DIGITAL ELECTRONICS

Digital circuits use discrete voltage levels, typically representing binary values (0 and 1), to perform logic operations. These circuits form the foundation of computers, calculators, and digital systems.

Number System:

- **Decimal (Base 10):** Uses digits 0–9. It's the standard number system used in daily life.
- **Binary (Base 2):** Uses only 0 and 1; fundamental to digital electronics.
- **Hexadecimal (Base 16):** Uses 0–9 and A–F (where A = 10 to F = 15); compact representation of binary.
- **Octal (Base 8):** Uses digits 0–7; sometimes used for memory addressing.

Gray Code:

A binary numeral system where only one bit changes between successive numbers. It is used in error correction, digital encoders, and rotary position sensors to prevent misreading during transitions.

Flip-Flops:

Flip-flops are bistable devices used for storage (1-bit memory). They change state based on clock input and are used in sequential logic. Common types:

- **SR Flip-Flop**
- **JK Flip-Flop**
- **D Flip-Flop**
- **T Flip-Flop**

Registers:

Registers are groups of flip-flops used to store multi-bit data. They temporarily hold data for processing in CPUs and other digital systems. Types include:

- **Shift Registers** – Move bits left or right.
- **Parallel Registers** – Store multiple bits simultaneously.

1. What are the Properties of Boolean Algebra?

Some basic switching properties of Boolean algebra are:

- Annulment law: A.0 = 0 ; A + 1 = 1
- Associative law: A+(B+C) = (A+B)+C ; A.(B.C) = (A.B).C
- Absorption law: A. (A+B) =A ; A+AB = A
- Complement law: A+A' =1 ; A.A' = 0
- Commutative law: A+B = B+A; A.B =B.A
- De Morgan Law: (A.B)' = A' +B' ; (A+B)' = A'.B'
- Distributive law: A. (B+C) = (A.B)+(A.C)
- Double negation law: ((A)')' = A
- Identity law: A.1 = A; A + 0 = A
- Idempotent law: A+A =A ; A.A=A

2. Explain the Consensus Theorem.

The consensus theorem is defined as follows in digital electronics:

AB + A'C + BC = AB + A'C

The consensus or resolvent of the terms AB and A'C is BC. It is the intersection of all the unique literals of the terms, excluding the literal that appears negated in one term and unnegated in the other.

3. What is Gray code?

Gray Code is also known as Reflected Binary code. It is a binary system in which each successive pair of numbers differs with only 1-bit data. These codes are very useful in binary numbers generated by hardware that can produce an error during the transition from one number to another.

4. What is Encoder and Decoder?

The encoder and decoder are combinational logic circuits. An encoder is a device that converts analog or active data into digital or coded data. But the decoder's operation is exactly the reverse of the encoder. A decoder is a device that converts the original signal as output from the coded input signal and converts n lines of input into 2n lines of output.

5. Explain the Difference Between Sequential and Combinational Circuits.

Combinational Circuit	Sequential Circuit
The output depends on the present input only and there is no need for feedback for input and output, so a memory element is not required.	The output depends upon both the present input and the present state (previous output), so a memory element is required to save the feedback state.
Clock signals are not required and the combinational circuit is not dependent on time.	Clock signals are required and sequential circuits are dependent on time and clock so it needs triggering.
It is easier to use, design, and handle.	It is more complex to use, design, and handle.
Faster logic circuits.	Slower than combinational circuits.

Elementary building blocks are logic gates only.	Elementary building blocks are Flip-Flops.

6. What are the Flip-Flops?

Flip-flops are the basic digital memory circuit. It has two states logic 1(High) and logic 0(low) states. A flip-flop is a sequential circuit that consists of a single binary state of information or data. It is also known as a Bistable Multivibrator. Flip-flops are used as the delay element they are also used for Frequency Division, Data transfer, Counting, and as a memory element.

8. Explain De Morgan's Theorem.

De Morgan's Theorem is expressed using the following two theorems:

1. The complement of a product of two numbers is the sum of the complements of those numbers.
   (A. B)' = A' + B'
2. The complement of the sum of two numbers is equal to the product of the complement of two numbers.
   (A + B)' = A'B'

9. How Many Types of Number Systems are There?

A Number system is defined as an elementary system to represent numbers and figures. It is a unique way of expressing numbers in arithmetic and algebraic structure. Based on the base value and the number of allowed digits, number systems are of many types. The four common types of Number systems are:

1. Binary Number System.

2. Octal Number System.
3. Decimal Number System.
4. Hexadecimal Number System.

10. What is a Logic Gate?

A logic gate is a switching circuit that decides whether an input pulse can pass to the output in digital circuits. Logic gates are the building blocks of a digital circuit, that executes various logical operations required by any digital circuit. It can take two or more inputs but produces only one output.

The combination of inputs applied to a logic gate identifies its output. Logic gates use Boolean Algebra expressions to execute logical processes. Logic gates are found in nearly every digital device.

11. What are the Types of Logic Gates?

There are three basic logic gates, two universal gates, and a few other combinational logic gates in digital electronics.

Basic Gates

- AND gate.
- OR gate.
- NOT gate.

Universal Gates

- NAND gate
- NOR gate

Other Gates:

- XOR gate

- XNOR gate

12. What is Meant by K-Map or Karnaugh Map?

K-map is a table-like representation of a Boolean expression. K-map is used to minimize the Boolean expression so that the circuit can be implemented using the least number of gates and become more efficient. K-map is a table-like representation but it gives more information than TRUTH TABLE. Boolean expressions with 3 and 4 variables can be minimized very easily using K-map without using any Boolean algebra theorems, but using K-map for more than 4 variables is a bit complex as it needs two or more K-maps and it cannot apply for more than 6 variable. K-map can be resolved into two forms Sum of Product (SOP) and Product of Sum (POS) as per the need of the problem.

14. Write Down the Characteristics of Digital ICs.

The characteristics of digital ICs are:

- **Propagation delay:** It is the average transition time delay for the propagation of a signal.
- **Power Dissipation:** Total power consumption by the gate when it is completely occupied.
- **Fan-in:** Number of inputs connected to a circuit without any degradation in the voltage level.
- **Fan-out:** Number of standard loads carried out by the gate without halting its normal operation.
- **Noise Margin:** It is the maximum noise added to the input of the circuit so that there is no change in the output.

15. What is a Mealy Machine?

A Mealy machine is a finite state machine where the outputs depend on both the current state and the current inputs.

16. What is a Moore Machine?

A Moore machine is a finite state machine where the outputs depend only on the current state.

17. Define Pair, Quad, and Octet.

- **Pair:** Two adjacent cells of the K-map are known as **Pair**. It cancels or minimizes expression with one variable in a K-Map simplification.
- **Quad:** Four adjacent pairs in a K-map are known as **quads**. It cancels or minimizes expression with two variables in a K-Map simplification.
- **Octet**: Eight adjacent pairs in a K-map are known as **octets**. It cancels or minimizes expression with four variables in a K-map simplification.

18. Explain the Quine-McCluskey Method?

The Quine McCluskey method or tabulation method is used to minimize the Boolean functions. This method simplifies Boolean expression into the simplified form using prime applicants. This method is convenient to simplify when Boolean expressions have more than 4 input variables.

19. What is Duality Theorem?

Dual expression is equal to a negative logic of the given Boolean relation. For this, we have to,

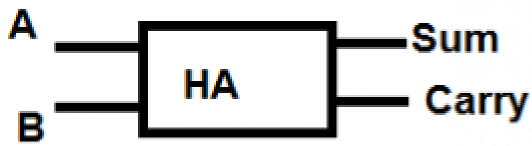
1. Change each OR sign by and AND sign and vice-versa.
2. Complement any 0 or 1 appearing in the expression.
3. Keep the literal same.

Example:

Dual of A(B+C) = A+(B.C) = (A+B)(A+C)

20. What is Half-Adder?

Half adder is used to perform the addition of 2 bits using a combinational circuit. The input variables are augend and addend bits and the output variables are sum & carry bits.



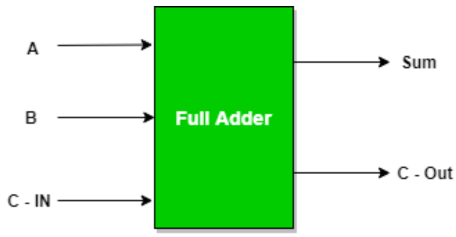
Half Adder

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

21. What is Full-Adder?

Full Adder adds three inputs and produces two outputs. The first two inputs are A and B and the third input is carried input denoted as C-IN. The output carry is defined as C-OUT and the normal output is defined as S which is SUM.

A full adder logic is designed in such a manner that can take eight inputs together to create a byte-wide adder and cascade the carry bit from one adder to another.



Inputs			Outputs	
A	B	C – IN	Sum	C - Out
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

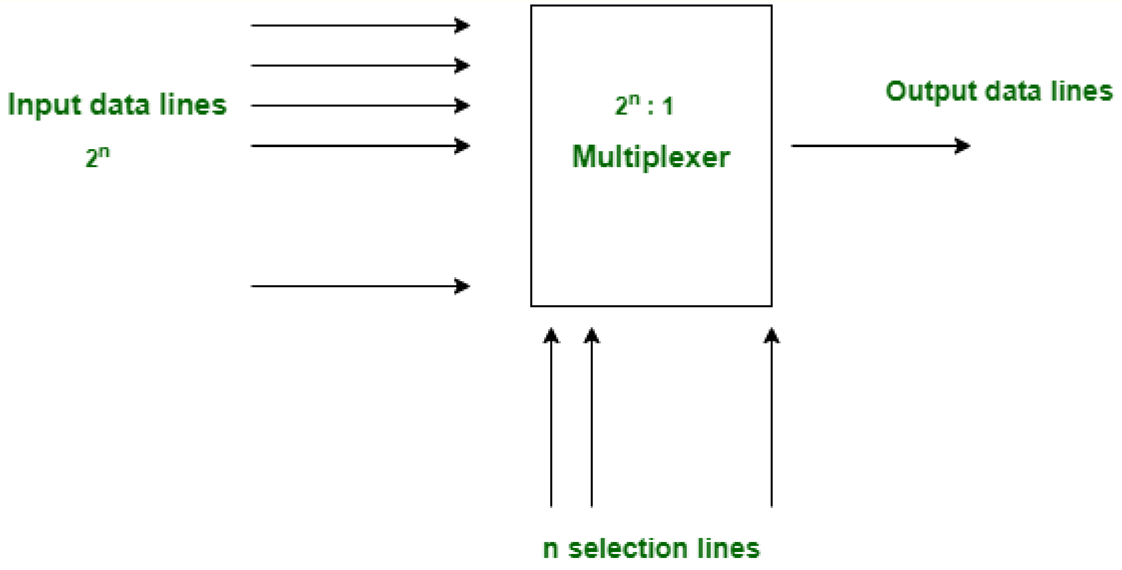
22. What is a Multiplexer?

The multiplexer is a combinational circuit it has many data inputs and a single output depending on the control/select lines. For N number of input lines, log n (base2) is the total selection lines, or for 2n input lines, the total n number of selection lines is needed.

Multiplexers are also known as **"Data n selector, parallel to serial converter, many to one circuit, parallel to serial converter, universal logic circuit"**. Multiplexers are basically used to increase the amount of data that can be sent over the network within a specific amount of time and bandwidth.

Some of the applications of the multiplexer are as follows:

- Used in the time-multiplexing system.
- It is used as an A/D to D/A Converter.
- Used in the data acquisition system
- It is used as a data selector.

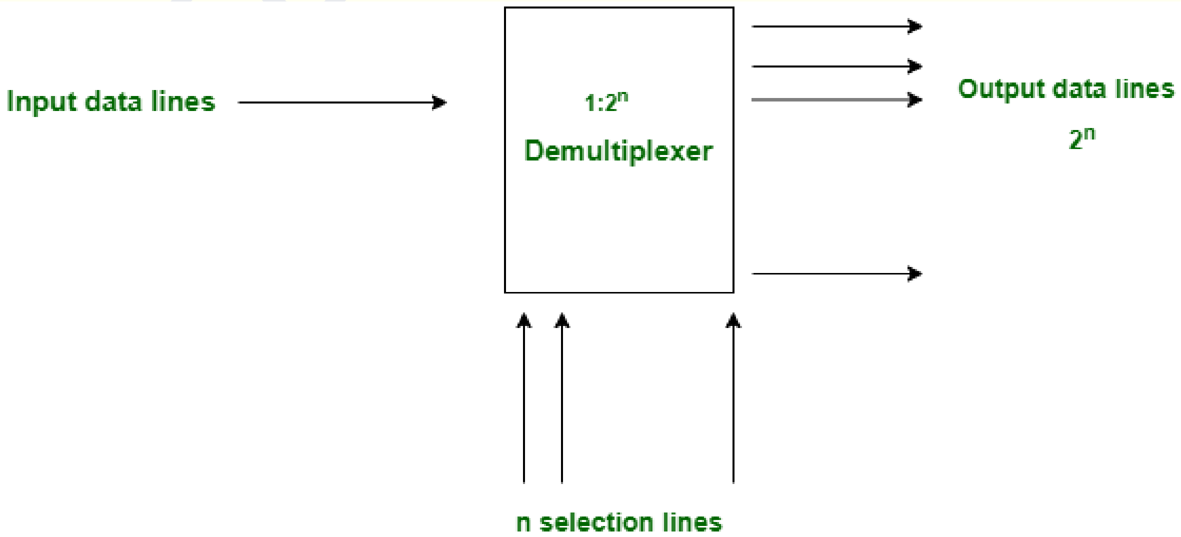


23. What is a Demultiplexer?

The demultiplexer is a data distributor that takes a single input and gives multiple outputs. Demultiplexers have 1 input and 2n output lines where n is the selection line.

Some of the applications of the demultiplexer are as follows

- It is used as a decoder for the conversion of binary to decimal.
- It is used as a serial-to-parallel converter.
- Used in the data transmission system for error detection.



24. What is Propagation Delay in Digital Circuits?

Propagation delay is the time taken for a signal to travel from the input to the output of a digital circuit.

25. What is a Race Condition in Digital Circuits?

A race condition occurs when multiple inputs change simultaneously, causing unpredictable outputs due to varying propagation delays.

26. Define Rise Time, Fall Time, Hold Time, and Setup Time.

- **Rise time**: Time required to change the voltage level from 10% to 90%.
- **Fall time:** Time that is required to change the voltage level from 90% to 10%.
- **Hold Time:** The lowest time at which the voltage level becomes constant after triggering the clock pulse to clock into the flip flop reliably is known as the **Hold time**. It is denoted by **thold.**
- **Setup time:** The minimum time required to maintain the constant voltage levels at the excitation inputs of the flip-flop device before the triggering edge of the clock pulse reliably clocked in the flip-flop is called the **Setup time**. It is denoted as **tsetup**.

27. What is the Difference Between Synchronous and Asynchronous Counters?

Synchronous Counter	Asynchronous Counter
All flip-flops are triggered with the same clock simultaneously.	Different flip-flops are triggered with different clocks, not simultaneously.

A synchronous Counter is faster than an asynchronous counter in operation.	The asynchronous Counter is slower than the synchronous counter in operation.
Also known as Parallel Counter.	Also known as Serial Counter.
Examples: Ring counter, Johnson counter.	Examples: Ripple UP counter and the Ripple DOWN counter.
In synchronous counter, propagation delay is less.	In the asynchronous counter, there is a high propagation delay.

28. Explain One-hot Key Design?

One hot encoding is used in the process of categorizing data variables to be used in machine learning algorithms for making better predictions. In one-hot encoding, we convert each categorical value into a different column, and in return, it gives a binary value, either 0 or 1 to each column. And each integer value represents a binary vector.

29. Define CAM?

Content addressable memory (CAM) is a data storage device, that stores memory in cells. When any data is entered into the memory, the CAM compares the input with all the stored data. It is a high-speed technology. In CAM, memories are unsorted, which means they are not arranged in chronological order and are not packed in isolated modules.

30. What are Standard and Canonical forms?

- **Standard Form:** A Boolean variable that can be represented in either true form or complemented form. In standard form, the Boolean function will contain all the variables in either true form or complemented form while a canonical number of variables depends on the output of SOP or POS.
- **Canonical Form:** In Boolean algebra, the Boolean function can be expressed as Canonical Disjunctive Normal Form known as **minterms** and some are expressed as Canonical Conjunctive Normal Form known as **maxterm**.
  In Minterm, we look for the functions where the output results in "1" while in Maxterm we look for functions where the output results in "0".
  We perform the **Sum of minterms** also known as the Sum of products (SOP).
  We perform **Product of Maxterm** also known as Product of Sum (POS).
  Boolean functions expressed as a sum of minterms or product of maxterms are said to be in canonical form.

31. What is Functional Completeness?

A set of operations is said to be functionally complete or universal if every switching function can be represented by operations in it. In simple words, a set of Boolean functions is functionally complete, if all other Boolean functions can be constructed from this set and a set of input variables are provided, e.g.

- Set B = {+,'} are functionally complete
- Set A = {+,*,' (OR, AND, complement) } are functionally complete.
- Set C = {*,'} are functionally complete

32. Discuss Various Implicants in K-Map.

Implicant is defined as a product/Minterm term in SOP or sum/maxterm term in POS of a Boolean function. Consider a Boolean function, F = AB + ABC + BC. The implicants are AB, ABC, and BC. There are various implicants in the K-Map, which are as follows:

- **Prime Implicant:** A group of squares or rectangles made up of a bunch of adjacent minterms which is allowed by the definition of K-Map are called **prime implicants(PI)** i.e. all possible groups formed in K-Map.
- **Redundant Prime Implicant:** The prime implicants for which each of its minterms is covered by some essential prime implicants are **redundant prime implicants(RPI)**. This prime implicant never appears in the final solution.
- **Essential Prime Implicant:** These are those sub cubes(groups) that cover at least one Minterm that can't be covered by any other prime implicant. **Essential prime implicants(EPI)** are those prime implicants that always appear in the final solution.
- **Selective Prime Implicant:** The prime implicants that are neither essential nor redundant prime implicants are called **selective prime implicants(SPI) or non-essential prime implicants**. They may appear in some solutions or may not appear in some solutions.

33. What is Hazard?

A H**azard**, in a digital circuit, causes a transient fluctuation in the output of the circuit. A hazard in a digital circuit is a temporary disruption in the operation of the circuit which resolves itself after some time. These fluctuations happen when different paths from the input to output have delays and this leads to changes in input variables. These do not change the output instantly but appear at the output after a small delay.

There are three different kinds of hazards found in digital circuits:

- Static hazard
- Functional hazard
- Dynamic hazard

34. What is Static Hazard?

A **Static Hazard** happens when a change in input causes the output before stabilizing to its correct value. There are two types of static hazards, which are as follows:

- **Static-0 Hazard:** If the output is currently at logic state 0 and after the input changes its state, the output changes momentarily to 1 before settling on 0, then it is said to be a **Static-0 hazard**.
- **Static-1 Hazard:** If the output is currently at logic state 1 and after the input changes its state, the output changes momentarily to 0 before settling on 1, then it is said to be a **Static-1 hazard**.

35. Define Dynamic Hazard?

When the output changes several times then it should change from 0 to 1 or 1 to 0 only once, it is called a **dynamic hazard**. Dynamic hazards occur only in multilevel circuits. Dynamic hazards take place when the output changes for two neighboring input combinations while changing, the output should change only once. But sometimes it may change three or more times in short intervals because of different delays in several paths.

37. Explain the Types of Flip Flop.

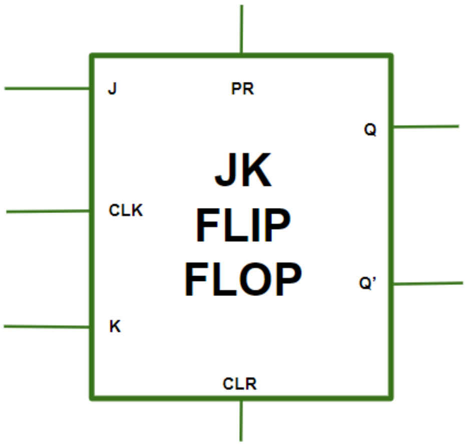
Flip-flops are the basic digital memory circuit. It has two states logic 1(High) and logic 0(low) states. A flip-flop is a sequential circuit that consists of a single binary state of information or data. It is also known as a Bistable Multivibrator.

Types of flip-flops:

1. RS Flip Flop
2. JK Flip Flop
3. D Flip Flop
4. T Flip Flop

38. Difference Between JK and SR Flip Flop?

JK Flip Flop: The JK flip-flop's diagram describes the basic structure which has Clock (CLK), Clear (CLR), and Preset (PR).



Operations in JK Flip-Flop

- **Case-1:**

PR = CLR = 0

This condition is in an invalid state.

- **Case-2:**

PR = 0 and CLR = 1

The PR is activated, which means the output in the Q is set to 1. So, the flip-flop is in the set state.

- **Case-3:**

PR = 1 and CLR = 0

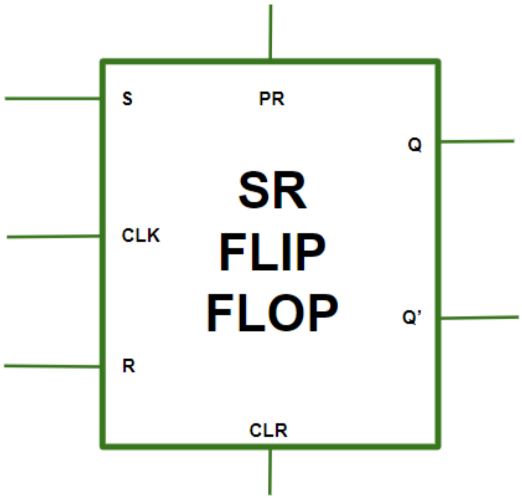
The CLR is activated which means the output in the Q' is set to 1. So, the flip-flop is in the reset state.

- **Case-4:**

PR = CLR = 1

In this condition, the flip-flop works in its normal way whereas the PR and CLR get deactivated.

SR Flip Flop: In SR flip flop, with the help of Preset and Clear, when the power is switched ON, the state of the circuit is uncertain and keeps on changing. It may Set (Q = 1) or Reset (Q' = 0) state. In many applications, it is desired to initially Set or Reset the flip flop. This thing is accomplished by the Preset (PR) and the Clear (CLR).



Operations in SR Flip-Flop

- **Case-1:**

PR = CLR = 1

The asynchronous inputs are inactive and the flip-flop responds independently to the S, R, and CLK inputs.

- **Case-2:**

PR = 0 and CLR = 1

When the Q is set to 1.

- **Case-3:**

PR = 1 and CLR = 0

When the Q’ is set to 1.

- **Case-4:**

PR = CLR = 0

This is an invalid state.

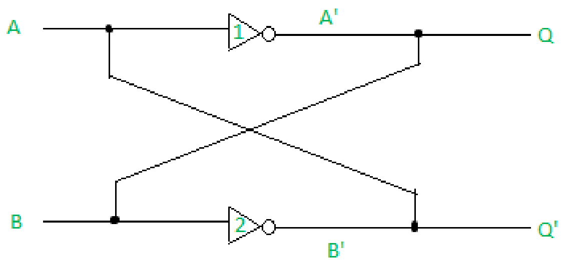
39. What is Master-Slave JK Flip Flop?

The Master-Slave Flip-Flop is a combination of two JK flip-flops linked together in a series manner. One of them acts as the **“master”** and the other behaves as a **“slave”**. The output from the master flip flop is linked with the two inputs of the slave flip flop whose output is again feedback to the inputs of the master flip flop.

Other than this, the circuit has an **inverter**. The inverter is connected to the clock pulse in such a manner that the inverted clock pulse is given to the slave flip-flop. In other words, if the clock pulse equals zero, i.e. CP=0 for a master flip-flop, then the clock pulse equals one, i.e. CP=1 for a slave flip-flop, and if CP=1 for the master flip flop then it becomes 0 for the slave flip-flop.

40. What is the Basic Bistable Element?

A bit memory cell is also called a **Basic Bistable element**. It has two cross-coupled inverters, and 2 outputs Q and Q’. It is called “Bistable” as the basic bistable element circuit has two stable states logic 0 and logic 1.



(A) when **A=0**,

In inverter1, Q = A'= B= 1

In inverter2, Q' = B' = A = 0

(B) when **A=1**,

In inverter1, Q = A'= B= 0

In inverter2, Q' = B' = A = 1

To read more, refer to the article: *One-bit memory cell*

41. What is a Counter?

It is a device that stores (and sometimes displays) the number of times a particular event or process has occurred, often in relationship to a clock signal. Counters are used in digital electronics for counting purposes, they can count specific events happening in the circuit. For example, in the UP counter, a counter increases the count for every rising edge of the clock. Not only counting, but a counter can also follow a certain sequence based on our design like any random sequence 0,1,3,2….They can also be designed with the help of flip-flops.

Counters are broadly divided into two categories:

1. Asynchronous counter
2. Synchronous counter

To read more, refer to the article*: Counters*

42. What is Johnson Counter?

Johnson counters also called creeping counter is a type of synchronous counter. In the Johnson counter, the complemented output of the last flip-flop is linked to the input of the first flip-flop, and for implementing the n-bit Johnson counter we need n number of flip-flops. It is one of the most important types of shift register counter. It originated from the feedback of the output to its own input. Johnson counter is a ring with an inversion. Other names for the Johnson counter are the walking counter, creeping counter, mobile counter, twisted ring counter, and switch tail counter.

43. Up to How Many States Ripple Counter can Count?

A ripple counter can count up to 2n states with n-bits. It is also known as MOD n counter. It is known as a ripple counter because the clock pulse ripples through the flip-flops. Some of the features of the ripple counter are:

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

44. What are Shift Registers?

A **Register** is used to store information. A register is a group of flip-flops that are connected in series and used to store multiple bits of data.

The information stored within registers can be transferred with the help of **shift registers**. Shift Register is also a group of flip-flops that is used to store multiple bits of data. The bits stored in shift registers can be moved within the registers and in/out of the registers by using clock pulses. An n-bit shift register can be obtained by joining n flip-flops.

The registers that will shift the bits to the right are called “Shift right registers”.
The registers that will shift the bits to the left are called “Shift left registers”.

Shift registers are basically of 4 types. These are:

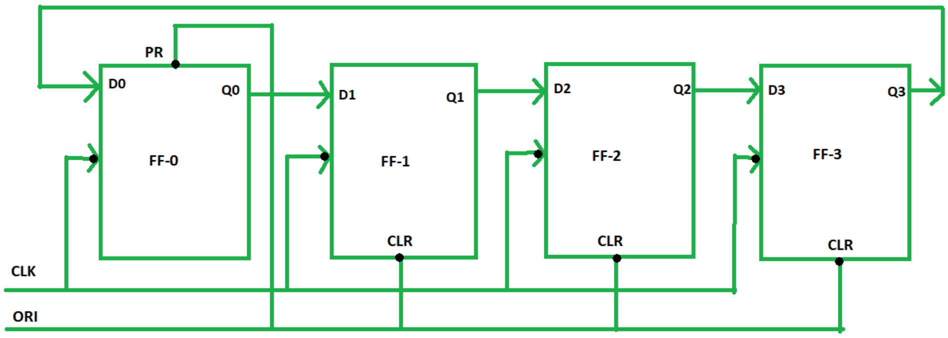
1. Parallel In parallel Out shift register
2. Parallel In Serial Out shift register
3. Serial In Serial Out shift register
4. Serial In parallel Out shift register

45. Explain Ring Counter?

A ring counter is a typical application of the Shift register. The ring counter is almost the same as the shift counter. The only change is that the output of the last flip-flop is connected to the input of the first flip-flop in the case of the ring counter but in the case of the shift register it is taken as output. Except for this, all the other things are the same.

No. of states in Ring counter = No. of flip-flop used

So, for designing a 4-bit Ring counter we need 4 flip-flops.



Ring Counter

46. What is Scrambling?

Scrambling is a technique that does not increase the number of bits and does provide synchronization. The problem with techniques like Bipolar AMI(Alternate Mark Inversion) is that continuous sequences of zeroes create synchronization problems one solution to this is Scrambling.

There are two common scrambling techniques:

1. B8ZS(Bipolar with 8-zero substitution)
2. HDB3(High-density bipolar3-zero)