第 6 章 时序逻辑电路

Sequential Logic Circuits

§ 6.1 概述 Introduction

时序电路

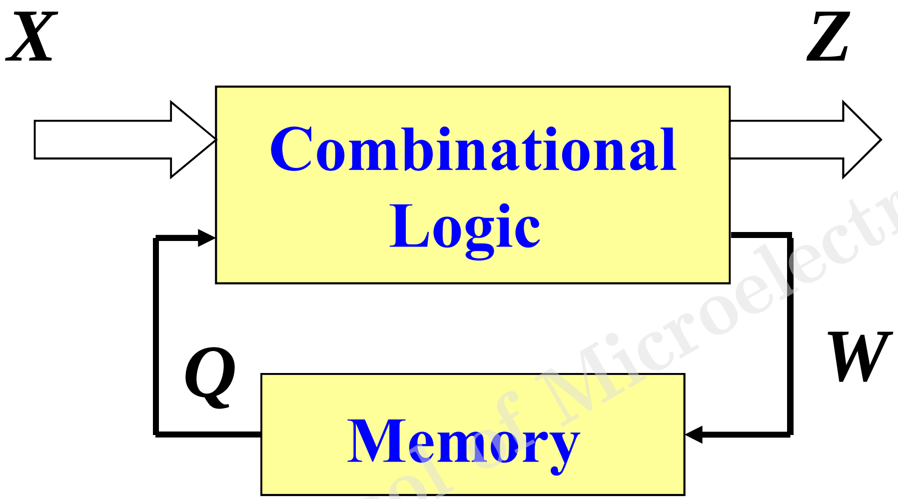
- 输出
  - 输入
  - 以前状态　　　记忆
- 基本单元: FF (逻辑门 + 反馈线)

逻辑电路

- 同步　所有的触发器在*CLK*同一边沿触发
- 异步

时序电路结构:

组合电路 + 记忆元件



X： 外输入

Z： 外输出

W: 控制输入 —— *J, K, D, T*

Q: 触发器输出（状态）

外输入 X　　　控制输入 W

外输出 Z　　　状态 Q

关系:

- **输出方程**　$Z = F(X, Q)$
- **驱动方程**　$W = H(X, Q)$
- **特征方程**　$Q^{n+1} = G(W, Q^n)$

按照电路中输出变量是否和输入变量直接相关

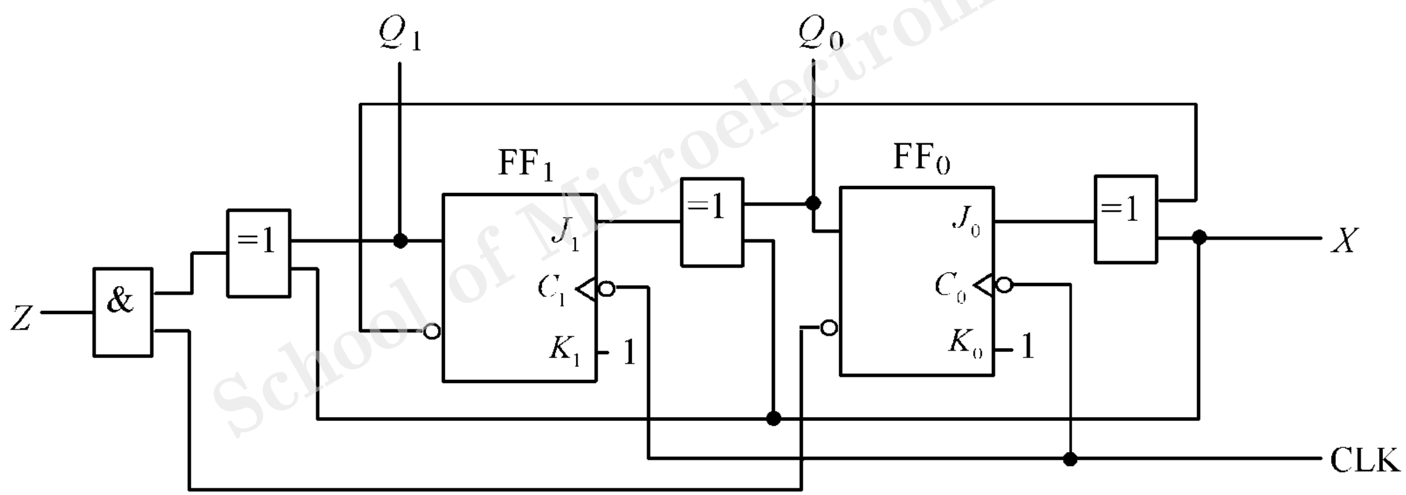
时序电路

- 米里型 (Mealy)　输出 Z $\begin{cases} Q^n \\ X \end{cases}$
- 莫尔型 (Moore)　输出 $Z \sim Q^n$

§6.2 同步时序电路分析
Sequential Logic Circuits Analysis

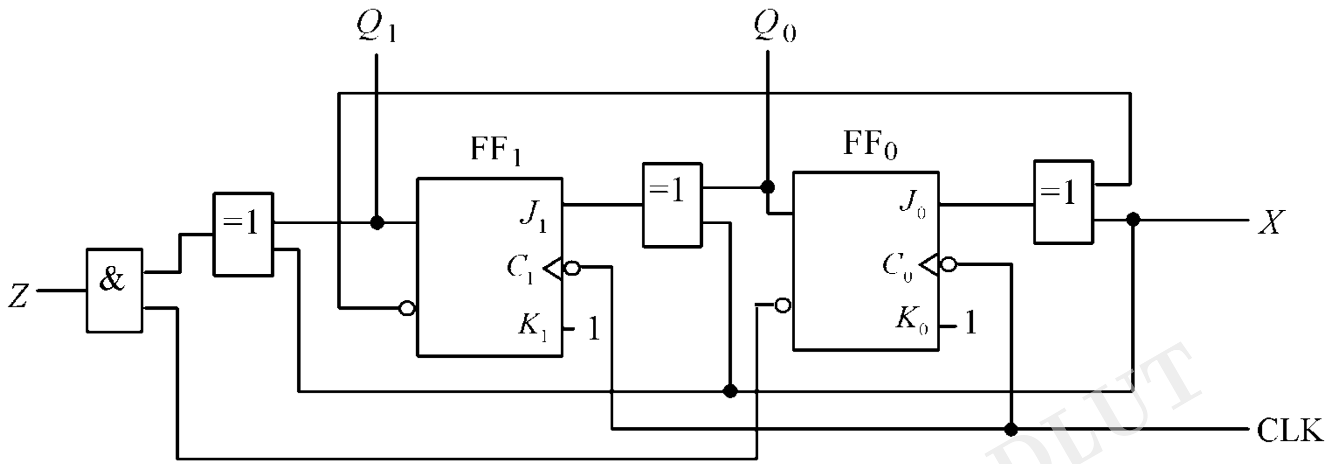
分析: 已知电路, 描述电路原理及功能

例1: 分析下图时序逻辑电路



1) 输入 X 控制输入 J_0, K_0, J_1, K_1

输出 Z 状态 Q_1 (MSB), Q_0



2) 方程

输出方程 $$Z=(X\oplus Q_1^n)\cdot\overline{Q_0^n}$$

驱动方程 $$\begin{cases} J_0=X\oplus\overline{Q_1^n} \\ K_0=1 \end{cases} \qquad \begin{cases} J_1=X\oplus Q_0^n \\ K_1=1 \end{cases}$$

特征方程 $$\begin{cases} Q_0^{n+1}=J_0\overline{Q_0^n}+\overline{K_0}Q_0^n=(X\oplus\overline{Q_1^n})\cdot\overline{Q_0^n} \\ Q_1^{n+1}=J_1\overline{Q_1^n}+\overline{K_1}Q_1^n=(X\oplus Q_0^n)\cdot\overline{Q_1^n} \end{cases}$$

3) 状态表和状态图

已知：输入 X，Q^n

求：输出 Z，Q^{n+1}

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

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

$$Z = (X \oplus Q_1^n) \cdot \overline{Q_0^n}$$

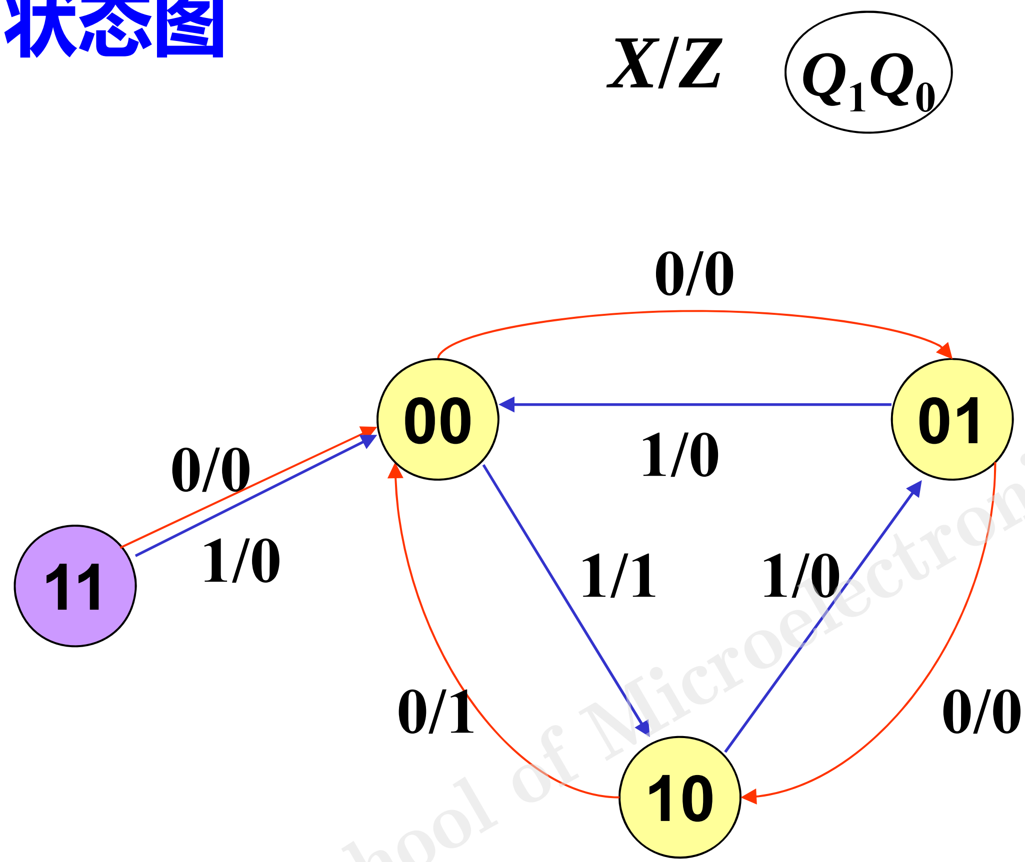
状态表

	X	Q_1^n	Q_0^n	Q_1^{n+1}	Q_0^{n+1}	Z
X=0	0	0	0	0	1	0
	0	0	1	1	0	0
	0	1	0	0	0	1
	0	1	1	0	0	0
X=1	1	0	0	1	0	1
	1	0	1	0	0	0
	1	1	0	0	1	0
	1	1	1	0	0	0

X=0
$$\begin{cases} Q_1^{n+1} = Q_0^n \cdot \overline{Q}_1^n \\ Q_0^{n+1} = \overline{Q_1^n} \cdot \overline{Q_0^n} = \overline{Q_1^n + Q_0^n} \\ Z = Q_1^n \cdot \overline{Q_0^n} \end{cases}$$

X=1
$$\begin{cases} Q_1^{n+1} = \overline{Q_0^n} \cdot \overline{Q_1^n} \\ Q_0^{n+1} = Q_1^n \cdot \overline{Q_0^n} \\ Z = \overline{Q_1^n} \cdot \overline{Q_0^n} \end{cases}$$

状态图



状态表

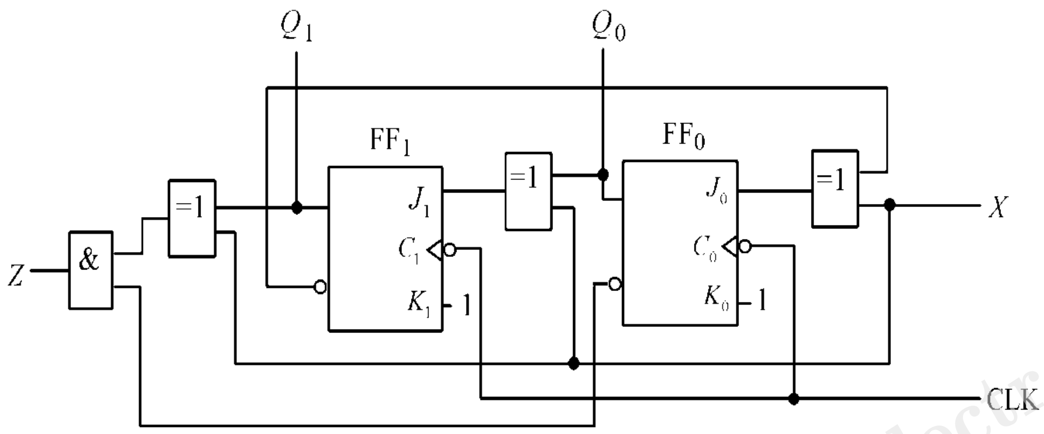
X	Q_1^n	Q_0^n	Q_1^{n+1}	Q_0^{n+1}	Z
0	0	0	0	1	0
0	0	1	1	0	0
0	1	0	0	0	1
0	1	1	0	0	0
1	0	0	1	0	1
1	0	1	0	0	0
1	1	0	0	1	0
1	1	1	0	0	0

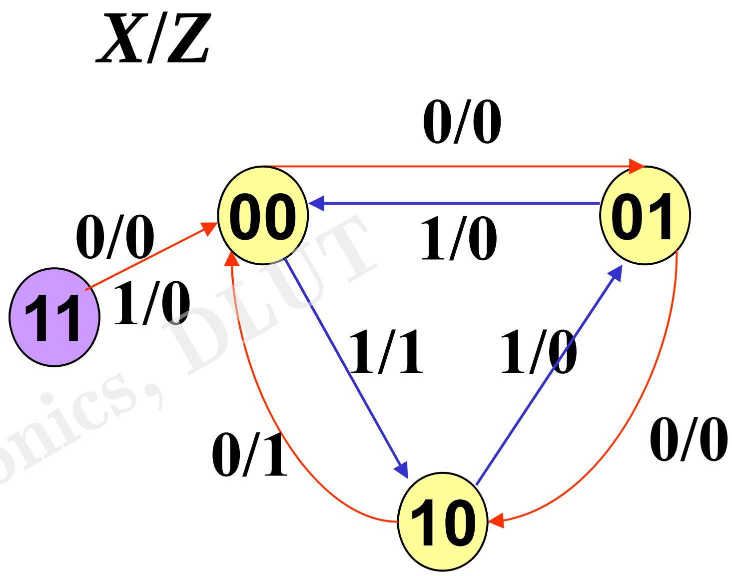
⟶ 对应一个*CLK*

输出Z是原状态下的输出。

每条转换线对应真值表的一行

4) 电路功能



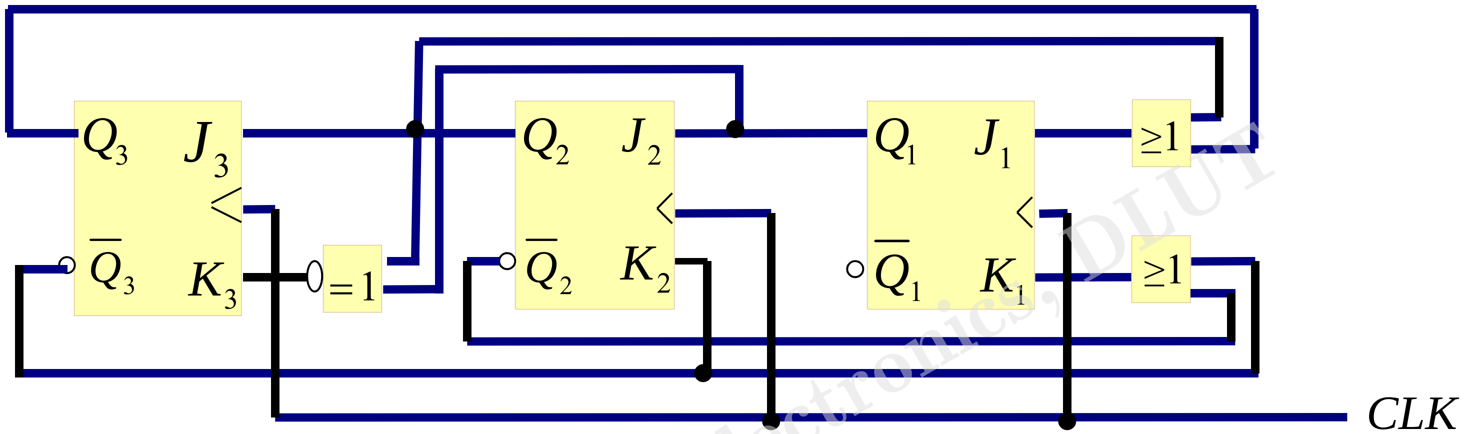


状态图主循环：模 3 加减双向计数器

X=0, M-3 加法计数：$Z=1$，进位输出；

X=1, M-3 减法计数：$Z=1$，借位输出。

例 2. 分析下图时序电路



无外输入，无外输出

$$\begin{cases} J_3 = Q_2^n \\ K_3 = \overline{Q_2^n \oplus Q_1^n} \end{cases} \quad \begin{cases} J_2 = Q_1^n \\ K_2 = \overline{Q_3}^n \end{cases} \quad \begin{cases} J_1 = Q_2^n + Q_3^n \\ K_1 = \overline{Q_2}^n + \overline{Q_3}^n = \overline{Q_2^n Q_3^n} \end{cases}$$

$$Q_3^{n+1} = J_3\overline{Q_3^n} + \overline{K}_3 Q_3^n = Q_2^n\overline{Q_3^n} + (Q_2^n \oplus Q_1^n)Q_3^n$$

$$Q_2^{n+1} = J_2\overline{Q_2^n} + \overline{K}_2 Q_2^n = Q_1^n\overline{Q_2^n} + Q_3^n Q_2^n$$

$$Q_1^{n+1} = J_1\overline{Q_1^n} + \overline{K}_1 Q_1^n = (Q_2^n + Q_3^n)\overline{Q_1^n} + Q_2^n Q_3^n Q_1^n$$

Q_3^n	Q_2^n	Q_1^n	Q_3^{n+1}	Q_2^{n+1}	Q_1^{n+1}
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	1	0	1
0	1	1	1	0	0
1	0	0	0	0	1
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	1	1

$$Q_3^{n+1} \begin{cases} Q_2^n & Q_3^n = 0, \\ Q_2^n \oplus Q_1^n & Q_3^n = 1, \end{cases}$$

$$Q_2^{n+1} \begin{cases} Q_1^n & Q_2^n = 0, \\ Q_3^n & Q_2^n = 1, \end{cases}$$

$$Q_1^{n+1} \begin{cases} Q_2^n + Q_3^n & Q_1^n = 0, \\ Q_2^n Q_3^n & Q_1^n = 1, \end{cases}$$

Q_3^n	Q_2^n	Q_1^n	Q_3^{n+1}	Q_2^{n+1}	Q_1^{n+1}
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	1	0	1
0	1	1	1	0	0
1	0	0	0	0	1
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	1	1

000 **孤立状态**

自启动