FCO(cc-201)

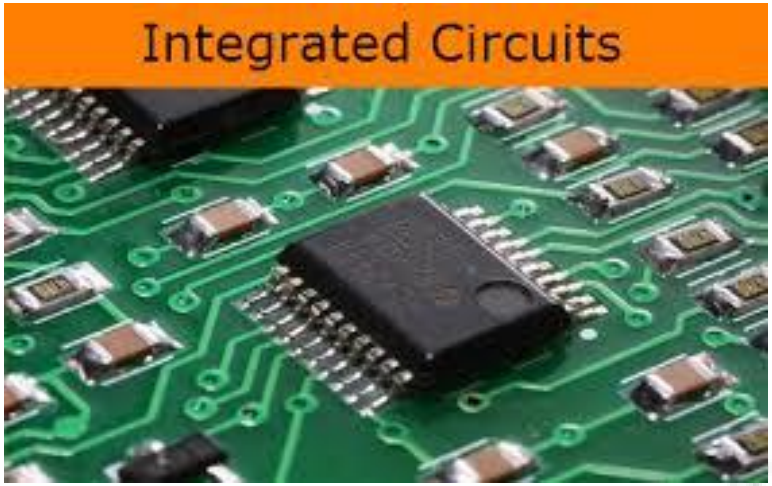
UNIT-1 Digital Components

Introduction

- The digital era started with the invention of vacuum tubes. Vacuum based computers were rare and expensive.
- This was then replaced by transistors, which were **faster in use and smaller in size, cost effective, less power consuming and reliable.**
- Then came the invention of integrated circuits which just revolutionized the use of computers.
- Due to its small dimension, low cost, and very high reliability even the common man is familiar with its applications like smart phones and laptops.

Integrated circuits

- Integrated circuit (IC), also called **microelectronic circuit, microchip, or chip**, an assembly of electronic components, fabricated as a single unit, in which **miniaturized active** devices (e.g., transistors and diodes) and passive devices (e.g., capacitors and resistors) and their interconnections are built up on a thin substrate of semiconductor material (typically **silicon**).
- The resulting circuit is thus a small monolithic "chip," which may be as small as a few square centimetres or only a few square millimetres.
- The individual circuit components are generally microscopic in size.


Integrated Circuits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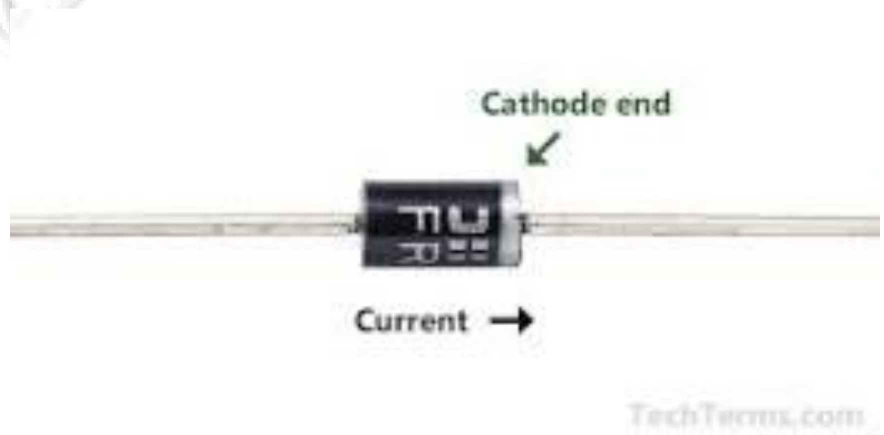
Cathode end
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TechTerms.com

Integrated circuits

- An integrated circuit (IC) is manufactured using silicon material and mounted in a ceramic or plastic container (known as Chip).
- The basic components of an IC consist of electronic circuits for the digital gates.
- The various gates are interconnected inside an IC to form the required circuit.

Classification of IC

- **SSI (Small Scale Integration Devices)**
  - These type of devices contain several independent gates in a single package. The inputs and outputs of these gates are connected directly to the pins in the package. The number of logic gates are usually **less than 10** and are limited by the number of pins available in the IC.
- **MSI (Medium Scale Integration Devices)**
  - These type of devices has a complexity of approximately **10 to 200 gates** in a single package. The basic components include decoders, adders, and registers.
- **LSI (Large Scale Integration Devices)**
  - LSI devices contain about **200 to a few thousand gates** in a single package. The basic components of an LSI device include digital systems, such as processors, memory chips, and programmable modules.
- **VLSI (Very Large Scale Integration Device)**
  - This type of devices contains **thousands of gates** within a single package. The most common example of a VLSI device is a complex microcomputer chip.

Encoder

- An encoder is a combinational circuit that **converts binary information in the form of a 2^N input lines into N output lines**, which represent N bit code for the input.
- For simple encoders, it is assumed that only one input line is active at a time.
- The encoder is a device or a transducer or a circuit.
- The encoder will convert the information from one format to another format i.e like electrical signals to counters.
- The feedback signal of the encoder will determine the position, count, speed, and direction.
- The control devices are used to send the command to a particular function.

4 to 2 Encoder

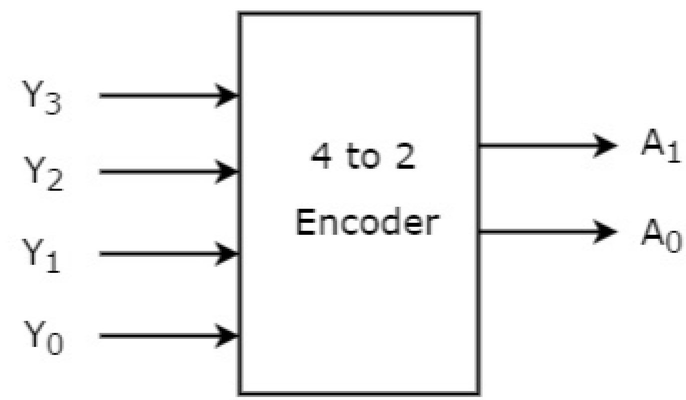
- Let 4 to 2 Encoder has four inputs Y_3, Y_2, Y_1 & Y_0 and two outputs A_1 & A_0.
- At any time, only one of these 4 inputs can be '1' in order to get the respective binary code at the output.
- we can write the **Boolean functions** for each output as

$$A1=Y3+Y2$$
$$A0=Y3+Y1$$

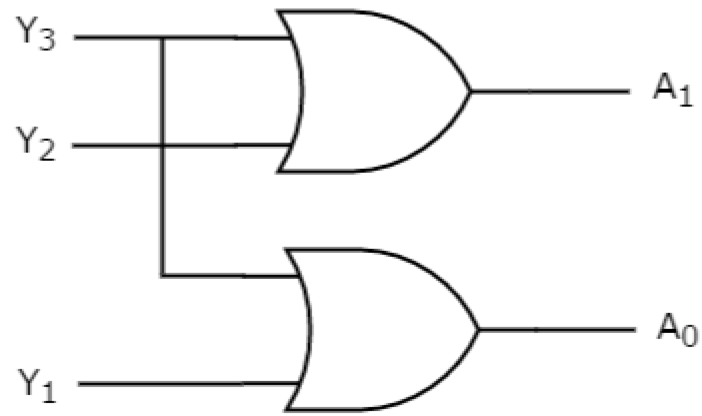
Truth table

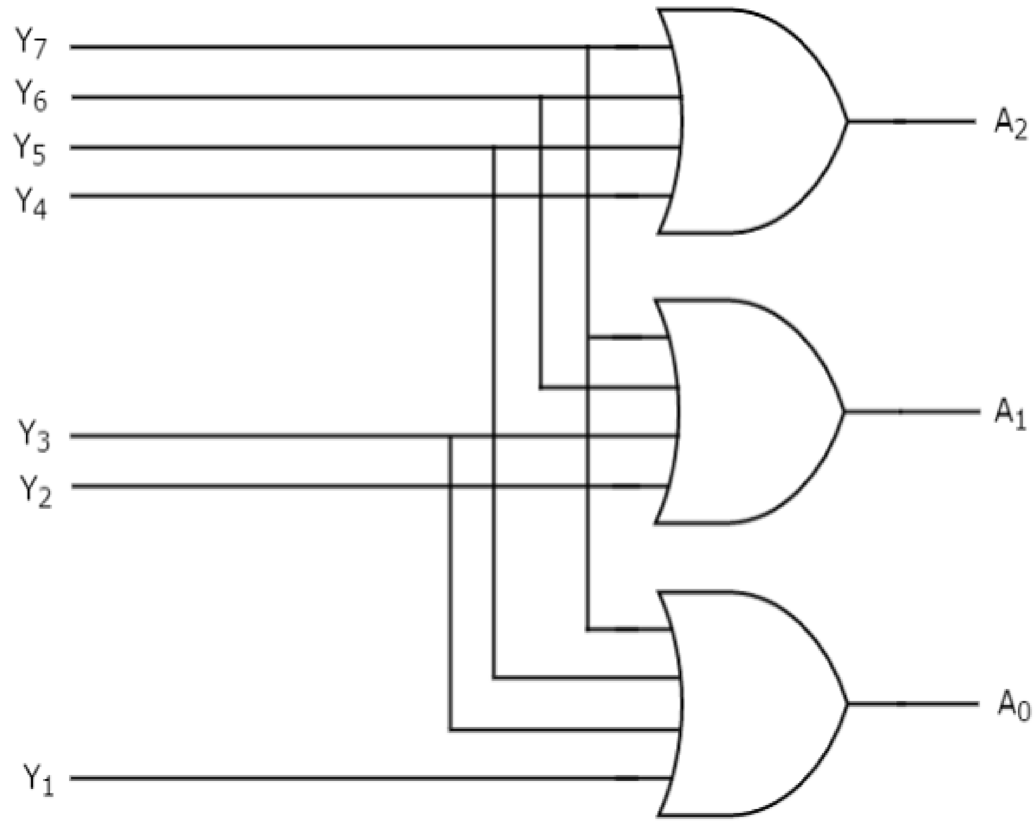
Inputs				Outputs	
Y_3	Y_2	Y_1	Y_0	A_1	A_0
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1

block diagram



circuit diagram of 2 to 4 and Octal to Binary(8 to 3) Encoder



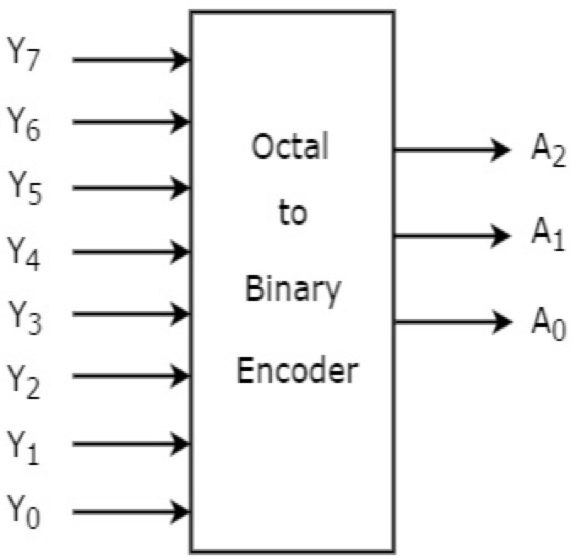


Octal to Binary Encoder

- Octal to binary Encoder has eight inputs, Y7 to Y0 and three outputs A2, A1 & A0. Octal to binary encoder is nothing but 8 to 3 encoder.
- At any time, only one of these eight inputs can be '1' in order to get the respective binary code.
- We can write the **Boolean functions** for each output as:

A2=Y7+Y6+Y5+Y4
A1=Y7+Y6+Y3+Y2
A0=Y7+Y5+Y3+Y1

block diagram



Truth table

Inputs								Outputs		
Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0	A_2	A_1	A_0
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	1
0	0	0	1	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	0	0	1	1	0
1	0	0	0	0	0	0	0	1	1	1

Decoders

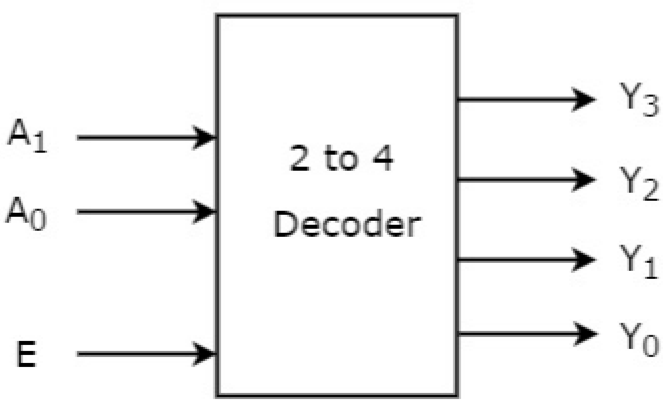
- A decoder does the opposite job of an encoder. It is a combinational circuit that converts n lines of input into 2^n lines of output.
- In the digital electronics, the binary decoder is a combinational logic circuit that converts the binary integer to the associated pattern of output bits.
- These are used in different applications like seven segment display, memory address decoding.
- The function of the binary decoder is obtained if the given input combination has occurred.

2 to 4 Decoder

- Let 2 to 4 Decoder has two inputs A1 & A0 and four outputs Y3, Y2, Y1 & Y0.
- One of these four outputs will be ‘1’ for each combination of inputs when enable, E is ‘1’.
- we can write the **Boolean functions** for each output as :

$$Y3=E.A1.A0$$
$$Y2=E.A1.A0'$$
$$Y1=E.A1'.A0$$
$$Y0=E.A1'.A0'$$

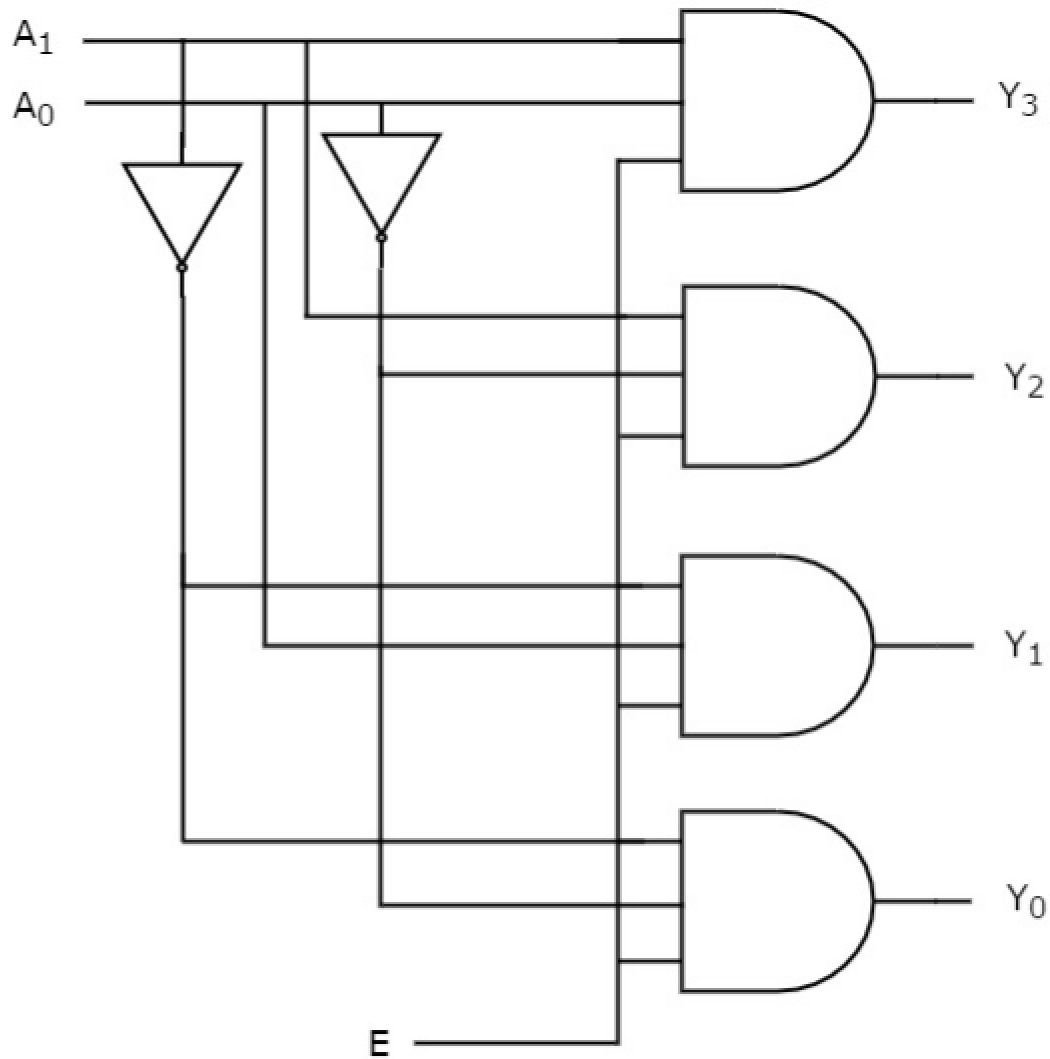
block diagram



Truth table

Enable	Inputs		Outputs			
E	A_1	A_0	Y_3	Y_2	Y_1	Y_0
0	x	x	0	0	0	0
1	0	0	0	0	0	1
1	0	1	0	0	1	0
1	1	0	0	1	0	0
1	1	1	1	0	0	0

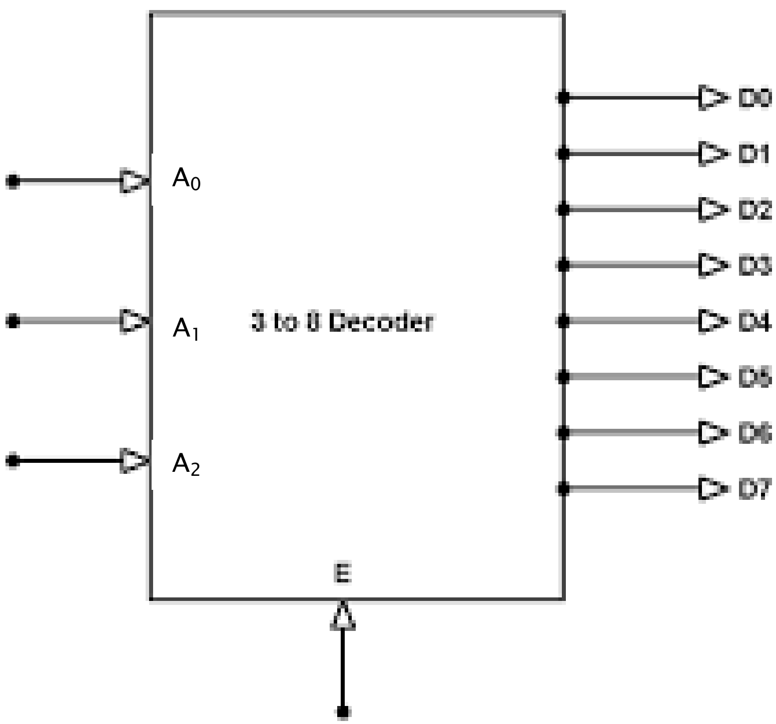
circuit diagram of 2 to 4 decoder



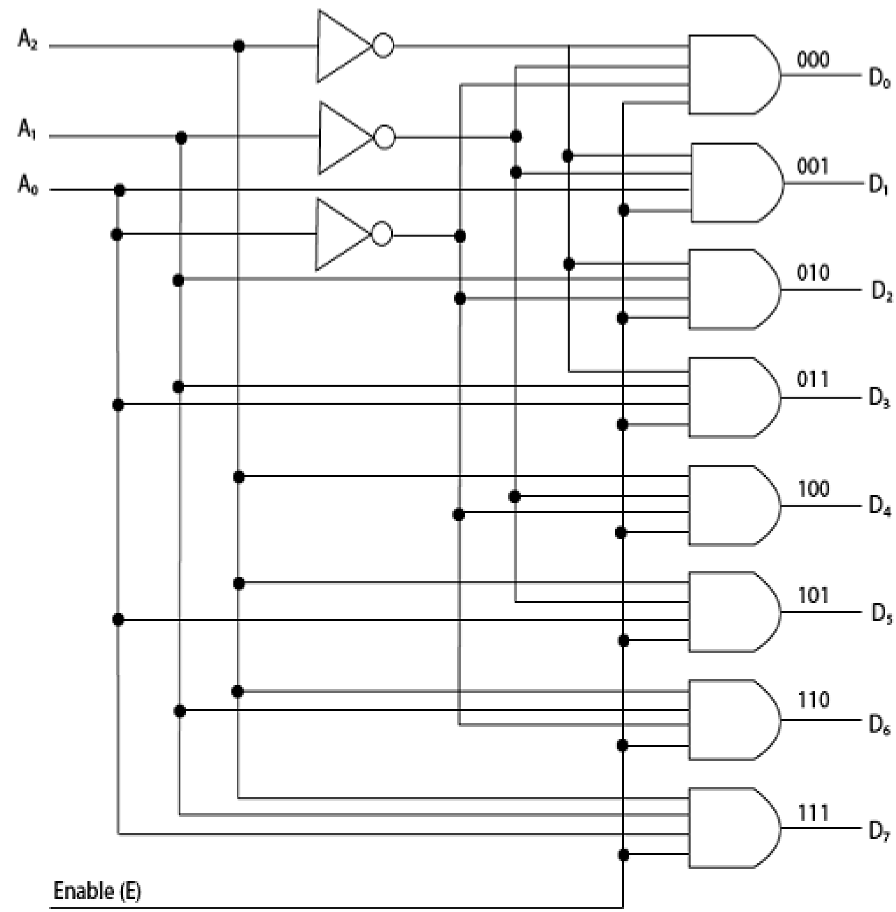
3 to 8 Decoder

- The most common application of this decoder is binary-to-octal conversion.
- 3 to 8 Decoder has three inputs A2, A1 & A0 and eight outputs, Y7 to Y0.
- One of these eight outputs will be '1' for each combination of inputs when enable, E is '1'.

Block diagram



Circuit diagram of 3 to 8 decoder



$D_0 = \bar{A}\bar{B}\bar{C}$, $D_1 = \bar{A}\bar{B}C$, $D_2 = \bar{A}B\bar{C}$,

Boolean Algebra $D_3 = \bar{A}BC$, $D_4 = A\bar{B}\bar{C}$, $D_5 = A\bar{B}C$,

$D_6 = AB\bar{C}$, $D_7 = ABC$

Truth table

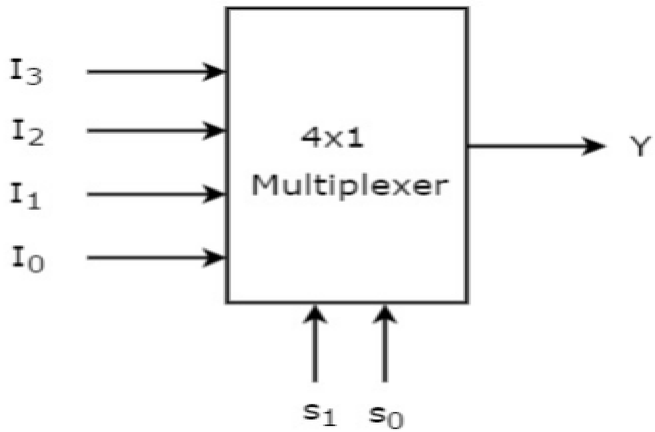
A_2	A_1	A_0	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
0	0	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	1	0	0
0	1	1	0	0	0	0	1	0	0	0
1	0	0	0	0	0	1	0	0	0	0
1	0	1	0	0	1	0	0	0	0	0
1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0

Multiplexers

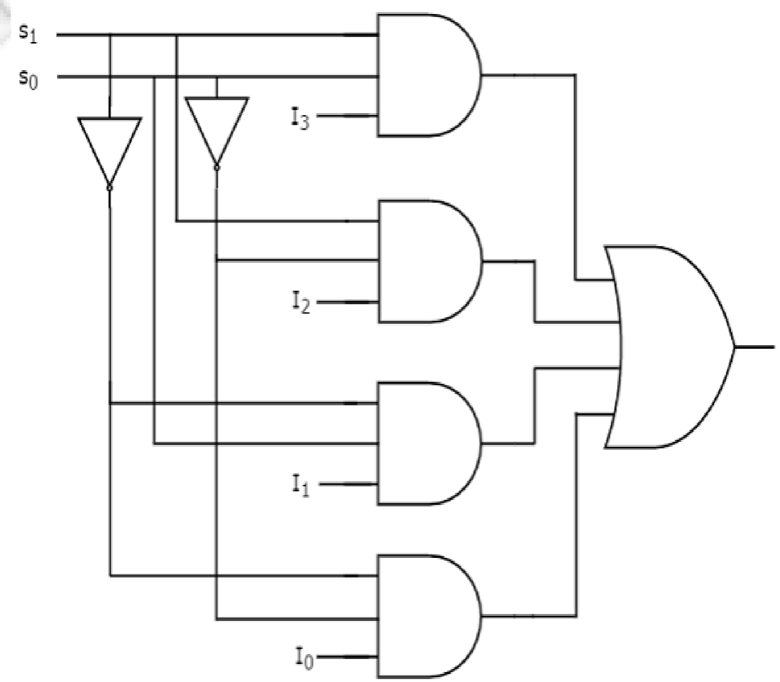
- A Multiplexer (MUX) can be described as a combinational circuit that receives binary information from one of the 2^n input data lines and directs it to a single output line.
- **The selection of a particular input data line for the output is decided on the basis of selection lines.**
- The multiplexer is often called as **data selector** since it selects only one of many data inputs.
- A 2^n-to-1 multiplexer has 2^n input data lines and n input selection lines whose bit combinations determine which input data are selected for the output.
- Out of these four input data lines, a particular input data line will be connected to the output based on the combination of inputs present at these two selection lines.
- The multiplexer used for digital applications, also called digital multiplexer, is a circuit with many input but only one output.
- By applying control signals, we can steer any input to the output.
- Few types of multiplexer are 2-to-1, 4-to-1, 8-to-1, 16-to-1 multiplexer.

Multiplexers

- 4x1 Multiplexer has four data inputs I_3, I_2, I_1 & I_0, two selection lines s_1 & s_0 and one output Y.
- One of these 4 inputs will be connected to the output based on the combination of inputs present at these two selection lines.
- we can directly write the **Boolean function** for output, Y as Y=S1'S0'I0+S1'S0I1+S1S0'I2+S1S0I3



circuit diagram of 4*1 Multiplexer



Selection Lines		Output
S_1	S_0	Y
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

Applications of Multiplexer:

- Multiplexer are used in various fields where multiple data need to be transmitted using a single line. Following are some of the applications of multiplexers –

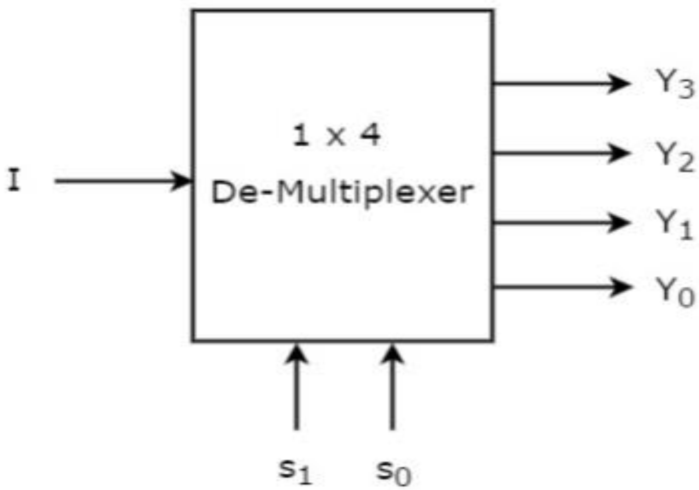
1. **Communication system** – Communication system is a set of system that enable communication like transmission system, relay and tributary station, and communication network. The efficiency of communication system can be increased considerably using multiplexer. Multiplexer allow the process of transmitting different type of data such as audio, video at the same time using a single transmission line.
2. **Telephone network** – In telephone network, multiple audio signals are integrated on a single line for transmission with the help of multiplexers. In this way, multiple audio signals can be isolated and eventually, the desire audio signals reach the intended recipients.
3. **Computer memory** – Multiplexers are used to implement huge amount of memory into the computer, at the same time reduces the number of copper lines required to connect the memory to other parts of the computer circuit.
4. **Transmission from the computer system of a satellite** – Multiplexer can be used for the transmission of data signals from the computer system of a satellite or spacecraft to the ground system using the GPS (Global Positioning System) satellites.

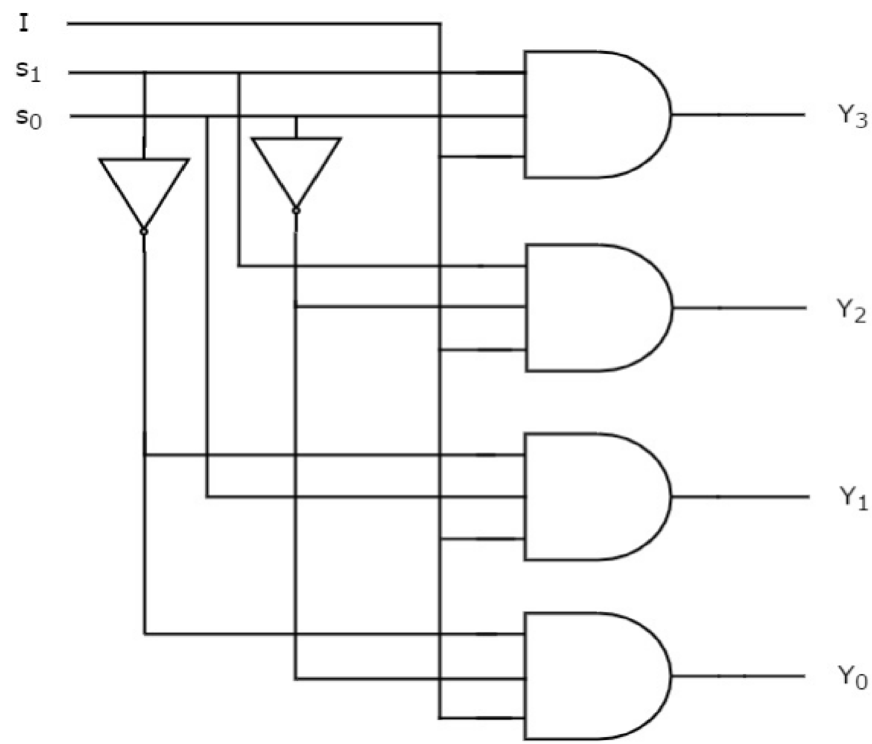
Demultiplexer

- Demultiplexer means **one to many**.
- A demultiplexer is a circuit with one input and many output. By applying control signal, we can steer any input to the output.
- Few types of demultiplexer are 1-to-2, 1-to-4, 1-to-8 and 1-to 16 demultiplexer.
- The main difference between a multiplexer and a de-multiplexer is that a multiplexer takes two or more signals and encodes them on a wire, whereas a de-multiplexer does reverse to what the multiplexer does.

Demultiplexer

- 1x4 De-Multiplexer has one input I, two selection lines, s_1 & s_0 and four outputs Y_3, Y_2, Y_1 &Y_0.
- The single input 'I' will be connected to one of the four outputs, Y_3 to Y_0 based on the values of selection lines s_1 & s0.
- the **Boolean functions** for each output as Y3=s1s0I , Y2=s1s0'I , Y1=s1's0I , Y0=s1's0'I





Selection Inputs		Outputs			
S_1	S_0	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	I
0	1	0	0	I	0
1	0	0	I	0	0
1	1	I	0	0	0

Applications of De multiplexer

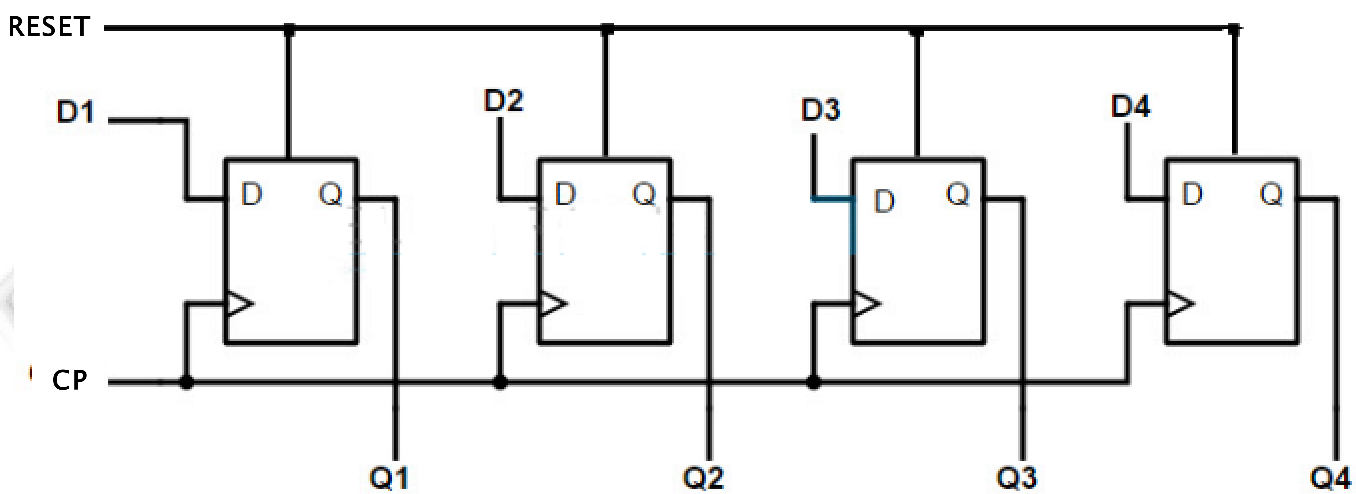
1. **Communication System**: Mux and demux both are used in communication system to carry out the process of data transmission. A De-multiplexer receives the output signals from the multiplexer and at the receiver end it converts them back to the original form.
2. **Arithmetic Logic Unit**: The output of the ALU is fed as an input to the De-multiplexer, and the output of the demultiplexer is connected to a multiple register. The output of the ALU can be stored in multiple registers.
3. **Serial to Parallel Converter**: This converter is used to reconstruct parallel data. In this technique, serial data is given as an input to the De-multiplexer at a regular interval, and a counter is attached to the demultiplexer at the control input to detect the data signal at the output of the demultiplexer. When all data signals are stored, the output of the demux can be read out in parallel.

Registers

- A Register is a fast memory **used to accept, store, and transfer data and instructions** that are being used immediately by the CPU.
- A Register can also be considered as a group of flip-flops with each flip-flop capable of storing one bit of information.
- A register with *n flip-flops* is capable of **storing binary** information of n-bits.
- The flip-flops contain the binary information whereas the gates control the flow of information, i.e. when and how the informations are transferred into a register.
- Different types of registers are available commercially.
- A simple register consists of only flip-flops with no external gates.
- The transfer of new data into a register is referred to as loading the register.

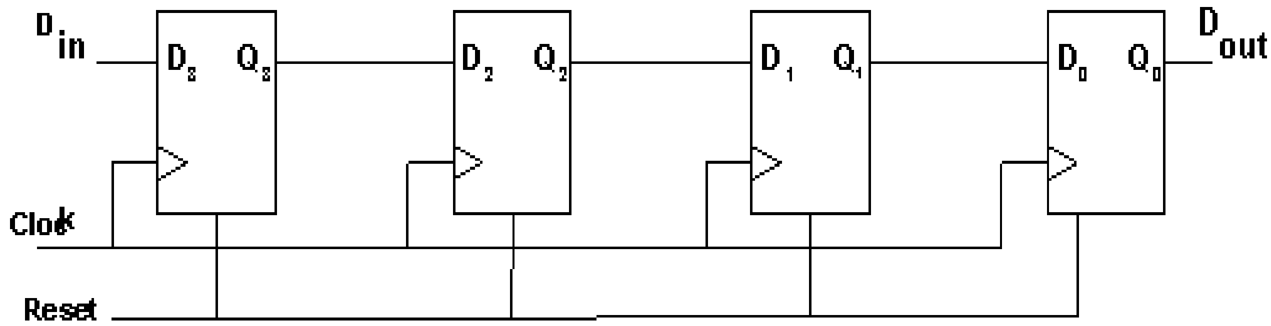
4 bit Register

- The figure shows a register constructed with four D-type flip-flops and a common clock pulse-input.
- The clock pulse-input, CP, enables all flip-flops so that the information presently available at the four inputs can be transferred into the four-bit register.



Shift – Registers

- Shift – Registers are capable of shifting their binary information in one or both directions.
- The logical configuration of a Shift – Register consists of a series of flip-flops, with the output of one flip-flop connected to the input of the next flip-flop.
- The most general Shift – Registers are often referred to as **Bidirectional Shift Register with parallel load**.
- A common clock is connected to each register in series to synchronize all operations.
- A serial input line is associated with the left-most register, and a serial output line is associated with the right-most register.
- A control state is connected which leaves the information in the register unchanged even though clock pulses are applied continuously.



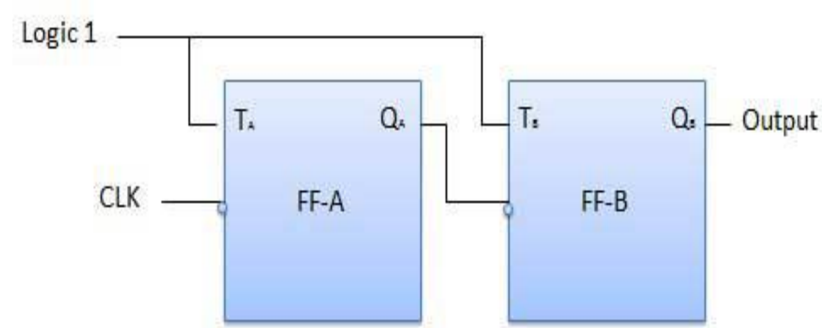
- A *shift register* is typically used to send and receive data, one bit at a time, under the control of a clock signal. **Figure shows** a 4-bit shift register built using positive-edge triggered D-type flip flops. On each positive clock edge, the value of the signal D_i is copied onto the value of Q_i. It takes four clock cycles for the original value of D_{in} to appear at D_{out}. The entire contents of the shift register can be initialized by resetting each flip-flop with a reset signal.
- A clear control to clear the register to 0.
- A clock input to synchronize the operations.
- A shift-right control to enable the shift operation and the serial input and output lines associated with the shift right.
- A shift-left control to enable the shift operation and the serial input and output lines associated with the shift left.

Counters

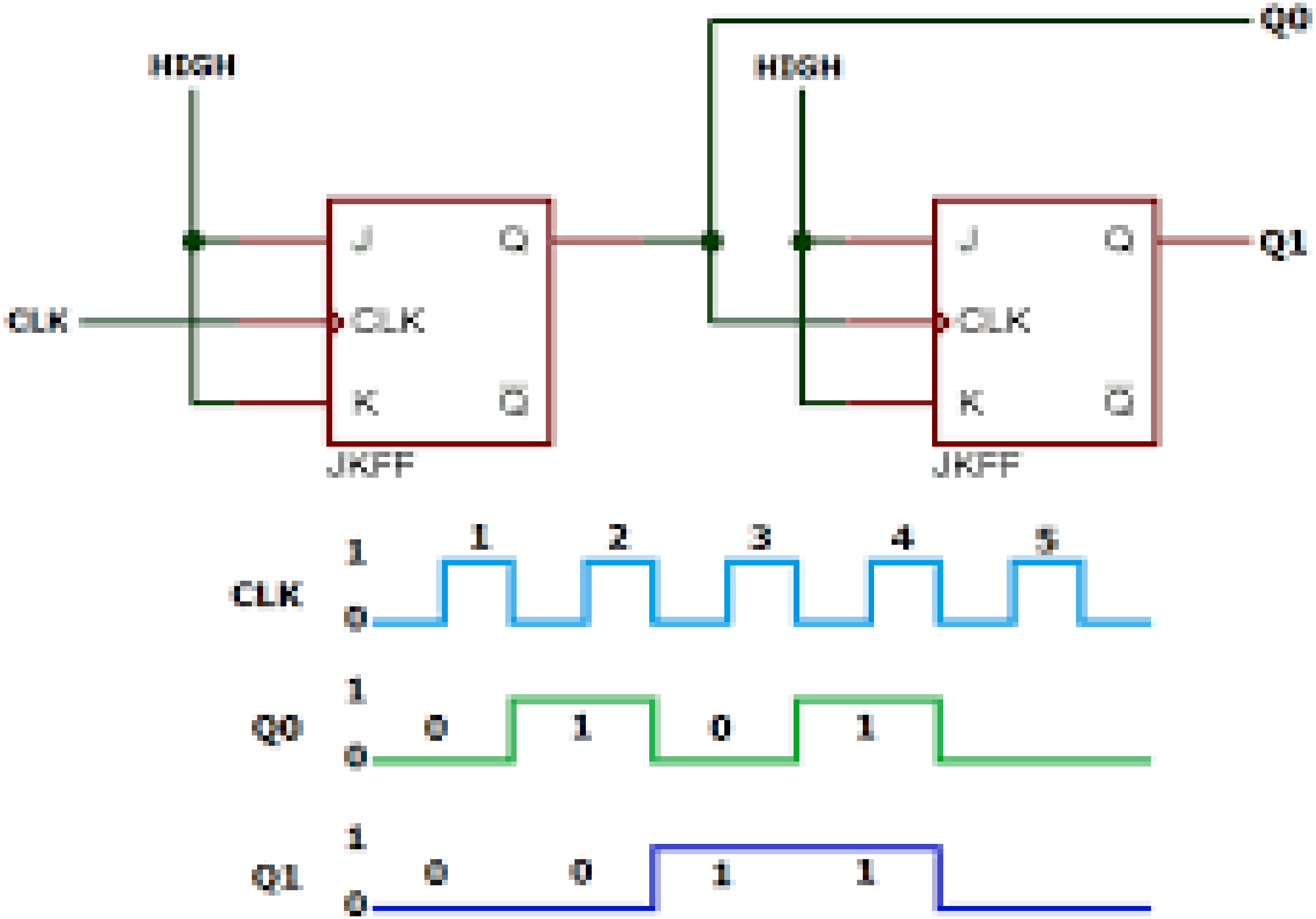
- A **counter** is basically used to count the number of clock pulses applied to a flip-flop. It can also be used for Frequency divider, time measurement, frequency measurement, distance measurement and also for generating square waveforms.
- Counter is a sequential circuit.
- **A digital circuit which is used for a counting pulses is known counter.**
- Counter is the widest application of flip-flops.
- It is a group of flip-flops with a clock signal applied.
- As the name suggests, it is a circuit which counts. The main purpose of the counter is to record the number of occurrence of some input.
- Counters can be classified into two broad categories according to the way they are clocked:
- **Asynchronous (Ripple) Counters** – The first flip-flop is clocked by the external clock pulse, and then each successive flip-flop is clocked by the Q or Q' output of the previous flip-flop.
- **Synchronous Counters** – All memory elements are simultaneously triggered by the same clock.

Asynchronous or Ripple counters.

- If the flip-flops do not receive the same clock signal, then that counter is called as **Asynchronous counter**.
- The output of system clock is applied as clock signal only to first flip-flop. The remaining flip-flops receive the clock signal from output of its previous stage flip-flop. Hence, the outputs of **all flip-flops do not change affect at the same time**.
- The toggle *T flip-flop are being* used. But we can use the JK flip-flop also with J and K connected permanently to logic 1.
- External clock is applied to the clock input of flip-flop A and B.
- A output is applied to the clock input of the next flip-flop i.e. FF-B.

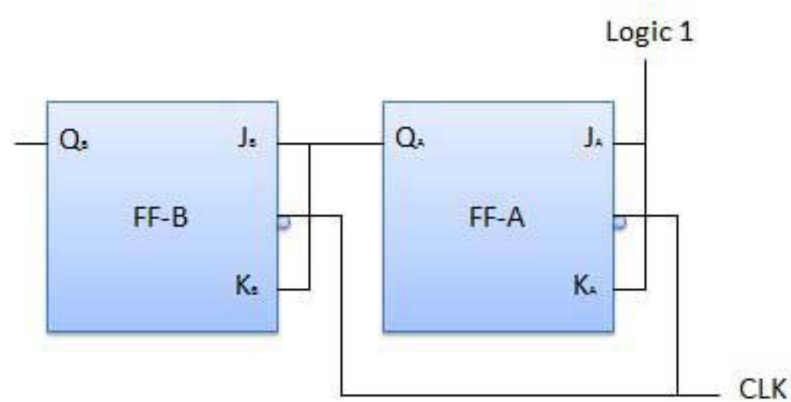


2-Bit Asynchronous Counter



Synchronous Counter

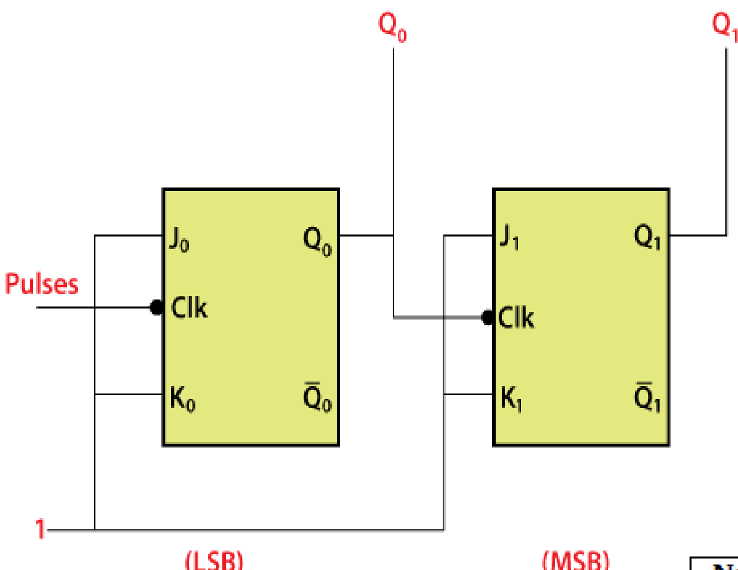
- If all the flip-flops receive the same clock signal, then that counter is called as **Synchronous counter**. Hence, the outputs of all flip-flops change affect at the same time.
- In the **Asynchronous counter**, the present counter's output passes to the input of the next counter. So, the counters are connected like a chain. The drawback of this system is that it creates the **counting delay, and the propagation delay** also occurs during the counting stage.
- Clock is directly connected to the flip-flop clock inputs
- Logic is used to implement the desired state sequencing
- The JA and KA inputs of FF-A are tied to logic 1. So FF-A will work as a toggle flip-flop. The JB and KB inputs are connected to QA.

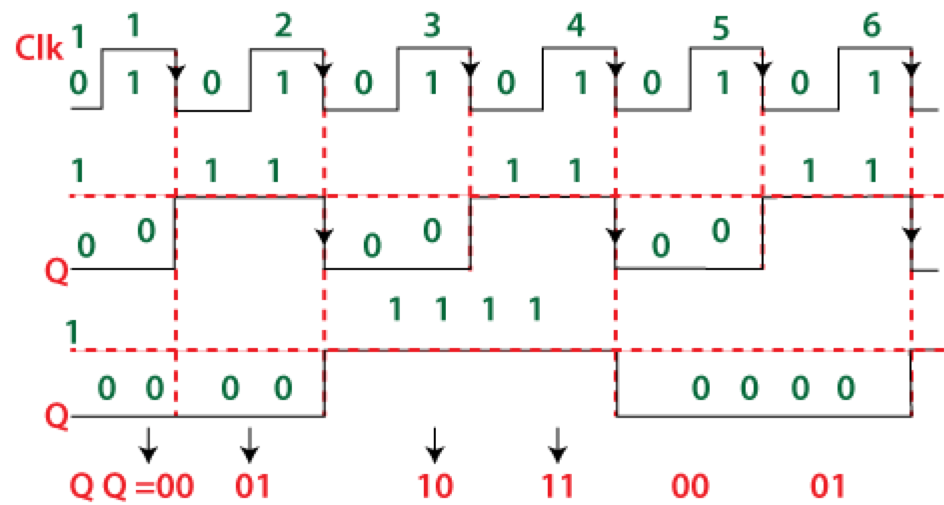


Binary Counters

- Normally binary counters are used for counting the number of pulses coming at the input line in a specified time period.
- The binary counters must possess memory since it has to remember its past states.
- In the circuit design of the binary counter, two JK flip flops are used.
- The high voltage signal is passed to the inputs of both flip flops. This high voltage input maintains the flip flops at a state 1. In JK flip flops, the negative triggered clock pulse use.
- Binary counters are circuits that generate binary sequences that can be associated with the number of clock signal pulses applied to the input.
- A binary counter counts a sequence of binary numbers. A binary counter with four output bits counts 24 or 16 numbers in its sequence, ranging from 0 to 15.

- The output of each flip-flop is connected to the C input of the next flip-flop in sequence.
- The flip-flop holding the last significant bit receives the incoming count pulse.
- A complementing flip-flop can be obtained from: n JK flip-flop with the J and K inputs tied together.
- T flip-flop n D flip-flop with the complement output connected to the D input.





Number of input pulses	Q_1	Q_0
0	–	-
1	0	0
2	0	1
3	1	0
4	1	1

Application of counters

- Frequency counters
- Digital clock
- Time measurement A to D converter
- Frequency divider circuits
- Digital triangular wave generator.

Memory unit

- The memory unit is an essential component in any digital computer since it is needed for storing programs and data.
- Memory is a collection of storage registers used to transfer information in and out of the unit.
- The actual work is done in (memory) and the finished result is stored in (disk).
- A memory unit is the collection of storage units or devices together. The memory unit stores the binary information in the form of group of bits called word. Generally, memory/storage is classified into 2 categories:
- **Volatile Memory**: This loses its data, when power is switched off.
- **Non-Volatile Memory**: This is a permanent storage and does not lose any data when power is switched off.

Primary Memory

Main Memory

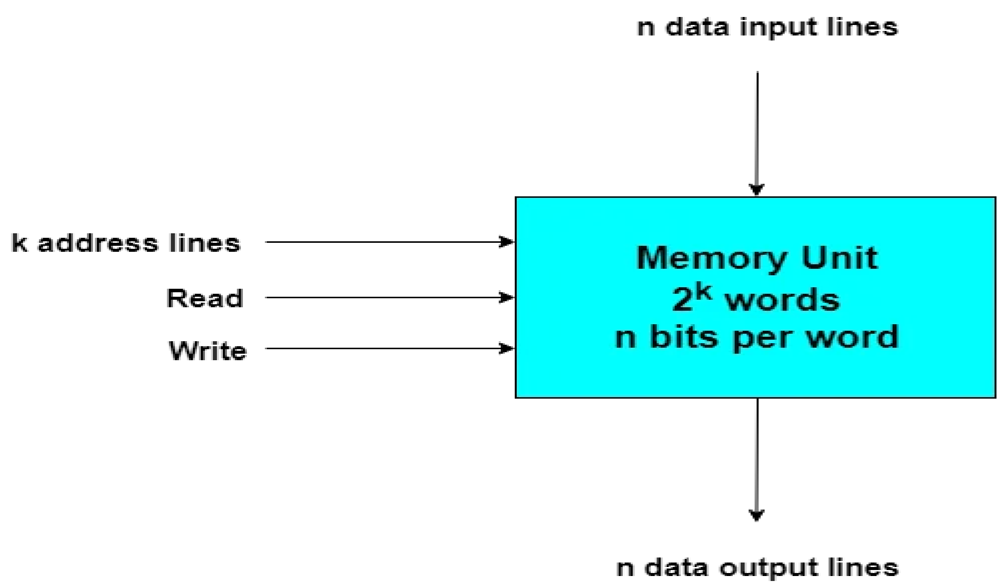
- The main memory have direct connection with the CPU so, it is also known as central memory.
- The main memory holds the data and the programs that are needed by the CPU.
- The main memory acts as the central storage unit in a computer system. It is a relatively large and fast memory which is used to store programs and data during the run time operations.
- The primary technology used for the main memory is based on semiconductor integrated circuits.
- The major types of main memory are used in computer system.

1. RAM (Random Access Memory)
2. ROM (Read Only Memory)

[1] RAM

- Random Access Memory (RAM) is the memory that the computer uses to temporarily store the information as it is being processed.
- RAM is considered "random access" because you can access any memory cell directly if you know the row and column that intersect at that cell which is volatile in nature.
- In **RAM** the memory cells can be accessed for information transfer from any desired random location.
- That is, the process of locating a word in memory is the same and requires an equal amount of time no matter where the cells are located physically in memory.
- Communication between a memory and its environment is achieved through data input and output lines, address selection lines, and control lines that specify the direction of transfer.
- The **n** data input lines provide the information to be stored in memory, and the **n** data output lines supply the information coming out of particular word chosen among the 2^k available inside the memory. The two control inputs specify the direction of transfer desired.

Random Access Memory



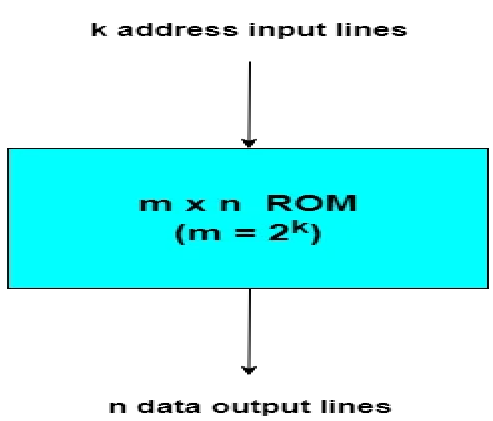
CS	WR	State
0	×	None
1	0	Read
1	1	Write

Types of RAM

- **Static RAM (SRAM)**
  - A bit of data is stored using the state of a flip-flop.
  - Retains value indefinitely, as long as it is kept powered.
  - Mostly uses to create cache memory of CPU.
  - Faster and more expensive than DRAM.
- **Dynamic RAM (DRAM)**
  - Each cell stores bit with a capacitor and transistor.
  - Large storage capacity
  - Needs to be refreshed frequently.
  - Used to create main memory.
  - Slower and cheaper than SRAM.

Read Only Memory

- ROM is used for storing programs that are Permanently resident in the computer and for tables of constants that do not change in value once the production of the computer is completed
- The ROM portion of main memory is needed for storing an initial program called bootstrap loader, witch is to start the computer software operating when power is turned on.
- Read-Only Memory (ROM) is a class of storage medium used in computers and other electronic devices.
- Data stored in ROM cannot be modified, or can be modified only slowly or with difficulty. Sometimes called non-volatile memory as it is not erased when the system is switched off.
- ROM memories have gradually evolved from fixed read-only memories to memories than can be programmed and then re-programmed.



Types of ROM

- **ROM (Read Only Memory).**
  - Data are written into a ROM when it is manufactured.
- **PROM (Programmable Read Only Memory).**
  - Allow the data to be loaded by a user.
  - Process of inserting the data is irreversible.
  - Storing information specific to a user in a ROM is expensive.
  - Providing programming capability to a user may be better.
- **EPROM (Erasable Programmable Read Only Memory).**
  - Stored data to be erased and new data to be loaded.
  - Flexibility, useful during the development phase of digital systems.
  - Erasable, reprogrammable ROM.
  - Erasure requires exposing the ROM to UV light.
- **EEPROM (Electrically Erasable Programmable Read Only Memory).**
  - To erase the contents of EPROMs, they have to be exposed to ultraviolet light.
  - Physically removed from the circuit.
  - EEPROMs the contents can be stored and erased electrically.

Assignment

1. What is IC? Discuss its classification.
2. Explain Octal to Binary Encoder.
3. Explain 2*4 Decoder.
4. Explain 4*1 MUX and 1*4 DEMUX.
5. Write short note on 4 bit Shift Register.
6. Explain Binary counter in detail.
7. Explain counter with its types.
8. Explain main memory with its types.