# Unit V

# Synchronous Counters

*by*

Dr. Krishan Arora
Associate Professor and Head
Lovely Professional University

# How To design Synchronous Counter

- **Let us employ these techniques to design a MOD-8 counter to count in the following sequence: 0, 1, 2, 3, 4, 5, 6, 7.**
- **Step1:** Determined Flip Flop Used and Creating **state transition diagram.** (*Rajah Keadaan*)

$$N = 2^n$$

$$8 = 2^n$$

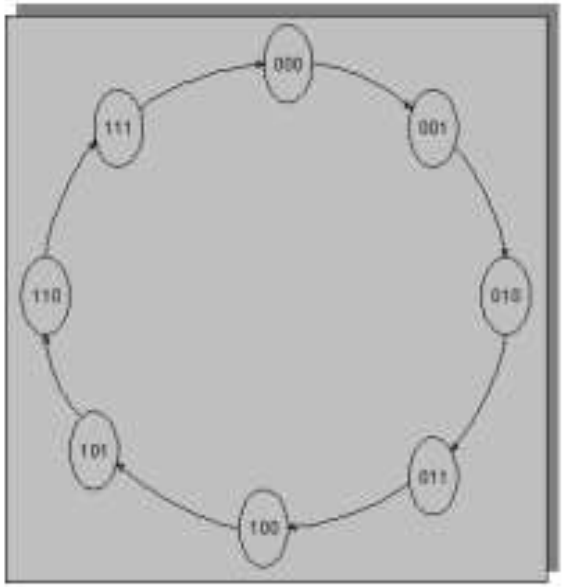
$$n = \log 8 \ / \ \log 2$$

= 3 Flip Flop ( 3 Bit )

$$M = 2^n - 1$$

$$= 2^3 - 1 = 8 - 1 = 7$$

N = Modulo/MOD
n = Flip Flop Used
M = Maximum Number To Be Count



# How To design Synchronous Counter

- **Step 2:** Creating present state-next state table

| Present State | | | Next State | | |
|---|---|---|---|---|---|
| $Q_2$ | $Q_1$ | $Q_0$ | $Q_2$ | $Q_1$ | $Q_0$ |
| 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 | 0 |
| 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 |
| | | | | | |

$Q_0 = Q_A$
$Q_1 = Q_B$
$Q_2 = Q_C$

# How To Design Synchronous Counter

- **Step 3:** Expand the present state-next state table to form the transition table.

| Excitation Table (*Jadual Ujaan Flip Flop JK*) | | | |
|---|---|---|---|
| **Q** | **$\bar{Q}$** | J | K |
| 0 | 0 | 0 | X |
| 0 | 1 | 1 | X |
| 1 | 0 | X | 1 |
| 1 | 1 | X | 0 |

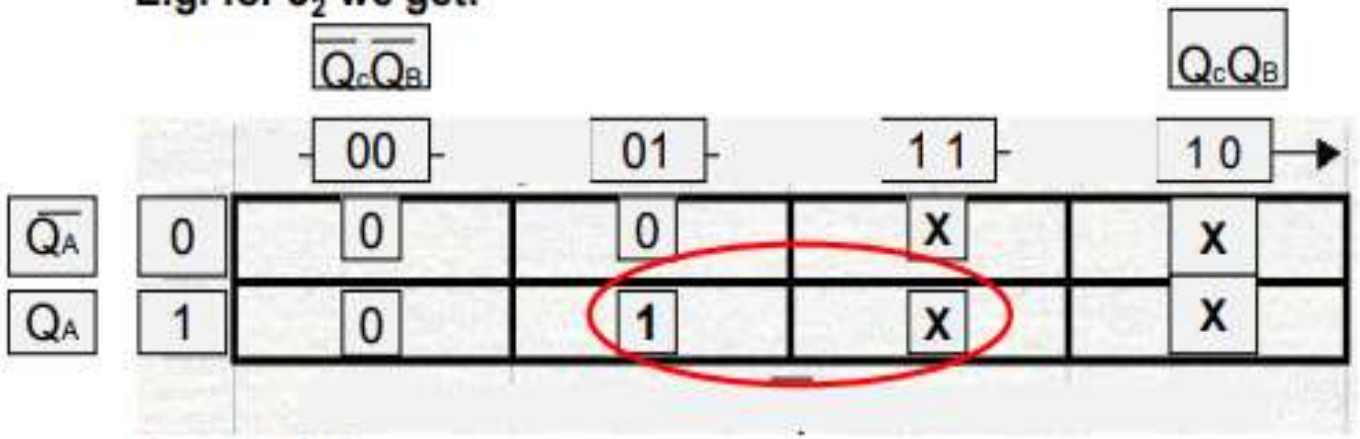
'X' indicates a **"don't care"** condition.

| Present State | | | Next State | | | Present inputs | | |
|---|---|---|---|---|---|---|---|---|
| $Q_C$ | $Q_B$ | $Q_A$ | $Q_C$ | $Q_B$ | $Q_A$ | $J_CK_C$ | $J_BK_B$ | $J_AK_A$ |
| 0 | 0 | 0 | 0 | 0 | 1 | 0X | 0X | 1X |
| 0 | 0 | 1 | 0 | 1 | 0 | 0X | 1X | X1 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0X | X0 | 1X |
| 0 | 1 | 1 | 1 | 0 | 0 | 1X | X1 | X1 |
| 1 | 0 | 0 | 1 | 0 | 1 | X0 | 0X | 1X |
| 1 | 0 | 1 | 1 | 1 | 0 | X0 | 1X | X1 |
| 1 | 1 | 0 | 1 | 1 | 1 | X0 | X0 | 1X |
| 1 | 1 | 1 | 0 | 0 | 0 | X1 | X1 | X1 |

# How To Design Synchronous Counter

- **Step 4:** Use Karnaugh maps to identify the present state logic functions for each of the inputs.

**E.g. for $J_2$ we get:**




$J_C = Q_B Q_A$

Using similar techniques for the other inputs we get:

$K_C = Q_B Q_A$

$J_B = Q_A$

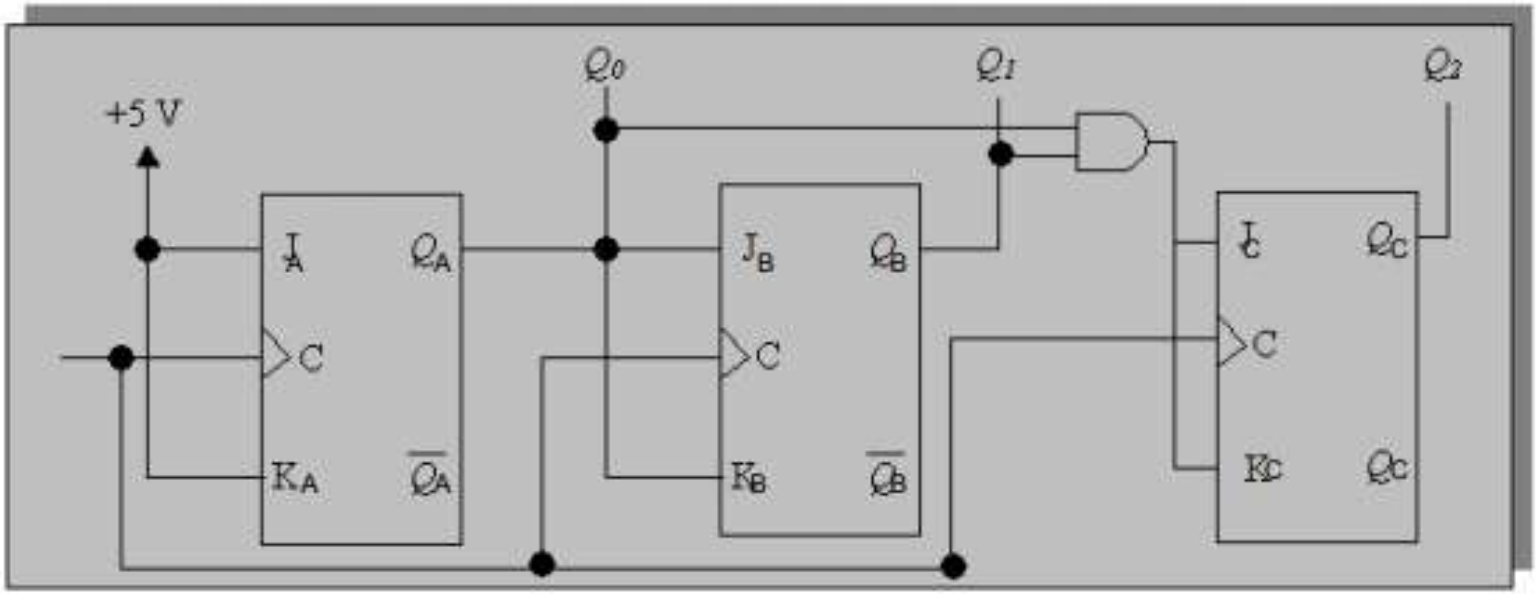
$K_B = Q_A$

$J_A = 1$

$K_A = 1$

# How To Design Synchronous Counter

- **Step 5:** Constructing Circuit



# Design a mod 6 synchronous up counter using J-K flip flop

**Find number of flip-flops required to build the counter.**

Flip-flops required are : $2^n \geq N$.

Here $N = 6 \quad \therefore n = 3$

i.e. Three flip-flops are required.

## JK flip-flop

| Q(t) | Q(t+1) | J | K |
|---|---|---|---|
| 0 | 0 | 0 | x |
| 0 | 1 | 1 | x |
| 1 | 0 | x | 1 |
| 1 | 1 | x | 0 |

Determine the transition table.

| Present state | | | Next state | | | Flip-flop inputs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Q_A$ | $Q_B$ | $Q_C$ | $Q_{A+1}$ | $Q_{B+1}$ | $Q_{C+1}$ | $J_A$ | $K_A$ | $J_B$ | $K_B$ | $J_C$ | $K_C$ |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | x | 0 | x | 1 | x |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | x | 1 | x | x | 1 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | x | x | 0 | 1 | x |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | x | x | 1 | x | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | x | 0 | 0 | x | 1 | x |
| 1 | 0 | 1 | 0 | 0 | 0 | x | 1 | 0 | x | x | 1 |
| 1 | 1 | 0 | x | x | x | x | x | x | x | x | x |
| 1 | 1 | 1 | x | x | x | x | x | x | x | x | x |

For $J_A$

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 0 |
| 1 | X | X | X | X |

$J_A = Q_B Q_C$

For $K_A$

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | X | X | X | X |
| 1 | 0 | 1 | X | X |

$K_A = Q_C$

For $J_B$

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 0 | 1 | X | X |
| 1 | 0 | 0 | X | X |

$J_B = \overline{Q}_A Q_C$

For $K_B$

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | X | X | 1 | 0 |
| 1 | X | X | X | X |

$K_B = Q_C$

For $J_C$

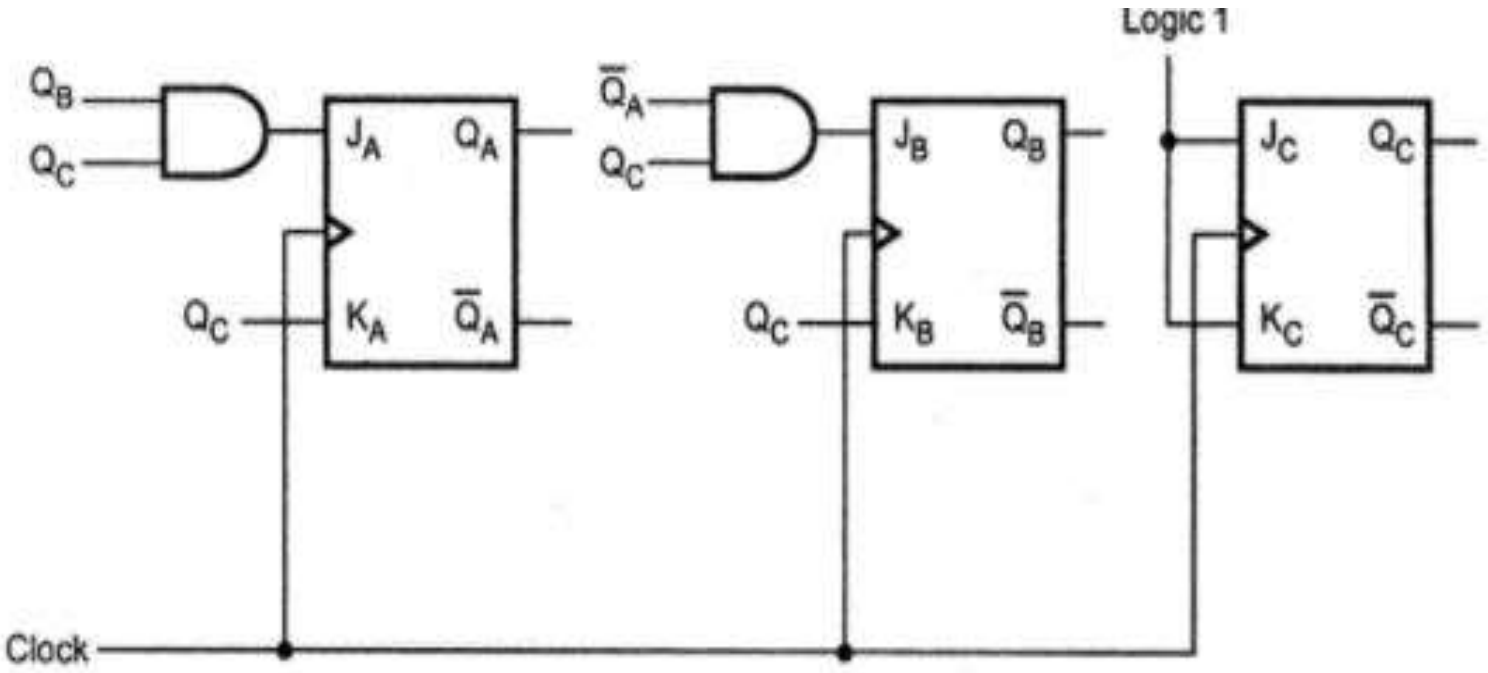
| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | X | X | 1 |
| 1 | 1 | X | X | X |

$J_C = 1$

For $K_C$

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | X | 1 | 1 | X |
| 1 | X | 1 | X | X |

$K_C = 1$


Logic 1
$Q_B$
$Q_C$
$J_A$
$Q_A$
$Q_C$
$K_A$
$\overline{Q}_A$
$\overline{Q}_A$
$Q_C$
$J_B$
$Q_B$
$Q_C$
$K_B$
$\overline{Q}_B$
$J_C$
$Q_C$
$K_C$
$\overline{Q}_C$
Clock

# Design a mod 5 synchronous up counter using J-K flip flop

**Step 1:**

Determine the number of flip flop needed

Flip flop required are

$$2^n \geq N$$

Mod 5 hence N=5

$$\therefore 2^n \geq N$$
$$\therefore 2^n \geq 5$$
$$N = 3 \text{ i.e. 3 flip flop are required}$$

**Step 2:**

Type of flip flop to be used: JK flip flop

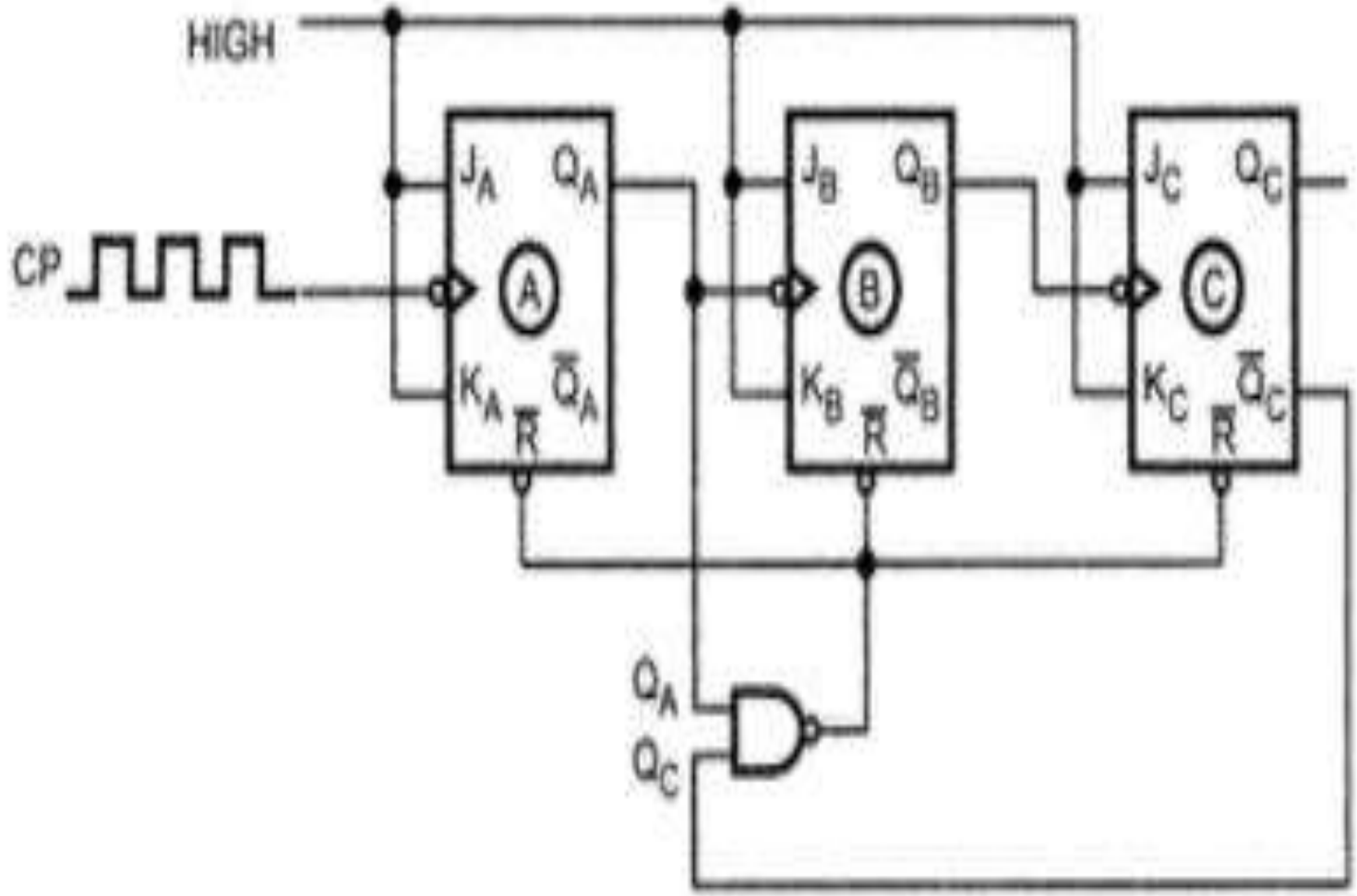
**Step 3:**

**1) Excitation table for JK flip flop**

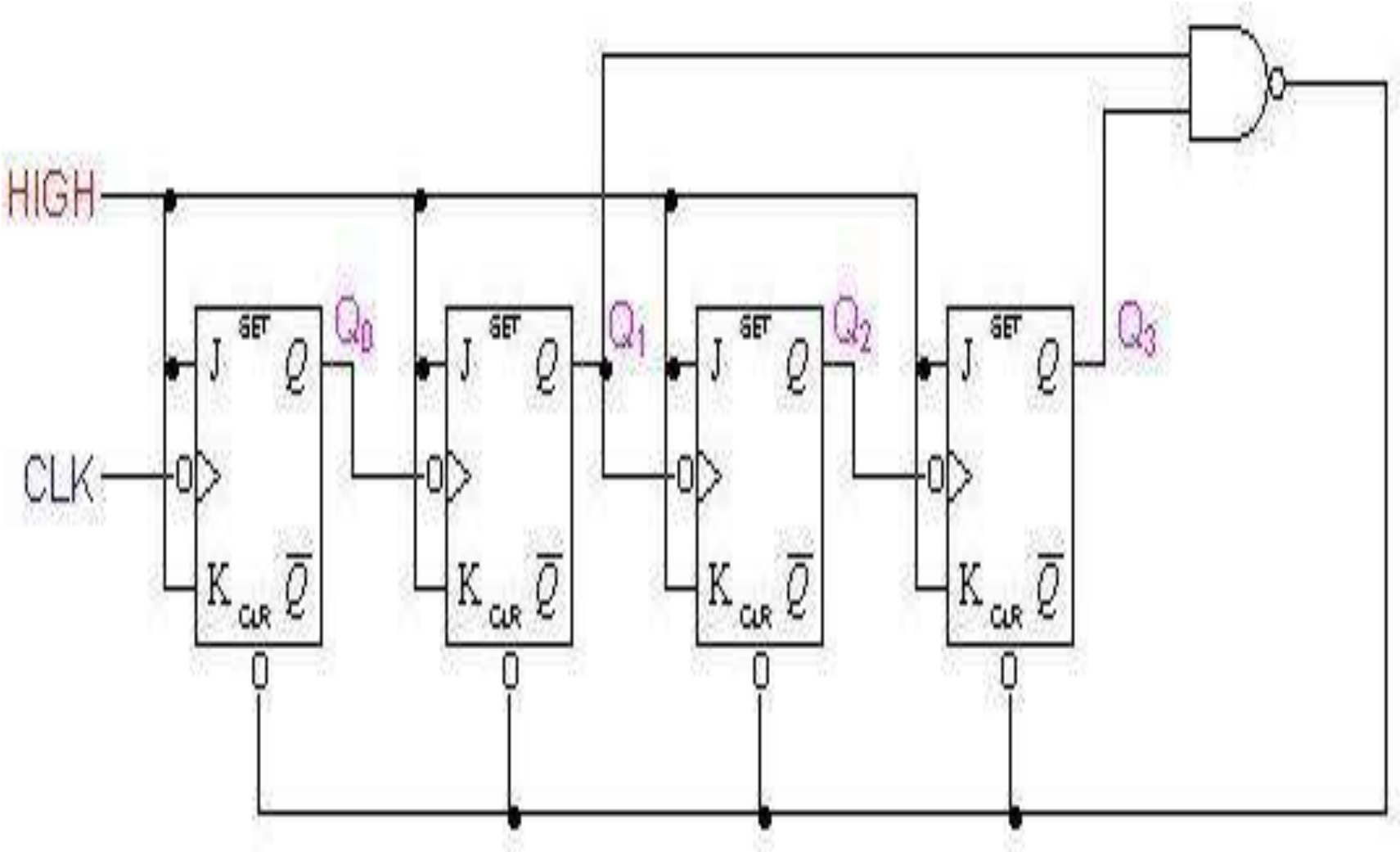
| JK flip-flop | | | |
|---|---|---|---|
| Q(t) | Q(t+1) | J | K |
| 0 | 0 | 0 | x |
| 0 | 1 | 1 | x |
| 1 | 0 | x | 1 |
| 1 | 1 | x | 0 |

## 2) Excitation table for counter

| Present state | | | Next state | | | Flip flop Input | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Q_c$ | $Q_B$ | $Q_A$ | $Q_{C+1}$ | $Q_{B+1}$ | $Q_{A+1}$ | $J_C$ | $K_C$ | $J_B$ | $K_B$ | $J_A$ | $K_a$ |
| 0 | 0 | 0 | 0 | 0 | 1 | × | 0 | 0 | × | 1 | × |
| 0 | 0 | 1 | 0 | 1 | 0 | × | 1 | 1 | × | × | 1 |
| 0 | 1 | 0 | 0 | 1 | 1 | × | × | × | 0 | 1 | × |
| 0 | 1 | 1 | 1 | 0 | 0 | × | × | × | 1 | × | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | × | 0 | × |
| 1 | 0 | 1 | × | × | × | × | × | × | × | × | × |
| 1 | 1 | 0 | × | × | × | × | × | × | × | × | × |
| 1 | 1 | 1 | × | × | × | × | × | × | × | × | × |


HIGH
CP
$J_A$
$Q_A$
A
$K_A$
$\overline{Q}_A$
$\overline{R}$
$J_B$
$Q_B$
B
$K_B$
$\overline{Q}_B$
$\overline{R}$
$J_C$
$Q_C$
C
$K_C$
$\overline{Q}_C$
$\overline{R}$
$Q_A$
$Q_C$

# Decade Counter



- **Once the counter counts to ten (1010), all the flip-flops are being cleared.**

| Clock Pulse | Q3 | Q2 | Q1 | Q0 |
|---|---|---|---|---|
| 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 | 1 | 0 | 0 | 1 |

*Design synchronous mod-3 counter with the following binary sequence using clocked JK flip-flops.*

*Count sequence : 0, 1, 2, 0, 1, 2,.....*

| Present state | | Next state | | Flip-flop inputs | | | |
|---|---|---|---|---|---|---|---|
| $Q_A$ | $Q_B$ | $Q_{A+1}$ | $Q_{B+1}$ | $J_A$ | $K_A$ | $J_B$ | $K_B$ |
| 0 | 0 | 0 | 1 | 0 | X | 1 | X |
| 0 | 1 | 1 | 0 | 1 | X | X | 1 |
| 1 | 0 | 0 | 0 | X | 1 | 0 | X |