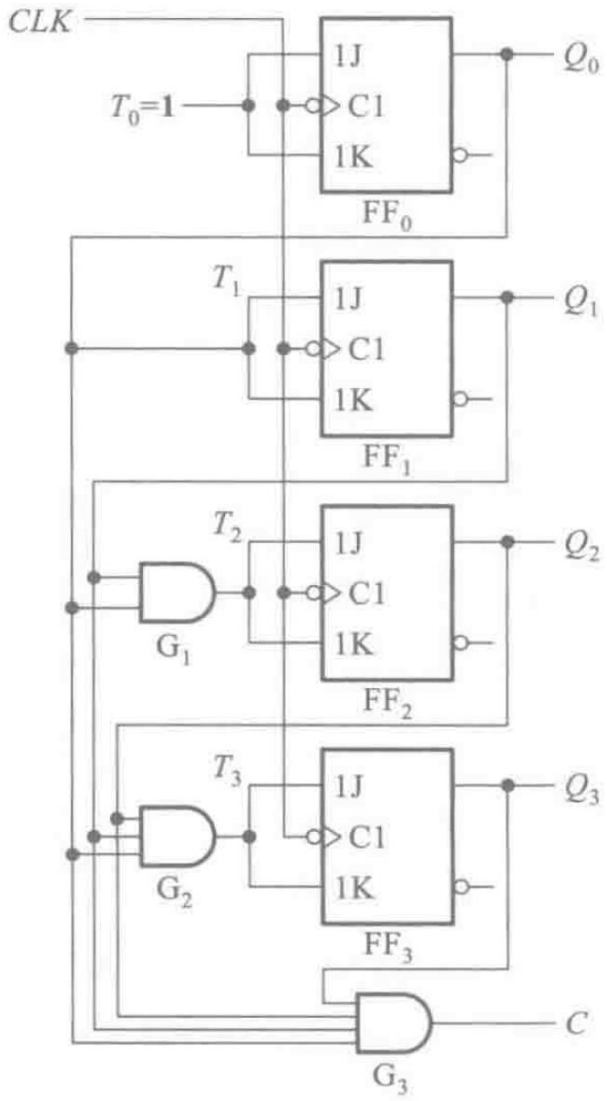
Up Synchronous Binary Counter

$$
\begin{array}{cccc|ccc}
 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\
+ & & & & & & & 1 \\
\hline
 & 1 & 0 & 1 & 1 & 1 & 0 & 0
\end{array}
$$

$$T_i = Q_{i-1} \cdot Q_{i-2} \cdot \cdots \cdot Q_1 \cdot Q_0$$

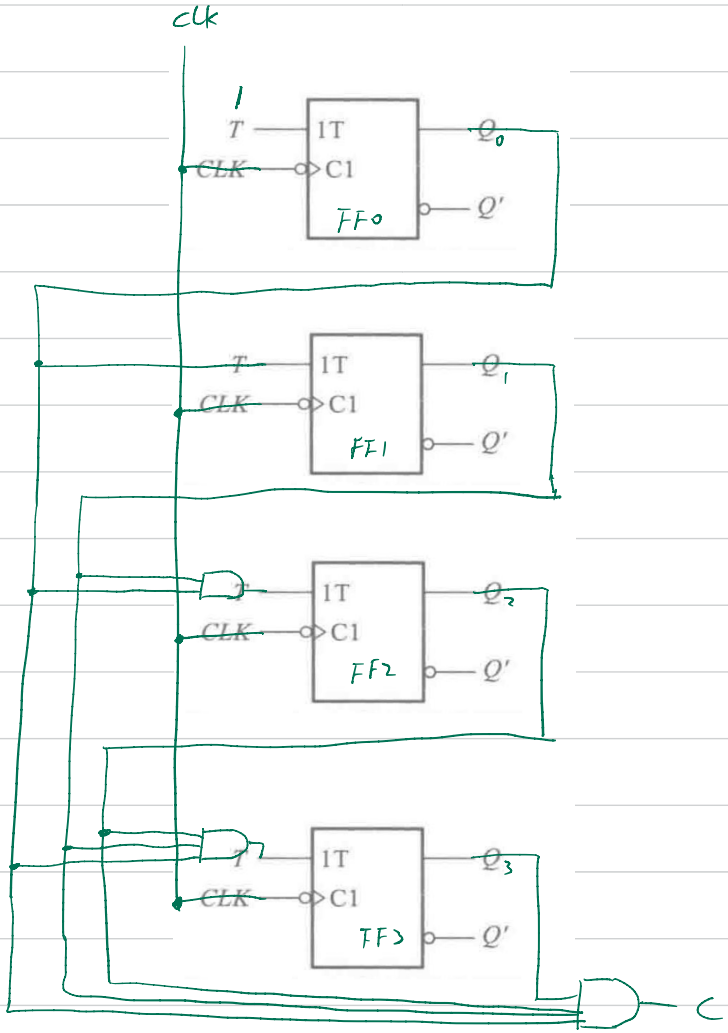
$$= \prod_{j=0}^{i-1} Q_j \qquad (i = 1, 2, \cdots, n-1)$$



C
0
0
0
0
0
0
0
0
1
1
1
1
1
1
1
1
0

T	Q	Q^*
0	0	0
0	1	1
1	0	1
1	1	0

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



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

驱动方程

$T_0 = 1$

$T_1 = Q_0$

$T_2 = Q_1 Q_0$

$T_3 = Q_2 Q_1 Q_0$

状态方程

$Q_0^* = Q_0'$

$Q_1^* = Q_0 Q_1' + Q_0' Q_1$

$Q_2^* = Q_1 Q_0 Q_2' + (Q_1 Q_0)' Q_2$

$Q_3^* = Q_2 Q_1 Q_0 Q_3' + (Q_2 Q_1 Q_0)' Q_3$

输出方程

$C = Q_3 Q_2 Q_1 Q_0$

clk	Q_3	Q_2	Q_1	Q_0	C
0	0	0	0	0	
1	0	0	0	1	
2	0	0	1	0	
3	0	0	1	1	
4	0	1	0	0	
5	0	1	0	1	
6	0	1	1	0	
7	0	1	1	1	
8	1	0	0	0	
9					
10					
11					
12					
13					

Up Synchronous Binary Counter

驱动方程

$$\begin{cases} T_0 = 1 \\ T_1 = Q_0 \\ T_2 = Q_0 Q_1 \\ T_3 = Q_0 Q_1 Q_2 \end{cases}$$

状态方程

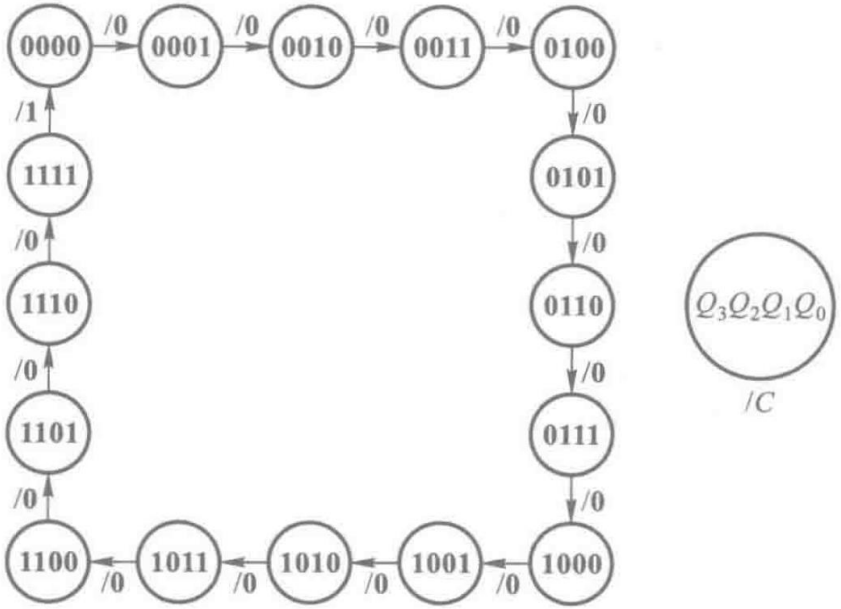
$$\begin{cases} Q_0^* = Q_0' \\ Q_1^* = Q_0 Q_1' + Q_0' Q_1 \\ Q_2^* = Q_0 Q_1 Q_2' + (Q_0 Q_1)' Q_2 \\ Q_3^* = Q_0 Q_1 Q_2 Q_3' + (Q_0 Q_1 Q_2)' Q_3 \end{cases}$$

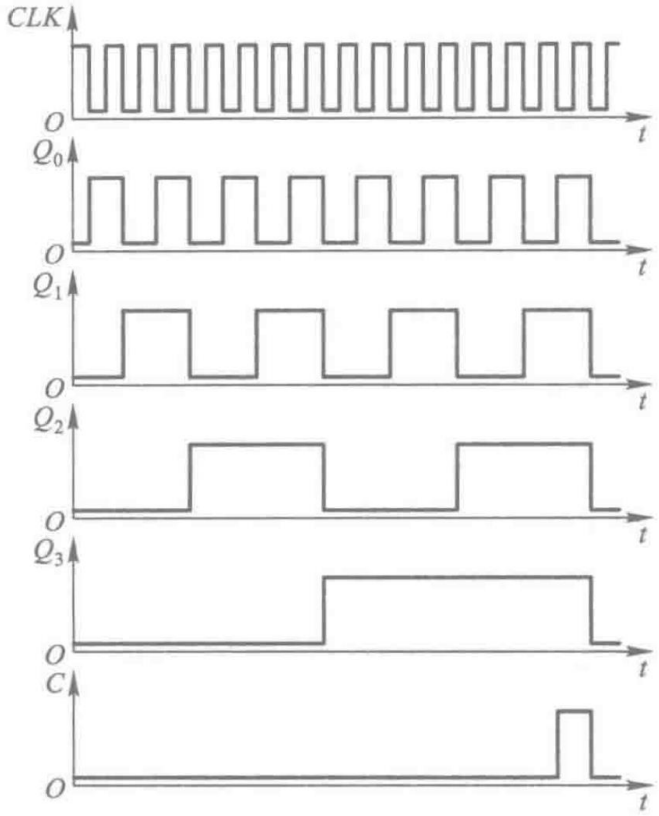
输出方程

$$C = Q_0 Q_1 Q_2 Q_3$$

计数顺序	电路状态				等效十进制数	进位输出
	Q_3	Q_2	Q_1	Q_0		C
0	0	0	0	0	0	0
1	0	0	0	1	1	0
2	0	0	1	0	2	0
3	0	0	1	1	3	0
4	0	1	0	0	4	0
5	0	1	0	1	5	0
6	0	1	1	0	6	0
7	0	1	1	1	7	0
8	1	0	0	0	8	0
9	1	0	0	1	9	0
10	1	0	1	0	10	0
11	1	0	1	1	11	0
12	1	1	0	0	12	0
13	1	1	0	1	13	0
14	1	1	1	0	14	0
15	1	1	1	1	15	1
16	0	0	0	0	0	0

Up Synchronous Binary Counter

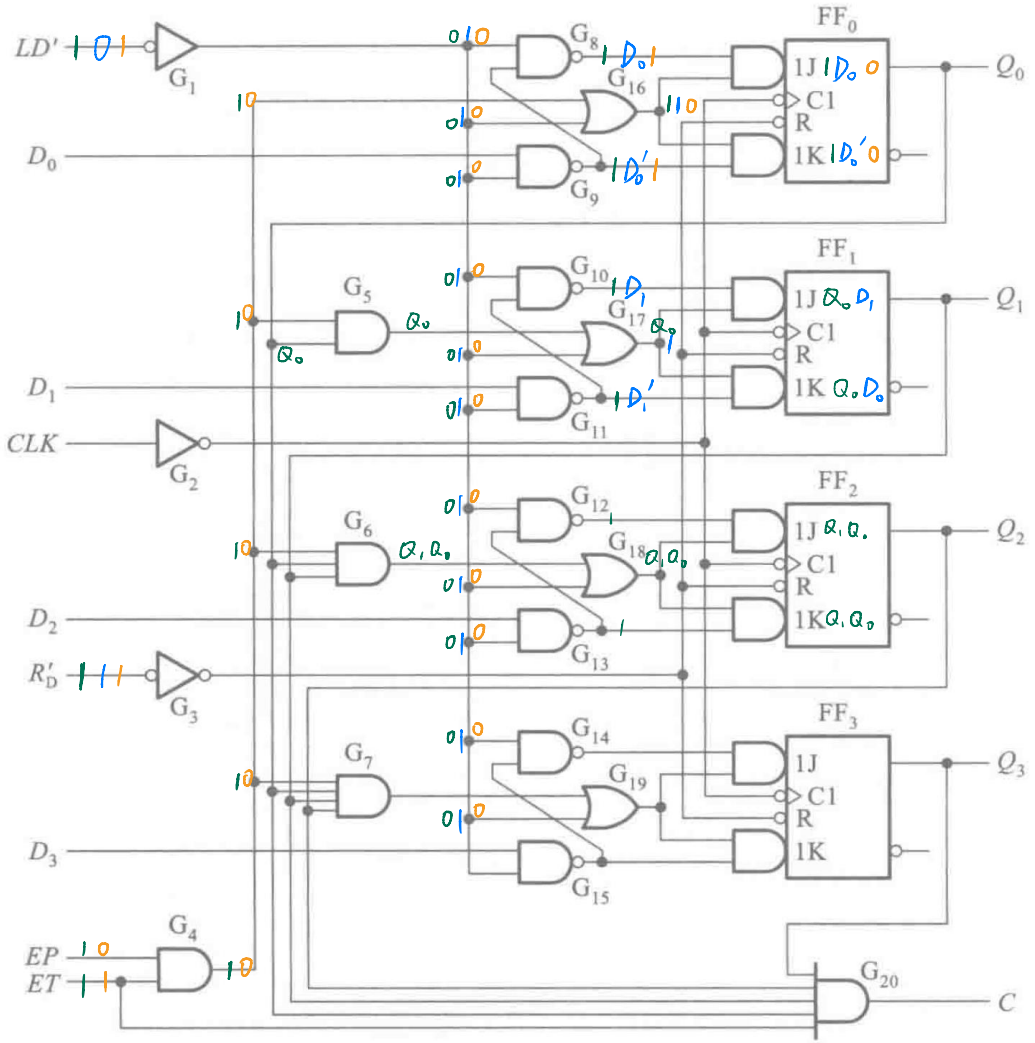




Up Synchronous Binary Counter – 74161

CLK	R'_D	LD'	EP	ET	工作状态
×	0	×	×	×	置零
↑	1	0	×	×	预置数
×	1	1	0	1	保持
×	1	1	×	0	保持(但 $C=0$)
↑	1	1	1	1	计数

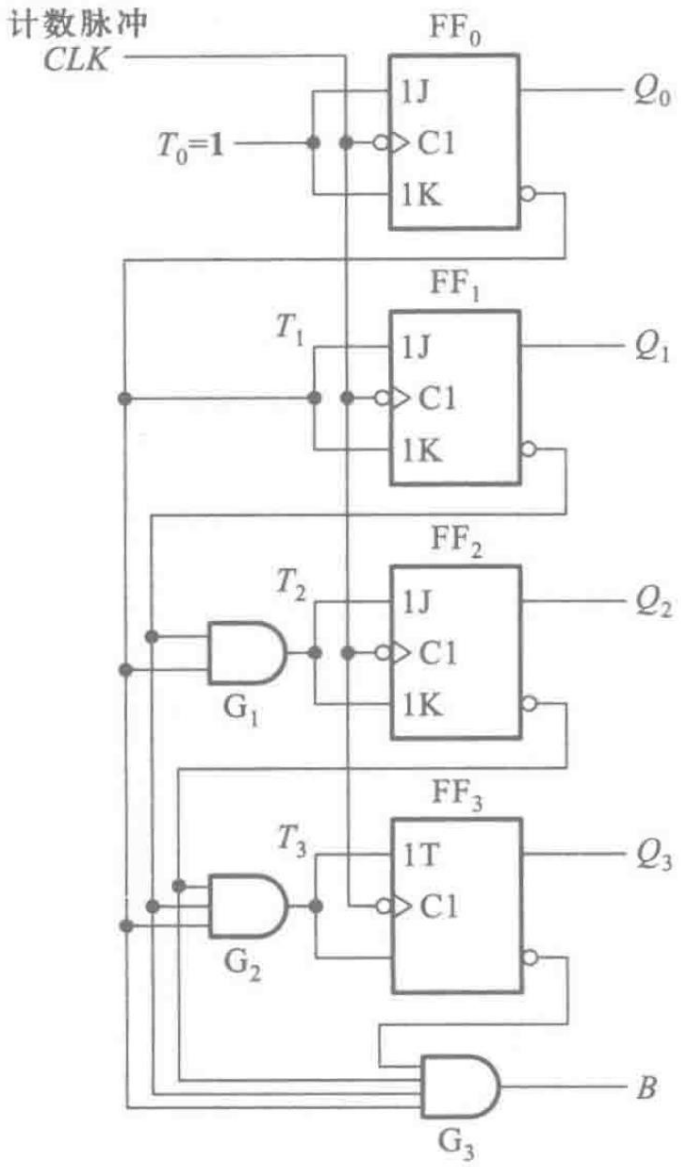
Up Synchronous Binary Counter – 74161



74161

- The same function can also be realized by 74LS161, 74HC161

Down Synchronous Binary Counter



$$T_i = Q'_{i-1} \cdot Q'_{i-2} \cdot \cdots \cdot Q'_1 \cdot Q'_0 = \prod_{j=0}^{i-1} Q'_j \qquad (i = 1, 2, \cdots, n-1)$$

1 1 1 1

1 1 1 0

1 1 0 1

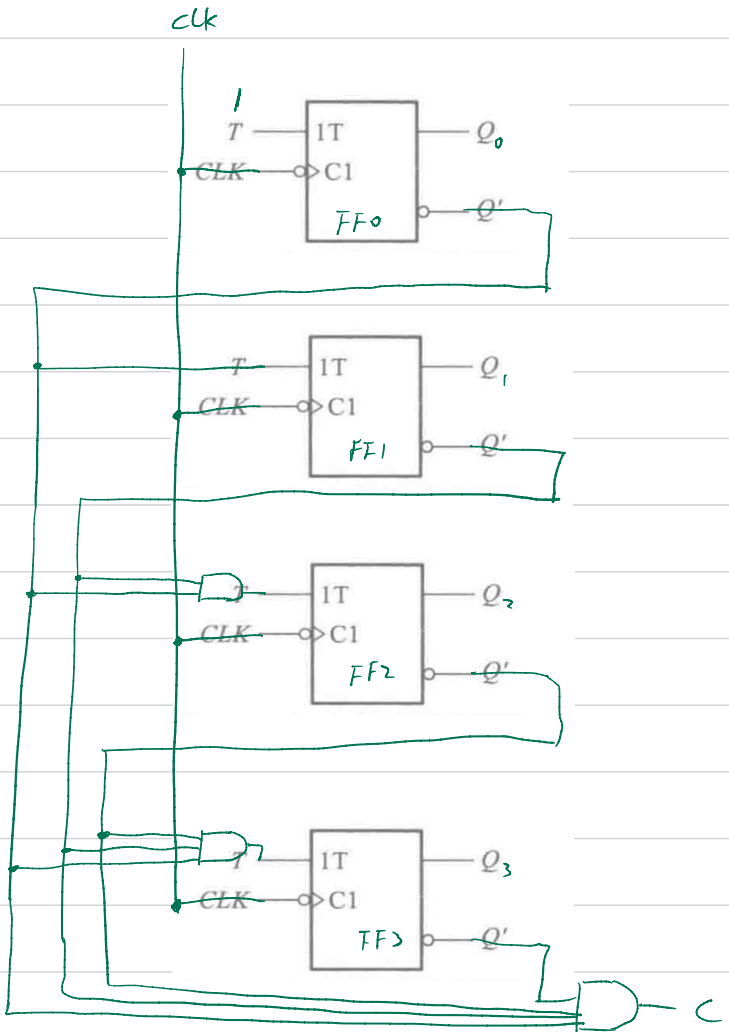
1 1 0 0

1 0 1 1

1 0 1 0

1 0 0 1

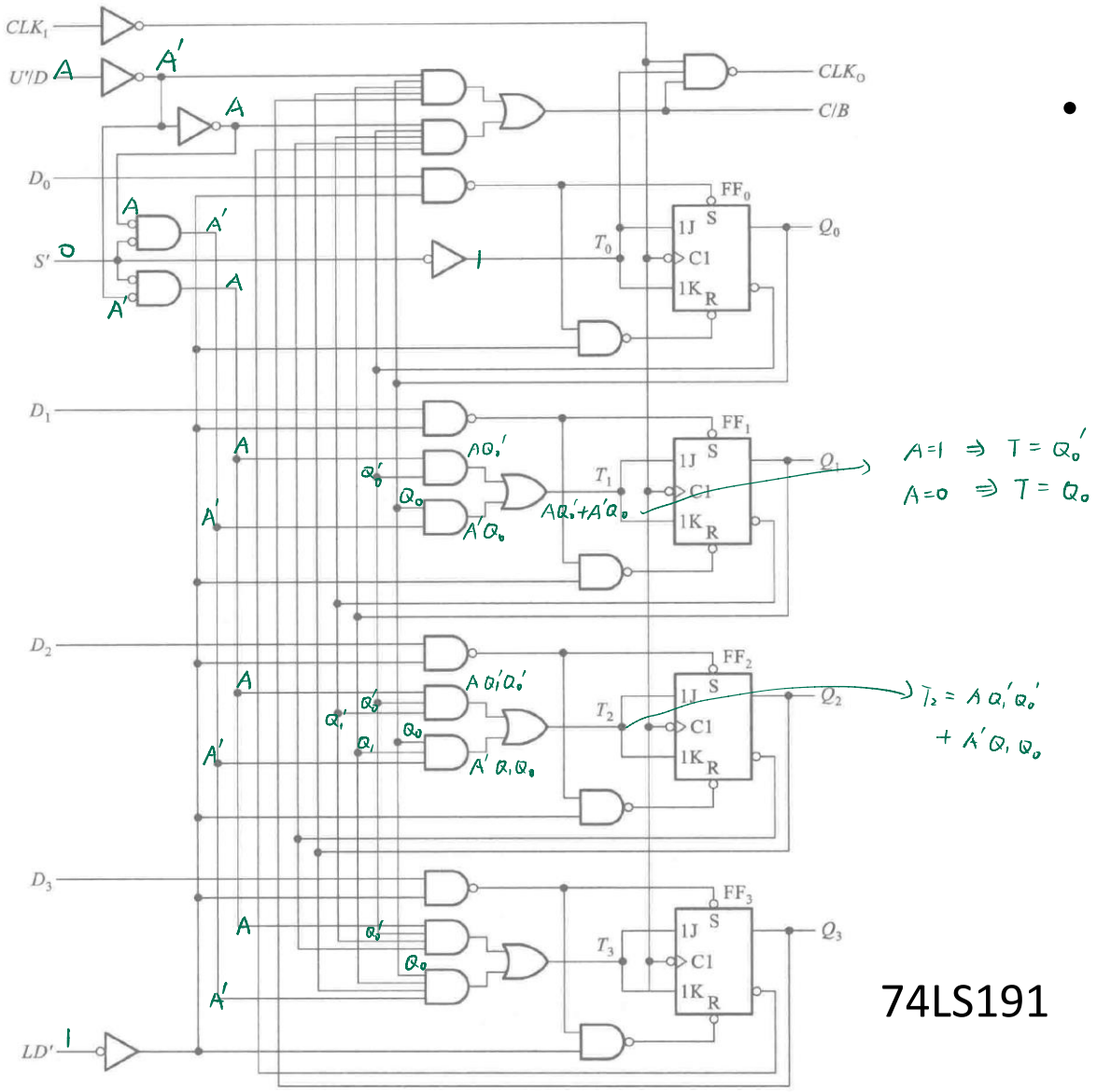
1 0 0 0



Up/Down Synchronous Binary Counter – 74161

CLK_1	S'	LD'	U'/D	工作状态
×	1	1	×	保持
×	×	0	×	预置数
↑	0	1	0	加法计数
↑	0	1	1	减法计数

Up/Down Synchronous Binary Counter – 74161



- C/B denotes the carry/borrow

Up/Down Synchronous Binary Counter – 74161

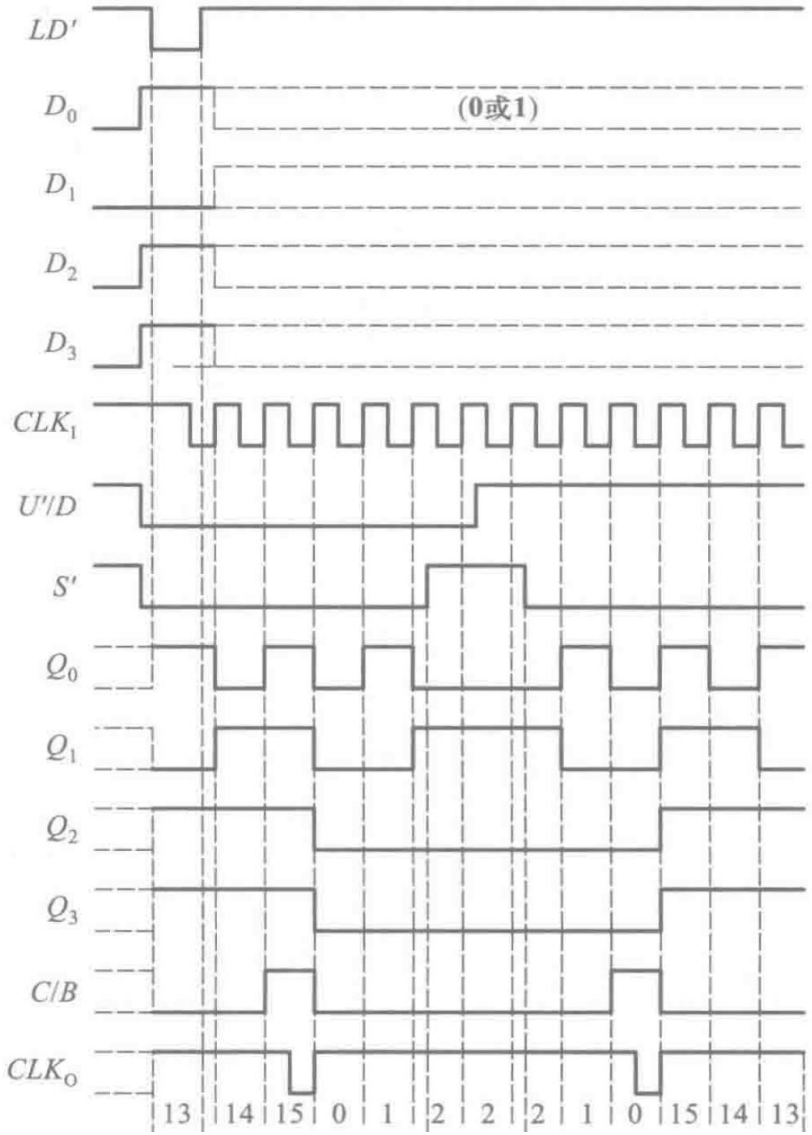
- When it does the counting

$$\begin{cases} T_0 = 1 \\ T_1 = (U'/D)'Q_0 + (U'/D)Q_0' \\ T_2 = (U'/D)'(Q_0Q_1) + (U'/D)(Q_0'Q_1') \\ T_3 = (U'/D)'(Q_0Q_1Q_2) + (U'/D)(Q_0'Q_1'Q_2') \end{cases}$$

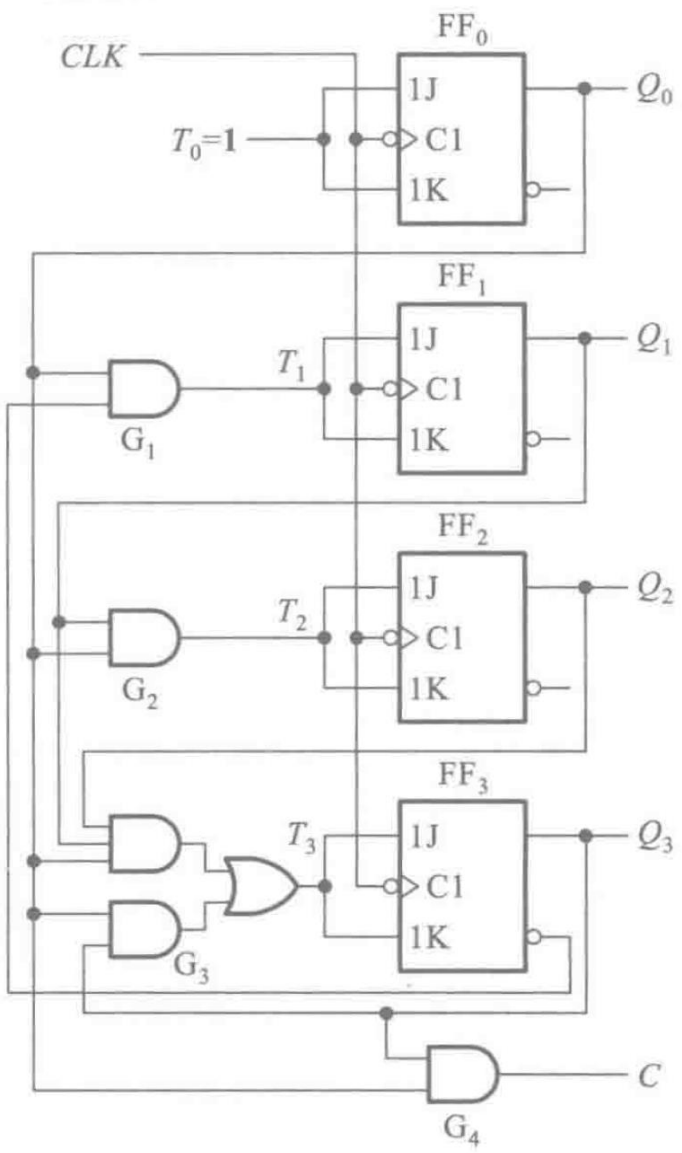
or

$$\begin{cases} T_i = (U'/D)' \prod_{j=0}^{i-1} Q_j + (U'/D) \prod_{j=0}^{i-1} Q_j' & (i = 1, 2, \cdots, n-1) \\ T_0 = 1 \end{cases}$$

Up/Down Synchronous Binary Counter – 74161



Up Synchronous Decimal Counter



驱动方程

$$\begin{cases} T_0 = 1 \\ T_1 = Q_0 Q_3' \\ T_2 = Q_0 Q_1 \\ T_3 = Q_0 Q_1 Q_2 + Q_0 Q_3 \end{cases}$$

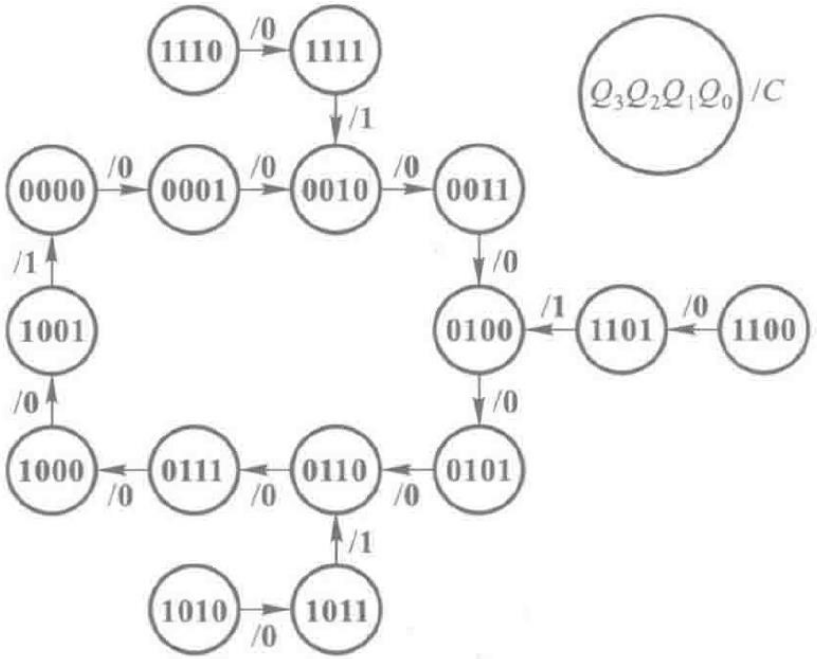
状态方程

$$\begin{cases} Q_0^* = Q_0' \\ Q_1^* = Q_0 Q_3' Q_1' + (Q_0 Q_3')' Q_1 \\ Q_2^* = Q_0 Q_1 Q_2' + (Q_0 Q_1)' Q_2 \\ Q_3^* = (Q_0 Q_1 Q_2 + Q_0 Q_3) Q_3' \\ \qquad + (Q_0 Q_1 Q_2 + Q_0 Q_3)' Q_3 \end{cases}$$

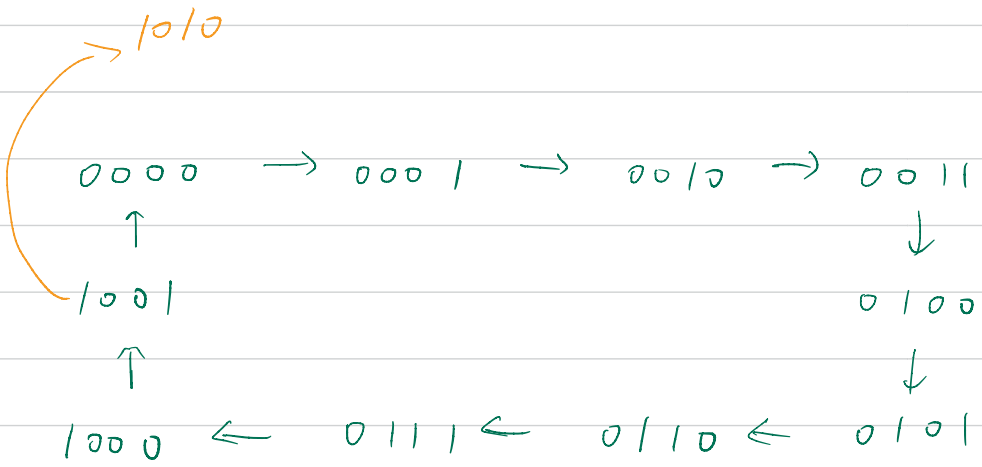
输出方程

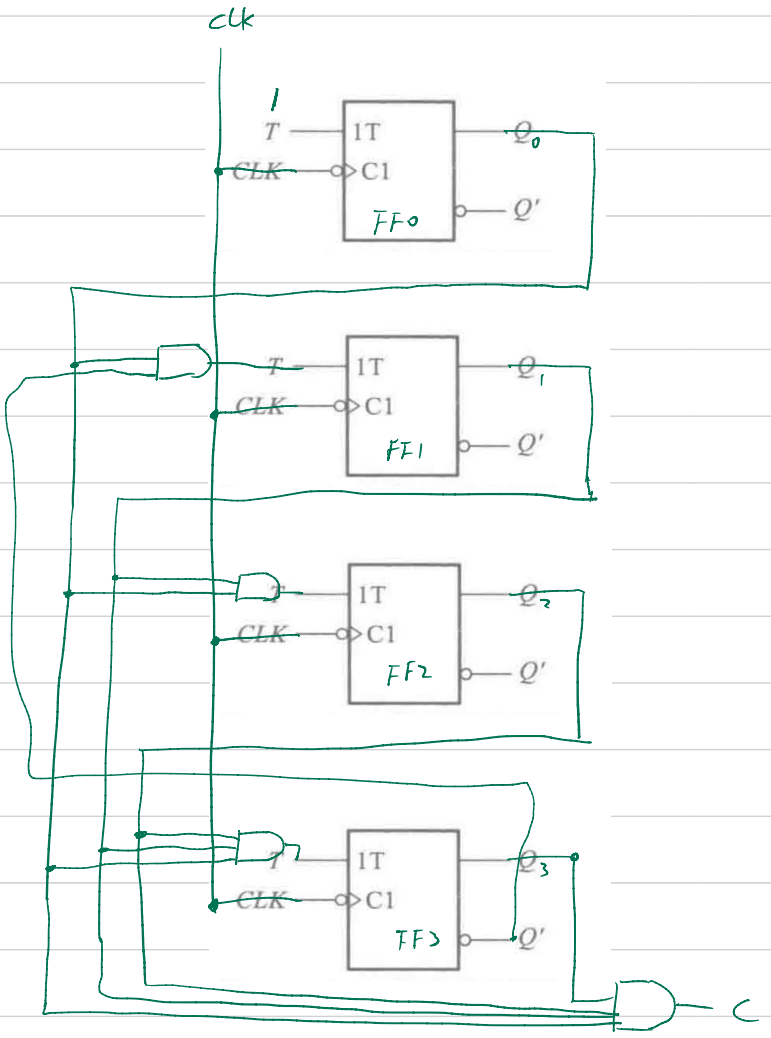
Up Synchronous Decimal Counter

计数顺序	电路状态				等效十进制数	输出 C
	Q_3	Q_2	Q_1	Q_0		
0	0	0	0	0	0	0
1	0	0	0	1	1	0
2	0	0	1	0	2	0
3	0	0	1	1	3	0
4	0	1	0	0	4	0
5	0	1	0	1	5	0
6	0	1	1	0	6	0
7	0	1	1	1	7	0
8	1	0	0	0	8	0
9	1	0	0	1	9	1
10	0	0	0	0	0	0
0	1	0	1	0	10	0
1	1	0	1	1	11	1
2	0	1	1	0	6	0
0	1	1	0	0	12	0
1	1	1	0	1	13	1
2	0	1	0	0	4	0
0	1	1	1	0	14	0
1	1	1	1	1	15	1
2	0	0	1	0	2	0

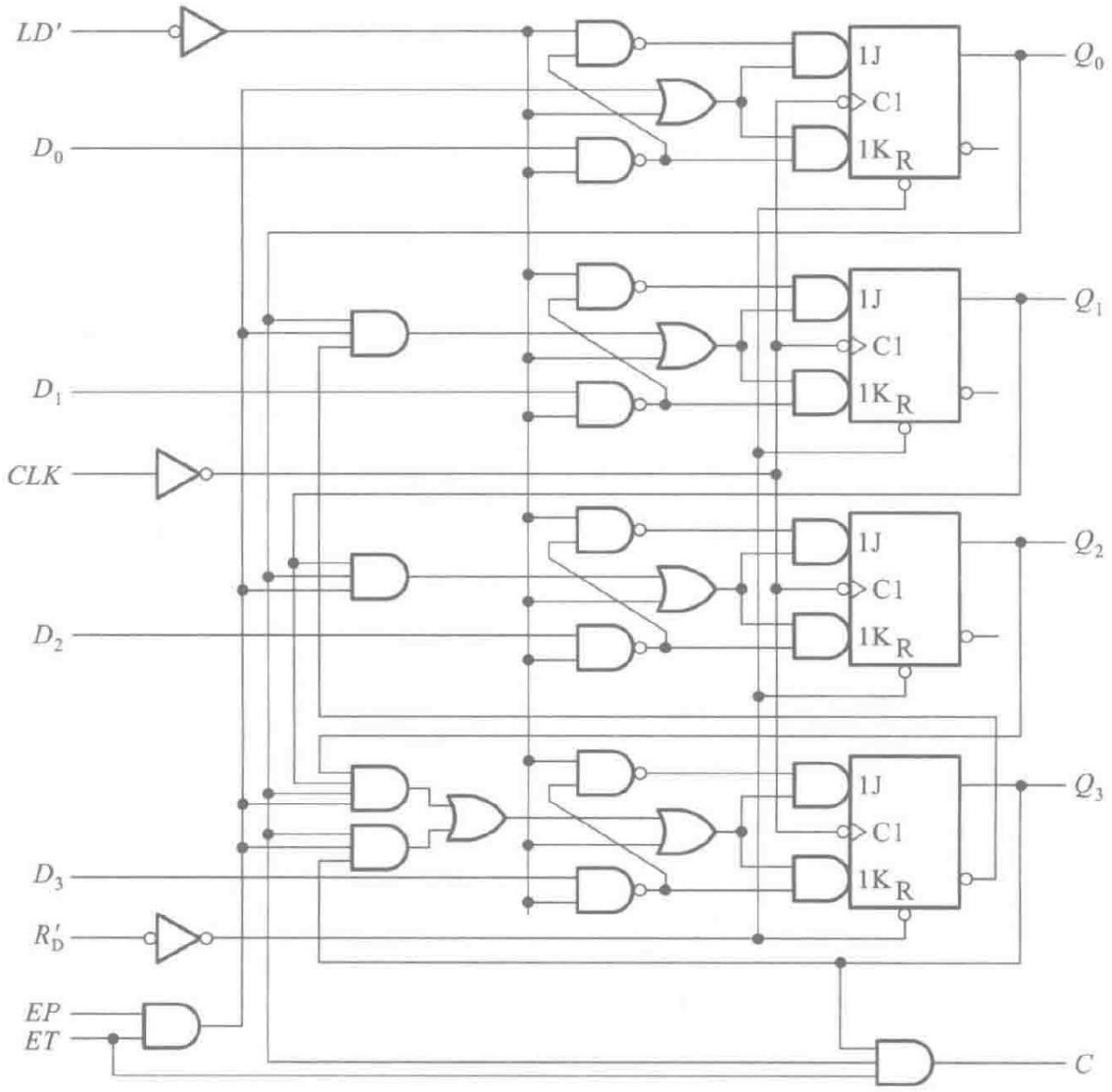


- 电路可以自启动


1010
0000
0001
0010
0011
0100
0101
0110
0111
1000
1001


clk
1
T
CLK
1T
C1
FF0
Q0
Q'
FF1
Q1
FF2
Q2
FF3
Q3
C

Up Synchronous Decimal Counter – 74160



CLK	R'_D	LD'	EP	ET	工作状态
×	0	×	×	×	置零
↑	1	0	×	×	预置数
×	1	1	0	1	保持
×	1	1	×	0	保持(但 $C=0$)
↑	1	1	1	1	计数

Reading materials

- Chapter 9 of Floyd book
- Section 6.3.2 of 阎石 book