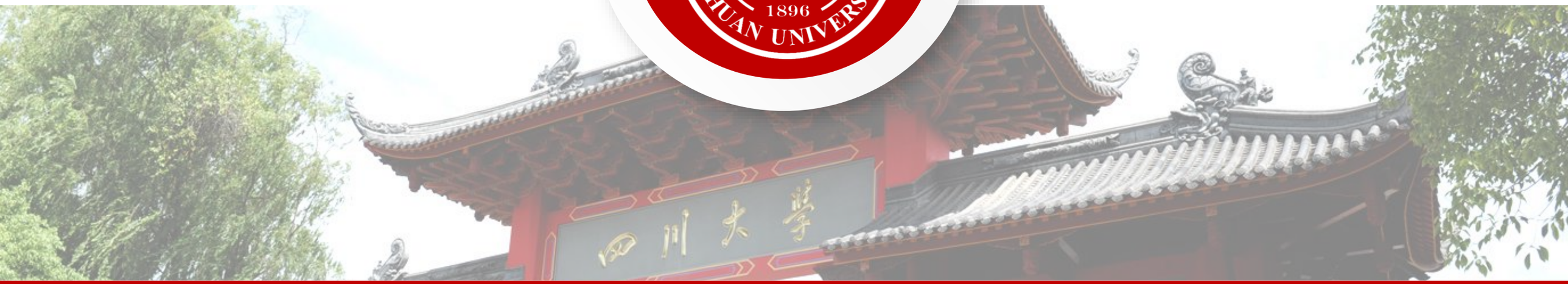



# DIGITAL LOGIC
# 数字逻辑

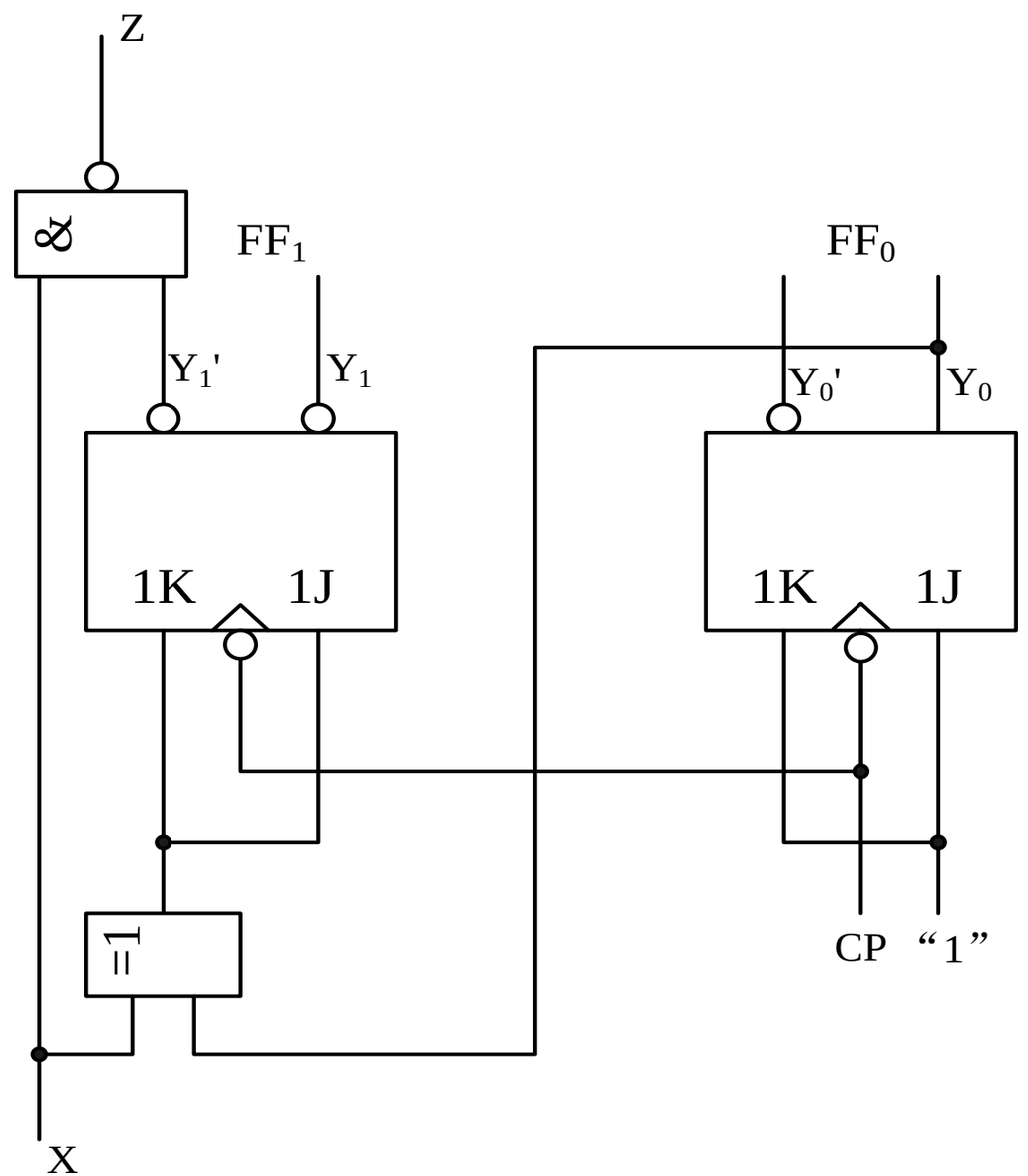
# Synchronous Sequential Circuit Analysis



- Analysis Principles
  - 1. Determine the system variables: input, state, and output.
  - 2. Determine  the flip-flop type. Write the characteristic equations.
  - 3. write the excitation equations.
  - 4. write the next state equations.
  - 5. Write the output variable equations.
  - 6. Construct a transition table.
  - 7. Assign symbols to the states and construct a table or state diagram.
  - 8. When possible, construct a timing diagram.
  - 9. Functionality analysis

# Analysis Examples

- E.g.1: Analysis the following synchronous sequential circuit, suppose the present state is 00, the input sequence is 0000011111, give the timing diagram.



# Analysis Examples

– 1. Determine the system variables: input, state, and output.

input=x

output=Z

state variables=$y_1$ and $y_0$

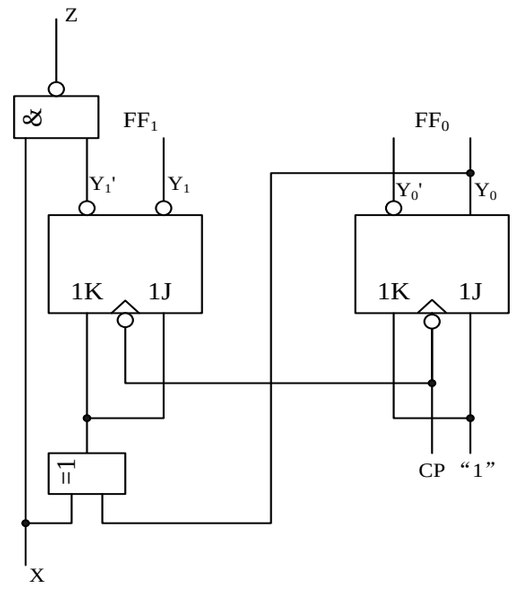
– 2. Determine the flip-flop type. Write the characteristic equations.

$$y^{n+1}=Jy^{n\prime}+k'y^n$$

– 3. write the excitation equations.

$$K_0=J_0=1$$

$$K_1=J_1=x\oplus y_0$$



# Analysis Examples

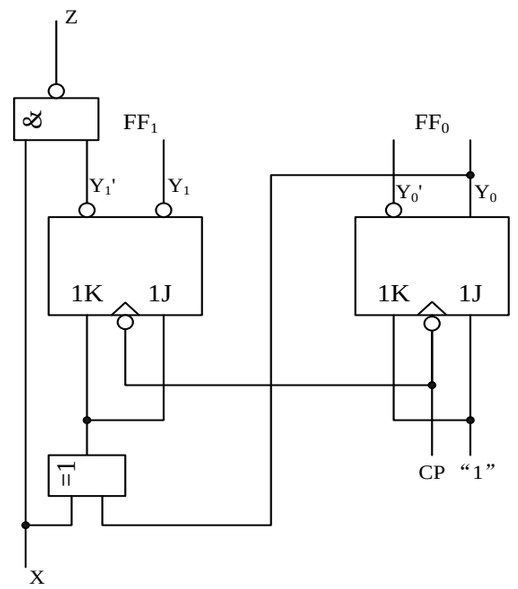


–4. write the next state equations.

$$\left.\begin{aligned} y_1^{n+1} &= J_1 y_1' + k_1' y_1 \\ y_0^{n+1} &= J_0 y_0' + k_0' y_0 \end{aligned}\right\} \longrightarrow \left\{\begin{aligned} y_1^{n+1} &= x' y_1' y_0 + x' y_1 y_0' + x y_1' y_0' + x y_1 y_0 \\ y_0^{n+1} &= y_0' \end{aligned}\right.$$

–5. Write the output variable equations.

$$Z=(xy_1')'=x'+y_1$$




–6. Construct a transition table.

# Analysis Examples

$$\begin{cases} y_1^{n+1} = x'y_1'y_0 + x'y_1y_0' + xy_1'y_0' + xy_1y_0 \\ y_0^{n+1} = y_0' \\ Z = (xy_1')' = x' + y_1 \end{cases}$$

| $Y_1Y_0$ \ X | 0 | 1 |
|---|---|---|
| 00 | 0 | 1 |
| 01 | 1 | 0 |
| 11 | 0 | 1 |
| 10 | 1 | 0 |

$Y_1^{n+1}$ K-Map

| $Y_1Y_0$ \ X | 0 | 1 |
|---|---|---|
| 00 | 1 | 1 |
| 01 | 0 | 0 |
| 11 | 0 | 0 |
| 10 | 1 | 1 |

$Y_0^{n+1}$ K-Map

| $Y_1Y_0$ \ X | 0 | 1 |
|---|---|---|
| 00 | 1 | 0 |
| 01 | 1 | 0 |
| 11 | 1 | 1 |
| 10 | 1 | 1 |

Z K-Map

| Present state Y1 Y0 | Next state x/z | |
|---|---|---|
| | X=0 Y1+ Y0+ / Z | X=1 Y1+ Y0+ /Z |
| 00 | 01/1 | 11/0 |
| 01 | 10/1 | 00/0 |
| 11 | 00/1 | 10/1 |
| 10 | 11/1 | 01/1 |

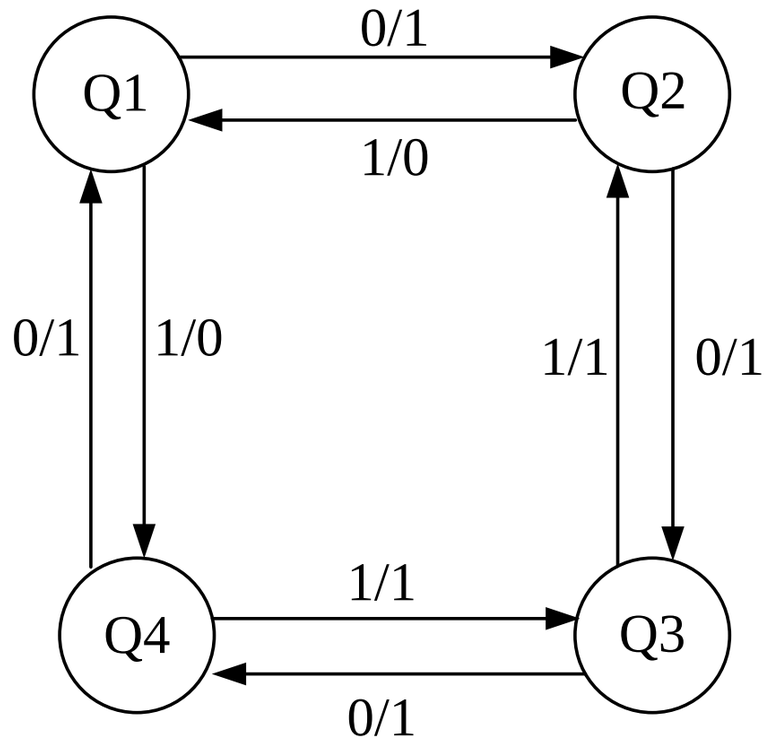
transition table

# Analysis Examples

– 7. Assign symbols to the states and construct a table or state diagram

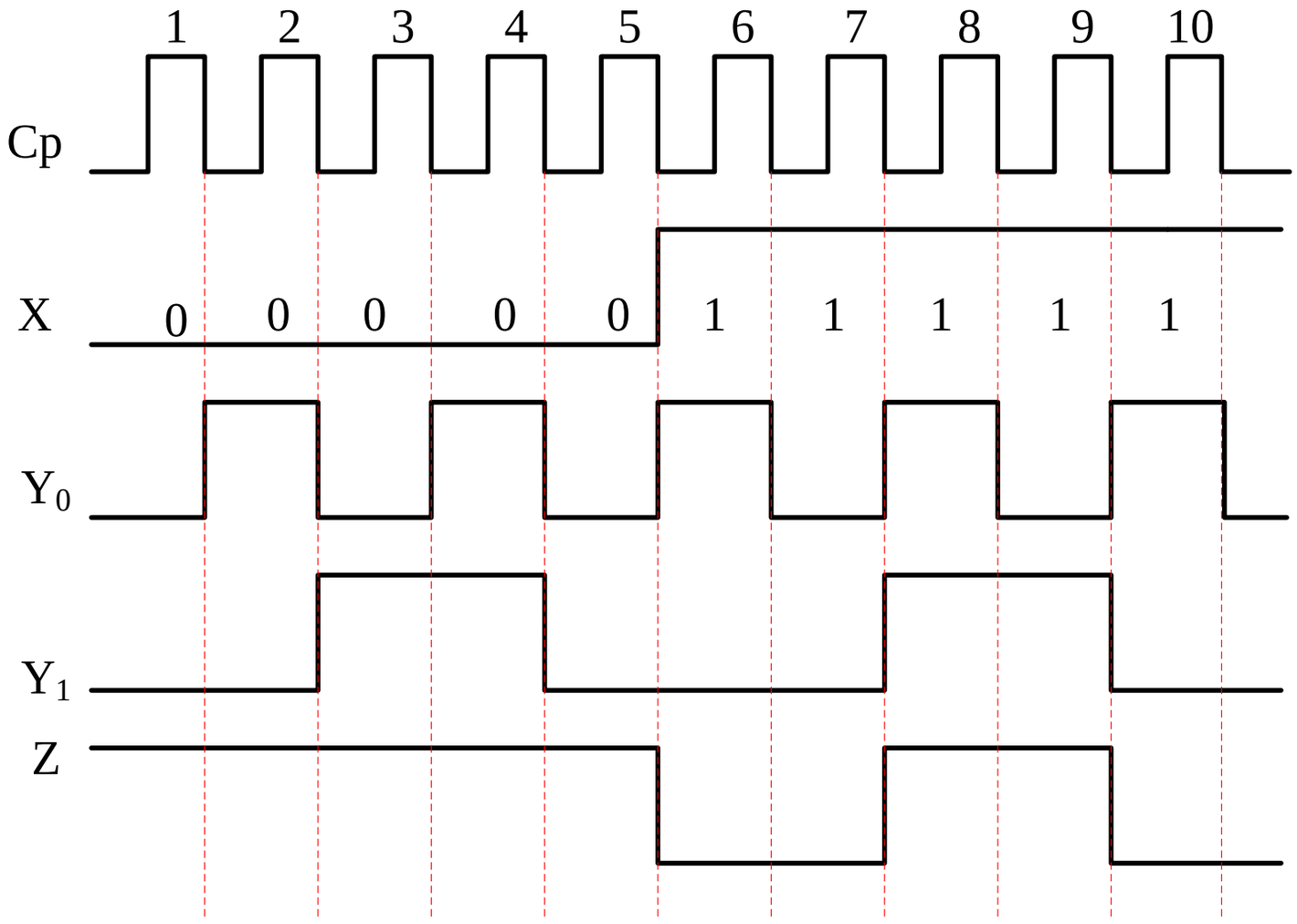
| Present state $Y_0$ $Y_1$ | Next state x/z | |
|---|---|---|
| | X=0 | X=1 |
| | $Y_0+$ $Y_1+$ / Z | $Y_0+$ $Y_1+$ /Z |
| $Q_1$ 00 | 01/1 | 11/0 |
| $Q_2$ 01 | 10/1 | 00/0 |
| $Q_4$ 11 | 00/1 | 10/1 |
| $Q_3$ 10 | 11/1 | 01/1 |

| Present state $Y_0$ $Y_1$ | Next state x/z | |
|---|---|---|
| | X=0 | X=1 |
| | $Y_0+$ $Y_1+$ / Z | $Y_0+$ $Y_1+$ /Z |
| $Q_1$ | $Q_2$/1 | $Q_4$/0 |
| $Q_2$ | $Q_3$/1 | $Q_1$/0 |
| $Q_3$ | $Q_4$/1 | $Q_2$/1 |
| $Q_4$ | $Q_1$/1 | $Q_3$/1 |



# Analysis Examples

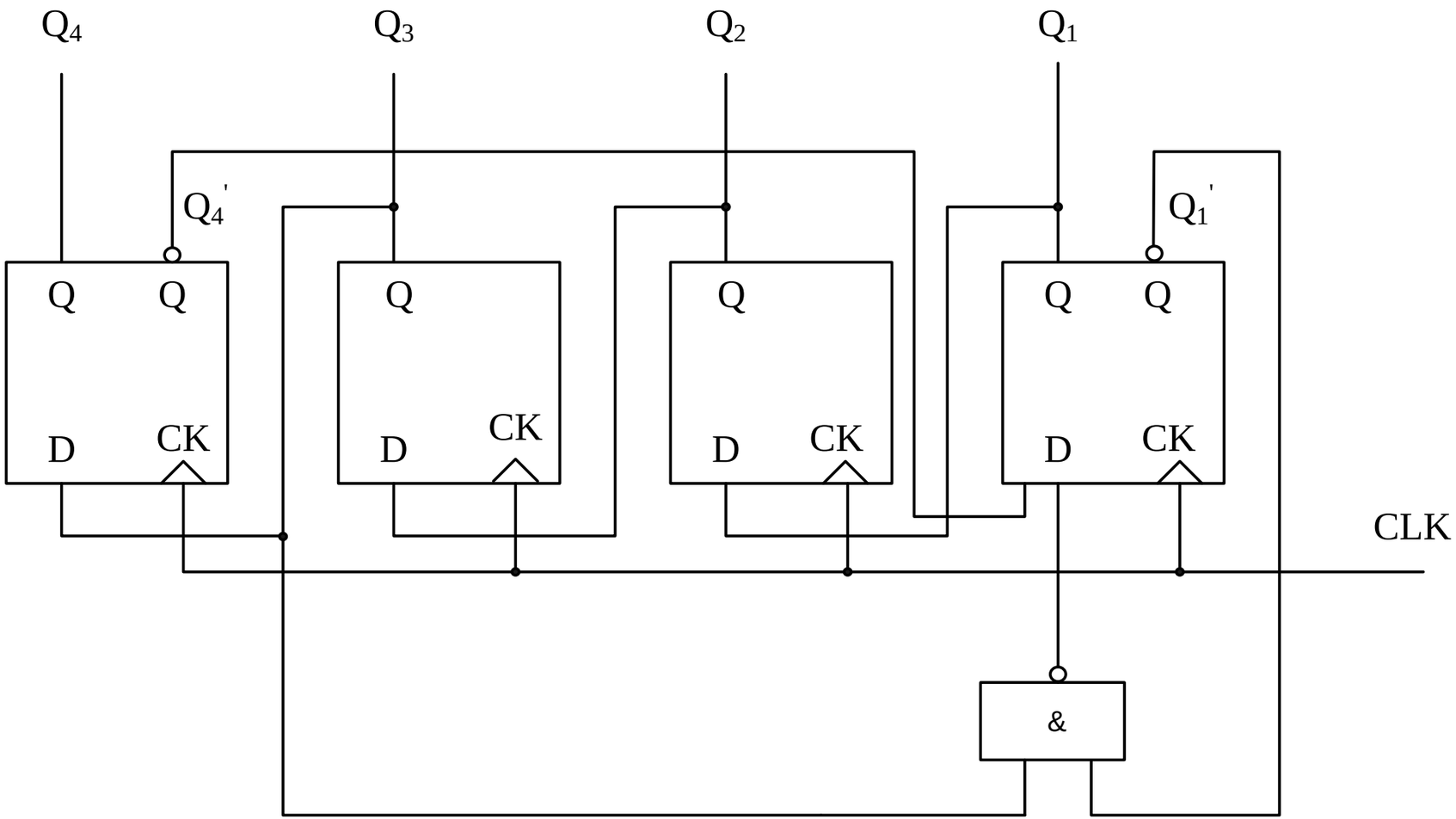
– 8. construct a timing diagram.




$$\begin{cases} y_1^{n+1} = x'y_1'y_0 + x'y_1y_0' + xy_1'y_0' + xy_1y_0 \\ y_0^{n+1} = y_0' \\ Z = (xy_1')' = x' + y_1 \end{cases}$$

# Analysis Examples

- E.g.2: Analysis the following circuit



# Analysis Examples

- 1. Determine the system variables: input, state, and output.

  state variables: $Q_1$,$Q_2$,$Q_3$, and $Q_4$

- 2. Determine the flip-flop type. Write the characteristic equations.

  $Q^{n+1}=D$

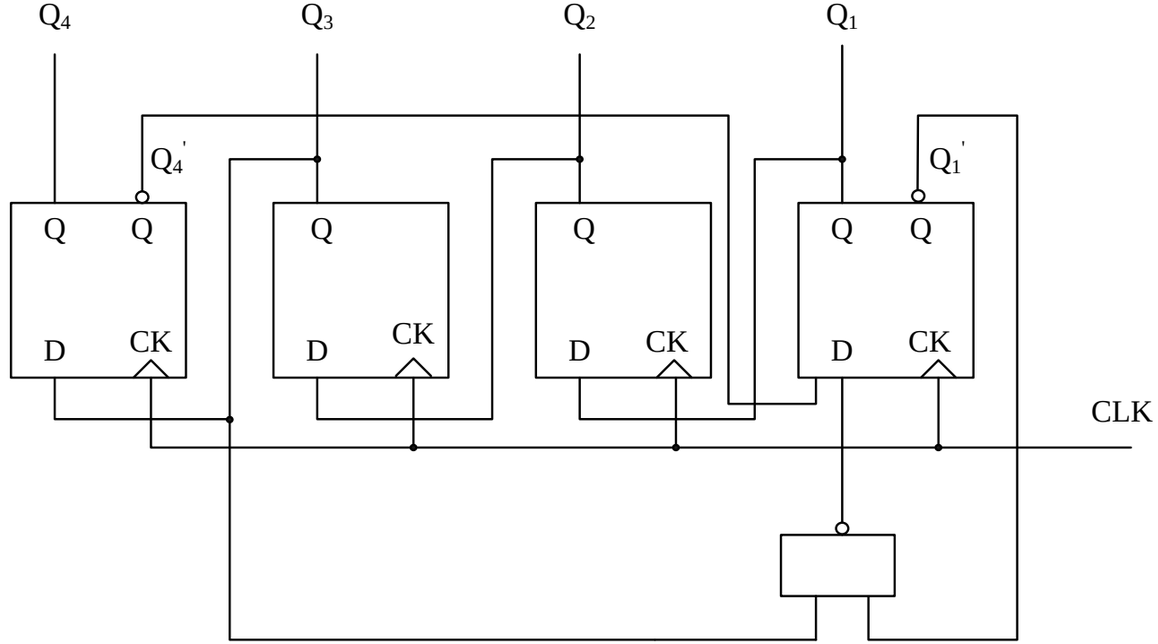
- 3. excitation equations.

  $D_4=Q_3$

  $D_3=Q_2$

  $D_2=Q_1$

  $D_1=Q_4'(Q_3Q_1')'=Q_4'Q_3'+Q_4'Q_1$



# Analysis Examples

– 4. the next state equations.

$$Q_4^{n+1}=Q_3$$

$$Q_3^{n+1}=Q_2$$

$$Q_2^{n+1}=Q_1$$

$$Q_1^{n+1}=Q_4'Q_3'+Q_4'Q_1$$

$Q^{n+1}=D$

$D_4=Q_3$
$D_3=Q_2$
$D_2=Q_1$
$D_1=Q_4'(Q_3Q_1')'=Q_4'Q_3'+Q_4'Q_1$

# Analysis Examples

– 5. Construct a transition table.

$Q_4^{n+1}=Q_3$

$Q_3^{n+1}=Q_2$

$Q_2^{n+1}=Q_1$

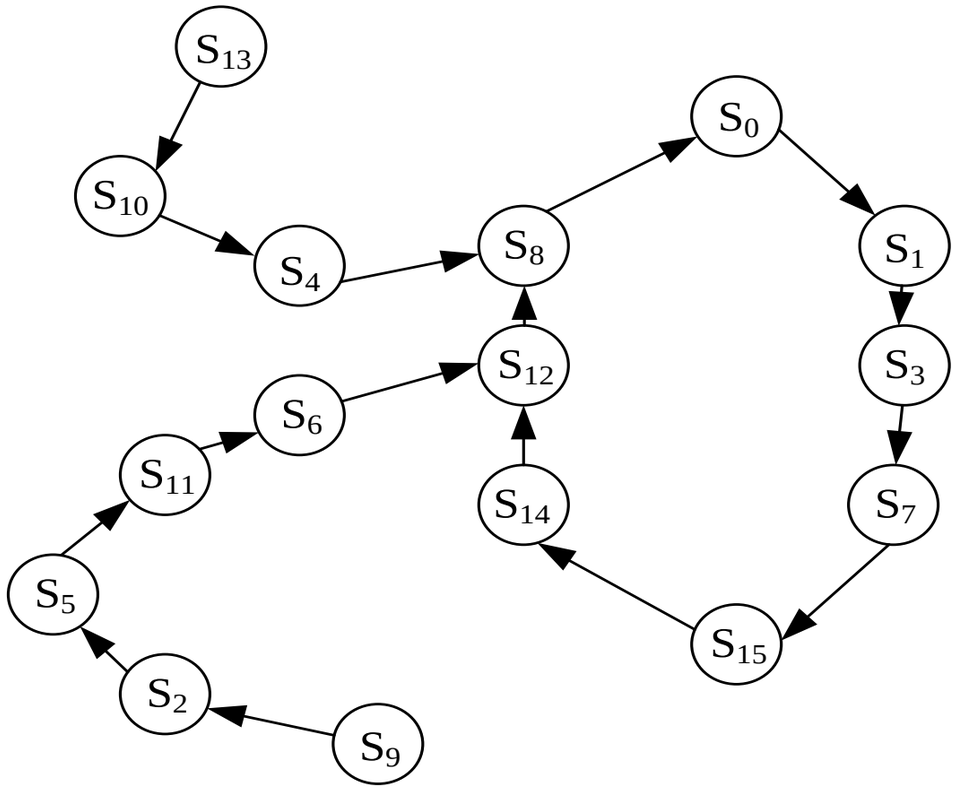
$Q_1^{n+1}=Q_4'Q_3'+Q_4'Q_1$

| $Q_4$ | $Q_3$ | $Q_2$ | $Q_1$ | $Q_4^{n+1}$ | $Q_3^{n+1}$ | $Q_2^{n+1}$ | $Q_1^{n+1}$ |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

# Analysis Examples

– 6. Assign symbols to the states and construct a table or state diagram.

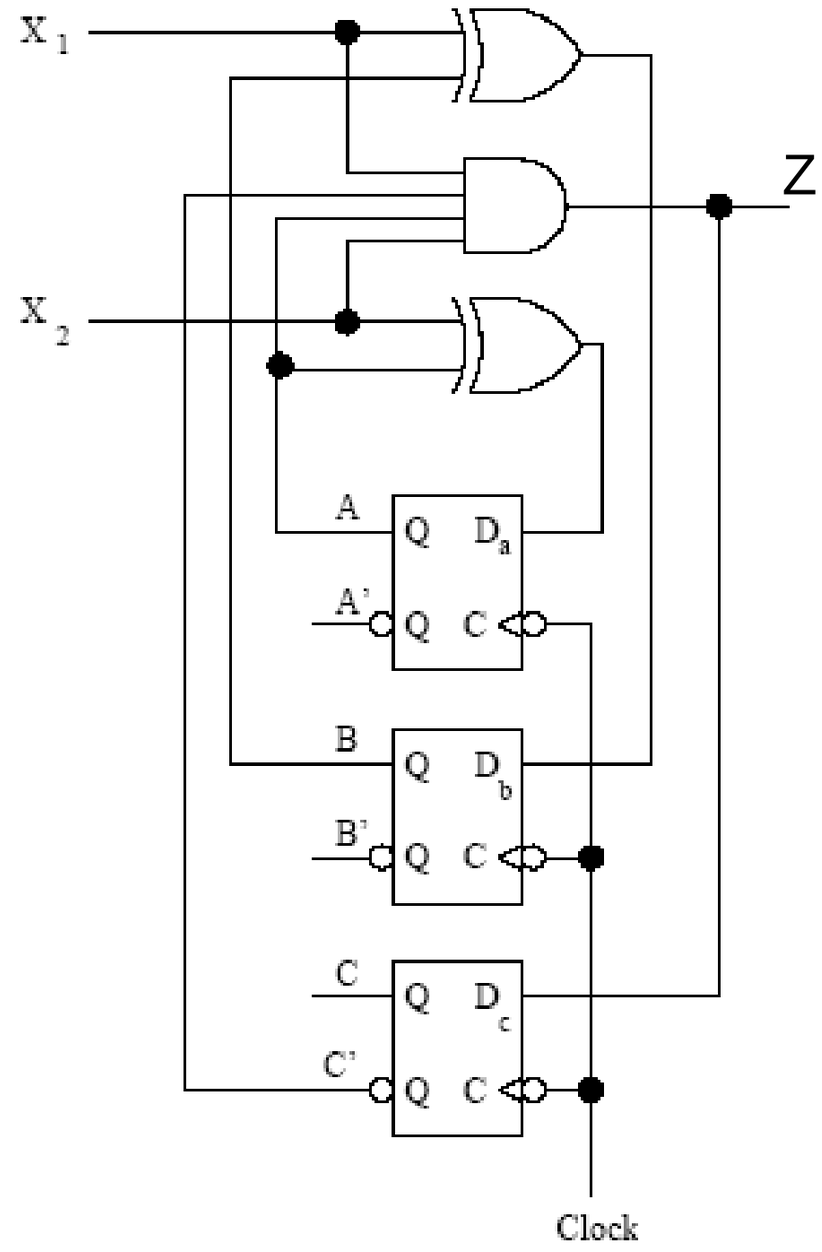
| $Q_4\ Q_3\ Q_2\ Q_1$ | $S_0$ | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | $S_7$ | $S_8$ | $S_9$ | $S_{10}$ | $S_{11}$ | $S_{12}$ | $S_{13}$ | $S_{14}$ | $S_{15}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Q_4^{n+1}Q_3^{n+1}Q_2^{n+1}Q_1^{n+1}$ | $S_1$ | $S_3$ | $S_5$ | $S_7$ | $S_8$ | $S_{11}$ | $S_{12}$ | $S_{15}$ | $S_0$ | $S_2$ | $S_4$ | $S_6$ | $S_8$ | $S_{10}$ | $S_{12}$ | $S_{14}$ |




| $Q_4$ | $Q_3$ | $Q_2$ | $Q_1$ | $Q_4^{n+1}$ | $Q_3^{n+1}$ | $Q_2^{n+1}$ | $Q_1^{n+1}$ |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

# Analysis Examples

- E.g.3: Find the transition table and the state table for the Mealy sequential circuit below.



# Analysis Examples

- 1. Determine the system variables: input, state, and output.

  input: $x_1, x_2$

  output: Z

  state variable: $D_a$ , $D_b$ ,$D_c$

- 2. Determine the flip-flop type. Write the characteristic equations.

  $Q_{n+1}=D$

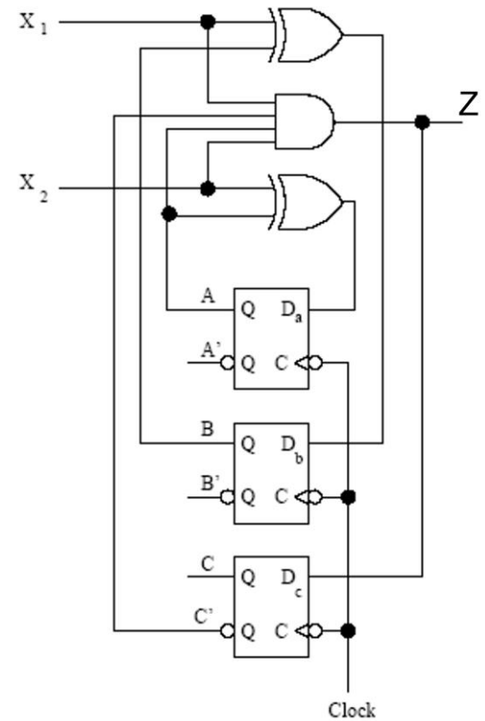
- 3. Excitation equations and output equations.

  $D_a=Q_a \oplus X_2$

  $D_b=Q_b \oplus X_1$

  $D_c=X_1X_2Q_c'Q_a$

  $Z=X_1X_2Q_c'Q_a$



# Analysis Examples

- 4. write the next state equations.

  $Q_a^{n+1}=Q_aX_2'+Q_a'X_2$

  $Q_b^{n+1}=Q_bX_1'+Q_b'X_1$

  $Q_c^{n+1}=X_1X_2Q_c'Q_a$

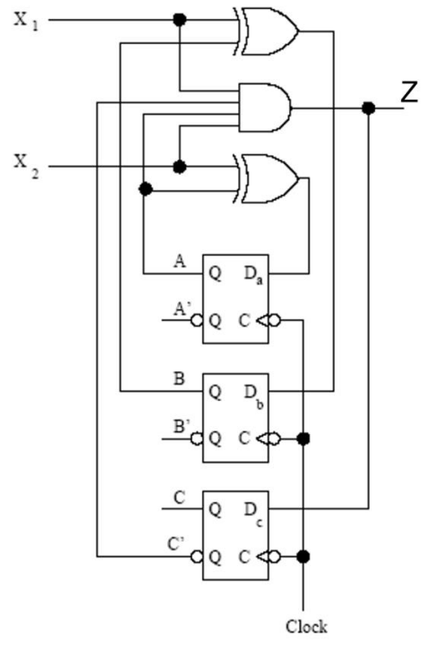
- 5. Construct a transition table.

$D_a=Q_a\oplus X_2$

$D_b=Q_b\oplus X_1$

$D_c=X_1X_2Q_c'Q_a$

$Z=X_1X_2Q_c'Q_a$




X1X2

| $Q_aQ_bQ_c$ | $Q_a+Q_b+Q_c+/Z$ | | | |
|---|---|---|---|---|
| | X=00 | X=01 | X=10 | X=11 |
| 000 | 000/0 | 100/0 | 010/0 | 110/0 |
| 001 | 000/0 | 100/0 | 010/0 | 110/0 |
| 010 | 010/0 | 110/0 | 000/0 | 100/0 |
| 011 | 010/0 | 110/0 | 000/0 | 100/0 |
| 100 | 100/0 | 000/0 | 110/0 | 011/1 |
| 101 | 100/0 | 000/0 | 110/0 | 010/0 |
| 110 | 110/0 | 010/0 | 100/0 | 001/1 |
| 111 | 110/0 | 010/0 | 100/0 | 000/0 |

# Analysis Examples

– 6. Assign symbols to the states and construct a state table

| $Q_aQ_bQ_c$ | $Q_a+Q_b+Q_c+/Z$ | | | |
|---|---|---|---|---|
| | X=00 | X=01 | X=10 | X=11 |
| 000 | 000/0 | 100/0 | 010/0 | 110/0 |
| 001 | 000/0 | 100/0 | 010/0 | 110/0 |
| 010 | 010/0 | 110/0 | 000/0 | 100/0 |
| 011 | 010/0 | 110/0 | 000/0 | 100/0 |
| 100 | 100/0 | 000/0 | 110/0 | 011/1 |
| 101 | 100/0 | 000/0 | 110/0 | 010/0 |
| 110 | 110/0 | 010/0 | 100/0 | 001/1 |
| 111 | 110/0 | 010/0 | 100/0 | 000/0 |

| $Q_aQ_bQ_c$ | $Q_a+Q_b+Q_c+/Z$ | | | |
|---|---|---|---|---|
| | X=00 | X=01 | X=10 | X=11 |
| A | A/0 | E/0 | C/0 | G/0 |
| B | A/0 | E/0 | C/0 | G/0 |
| C | C/0 | G/0 | A/0 | E/0 |
| D | C/0 | G/0 | A/0 | E/0 |
| E | E/0 | A/0 | G/0 | D/1 |
| F | E/0 | A/0 | G/0 | C/0 |
| G | G/0 | C/0 | E/0 | B/1 |
| H | G/0 | C/0 | E/0 | A/0 |

# Homework

# Thanks