# Counters

Counter is a sequential circuit. A digital circuit which is used for counting a pulses is known as counter. Counter is the widest application of flip-flops. It is a group of flip-flops with a clock signal applied. ( काउंटर एक sequential circuit है। वह डिजिटल सर्किट जो pulses की counting के लिए उपयोग किया जाता है, काउंटर के रूप में जाना जाता है। काउंटर फ्लिप-फ्लॉप का सबसे widest अनुप्रयोग है। यह फ्लिप-फ्लॉप का एक समूह है जिसमें clock signal apply किया जाता है।)

A counter circuit is usually constructed of a number of flip-flops connected in cascade. (एक काउंटर सर्किट आमतौर पर cascade में जुड़े फ्लिप-फ्लॉप की संख्या से निर्मित होता है। )

It stores or sometimes displays the number of times of a particular event or process has occurred.( यह स्टोर या कभी-कभी किसी विशेष घटना या प्रक्रिया के समय की संख्या को प्रदर्शित करता है।)

Counters are used not only for counting but also for measuring frequency and time. (काउंटर्स का उपयोग न केवल गिनती के लिए किया जाता है बल्कि आवृत्ति और समय को मापने के लिए भी किया जाता है)

Counters are designed by grouping of flip flops and applying a single clock signal. ( काउंटरों को फ्लिप फ्लॉप के समूह और single clock signal के द्वारा डिज़ाइन किया जाता है।)

the values of the output lines represent a number in the binary or BCD number system. Each pulse applied to the clock input indicates the increment or decrement the number in the counter. (आउटप ुट लाइनों का मान binary या BCD number system में एक संख्या का represent करता है। clock input पर लागू प्रत्येक pulse काउंटर में संख्या को बढ़ाने या घटाने का संकेत देता है।)

**Types of counters:-**

There are two types of counters available for digital circuits, they are-

1- Synchronous counters

२- Asynchronous counters

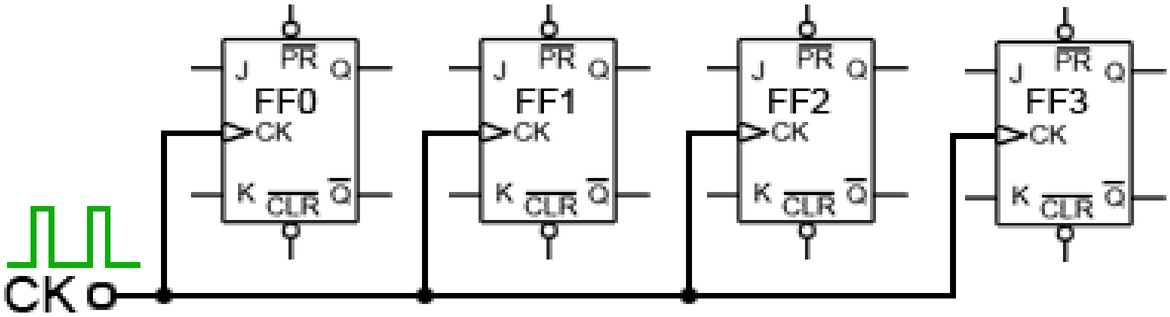
**1- Synchronous counters:-**

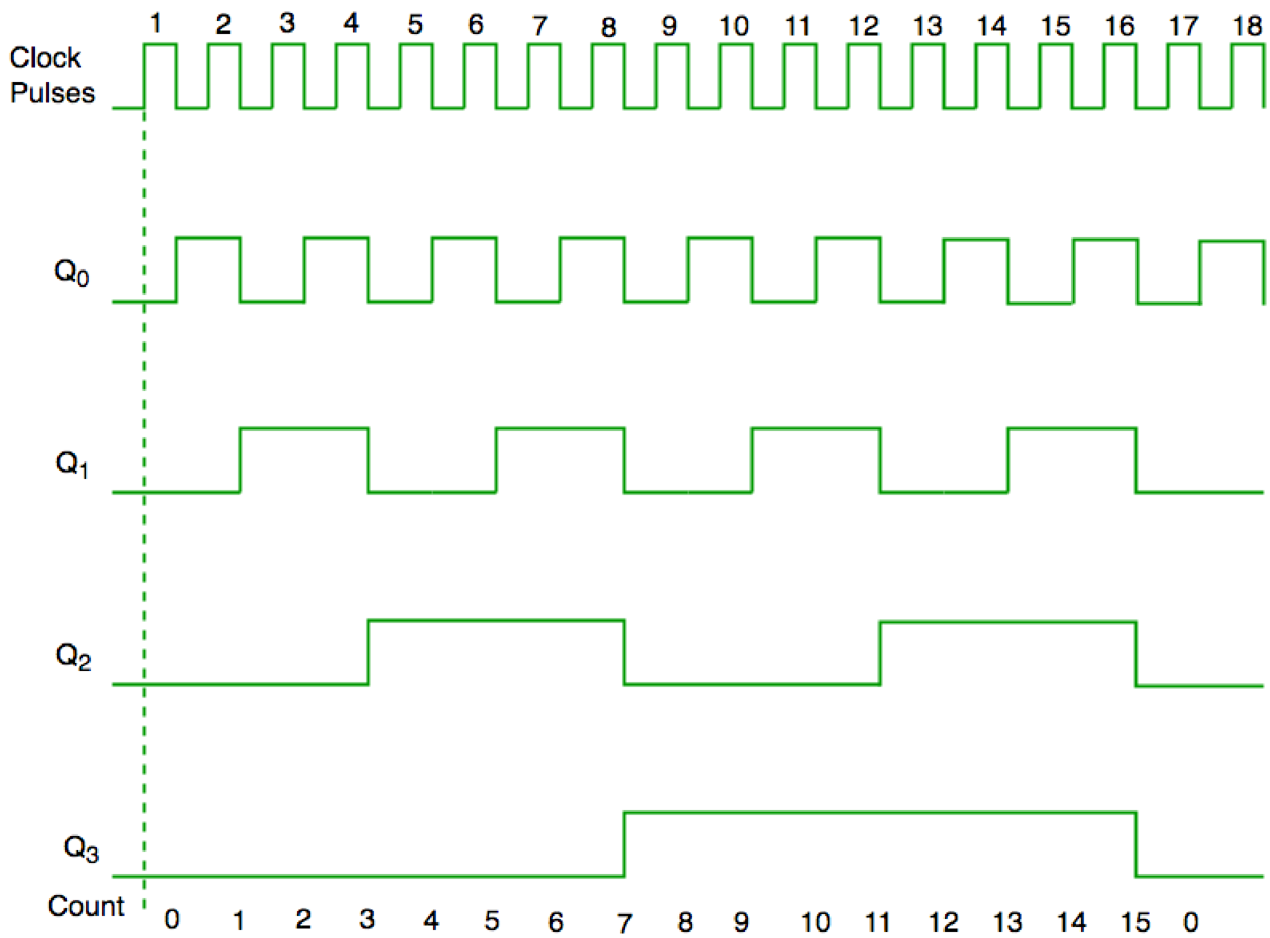
The counters which use a clock signal to change their transition are called “Synchronous counters”. This means the synchronous counters depends on their clock input to change state values. All flip flops in the synchronous counters are triggered by same clock signal.( वे काउंटर जो अपने transition को बदलने के लिए clock signal का उपयोग करते हैं, उन्हें " Synchronous counters " कहा जाता है। इसका मतलब है कि synchronous counters अपने state values के change के लिए clock input पर निर्भर रहता है। Synchronous counters में सभी फ्लिप फ्लॉप same clock signal द्वारा triggered किए जाते हैं।)

The synchronous counter provides a more reliable and high-speed operation for counting purposes because the clock pulses in this circuit are applied to every flip-flop at exactly the same time.( synchronous counter गिनती के उद्देश्यों के लिए एक अधिक विश्वसनीय और उच्च गति operation प्रदान करता है क्योंकि इस सर्किट में clock pulses को प्रत्येक फ्लिप-फ्लॉप पर एक समय पर लागू किया जाता है।)

Synchronous counters use JK flip-flops because the programmable J and K inputs allow the toggling of individual flip-flops to be enabled or disabled at various stages of the counting . (Synchronous counters JK flip-flops का उपयोग करते हैं क्योंकि programmable J and K का inputs , counting के लिए individual flip-flops के various stages में को enabled or disabled करने के लिए toggling करता हैं।)

it can operate on higher frequency (operation is fast)because it does not have cumulative delay as same clock is given to each flip flop. (यह उच्च आवृत्ति पर काम कर सकता है क्योंकि इसमें cumulative delay नहीं होती है क्योंकि प्रत्येक फ्लिप फ्लॉप को same clock दी जाती है।)




**2- <u>Asynchronous counters:-</u>**

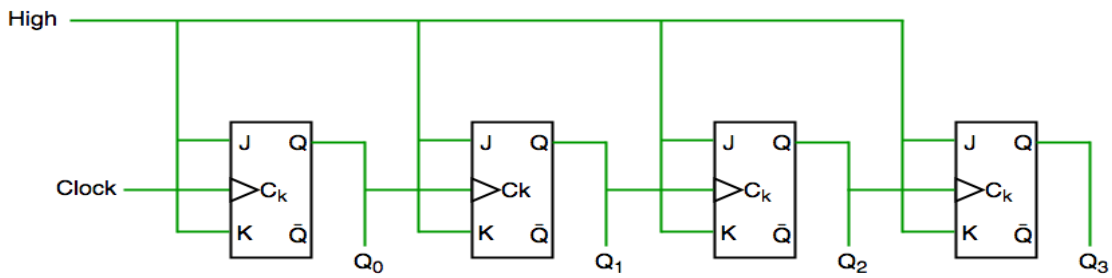
The counter in which the change in transition does not depend upon the input clock signal is known as “Asynchronous counters”. In these counters, the first flip flop is connected to the external clock signal, and the rest are clocked by the state outputs (Q & Q’) of the previous flip flop. ( जिन counters में transition का परिवर्तन input clock signal पर निर्भर नहीं करता है, उन्हें " Asynchronous counters " कहा जाता है। इन काउंटरों में, पहला फ्लिप फ्लॉप बाहरी क्लॉक सिग्नल से जुड़ा होता है, और बाकी फ्लिप फ्लॉप पिछले फ्लिप फ्लॉप के आउटपुट state द्वारा जुड़े होते हैं।)

Another name for Asynchronous counters is “Ripple counters.

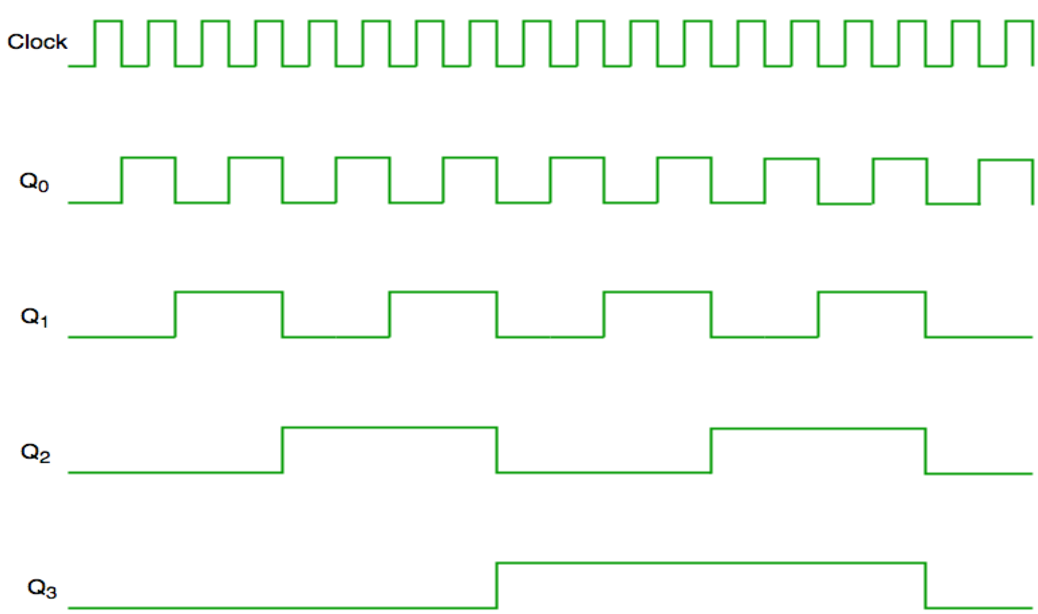
These are very simple in design.

Operation of asynchronous counters is very slow compared to synchronous counters.( synchronous counters की तुलना में asynchronous counters का संचालन बहुत धीमा है।)

A Asynchronous counters can be constructed by use of clocked T flip flop. ( एक एसिंक्रोनस काउंटर्स का निर्माण clocked T flip flop के उपयोग से किया जा सकता है।)



(a) Asynchronous counter



(b) Timing Diagram

## Comparision between Asynchronous Vs Synchronous Counters

| SYNCHRONOUS COUNTERS | ASYNCHRONOUS COUNTERS |
|---|---|
| The propagation delay is very low. | Propagation delay is higher than that of synchronous counters. |
| Its operational frequency is very high. | The maximum frequency of operation is very low. |
| These are faster than that of ripple counters. | These are slow in operation. |
| Large number of logic gates are required to design | Less number of logic gates required. |
| High cost. | Low cost. |
| Synchronous circuits are easy to design. | Complex to design. |
| Standard logic packages available for synchronous. | For asynchronous counters, Standard logic packages are not available. |

**Applications of counters :-**

Counter found their applications in many digital electronic devices. Some of their applications are listed below.

1- Frequency counters
2- Digital clocks
3- Analog to digital convertors.
4- With some changes in their design, counters can be used as frequency divider circuits. The frequency divider circuit is that which divides the input frequency exactly by ‘2’.
5- In time measurement. That means calculating time in timers such as electronic devices like ovens and washing machines.
6- design digital triangular wave generator by using counters.

There are many other type of counters rather than synchronous and asynchronous counters, such as Decade counter, Binary counter, Ring counter, Johnson counter, Up / Down counter etc. , which we will discuss about them in our upcoming sessions.

**Counters have modes**. The 'mod' of the counter represents the number of states of the cycles through it before setting the counter to its initial state. For example, a binary mod 8 counter has 8 countable states. They are from 000 to 111. So the mod 8 counter counts from 0 to 7.

A binary mod 4 counter has 4 count states, from 000 to 011. So the mod 4 counter counts from 0 to 4. This means, in general a mod N counter can contain n number of flip flops, where 2^n = N.

काउंटरों में मोड होते हैं। काउंटर cycles के उन number of number of states को represents करते है जो counter के initial state के पहले था. उदाहरण के लिए, एक binary mod 8 counter में 8 countable states होते हैं ,000 से 111 तक हैं। मॉड 8 काउंटर 0 से 7 तक गिना जाता है। सामान्य तौर पर N counter काउंटर में फ्लिप फ्लॉप की संख्या n हो सकती है, जहां 2^n = N.।

**Practical example of counter:-**

We use counters in many applications. Where ever we come across the use of timers, there we use counters of synchronous type.

Suppose, in our kitchen appliances we use microwave ovens. In that we set some temperature to heat the food item kept in it. Internally the counter calculates the increase or decrease in temperature and time. If it reaches the pre-set temperature, then it prevents from further heating and spoiling of that food item.

Washing machines: We use counters in washing machines also. Similar to the counting operation in microwave oven, the counter in washing machine counts the time which we set it to operate.

In both microwave oven and washing machine, we set the device to particular time, and it starts decreasing for every second. When the value of counter becomes zero, it activates the switch ON / OFF. Thus the operation of the device is controlled by counters.

Some other applications of counters: To calculate the number of people entering and leaving a stadium or auditorium we use , counters at entry gate or door. These counters will count the persons. For entry of each person, the value of counter increases by 1. In the same manner, for every leaving of each person, the counter value decreases by 1.

## BCD or Decade Counter:-

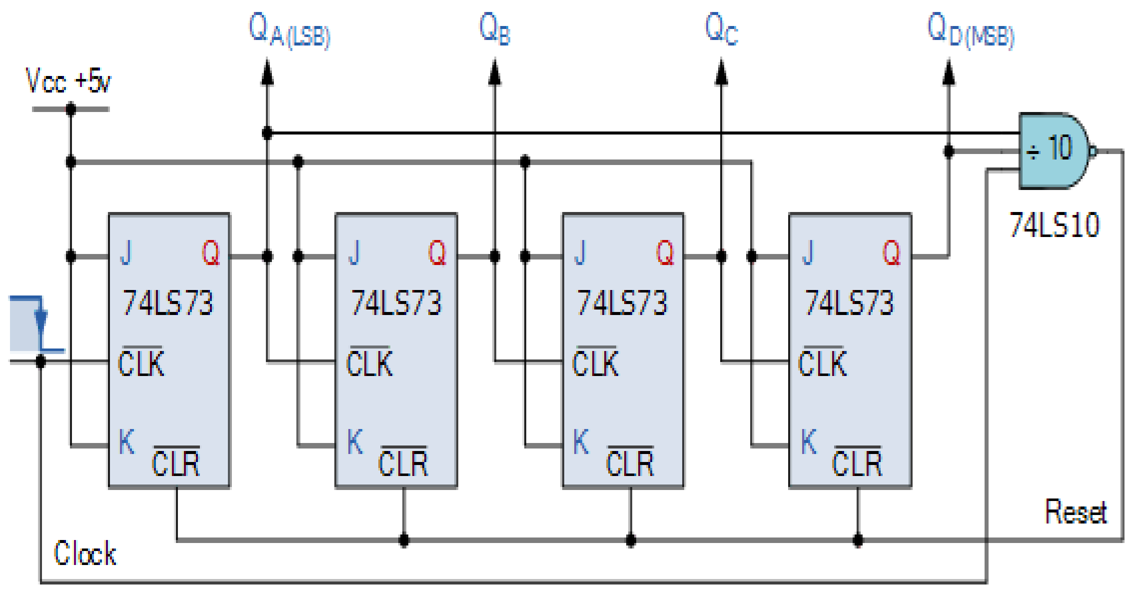
-A decade counter counts ten different states and then reset to its initial states. A simple decade counter will count from 0 to 9 . (for 4 bit counter).

Or

-A binary coded decimal (BCD) is a serial digital counter that counts ten digits.
And it resets for every new clock input. As it can go through 10 unique combinations of output, it is also called as "Decade counter". A BCD counter can count 0000, 0001, 0010, 1000, 1001, 1010, 1011, 1110, 1111, 0000, and 0001 and so on.

-The basic decade counter has a 4-bit binary output and an input signal (called a clock).

Decade counters are used in clock circuits, frequency dividers, state machines, and sequencers etc.




The above figure shows a decade counter constructed with JK flip flop. The J and K inputs are connected to logic 1 (toggle). The clock input of every flip flop is connected to the output of previous flip flop and external clock pulse applied in the first flip flop.

The output of the NAND gate is connected in parallel to the clear input 'CLR' to all the flip flops.

**Decade Counter Operation:-**

When the Decade counter is at REST then the count is equal to 0000. This is first stage of the counter cycle. When we connect a clock signal input to the counter circuit then the circuit will count the binary sequence. The first clock pulse can make the circuit to count up to 9 (1001). The next clock pulse advances to count 10 (1010).

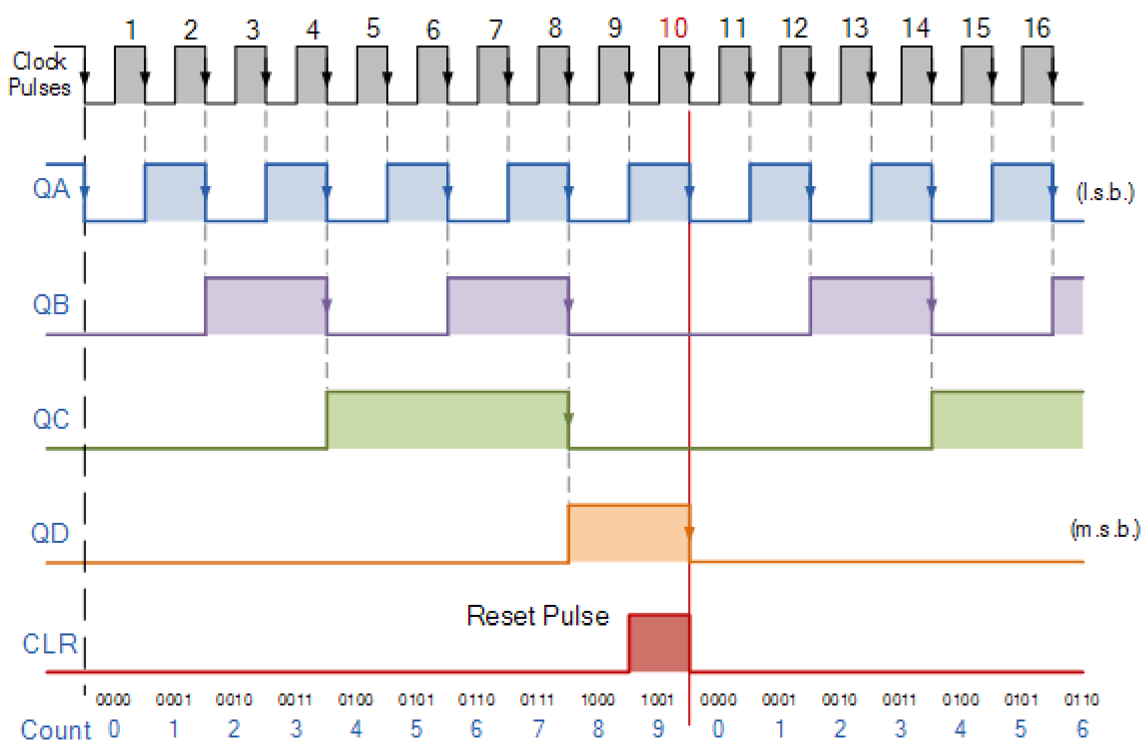
Then the ports QB and QD will be high. As we know that for high inputs, the NAND gate output will be low. The NAND gate output is connected to clear input, so it resets all the flip flop stages in decade counter. This means the pulse after count 9 will again start the count from count 0.

## Truth table

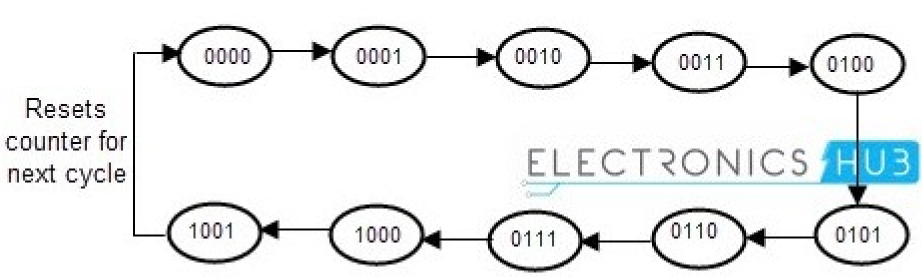
| Clock Count | Output bit Pattern | | | | Decimal Value |
|---|---|---|---|---|---|
| | QD | QC | QB | QA | |
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 1 | 1 |
| 3 | 0 | 0 | 1 | 0 | 2 |
| 4 | 0 | 0 | 1 | 1 | 3 |
| 5 | 0 | 1 | 0 | 0 | 4 |
| 6 | 0 | 1 | 0 | 1 | 5 |
| 7 | 0 | 1 | 1 | 0 | 6 |
| 8 | 0 | 1 | 1 | 1 | 7 |
| 9 | 1 | 0 | 0 | 0 | 8 |

| | | | | | |
|---|---|---|---|---|---|
| 10 | 1 | 0 | 0 | 1 | 9 |
| 11 | Counter Resets its Outputs back to Zero | | | | |

## Decade Counter Timing Diagram




# State Diagram of Decade



## Divide by N ripple counters:-

Ripple counter is an asynchronous counter in which only the first flip-flop is clocked by an external clock and all rest flip-flops are clocked by the output of the previous flip-flop. Asynchronous counters are also called ripple-counters because the clock pulse ripples it way through the flip-flops.

A n-bit ripple counter can count up to$2^n$states. It is also known as MOD n counter.

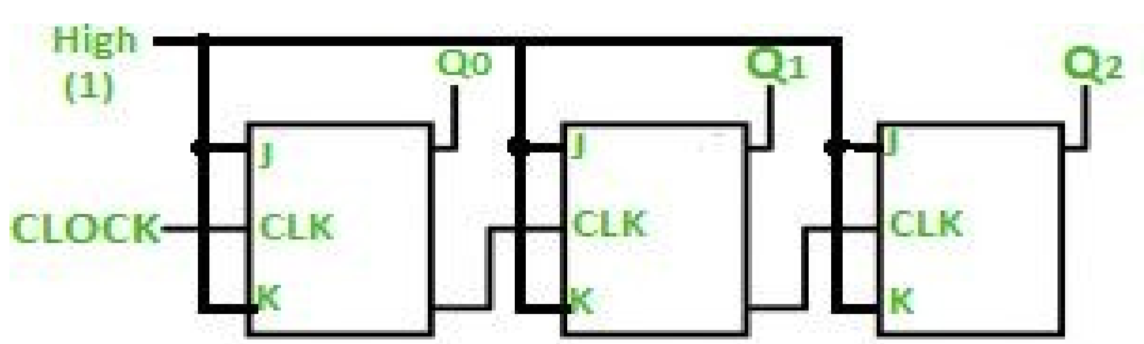
For a 4-bit counter, the range of the count is 0000 to 1111 ($2^4$-1)

A ripple counter may count up or count down or count up and down depending on the input control. When counting up, the count sequence goes from 0000, 0001, 0010, ... 1110 , 1111 ,etc. When counting down the count sequence goes in the opposite manner: 1111, 1110, ... 0010, 0001, 0000, ... etc.

Some of the features of ripple counter are:-

1. It is an asynchronous counter.
2. Different flip-flops are used with a different clock pulse.
3. All the flip-flops are used in toggle mode.
4. Only one flip-flop is applied with an external clock pulse and another flip-flop clock is obtained from the output of the previous flip-flop.
5. The flip-flop applied with external clock pulse act as LSB (Least Significant Bit) in the counting sequence

A 3-bit Ripple counter using JK flip-flop –



In the circuit shown in above figure, Q0(LSB) will toggle for every clock pulse because JK flip-flop works in toggle mode when both J and K are applied 1, 1 or high input. The following counter will toggle when the previous one changes from 1 to 0.

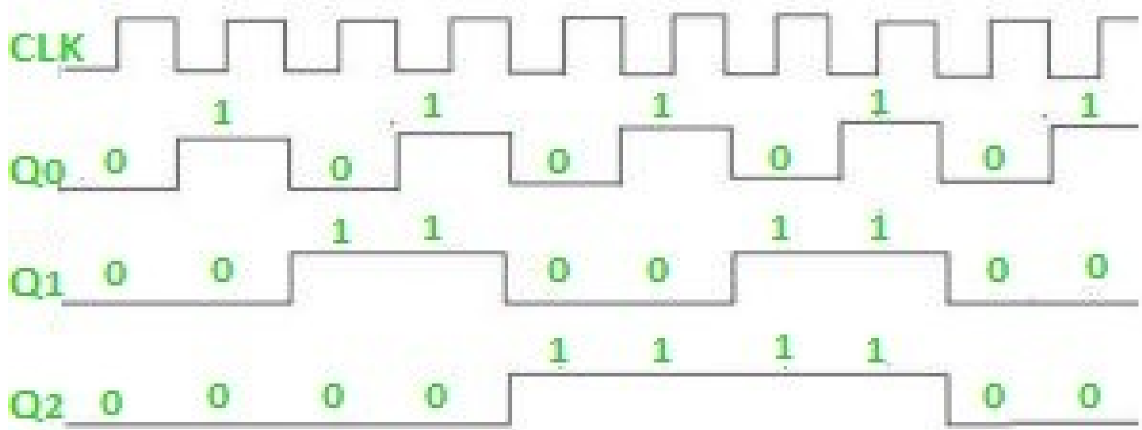
Truth Table –

| Counter State | $Q_2$ | $Q_1$ | $Q_0$ |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 2 | 0 | 1 | 0 |
| 3 | 0 | 1 | 1 |
| 4 | 1 | 0 | 0 |
| 5 | 1 | 0 | 1 |
| 6 | 1 | 1 | 0 |
| 7 | 1 | 1 | 1 |

The 3-bit ripple counter used in the circuit has eight different states each one of which represents a count value. Similarly a counter having n flip-flops can have a maximum of $\mathbf{2}^n$ state. The number of states that a counter owns is known as its mod (modulo) number. Hence a 3-bit counter is a mod-8 counter.

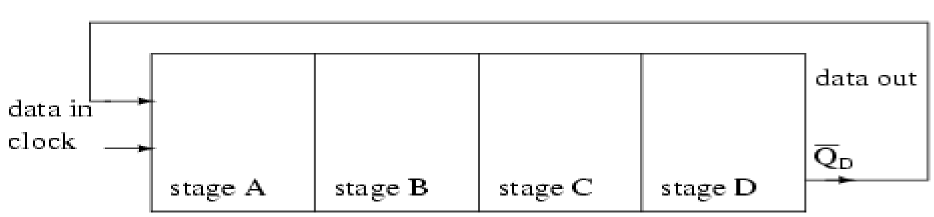
A mod-n counter may also be described as a divide-by-n counter. This is because the most significant flip-flop (the furthest flip-flop from the original clock pulse) produces one pulse for every n pulses at the clock input of the least significant flip-flop (the one triggers by the clock pulse).

**Timing diagram:-**

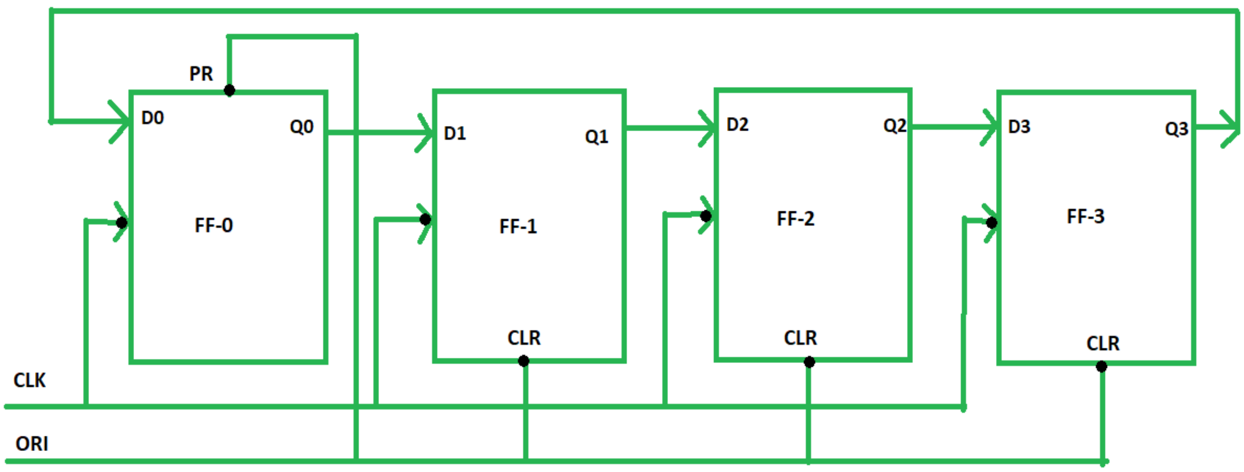



## Ring Counter:-

A ring counter is a Shift Register (a cascade connection of flip-flops) with the output of the last flip flop connected to the input of the first. It is initialized such that only one of the flip flop output is 1 while the remaining is 0. The 1 bit is circulated so the state repeats every n clock cycles if n flip-flops are used. The "MOD" or "MODULUS" of a counter is the number of unique states. The MOD of the n flip flop ring counter is n.




Ring Counter, shift register output fed back to input




Ring Counter

In this diagram, we can see that the clock pulse (CLK) is applied to all the flip-flop simultaneously. Therefore, it is a Synchronous Counter.

When PR is 0, then the output is 1. And when CLR is 0, then the output is 0. Both PR and CLR are active low signal that is always works in value 0.

PR = 0, Q = 1

CLR = 0, Q = 0

<u>Truth Table of 4-bit Ring Counter</u>

| Clock Cycle | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ |
|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 | 0 |
| 3 | 0 | 0 | 1 | 0 |
| 4 | 0 | 0 | 0 | 1 |
| 5 | 1 | 0 | 0 | 0 |
| 6<br>.<br>. | 0<br>.<br>. | 1<br>.<br>. | 0<br>.<br>. | 0<br>.<br>. |

Bit-pattern repeats for every 4 clock cycles

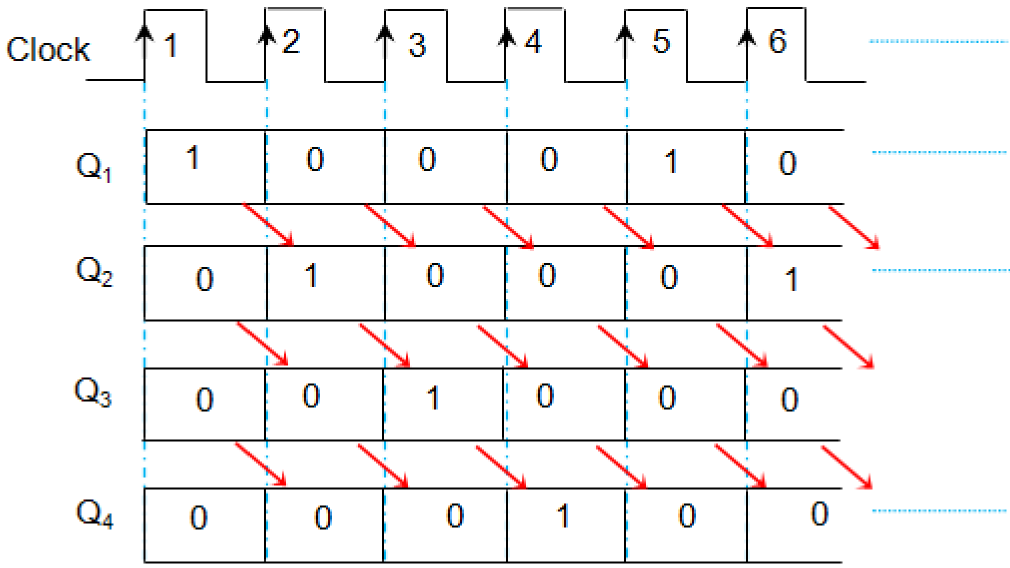



Figure 2 Output waveform of 4-bit ring counter

Merit-

Ring counters have only one bit high at any instant of time. This makes them readily decodable in nature unlike other counters which make use of additional logic circuitry.

Demerit-

A ring counter of n-bits has only n valid states instead of 2^n. This makes them inefficient in terms of state-usage.

## Up Down Counter :-

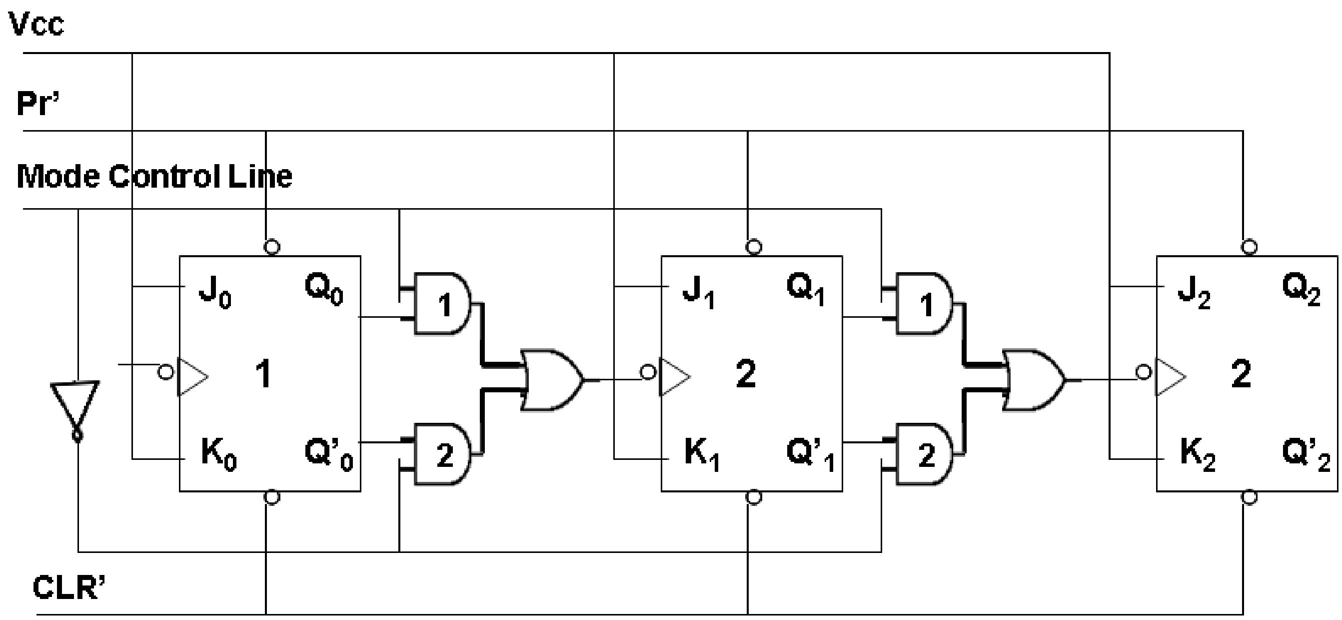
A counter which can be made to count in either the forward or reverse direction is called an up-down, a reversible or forward-backward counter.

**Down Counter:-**

A binary counter with a reverse count is called a binary down counter. In a down counter the binary counter is decremented by 1 with every input count pulse. The count of a 4-bit down counter starts from binary 15 and continues to binary counts 14, 13, 12… 0 and then back to 15. In a binary down counter, outputs are taken from the complement terminals Q' of all flip flops. For a down counter, when Q goes from 0 to 1, Q' will go from 1 to 0 and complement the next flip flop.

**Up Counter:-**

A binary counter with a normal count is called a binary up counter. In a up counter, the binary counter is incremented by 1 with every input clock pulse. Outputs are taken from the normal output terminal Q of all flip flops. For up counter when Q goes from 1 to 0, it complements the next flip flop.




**When mode control line is 1**, all gates labeled as 1 will be enabled and all gates labeled as 2 will be disabled. The counter works like a **Up Counter**.

| CLK | Q0' | Q1' | Q2' |
|---|---|---|---|
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 2 | 1 | 0 | 0 |
| 3 | 0 | 1 | 0 |
| 4 | 1 | 1 | 0 |
| 5 | 0 | 0 | 1 |
| 6 | 1 | 0 | 1 |
| 7 | 0 | 1 | 1 |
| 8 | 1 | 1 | 1 |

**When mode control line is 0**, all gates labeled as 1 will be disabled and all gates labeles as 1 will be enabled. The counter works like a **Down Counter.**

| CLK | Q2 | Q1 | Q0 |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 0 |
| 3 | 1 | 0 | 1 |
| 4 | 1 | 0 | 0 |
| 5 | 0 | 1 | 1 |
| 6 | 0 | 1 | 0 |
| 7 | 0 | 0 | 1 |
| 8 | 0 | 0 | 0 |