0	0	↓	Q^n	$\overline{Q}^n$	保持
1	1	0	1	↓	0	1	置0
1	1	1	0	↓	1	0	置1
1	1	1	1	↓	$\overline{Q}^n$	Q^n	翻转

(3)激励表

$Q^n \longrightarrow Q^{n+1}$		J	K
0	0	0	φ
0	1	1	φ
1	0	φ	1
1	1	φ	0

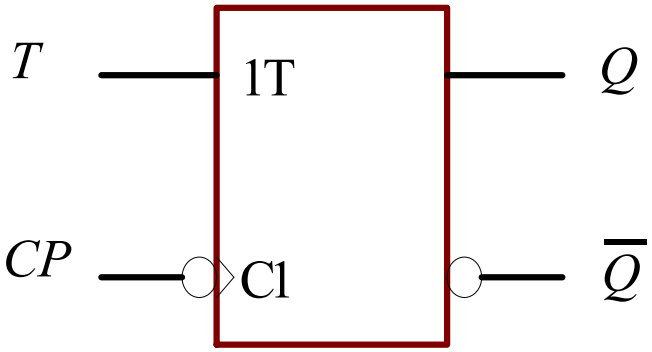
(4)波形图



三、TFF和T′FF

1.TFF

(1)下降沿触发

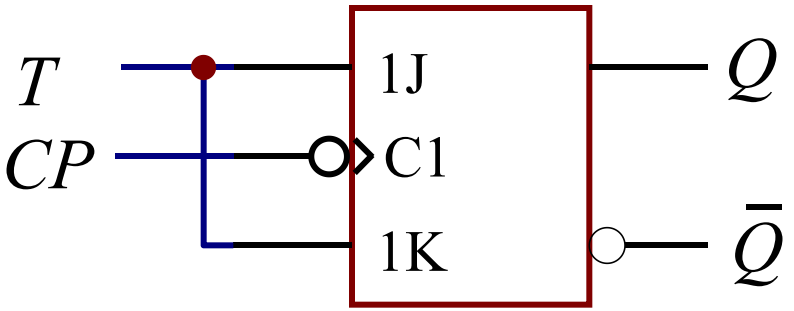


(a)逻辑符号

(b)功能表和次态方程

T	Q^{n+1}
0	Q^n
1	$\overline{Q}^n$

$$Q^{n+1}=[T\overline{Q}^n+\overline{T}Q^n]\cdot CP\downarrow$$

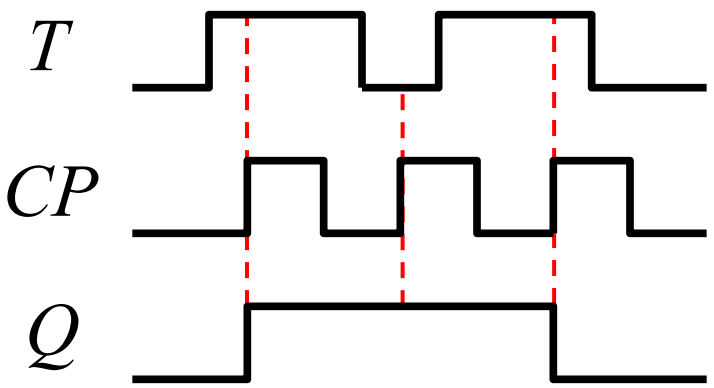


(c)实现电路

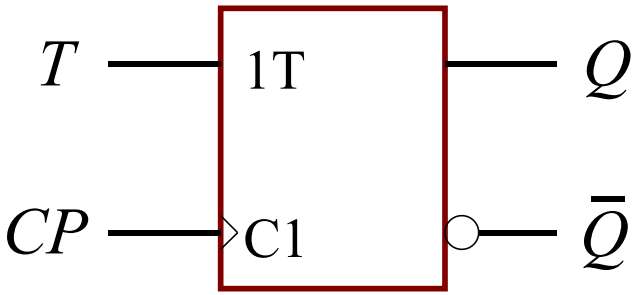
三、TFF和T′FF

1.TFF

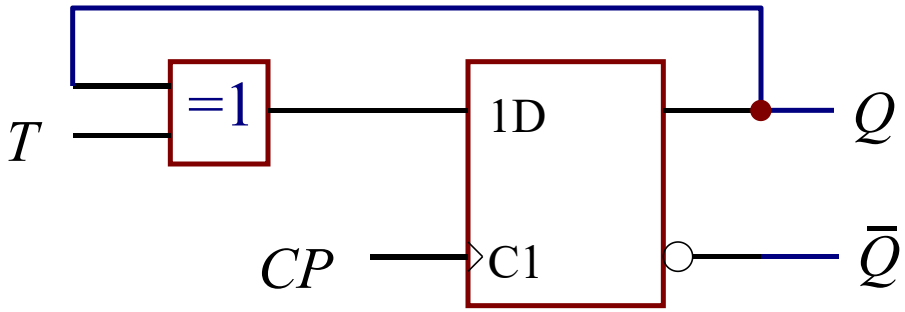
(2)上升沿触发



(e)波形图



(d)逻辑符号

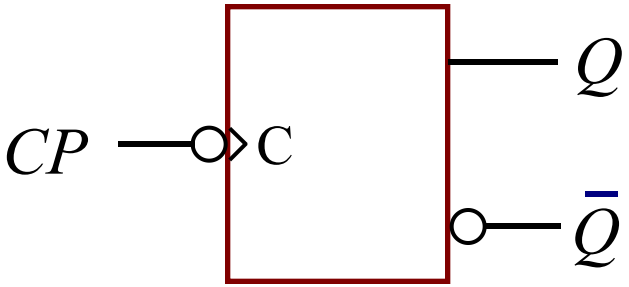


(f)实现电路

三、TFF和T′FF

2.T′ FF

(1)下降沿触发

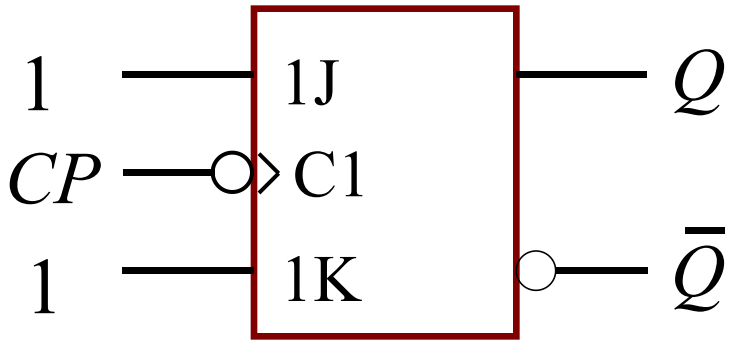


(g)逻辑符号

(h)功能表和次态方程

CP	Q^{n+1}
0	Q^n
↓	$\overline{Q}^n$

$$Q^{n+1}=[\,\overline{Q}^n\,]\cdot CP\downarrow$$

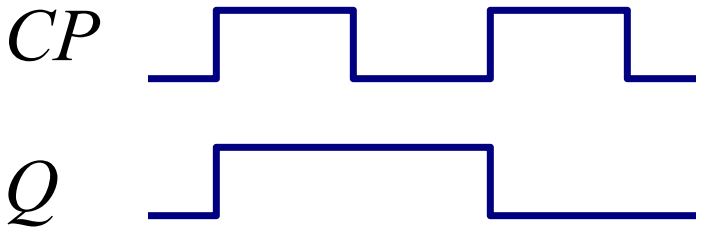


(i)实现电路

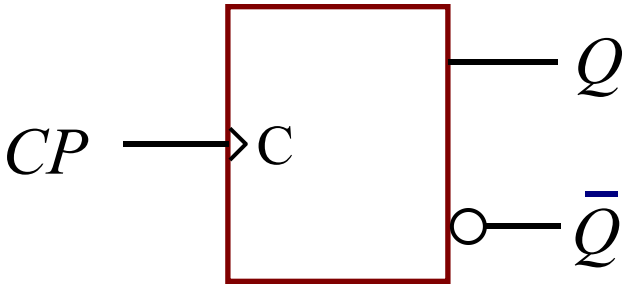
三、TFF和T′FF

2.T′ FF

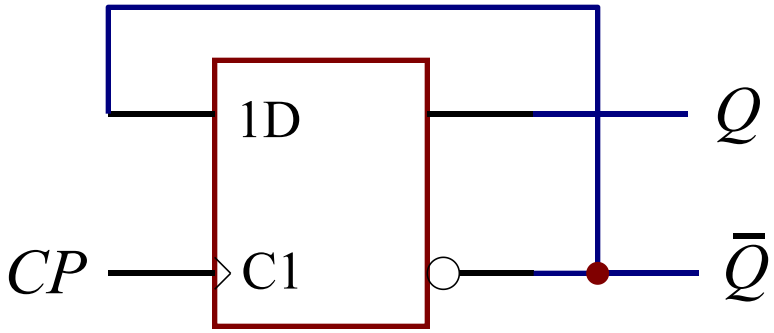
(2)上升沿触发



(k)波形图



(j)逻辑符号



(l)实现电路

3.在时钟信号作用下，实现功能最多的是边沿__。

A SRFF

B DFF

C JKFF

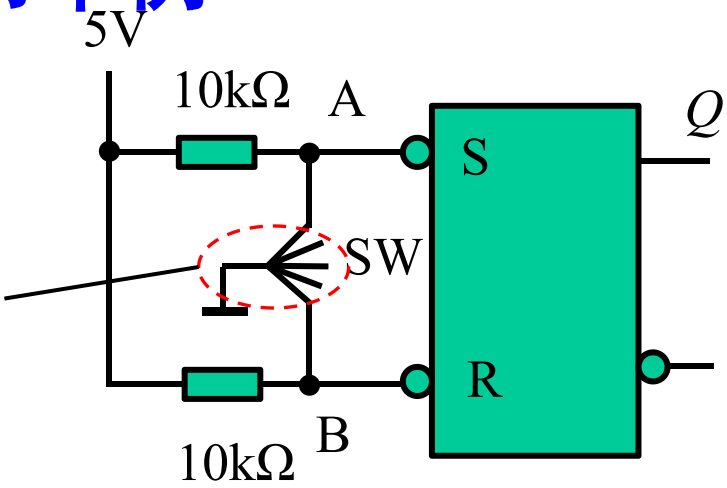
D TFF

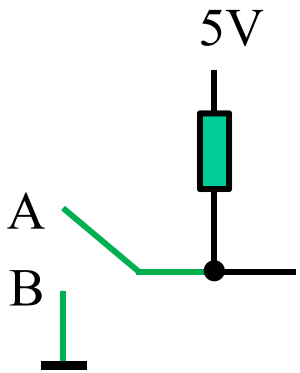
提交

4. 5触发器应用举例

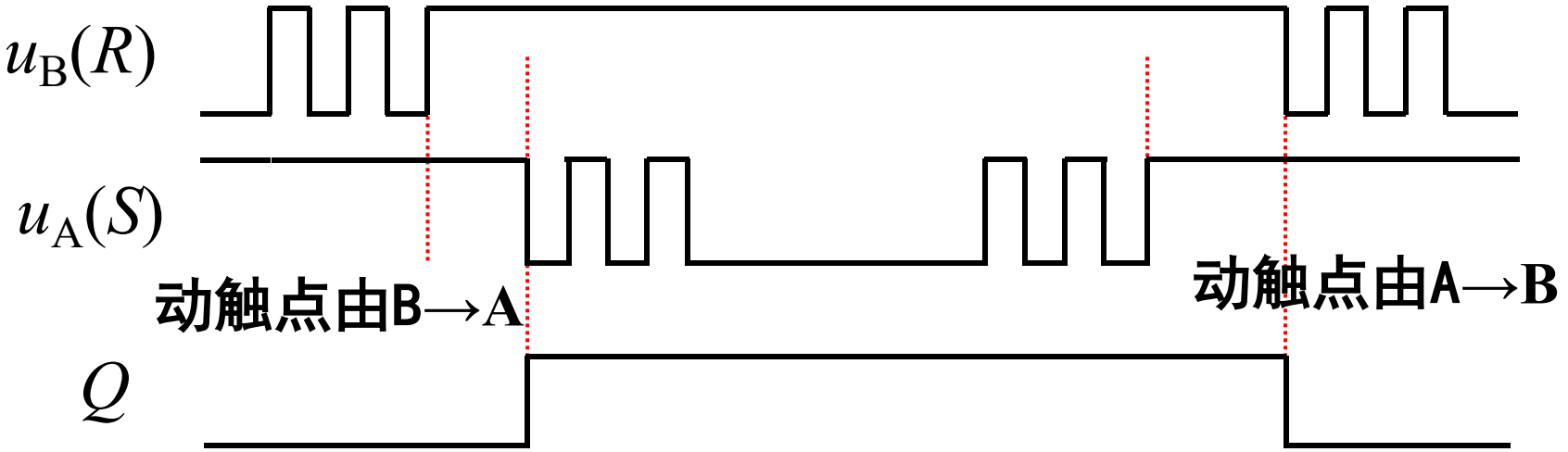
1. 消抖动开关

普通机械开关

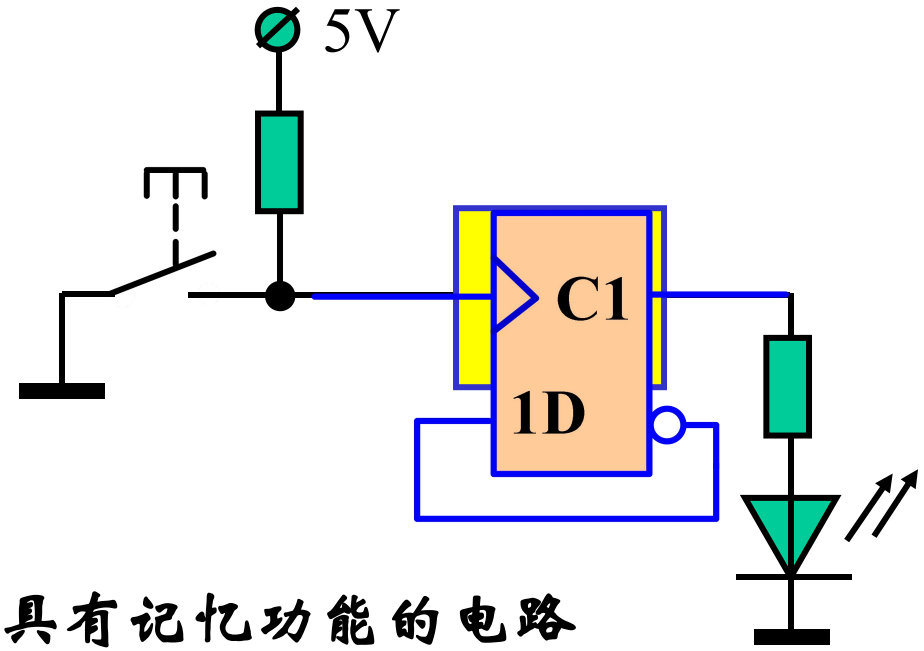




触点在闭合和断开瞬间会产生接触不稳定



【再讨论】为何引入触发器 ？



具有记忆功能的电路

原来功能

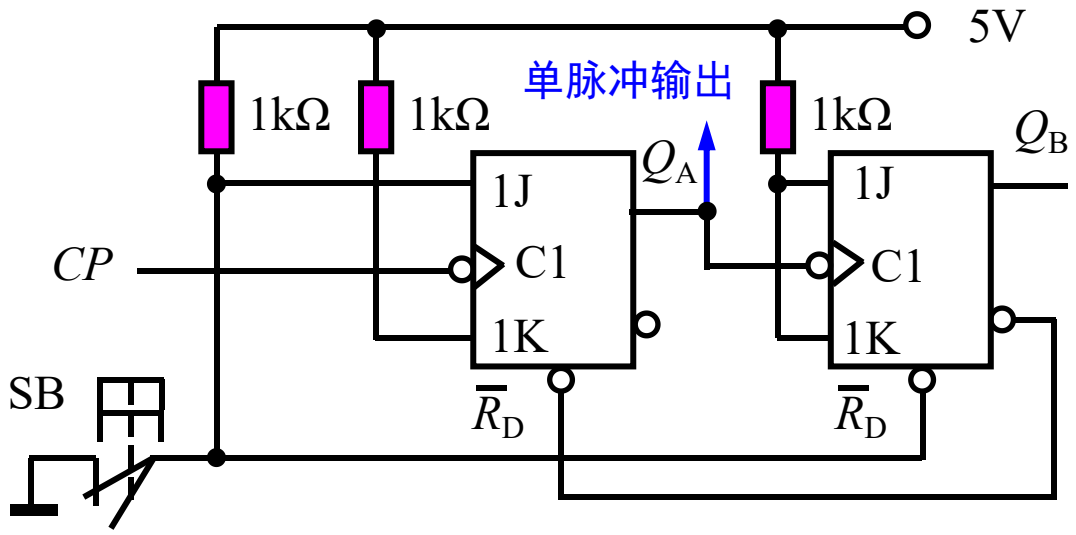
按键断开　LED熄灭

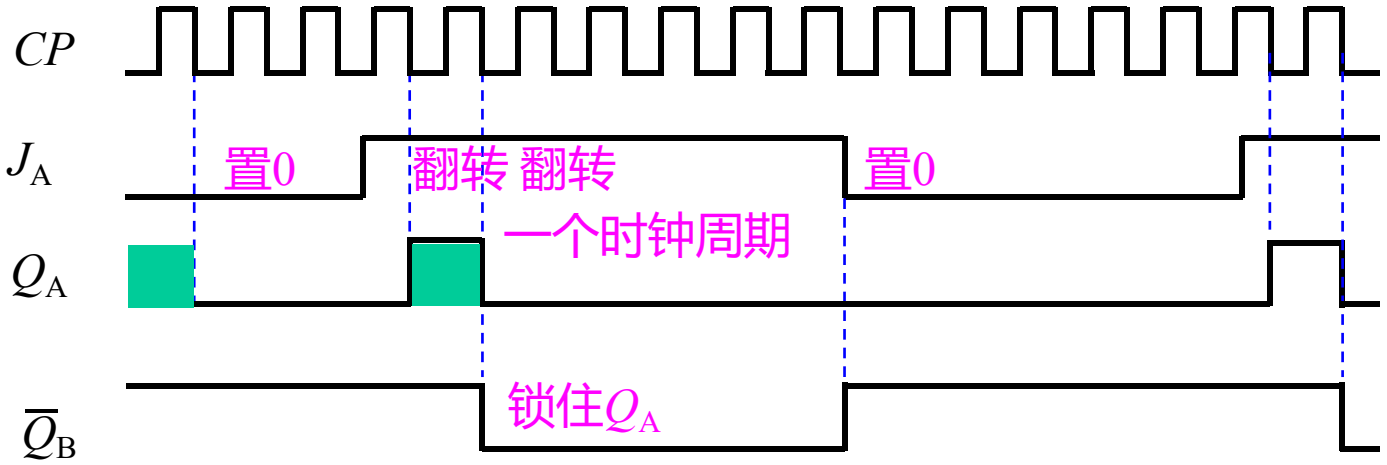
按键闭合　LED点亮

改进功能

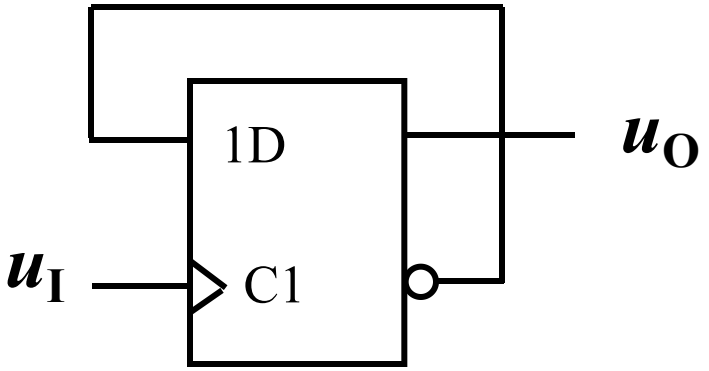
按一次，LED在点亮与熄灭状态循环

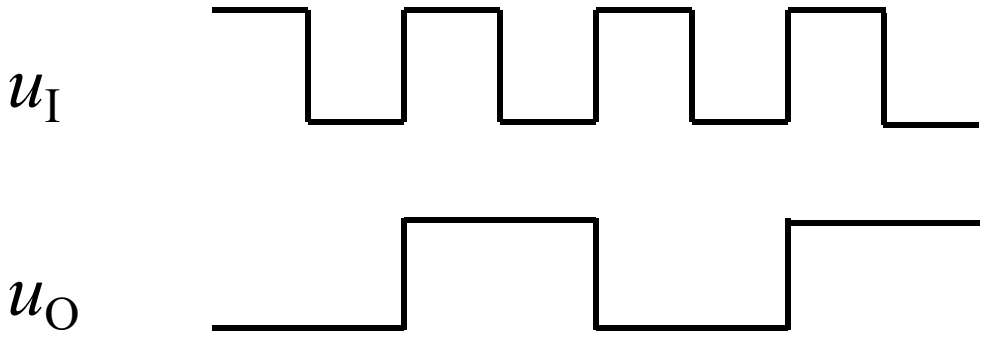
2. 单脉冲发生器


5V
单脉冲输出
1kΩ
1kΩ
1kΩ
Q_A
Q_B
1J
C1
1K
1J
C1
1K
CP
SB
$\overline{R}_D$
$\overline{R}_D$


CP
J_A
置0
翻转
翻转
置0
一个时钟周期
Q_A
锁住Q_A
$\overline{Q}_B$

3. 分频器



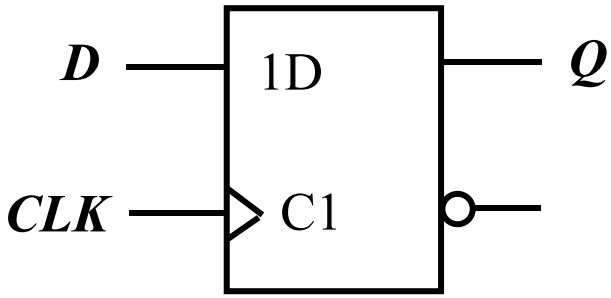


4.6Verilog描述触发器

一、行为建模描述DFF

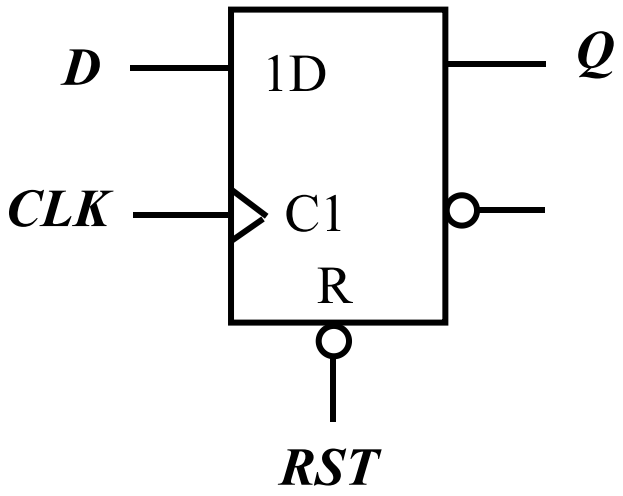
1. 没有异步清零端DFF

```
//D flip-flop without reset
module DFF (Q, D, CLK);
output  Q;
input D, CLK;
reg Q;
always @ (posedge CLK )
begin
Q <= D;
end
endmodule
```



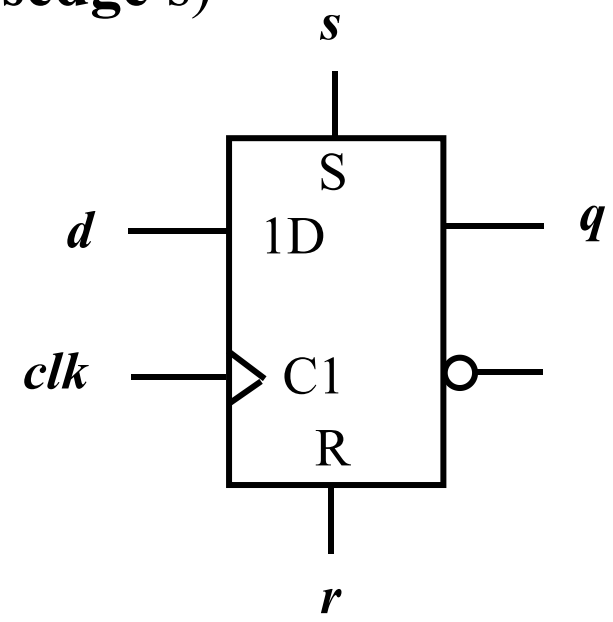
2. 有异步清零端DFF

```
//D flip-flop with asynchronous reset ( V2001,V2005)
module DFF (output reg Q, input D, CLK, RST);
always @ (posedge CLK , negedge RST)
begin
if (!RST)  Q <= 1'b0;    //same as: if (RST == 0)
else  Q <= D;
end
endmodule
```



3. 有异步清零、置位端DFF

```
module dff_rs_async(clk,r,s,d,q);
input clk,r,s,d;
output q;
reg q;
always@(posedge clk or posedge r or posedge s)
begin
if(r) q<=1'b0;
else if(s) q<=1'b1;
else q<=d;
end
endmodule
```



应用题

1.试用基本SRFF设计一个两组数字式抢答器。

作业题

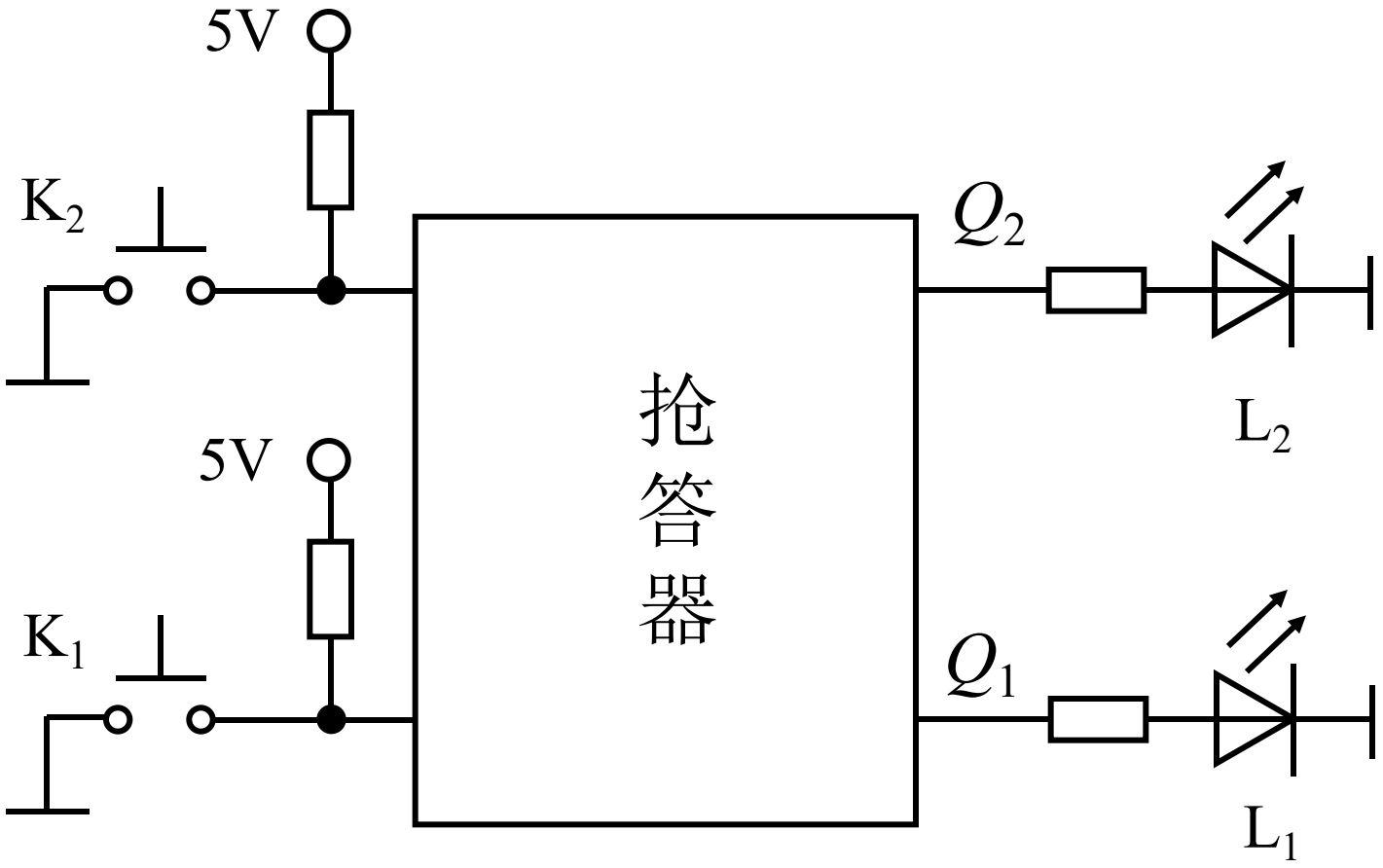
4.1

4.5

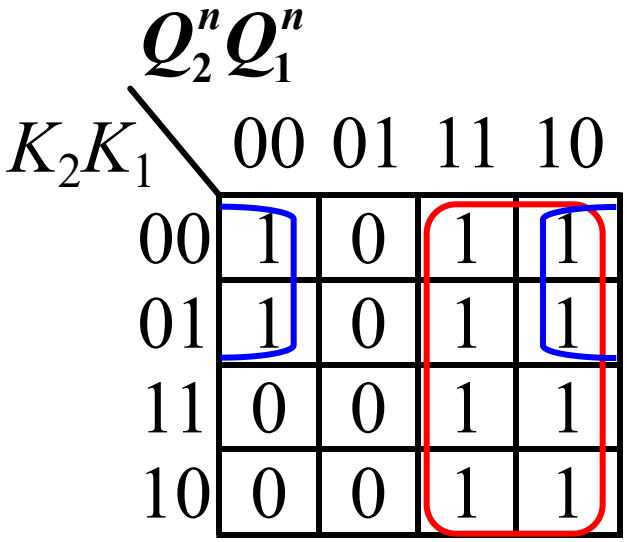
4.8

应用题

试用基本SRFF设计一个两组数字式抢答器。



K_2	K_1	Q_2^n	Q_1^n	Q_2^{n+1}	Q_1^{n+1}
0	0	0	0	1	1
0	1	0	0	1	0
1	0	0	0	0	1
1	1	0	0	0	0
x	x	0	1	0	1
x	x	1	0	1	0
x	x	1	1	1	1

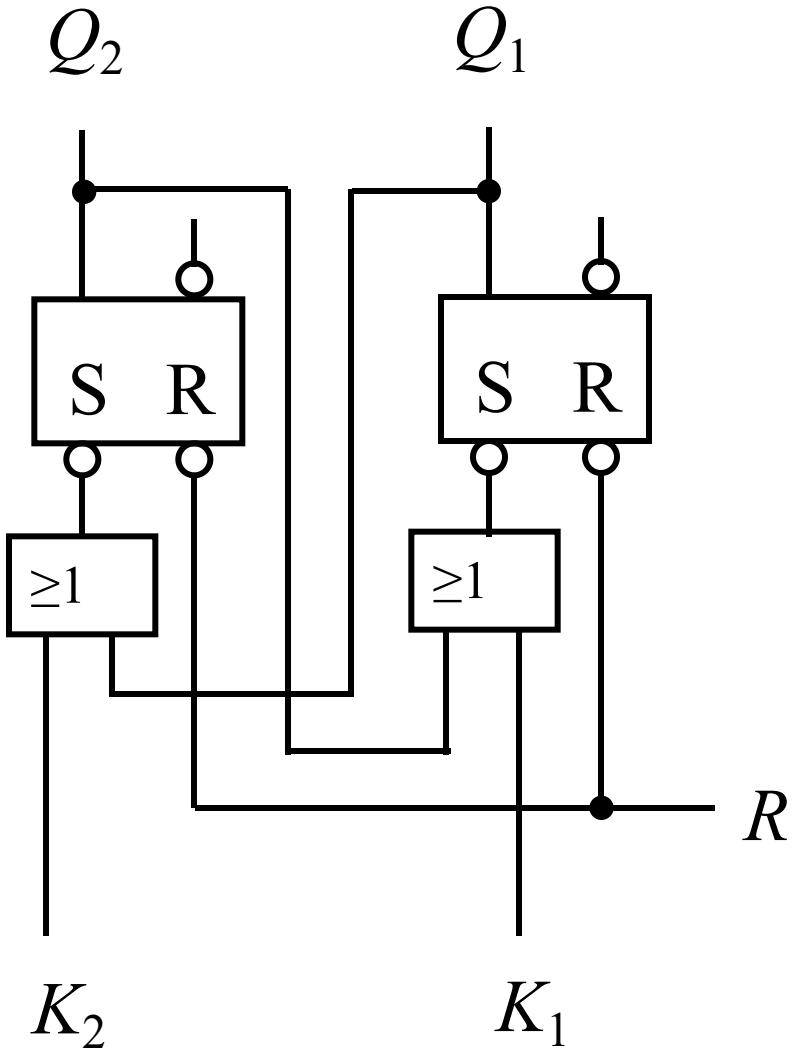


$$\bar{S}_{D2} = K_2 + Q_1^n, \bar{R}_{D2} = 1$$

$$\bar{S}_{D1} = K_1 + Q_2^n, \bar{R}_{D1} = 1$$

$$Q_2^{n+1} = \bar{K}_2\bar{Q}_1^n + Q_2^n = \overline{\bar{S}}_{D2} + \bar{R}_{D2}Q_2^n$$

$$Q_1^{n+1} = \bar{K}_1\bar{Q}_2^n + Q_1^n = \overline{\bar{S}}_{D1} + \bar{R}_{D1}Q_1^n$$


Q_2
Q_1
S R
S R
≥1
≥1
R
K_2
K_1