EE1212-

# Electronic System I

Lecture 5 - Counters

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# Counters

- Counters can be categorized as synchronous and asynchronous.
- Applications:
  - Control Circuits
  - Signal Generator
  - Timing units

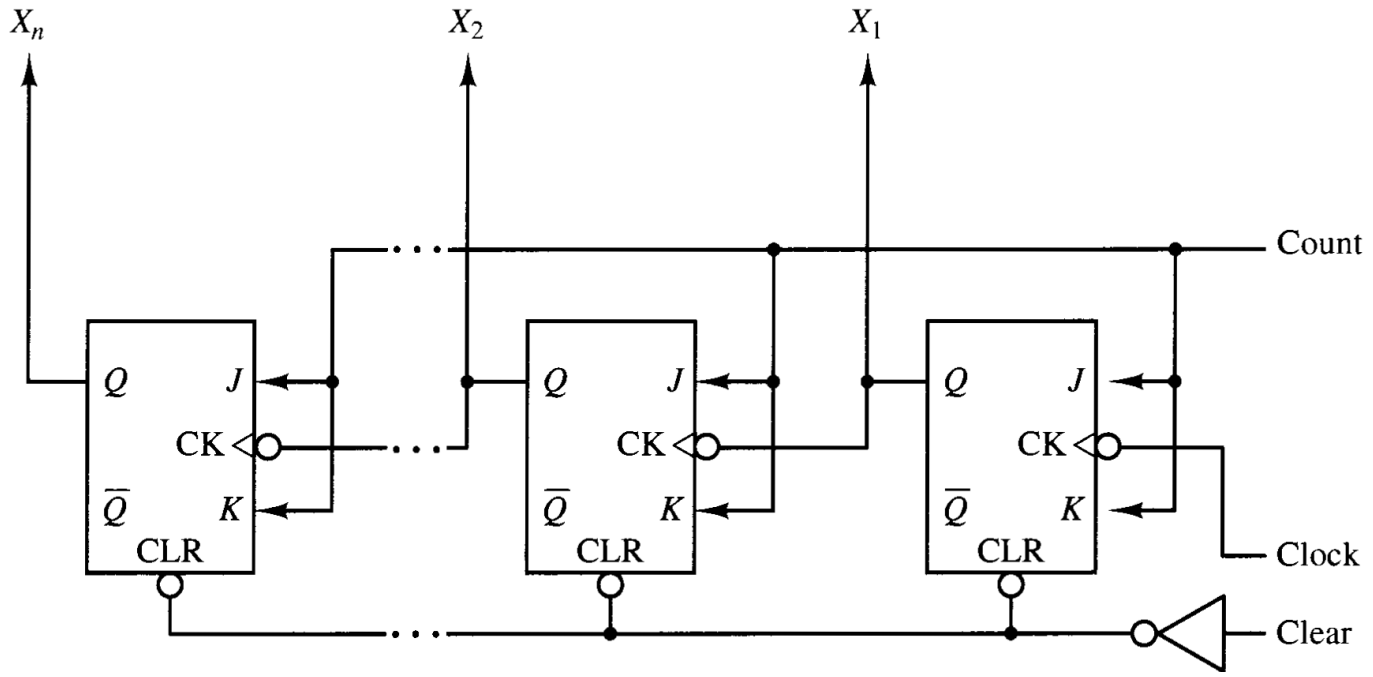
# Asynchronous Up Counter

- An asynchronous binary counter is one whose state changes are not controlled by a synchronizing clock pulse (Flip Flops do not operate according to a common clock).
- Counter stage $X_i$ is complemented each time $X_{i-1}$ makes a 1→ 0 transition.
- Stage $X_1$ is always complemented.

| $X_n$ | ... | $X_3$ | | $X_2$ | | $X_1$ |
|---|---|---|---|---|---|---|
| 0 | ... | 0 | | 0 | | 0 |
| 0 | ... | 0 | | 0 | | 1 |
| 0 | ... | 0 | | 1 | ← | 0 |
| 0 | ... | 0 | | 1 | | 1 |
| 0 | ... | 1 | ← | 0 | ← | 0 |

# Logic Diagram of the Up Counter

Initially all Q outputs are zero.



# Truth Table & Timing Diagram

# Up Counter as frequency divider

- when all the ‘J’s and ‘K’s are given ‘1’ as the input, frequency of

$$X_1 = \frac{1}{2}(frequency\ of\ clock)$$

$$X_2 = \frac{1}{2}(frequency\ of\ X_1)$$

- Therefore JK flip flops in toggling mode can be viewed as a frequency divider.
- Frequency can be divided by $2^n$ using n flip flops.

# Asynchronous Down Counters

- A down counter is one whose state transitions are reversed from those of the standard counter.

| $X_n$ | … | $X_3$ | $X_2$ | $X_1$ |
|---|---|---|---|---|
| 1 | … | 1 | 1 | 1 |
| 0 | … | 0 | 0 | 0 |
| 0 | … | 0 | 0 | 1 |
| 0 | … | 0 | 1 | 0 |
| 0 | … | 0 | 1 | 1 |
| 0 | … | 1 | 0 | 0 |

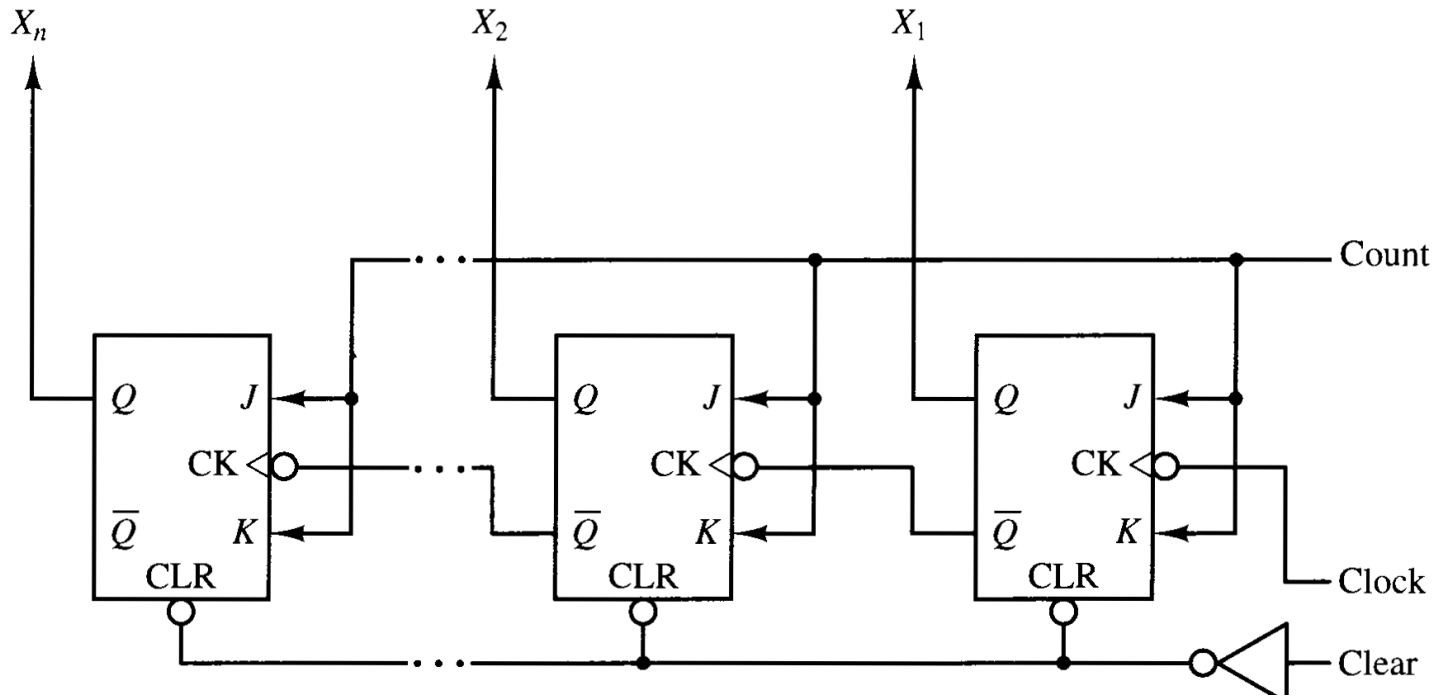
Up count mode

| $X_n$ | … | $X_3$ | $X_2$ | $X_1$ |
|---|---|---|---|---|
| 0 | … | 0 | 0 | 0 |
| 1 | … | 1 | 1 | 1 |
| 1 | … | 1 | 1 | 0 |
| 1 | … | 1 | 0 | 1 |
| 1 | … | 1 | 0 | 0 |
| 1 | … | 0 | 1 | 1 |

Down count mode

# Logic Diagram of the Down Counter

Initially all Q outputs are one.



# Truth Table & Timing Diagram

# Up Down Counter

# Example

It is desired to design a binary ripple counter that is capable of counting the number of items passing on a conveyor belt. Each time an item passes a given point, a pulse is generated that can be used as a clock input. If the maximum number of items to be counted is 6000, determine the number of flip-flops required

The counter should be able to count a maximum of 6000 items.

An N-flip-flop would be able to count up to a maximum of $2^N - 1$ counts.

On the $2^N$ th clock pulse, it will get reset to all 0s.

Now, $2^N - 1$ should be greater than or equal to 6000.

That is, $2^N - 1 \geq 6000$, which gives, $N \geq \log 6001/\log 2 \geq 3.778/0.3010 \geq 12.55$.

The smallest integer that satisfies this condition is 13.

Therefore, the minimum number of flip-flops required=13

# Synchronous Counters

- Asynchronous counters are not useful at very high frequencies, especially for counters with large number of bits.
- Another problem caused by propagation delays in asynchronous counts occurs when try to electronically detect (decode) the counter outputs states.
- Both of these problems can be overcome by the use of a synchronous or parallel counter.

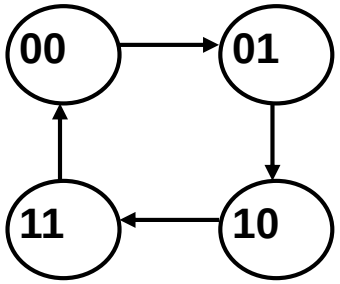
# Synchronous Counters

- Synchronous (parallel) counters: the flip-flops are clocked at the same time by a common clock pulse.
- Clock pulses are applied to the input of all FFs.
- All the flip-flops change state simultaneously (in parallel).

**Example:** 2-bit synchronous binary counter (using T flip-flops, or JK flip-flops with identical J, K inputs).

  - T=0 or J=K=0 (FF does not change state)
  - T=1 or J=K=1 (FF complements)

**Example:** 2-bit synchronous binary counter (using T flip-flops, or JK flip-flops with identical J, K inputs).




| Present state | | Next state | | Flip-flop inputs | |
|---|---|---|---|---|---|
| $A_1$ | $A_0$ | $A_1^+$ | $A_0^+$ | $TA_1$ | $TA_0$ |
| 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

**Example:** 2-bit synchronous binary counter (using T flip-flops, or JK flip-flops with identical J, K inputs).

| Present state | | Next state | | Flip-flop inputs | |
|---|---|---|---|---|---|
| $A_1$ | $A_0$ | $A_1^+$ | $A_0^+$ | $TA_1$ | $TA_0$ |
| 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

$TA_1 = A_0$

$TA_0 = 1$