模拟与数字电路

Analog and Digital Circuits

14_时序逻辑电路(2)

（数电P289-P302）

内容提纲

- 同步时序电路的设计
- 示例1 — 序列检测器
- 示例2 — 可逆六进制计数器

同步时序电路的设计

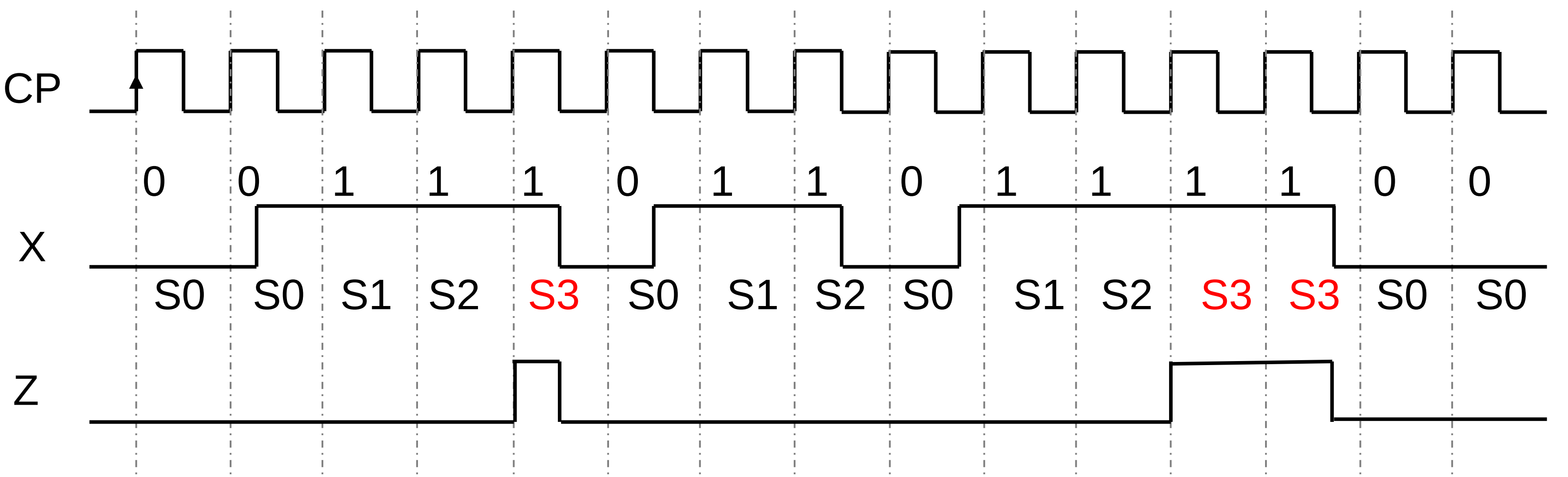
- **给定逻辑功能的要求，求相应的逻辑电路**
- **设计的一般步骤**
  - 建立原始状态图和原始状态表
  - 状态化简
  - 状态编码
  - 求状态方程和输出方程
  - 检查自启动
  - 选择触发器类型，求激励方程
  - 画出逻辑图

示例1—序列检测器

- 检测“111”序列，当连续输入三个“1”时，输出为“1”，否则输出为“0”

输入： 0 0 1 1 1 0 1 1 0 1 1 1 1 0 ......

输出： 0 0 0 0 1 0 0 0 0 0 0 1 1 0 ......

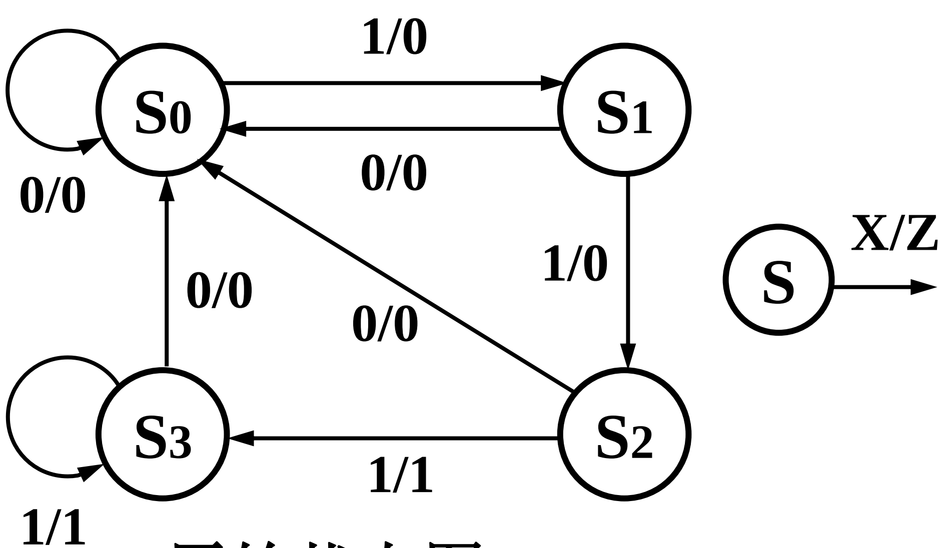


(1) 建立原始状态图和原始状态表

设输入、输出变量分别为X和Z，定义电路状态

S_0: 输入 “0”　　S_2: 连续输入 “11”

S_1: 输入 “1”　　S_3: 连续输入 “111”

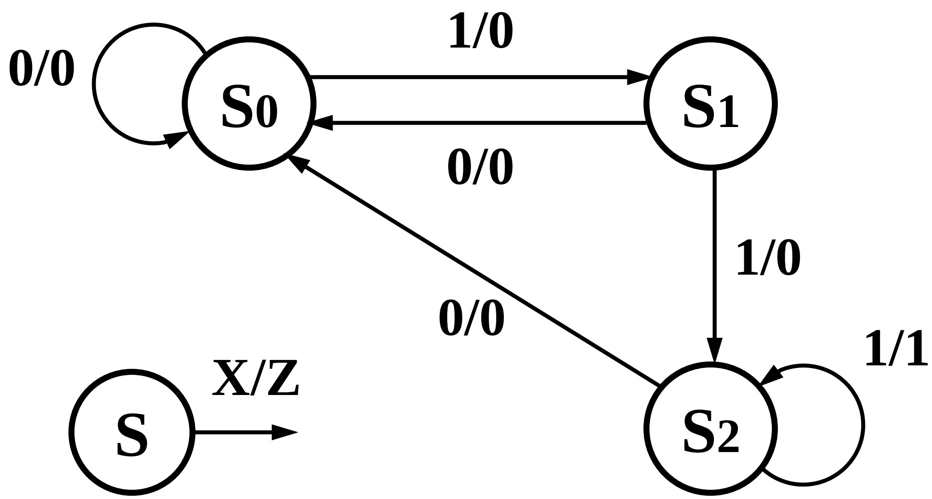


原始状态图

原始状态表

S^n	S^{n+1}/Z	
	X=0	X=1
S_0	$S_0/0$	$S_1/0$
S_1	$S_0/0$	$S_2/0$
S_2	$S_0/0$	$S_3/1$
S_3	$S_0/0$	$S_3/1$

(2) 状态化简



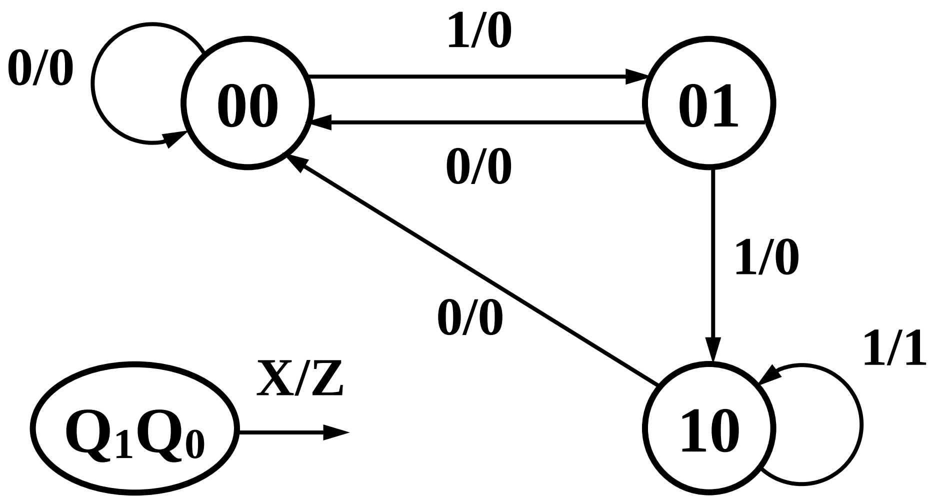
化简后状态图

化简后状态表

S^n	S^{n+1}/Z	
	X=0	X=1
S_0	$S_0/0$	$S_1/0$
S_1	$S_0/0$	$S_2/0$
S_2	$S_0/0$	$S_2/1$

（3）状态编码

采用顺序码，设S_0=00， S_1=01， S_2=10



状态图

状态表

$Q_1^nQ_0^n$	$Q_1^{n+1}Q_0^{n+1}/Z$	
	X=0	X=1
00	00/0	01/0
01	00/0	10/0
10	00/0	10/1
11	xx/x	xx/x

(4) 求出状态方程和输出方程

状态表

$Q_1^n Q_0^n$	$Q_1^{n+1}Q_0^{n+1}/Z$	
	X=0	X=1
00	00/0	01/0
01	00/0	10/0
10	00/0	10/1
11	xx/x	xx/x

Q_1^{n+1}

$Q_1^n Q_0^n$ \ X	0	1
00	0	0
01	0	1
11	×	×
10	0	1

Q_0^{n+1}

$Q_1^n Q_0^n$ \ X	0	1
00	0	1
01	0	0
11	×	×
10	0	0

Z

$Q_1^n Q_0^n$ \ X	0	1
00	0	0
01	0	0
11	×	×
10	0	1

$$Q_1^{n+1} = X(Q_0^n + Q_1^n)$$

$$Q_0^{n+1} = X\,\overline{Q_0^n}\,\overline{Q_1^n}$$

$$Z = XQ_1^n$$

(5) 检查自启动

$$Q_1^{n+1} = X(Q_0^n + Q_1^n)$$

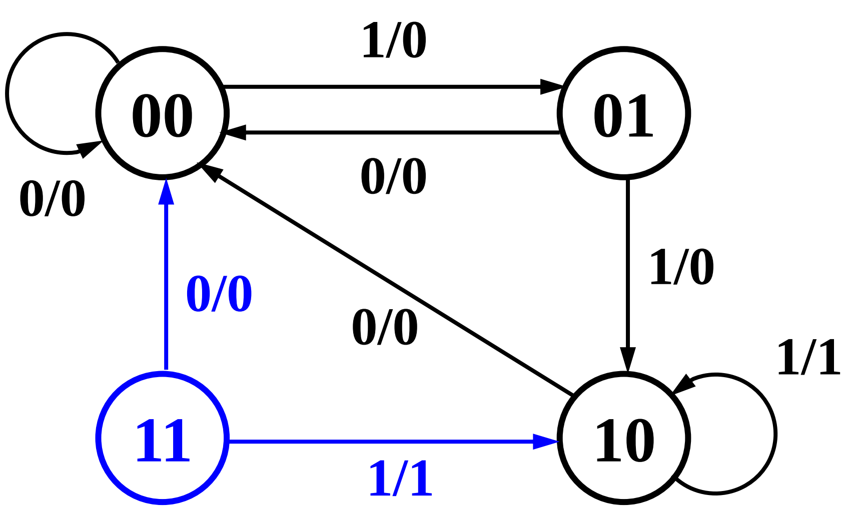
$$Q_0^{n+1} = X\,\overline{Q_0^n}\,\overline{Q_1^n}$$

$$Z = XQ_1^n$$

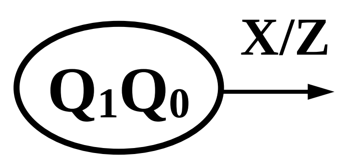
状态表

$Q_1^nQ_0^n$	$Q_1^{n+1}Q_0^{n+1}/Z$	
	X=0	X=1
00	00/0	01/0
01	00/0	10/0
10	00/0	10/1
11	00/0	10/1

具有自启动能力



状态图



(6) 选择触发器，求激励方程和输出方程

$$Q_1^{n+1} = X(Q_0^n + Q_1^n)$$

$$Q_0^{n+1} = X\,\overline{Q_0^n}\,\overline{Q_1^n}$$

$$Z = XQ_1^n$$

D触发器

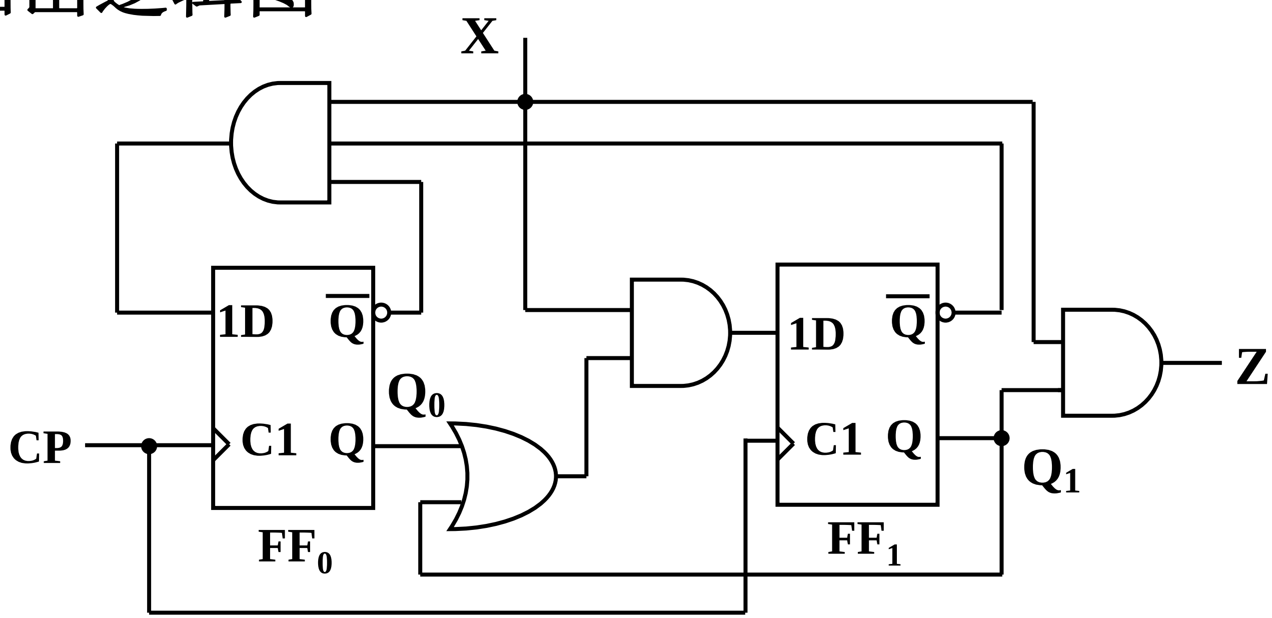
$$\xrightarrow{\quad Q^{n+1} = D \quad}$$

$$D_1 = X(Q_0 + Q_1)$$

$$D_0 = X\,\overline{Q_0}\,\overline{Q_1}$$

$$Z = XQ_1$$

(7) 画出逻辑图



设计的一般步骤 (1)

- **建立原始状态图和原始状态表**
  - 确定输入/输出变量、电路状态数
  - 定义输入/输出逻辑状态以及每个电路状态的含意
  - 按设计要求画出状态转换图，或列出状态转换表
- **状态化简**
  - 求出最简状态图(表)，以便用最少的触发器实现电路
  - 合并等价状态，消去多余状态
  - 等价状态：在相同的输入下有相同的输出，且转换到相同的次态

设计的一般步骤 (2)

- **状态编码：给每个状态赋予不同的二进制代码**
  - 根据状态数(M)，确定触发器的数目(n)
  - n的最小值满足： $2^{n-1} < M \le 2^n$, 即 $n = \lceil \log_2 M \rceil$
- **常用编码方法**
  - 顺序编码：状态从0至M-1编号，将编号用等值的二进制数码表示
  - 循环码：相邻代码只有1位不同
  - 独热(One-hot)码：n=M，任意状态的代码中只有1位为1，其余位都是为0

设计的一般步骤 (3)

- **求状态方程和输出方程**
  - 将状态代码代入状态表，得到状态变量和输出变量的真值表
  - 根据真值表，求出简化的状态函数和输出函数
- **检查自启动**
  - 画出全部状态图
  - 检查是否存在无效状态之间的循环
    - 若没有，称电路具有自启动(也称自校正)能力
    - 否则，重新定义无关项，以便消除无效循环，并求状态方程和输出方程

设计的一般步骤 (4)

- **选择触发器类型，求激励方程**
  - 根据选择触发器的特征方程和待实现的状态方程，求触发器的激励方程

例如，要实现状态方程： $Q_0^{n+1} = Q_0^n + Q_1^n$

- 选用D触发器：特征方程 $Q^{n+1} = D$ ⇨ $D_0 = Q_0^n + Q_1^n$
- 选用JK触发器：特征方程 $Q^{n+1} = J\overline{Q^n} + \overline{K}Q^n$

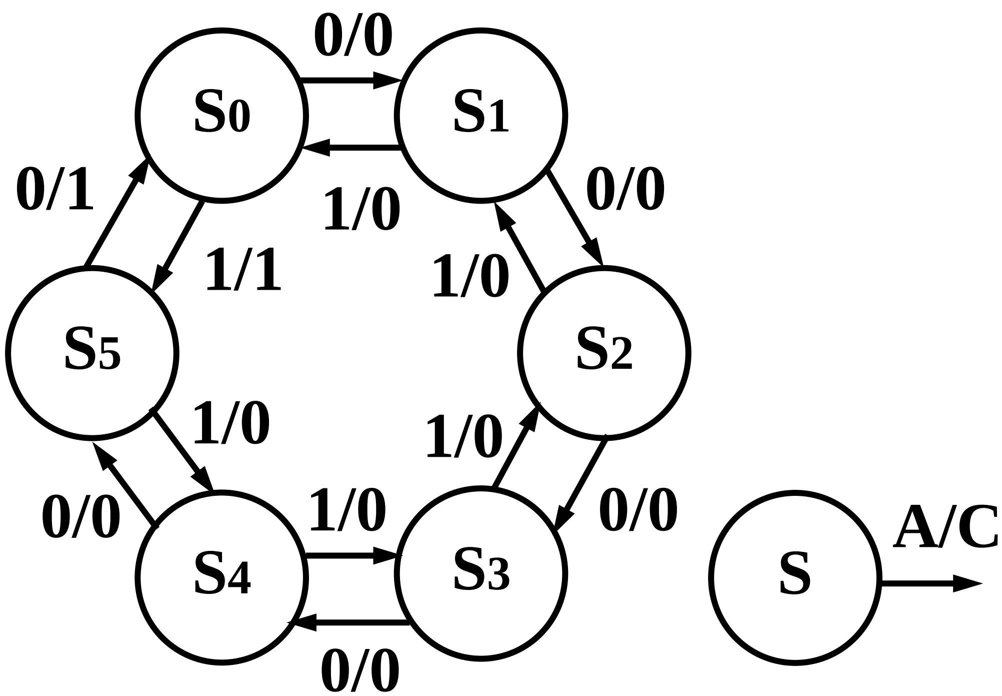
$$Q_0^{n+1} = Q_0^n + Q_1^n = Q_0^n + Q_1^n(Q_0^n + \overline{Q_0^n})$$

$$= Q_0^n + Q_1^n\overline{Q_0^n} \Rightarrow J = Q_1^n,\ K = 0$$

选用T触发器，如何?

示例2—可逆六进制计数器

- 建立状态图和状态表
  - 设A=0加法，A=1减法；C为进位或借位



状态图

状态表

S^n	S^{n+1}/C	
	A=0	A=1
S_0	$S_1/0$	$S_5/1$
S_1	$S_2/0$	$S_0/0$
S_2	$S_3/0$	$S_1/0$
S_3	$S_4/0$	$S_2/0$
S_4	$S_5/0$	$S_3/0$
S_5	$S_0/1$	$S_4/0$

- **状态编码**
  - 至少需要 $\lceil \log_2 6 \rceil = 3$ 位
  - 顺序码：000~101
  - 独热码需要6位
  - **循环码**（如左图）

Q_2 \ Q_1Q_0	00	01	11	10
0	S_0	S_1	x	S_5
1	x	S_2	S_3	S_4

Q_2 \ Q_1Q_0	00	01	11	10
0	S_0	S_1	S_2	S_3
1	S_5	x	x	S_4

状态表

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$	
	A=0	**A=1**
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	xxx/x	xxx/x
1 0 0	xxx/x	xxx/x

- 求状态方程和输出方程

Q^{+}_2

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	x	x
11	0	1	1	1
10	x	x	0	1

$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}$

Q^{+}_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	1	0	0
01	0	1	x	x
11	1	1	0	1
10	x	x	0	1

$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n}A$

Q^{+}_0

Q_2Q_1 \ Q_0A	00	01	11	10
00	1	0	0	1
01	0	0	x	x
11	0	1	1	0
10	x	x	1	1

$Q_0^{n+1}=Q_2^n A+\overline{Q_1^n}\,\overline{A}$

C

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	1	0	0
01	1	0	x	x
11	0	0	0	0
10	x	x	0	0

$C=\overline{Q_2^n}\,\overline{Q_0^n}\,(A\oplus Q_1^n)$

状态表

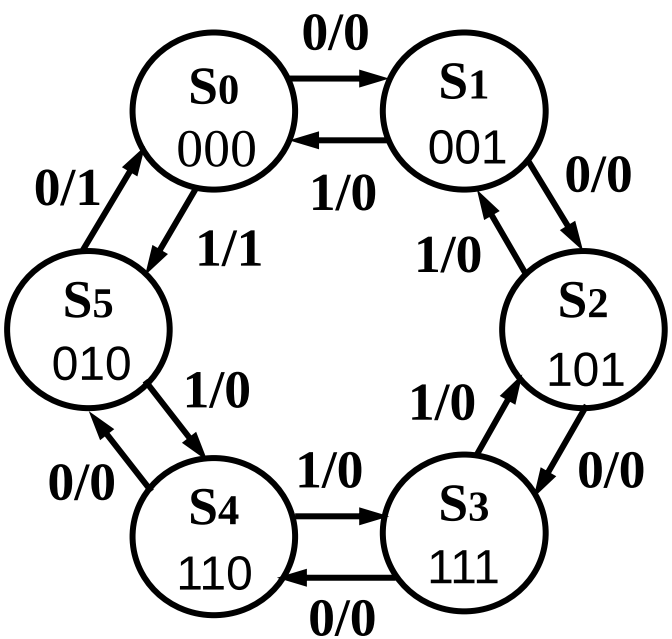
$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$	
	A=0	A=1
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	xxx/x	xxx/x
1 0 0	xxx/x	xxx/x

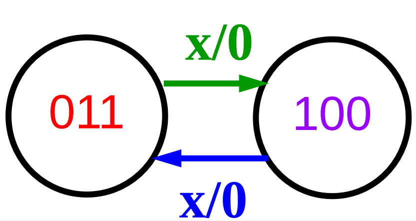
- 检查自启动

$$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A} \qquad C=\overline{Q_2^n}\,\overline{Q_0^n}\,(A \oplus Q_1^n)$$

$$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n} A$$

$$Q_0^{n+1}=Q_2^n A+\overline{Q_1^n}\,\overline{A}$$





不能自启动!

状态表

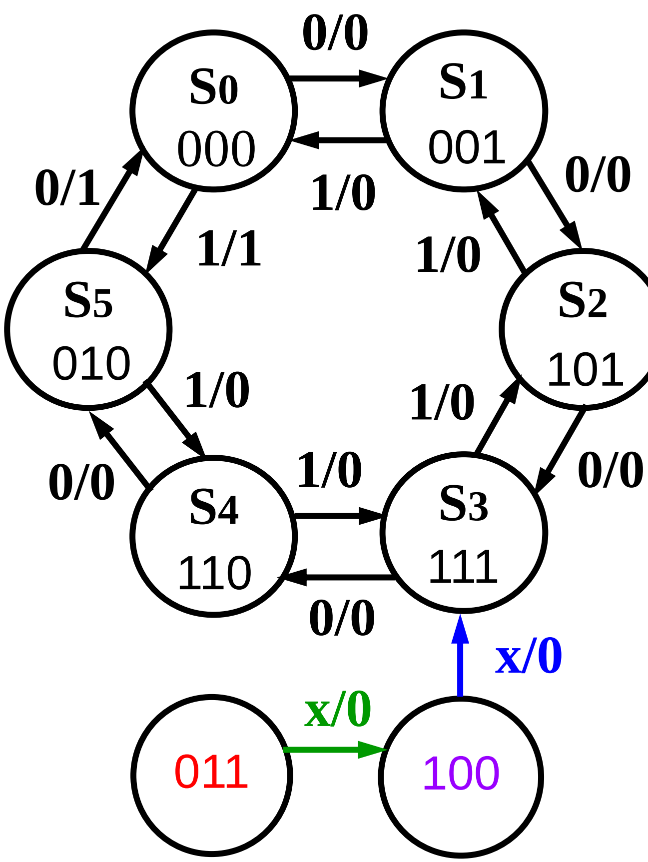
$Q_2^n Q_1^n Q_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$	
	A=0	A=1
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	**100**/0	**100**/0
1 0 0	**011**/0	**011**/0

- 修改设计，使其能够自启动

$$Q_2^{n+1}=Q_1^{n}A+Q_0^{n}\overline{A}$$

$$Q_1^{n+1}=Q_2^{n}\overline{A}+\overline{Q_0^{n}}A$$

$$Q_0^{n+1}=Q_2^{n}A+\overline{Q_1^{n}}\,\overline{A}$$



状态表

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$	
	A=0	A=1
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	100/x	100/x
1 0 0	$\boxed{1}$11/x	$\boxed{1}$11/x
~~1 0 0~~	~~011/x~~	~~011/x~~

- 修改设计，使其能够自启动

这里采用了011->100->111，
也可以采用100->011->101/110

$\cancel{Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}}$

$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0}^n A$

$Q_0^{n+1}=Q_2^n A+\overline{Q_1}^n \overline{A}$

Q^+_2 / Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	x	x
11	0	1	1	1
10	x	x	0	1

$\cancel{Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}}$

Q^+_2 / Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	1	1
11	0	1	1	1
10	1	1	0	1

$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}+Q_2^n \overline{Q_1}^n \overline{Q_0}^n$

状态表

$Q_2^n Q_1^n Q_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$ A=0	A=1
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	100/x	100/x
1 0 0	111/x	111/x
~~1 0 0~~	~~011/x~~	~~011/x~~

- 修改设计，使其能够自启动

$$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}+Q_2^n \overline{Q_1^n}\,\overline{Q_0^n}$$

$$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n} A$$ 保持不变

$$Q_0^{n+1}=Q_2^n A+\overline{Q_1^n}\,\overline{A}$$

Q^+_1 Q_0A

Q_2Q_1	00	01	11	10
00	0	1	0	0
01	0	1	x	x
11	1	1	0	1
10	x	x	0	1

Q^+_1 Q_0A

Q_2Q_1	00	01	11	10
00	0	1	0	0
01	0	1	**0**	**0**
11	1	1	0	1
10	**1**	**1**	0	1

$$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n} A$$

状态表

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$	
	A=0	A=1
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	**100**/x	**100**/x
1 0 0	$\boxed{1}$**11**/x	$\boxed{1}$**11**/x
~~**1 0 0**~~	~~**011**/x~~	~~**011**/x~~

- 修改设计，使其能够自启动

$$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}+Q_2^n \overline{Q_1^n}\,\overline{Q_0^n}$$

$$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n} A$$ 保持不变

$$Q_0^{n+1}=Q_2^n A+\overline{Q_1^n}\,\overline{A}$$ 保持不变

Q^+_0 $Q_0 A$

Q_2Q_1	00	01	11	10
00	1	0	0	1
01	0	0	x	x
11	0	1	1	0
10	x	x	1	1

Q^+_0 $Q_0 A$

Q_2Q_1	00	01	11	10
00	1	0	0	1
01	0	0	0	0
11	0	1	1	0
10	1	1	1	1

$$Q_0^{n+1}=Q_2^n A+\overline{Q_1^n}\,\overline{A}$$

状态表

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}/C$	
	A=0	A=1
0 0 0	001/0	010/1
0 0 1	101/0	000/0
1 0 1	111/0	001/0
1 1 1	110/0	101/0
1 1 0	010/0	111/0
0 1 0	000/1	110/0
0 1 1	100/x	100/x
1 0 0	111/x	111/x
~~1 0 0~~	~~011/x~~	~~011/x~~

- **求出对应的输出**

C

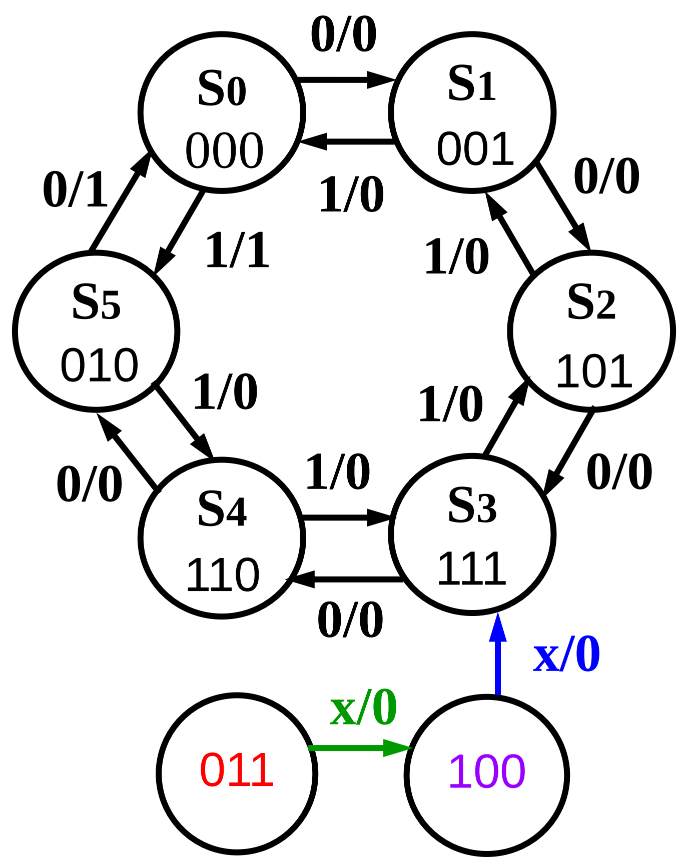
Q_2Q_1 \ Q_0A	00	01	11	10
00	0	1	0	0
01	1	0	x	x
11	0	0	0	0
10	x	x	0	0

$$C=\overline{Q_2}^n\,\overline{Q_0}^n\,(A\oplus Q_1^n)$$

或(不严格条件下)：

$$C=\overline{Q_2}^n\,Q_1^n\,\overline{A}+Q_2^n\,\overline{Q_0}^n A$$

在011和100两种状态下的C输出虽然已经固定，但是我们不用太过关心，因为这两个状态最迟在上电后两个时钟周期就进入到正常S_0-S_5中



- 选用JK触发器，求出激励方程

$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}+Q_2^n \overline{Q_1^n}\,\overline{Q_0^n}$

$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n} A$

$Q_0^{n+1}=Q_2^n A+\overline{Q_1^n}\,\overline{A}$

JK触发器特征方程：

$Q^{n+1} = J\,\overline{Q^n} + \overline{K}\,Q^n$

$$Q_0^{n+1} = Q_2^n A + \overline{Q_1^n}\,\overline{A}$$

$$= (Q_2^n A+\overline{Q_1^n}\,\overline{A})\,\overline{Q_0^n} + (Q_2^n A+\overline{Q_1^n}\,\overline{A})\,Q_0^n$$

$\Rightarrow$ $J_0 = Q_2^n A+\overline{Q_1^n}\,\overline{A}$ $\quad K_0 = \overline{J_0}$

$Q_1^{n+1}=Q_2^n \overline{A}+\overline{Q_0^n} A$ $\Rightarrow$ $J_1 = Q_2^n \overline{A}+\overline{Q_0^n} A$ $\quad K_1 = \overline{J_1}$

$Q_2^{n+1}=Q_1^n A+Q_0^n \overline{A}+Q_2^n \overline{Q_1^n}\,\overline{Q_0^n}$

$\Rightarrow$ $J_2 = Q_1^n A+Q_0^n \overline{A}$ $\quad K_2 = \overline{J_2+\overline{Q_1^n}\,\overline{Q_0^n}}$

- 画出逻辑图（略）

求激励方程的另一种方法

- 利用激励表和状态表求各触发器的激励方程

D触发器激励表

Q^n	Q^{n+1}	D
0	0	0
0	1	1
1	0	0
1	1	1

JK触发器激励表

Q^n	Q^{n+1}	J	K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

T触发器激励表

Q^n	Q^{n+1}	T
0	0	0
0	1	1
1	0	1
1	1	0

RS触发器激励表

Q^n	Q^{n+1}	R	S
0	0	0	x
0	1	1	0
1	0	0	1
1	1	x	0

激励表和状态表求激励方程

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$	
	A=0	A=1
000	001	010
001	101	000
101	101	001
111	110	101
110	010	111
010	000	110
011	100	100
100	111	111

状态表

JK触发器激励表

Q^n	Q^{n+1}	J	K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

由Q的变化情况，结合激励表，推导出各自的变化条件

画出卡诺图求JK（J_2K_2）

条件填入$Q_2^n\ Q_1^n\ Q_0^n\ A$

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$J_2K_2\ J_1K_1\ J_0K_0$	
	A=0	A=1	A=0	A=1
000	001	010	0x0x1x	0x1x0x
001	101	000	1x0xx0	0x0xx1
101	101	001	x01xx0	x10xx0
111	110	101	x0x0x1	x0x1x0
110	010	111	x1x00x	x0x01x
010	000	110	0xx10x	1xx00x
011	100	100	1xx1x1	1xx1x1
100	111	111	x01x1x	x01x1x

J_2

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	1	1
11	x	x	x	x
10	x	x	x	x

K_2

Q_2Q_1 \ Q_0A	00	01	11	10
00	x	x	x	x
01	x	x	x	x
11	1	0	0	0
10	0	0	1	0

$$J_2 = Q_1^n A + Q_0^n \overline{A} \qquad K_2 = Q_1^n \overline{Q_0^n}\,\overline{A} + \overline{Q_1^n}\, Q_0^n A$$

和第一种方法推导的结果做对比：

J_2

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	1	1
11	0	1	1	1
10	0	0	0	1

K_2

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	1	0
01	1	0	0	0
11	1	0	0	0
10	0	0	1	0

达到功能一致，
表达式一致

$$J_2 = Q_1^n A + Q_0^n \overline{A} \qquad K_2 = \overline{J_2 + \overline{Q_1^n}\,\overline{Q_0^n}}$$

画出卡诺图求JK（J_1K_1）

条件填入$Q_2^n\ Q_1^n\ Q_0^n\ A$

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$J_2K_2\ J_1K_1\ J_0K_0$	
	A=0	A=1	A=0	A=1
000	001	010	0x0x1x	0x1x0x
001	101	000	1x0xx0	0x0xx1
101	101	001	x01xx0	x10xx0
111	110	101	x0x0x1	x0x1x0
110	010	111	x1x00x	x0x01x
010	000	110	0xx10x	1xx00x
011	100	100	1xx1x1	1xx1x1
100	111	111	x01x1x	x01x1x

J_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	1	0	0
01	x	x	x	x
11	x	x	x	x
10	1	1	0	1

K_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	x	x	x	x
01	1	0	1	1
11	0	0	1	0
10	x	x	x	x

$J_1 = Q_2^n\,\overline{A} + \overline{Q_0}^n A$ $\qquad$ $K_1 = \overline{Q_2}^n\,\overline{A} + Q_0^n A$

和第一种方法推导的结果做对比：

J_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	1	0	0
01	0	1	0	0
11	1	1	0	1
10	1	1	0	1

K_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	1	0	1	1
01	1	0	1	1
11	0	0	1	0
10	0	0	1	0

$J_1 = Q_2^n\,\overline{A} + \overline{Q_0}^n A$ $\qquad$ $K_1 = \overline{J_1}$

达到功能一致，
表达式一致

画出卡诺图求JK（J_0K_0）

条件填入$Q_2^n\ Q_1^n\ Q_0^n\ A$

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$J_2K_2\ J_1K_1\ J_0K_0$	
	A=0	A=1	A=0	A=1
000	001	010	0x0x1x	0x1x0x
001	101	000	1x0xx0	0x0xx1
101	101	001	x01xx0	x10xx0
111	110	101	x0x0x1	x0x1x0
110	010	111	x1x00x	x0x01x
010	000	110	0xx10x	1xx00x
011	100	100	1xx1x1	1xx1x1
100	111	111	x01x1x	x01x1x

J_0

Q_2Q_1 \ Q_0A	00	01	11	10
00	1	0	x	x
01	0	0	x	x
11	0	1	x	x
10	1	1	x	x

K_0

Q_2Q_1 \ Q_0A	00	01	11	10
00	x	x	1	0
01	x	x	1	1
11	x	x	0	1
10	x	x	0	0

$$J_0 = Q_2^n A + \overline{Q_1}^n \overline{A} \qquad K_0 = Q_1^n \overline{A} + \overline{Q_2}^n A$$

和第一种方法推导的结果做对比：

J_0

Q_2Q_1 \ Q_0A	00	01	11	10
00	1	0	x	x
01	0	0	x	x
11	0	1	x	x
10	1	1	x	x

K_0

Q_2Q_1 \ Q_0A	00	01	11	10
00	x	x	1	0
01	x	x	1	1
11	x	x	0	1
10	x	x	0	0

达到功能一致，
表达式一致

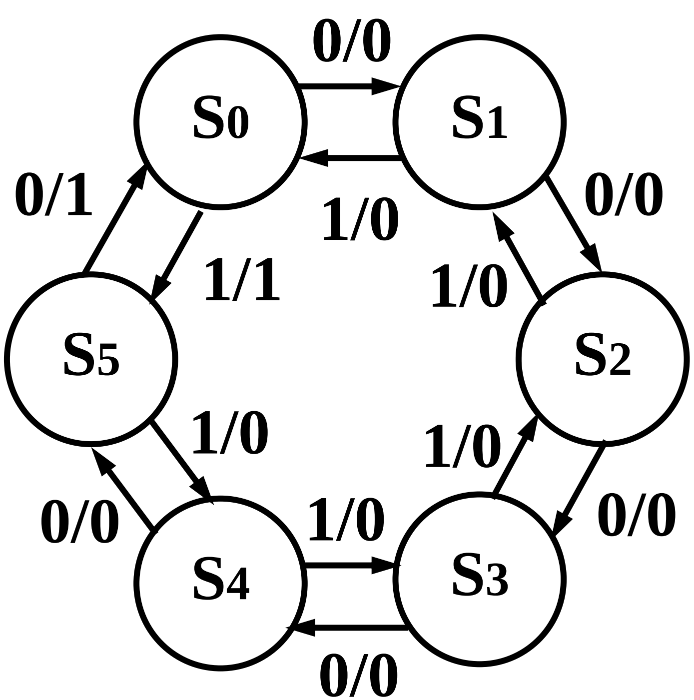
$$J_0 = Q_2^n A + \overline{Q_1}^n \overline{A} \qquad K_0 = \overline{J_0}$$

示例2—可逆六进制计数器

T触发器激励表

Q^n	Q^{n+1}	T
0	0	0
0	1	1
1	0	1
1	1	0

- 状态编码
  - 二进制码：000 ~ 101
  - T触发器实现



状态图

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$T_2T_1T_0$	
	A=0	A=1	A=0	A=1
S0:000	001	101	001	101
S1:001	010	000	011	001
S2:010	011	001	001	011
S3:011	100	010	111	001
S4:100	101	011	001	111
S5:101	000	100	101	001
S6:110	xxx	xxx	xxx	xxx
S7:111	xxx	xxx	xxx	xxx

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$T_2T_1T_0$	
	A=0	A=1	A=0	A=1
S0:000	001	101	001	101
S1:001	010	000	011	001
S2:010	011	001	001	011
S3:011	100	010	111	001
S4:100	101	011	001	111
S5:101	000	100	101	001
S6:110	xxx	xxx	xxx	xxx
S7:111	xxx	xxx	xxx	xxx

画出卡诺图求T

T_2

Q_2Q_1 \ Q_0A	00	01	11	10	
00	0	1	0	0	
01	0	0	0	1	
11	x	x	x	x	→ 1
10	0	1	0	1	

T_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	0	1
11	x	x → 1	x	x
10	0	1	0	0

T_1

Q_2Q_1 \ Q_0A	00	01	11	10	
00	1	1	1	1	
01	1	1	1	1	
11	x	x	x	x	→ 1
10	1	1	1	1	

$T_2 = \overline{Q_1}^n\overline{Q_0}^nA+(Q_2^n+Q_1^n)\overline{A}$

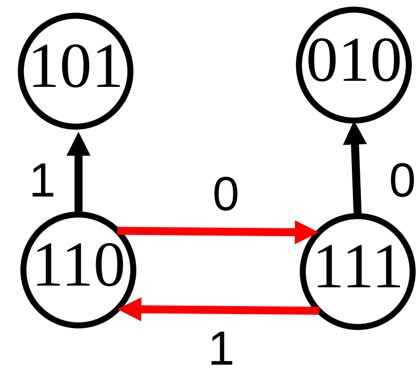
$T_1 = \overline{Q_2}^n\overline{Q_0}^nA+(Q_2^n+Q_1^n)\overline{Q_0}^nA$

$T_0 = 1$

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$T_2T_1T_0$	
	A=0	A=1	A=0	A=1
S0:000	001	101	001	101
S1:001	010	000	011	001
S2:010	011	001	001	011
S3:011	100	010	111	001
S4:100	101	011	001	111
S5:101	000	100	101	001
S6:110	111	101	001	011
S7:111	010	110	101	001

验证自启动：

先写出$T_2T_1T_0$，（圈中x->1,否则x->0）
再根据$Q_2^nQ_1^nQ_0^n$求出$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$
可能上电后：



T_2

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	1	0	0
01	0	0	0	1
11	x	x	x	x→1
10	0	1	0	1

T_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	0	1
11	x	x→1	x	x
10	0	1	0	0

T_0

Q_2Q_1 \ Q_0A	00	01	11	10
00	1	1	1	1
01	1	1	1	1
11	x	x	x	x→1
10	1	1	1	1

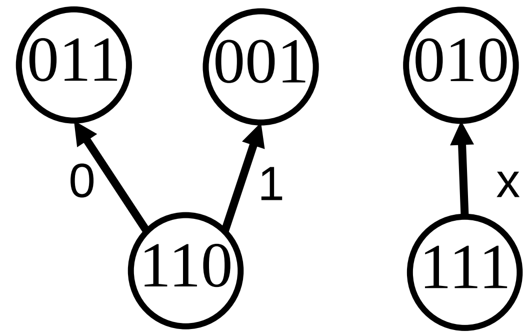
$T_2=\overline{Q_1}^n\overline{Q_0}^nA+(Q_2^n+Q_1^n)\overline{A}$　　$T_1=\overline{Q_2}^nQ_0^n\overline{A}+(Q_2^n+Q_1^n)\overline{Q_0}^nA$　　$T_0=1$

$Q_2^nQ_1^nQ_0^n$	$Q_2^{n+1}Q_1^{n+1}Q_0^{n+1}$		$T_2T_1T_0$	
	A=0	A=1	A=0	A=1
S0:000	001	101	001	101
S1:001	010	000	011	001
S2:010	011	001	001	011
S3:011	100	010	111	001
S4:100	101	011	001	111
S5:101	000	100	101	001
S6:110	011	001	101	111
S7:111	010	010	101	101

验证自启动：

扩展T_2　$T_2 = \overline{Q_1^n}\,\overline{Q_0^n}A + (Q_2^n+Q_1^n)\overline{A}$
$+Q_2^nQ_1^n$

求出输出C，画出逻辑图（略）



T_2

Q_2Q_1 \ Q_0A	00	01	11	10	
00	0	1	0	0	
01	0	0	0	1	
11	x	x	x	x	→ 1
10	0	1	0	1	

T_1

Q_2Q_1 \ Q_0A	00	01	11	10
00	0	0	0	1
01	0	1	0	1
11	x	x → 1	x	x
10	0	1	0	0

T_0

Q_2Q_1 \ Q_0A	00	01	11	10	
00	1	1	1	1	
01	1	1	1	1	
11	x	x	x	x	→ 1
10	1	1	1	1	

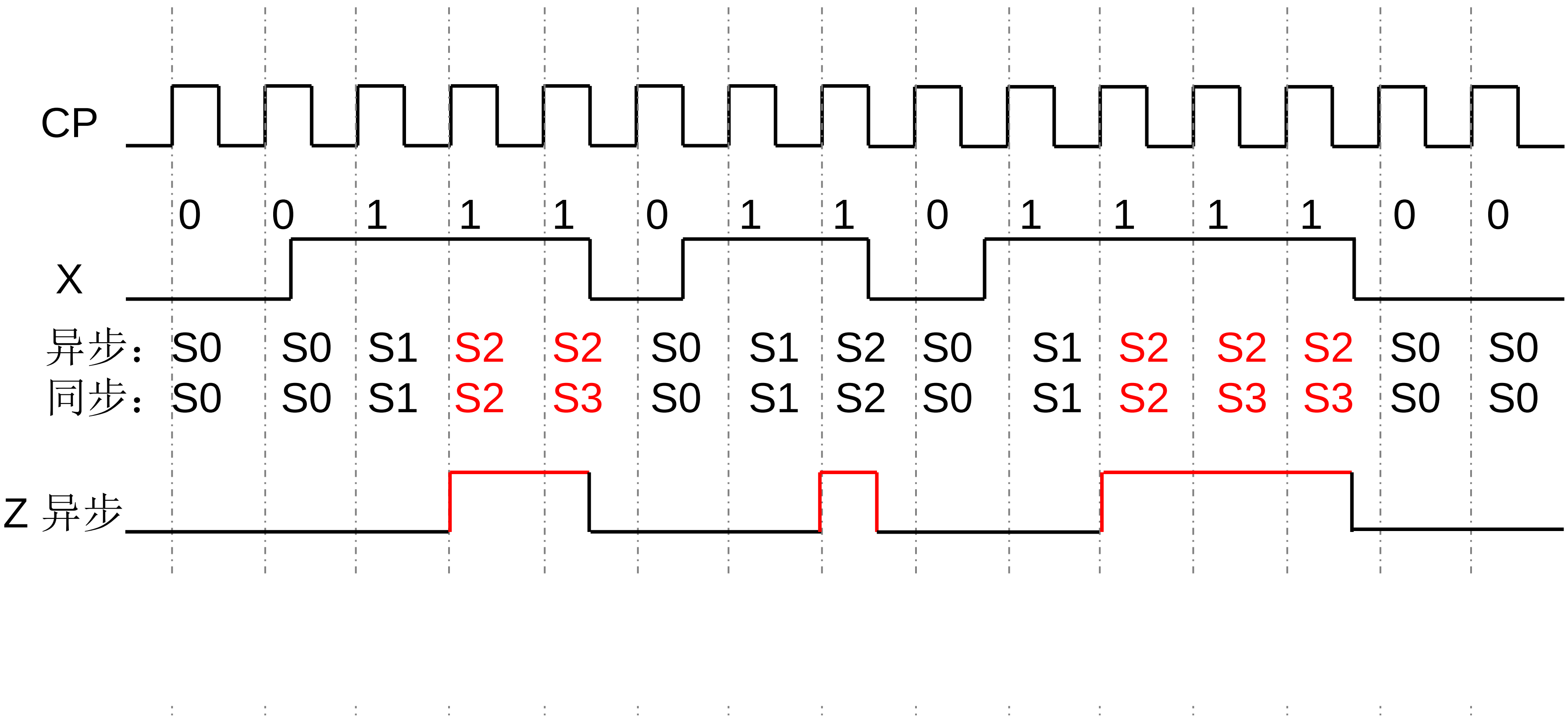
$T_1 = \overline{Q_2^n}\,\overline{Q_0^n}A + (Q_2^n+Q_1^n)\,\overline{Q_0^n}\,A$　　$T_0 = 1$

作业

- 电子技术基础-数字部分
- **P355-356（同步逻辑设计):**
  - 6.3.2，6.3.4，6.3.5，6.3.6，6.3.7

The End

彩蛋时间：Mealy实现 vs Moore实现



按Moore型时序电路分析

（1）建立原始状态图和原始状态表

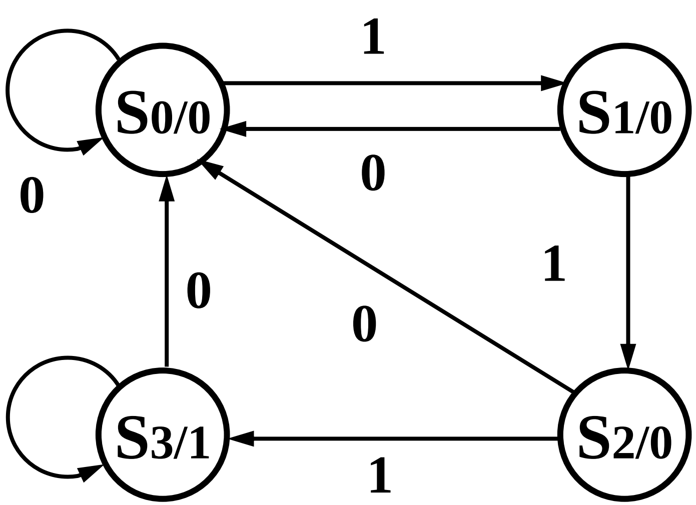
设输入、输出变量分别为X和Z，定义电路状态

S_0: 输入 “0”

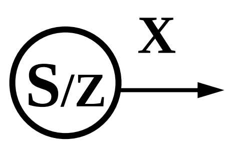
S_1: 输入 “1”

S_2: 连续输入 “11”

S_3: 连续输入 “111”



原始状态图

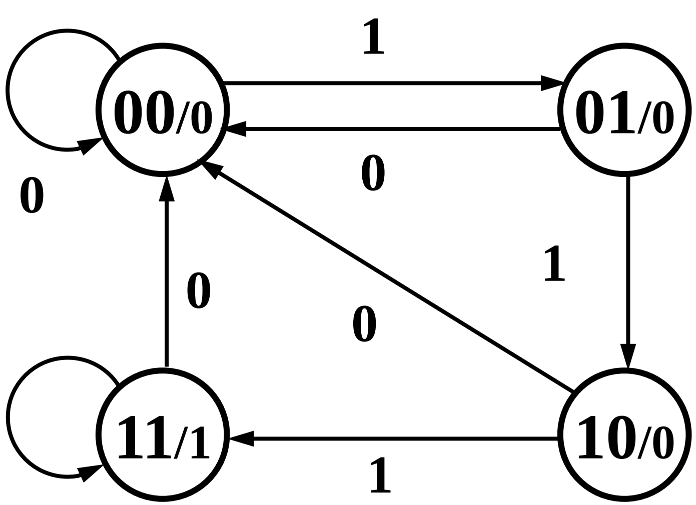


原始状态表

S^n	S^{n+1}		Z
	X=0	X=1	
S_0	S_0	S_1	0
S_1	S_0	S_2	0
S_2	S_0	S_3	0
S_3	S_0	S_3	1

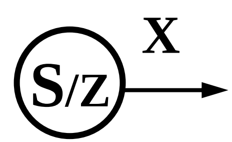
（2）状态化简：已经是最简

（3）状态编码：顺序码



状态图

状态表



S^n	S^{n+1}		Z
	X=0	X=1	
00	00	01	0
01	00	10	0
10	00	11	0
11	00	11	1

(4）求出状态方程和输出方程

S=[Q1,Q0]

状态表

S^n	S^{n+1}		Z
	X=0	X=1	
00	00	01	0
01	00	10	0
10	00	11	0
11	00	11	1

Q_1^{n+1}

$Q_1^nQ_0^n$ \ X	0	1
00	0	0
01	0	1
11	0	1
10	0	1

Q_0^{n+1}

$Q_1^nQ_0^n$ \ X	0	1
00	0	1
01	0	0
11	0	1
10	0	1

Z

$Q_1^nQ_0^n$	
00	0
01	0
11	1
10	0

$$Q_1^{n+1} = X(Q_0^n + Q_1^n)$$

$$Q_0^{n+1} = X(\overline{Q_0^n} + Q_1^n)$$

$$Z = Q_0^n Q_1^n$$

(6) 选择触发器，求激励方程

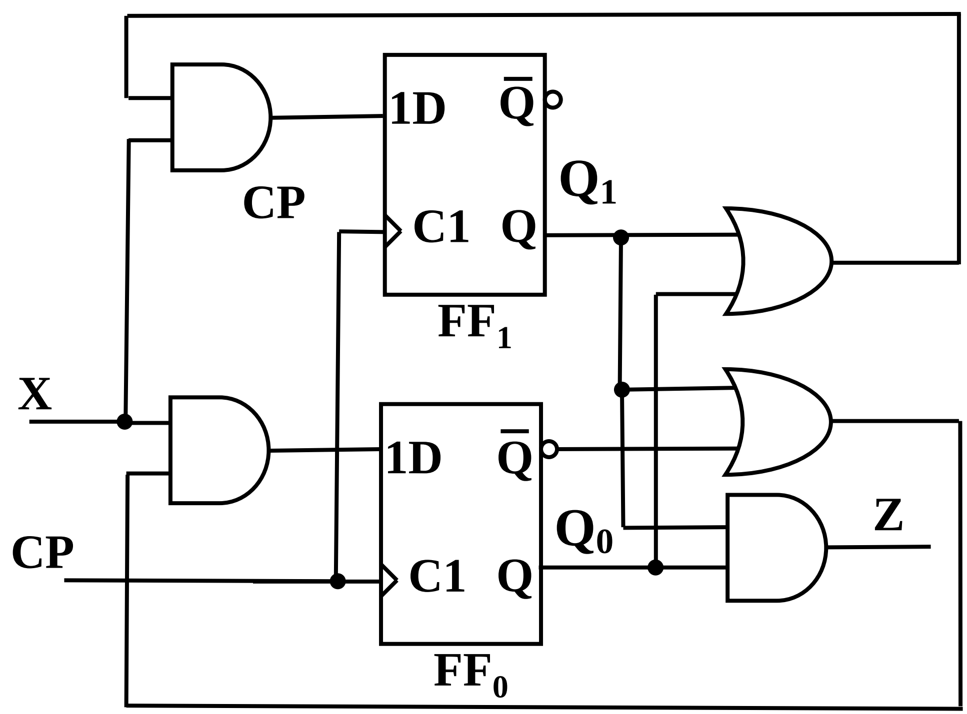
$$Q_1^{n+1} = X(Q_0^n + Q_1^n)$$
$$Q_0^{n+1} = X(\overline{Q_0^n} + Q_1^n)$$
$$Z = Q_0Q_1$$

D触发器

$Q^{n+1} = D$

$$D_1 = X(Q_0 + Q_1)$$
$$D_0 = X(\overline{Q_0} + Q_1)$$
$$Z = Q_0Q_1$$

(7) 画出逻辑图



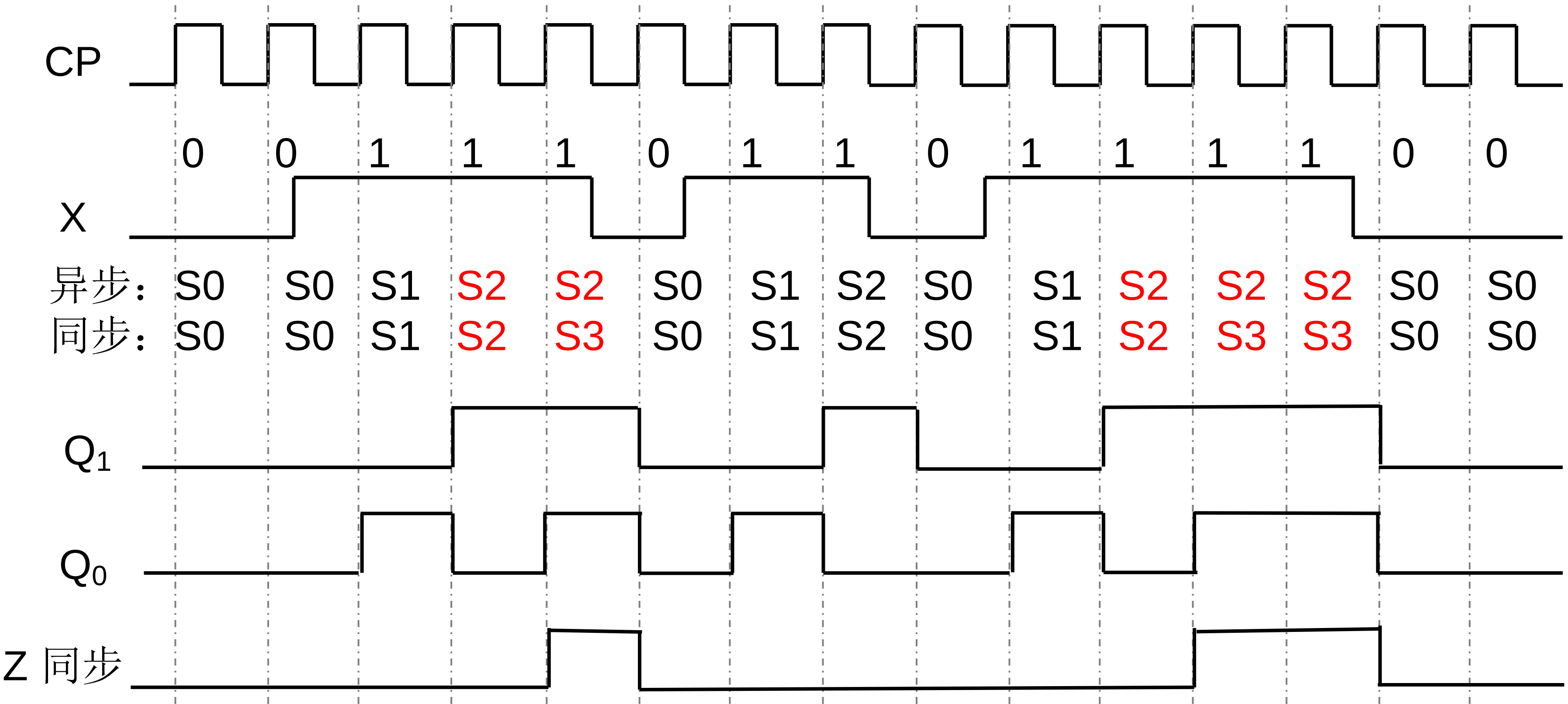
检查时序图

$$Q_1^{n+1} = X(Q_0^n + Q_1^n)$$

$$Q_0^{n+1} = X(\overline{Q_0^n} + Q_1^n)$$

$$Z = Q_0Q_1$$

无误！



- Moore型，仅在时钟边沿考察
- 输出与时钟严格同步，至少持续一个周期，~~不会产生“毛刺”~~