THE MENTOR

Study Material

II PUC

ELECTRONICS

(As per NCERT Text book &
Karnataka PU Board Question Bank)

Department of Science

ST.CLARET
PRE UNIVERSITY COLLEGE

1355, 5th Cross, 1st Main, Off MES Ring Road,
Sharadamba Nagar, Jalahalli, Bengaluru, Karnataka 560013
Ph: 080-23455151

MESSAGE

I am glad to know that the Department of Science is publishing “The Mentor” Electronics - Study Material for II PU students of St. Claret Pre- University College. I am sure this will facilitate quality education and academic excellence.

I sincerely thank and appreciate the Department of Electronics for the efforts to publish “The Mentor”. I hope and wish that the students will make use of this book to achieve academic excellence. God bless all Claretines

God bless all Claretines.

Fr. Sojan K Abraham
Principal
2024, Bengaluru

PREFACE

The Electronics department of St. Claret PU College is immensely grateful in presenting Study material for II PU students based on NCERT. It is a student friendly book designed to meet the needs of studentspreparing for Electronics II PU board exam.

This book provides you the following:

- Chapter wise notes.
- Additional information is provided wherever necessary.
- Each chapter is followed with a set of important questions.
- P U Board question papers .
- Blue print and chapter-wise weightage of marks.

It is our immense pleasure in showing our gratitude to all the people who have made this work possible, by offering help and guidance whenever required. It brings a sense of privilege to associate this work with the name of our institution St. Claret PU College' We also express our heartfelt thanks to our dear Principal Rev Fr. Sojan Abraham, for his vigilant supervision, constant encouragement, inspiring ideas, constructive criticism and timely expertise, which reflects in the final images of this work .

Mrs. Hema Sarathi, MSc (Tech)

Ms. Aneesha Johnson, M.Tech, B.Tech

(Dept. of electronics, St. Claret PU College)

2024, Bengaluru

CONTENTS

Chapter 1 FIELD EFFECT TRANSISTOR

History of Field Effect Transistor

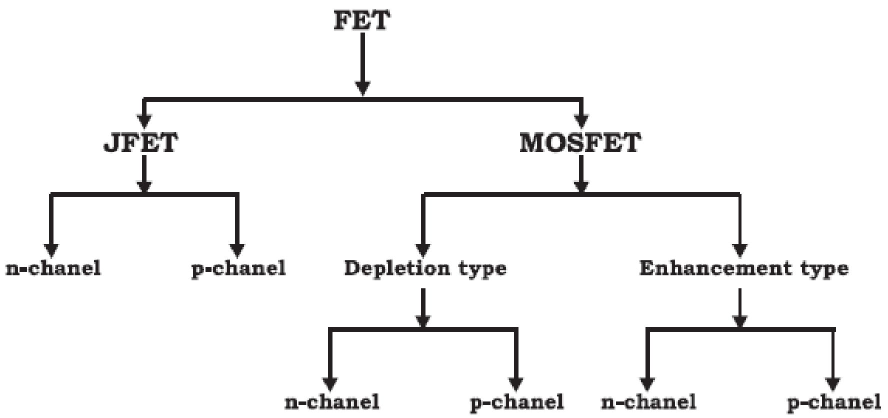
In the year 1926, the idea of field effect transistor (FET) was introduced by Lilienfield. After this in the year 1935, Heil had also put light on field effect transistor. But by this time FETs were not much popular. It was in the year 1940, the significance of FETs gain momentum. This is because duringthe 1940s the research was going on semiconductors at Bell laboratories.

What is an FET?

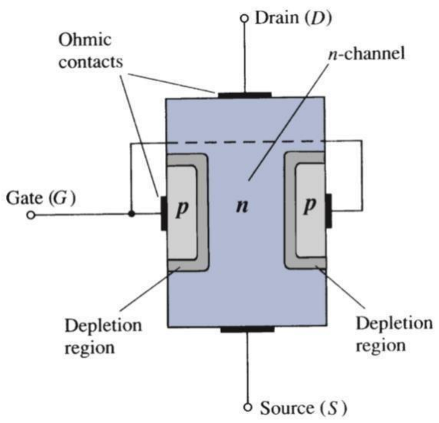
- The field-effect transistor (FET) is a type of transistor that uses an electric field to control the flow of current.
- FETs are devices with three terminals: source, gate, and drain.
- The FET is a unipolar device, which means that it is made using either p-type or n-type material as the main substrate.
- One of the many of its advantages is that it has a very high input impedance.

Classification of FETs

The classification of FET can be understood with the help ofchart described in the below image.



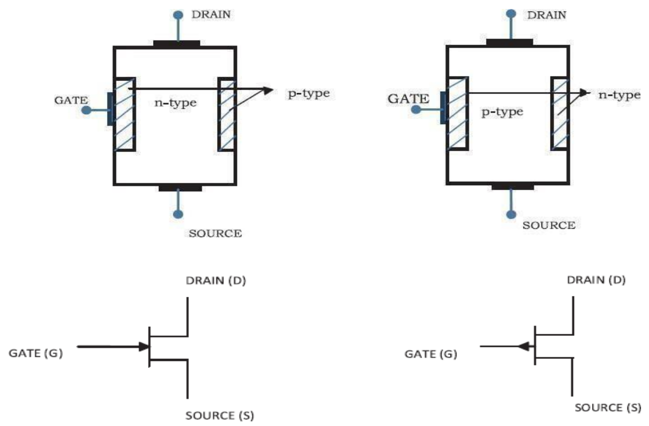
Construction of JFET



- An n type semiconductor bar is diffused on either side with p type semiconductor material.
- Two pn junctions ofuniform thickness is formed on both the sides.
- The two pn junctions are internally connected and a common terminal is taken out which is known as GATE.
- On the n type semiconductor bar, the DRAIN and SOURCE terminals are taken.
- Space between the two pn junctions where electrons can move is known as the channel.

Source: Source is the terminal through which the majority charge carriers are introduced in the FET.
Drain: Drain is the collecting terminal in which the majority charge carriers enter and thus contribute in the conduction procedure.Gate: Gate terminal is formed by diffusion of a type of semiconductor with another type of semiconductor. It basically creates high impurity region which controls the flow ofcarrier from source to drain.
Channel: This is the area in which majority charge carriers flow. When the majority charge carriers are entered in FET, then with the help of this channel only they flow from source to drain.

Symbol of FET



n-type JFET p-type JFET

Formation of the depletion region:
The Gate terminal can be left open or is always used in reverse bias in an FET. The drain is always at a higher potential than the source. Using batteries Vgg and Vdd, the FET is biased. Initially, there are two pn junctions on either sides existing. When a reverse voltage is applied to the Gate, the depletion layers on both the pn junctions start growing wide(reverse bias increases the width of depletion layers). As the Gate voltage increases, the width of the depletion layers also increases and at a certainvoltage, they almost touch each other. At this voltage, the channel is completely blocked and charges cannot move. The current in circuit becomes zero. This Gate voltage at which the Drain current becomes zeroand depletion layers overlap is known as the "pinch off voltage".

CHARACTERISTICS OF n-CHANNEL JFEET

The two main characteristics of JFEET are

a. Drain characteristics.
b. Transfer characteristics.

DRAIN CHARACTERISTICS:

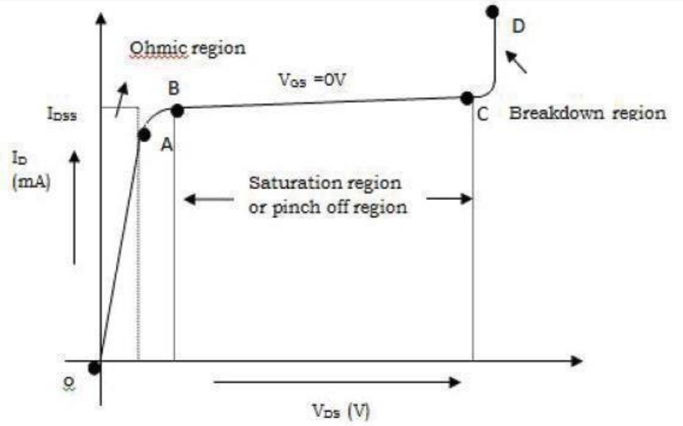
These are the set of curves drawn for the relationship between drain current (I_0) and drain-to-source voltage (V_{GS}) at a constant gate-to-source voltage (V_{GS}).

TRANSFER CHARACTERISTICS:

These are the set of curves drawn for the relationship between drain current (I_0) and gate-to-source voltage (V_{GS}) at a constant drain-to-source voltage (V_{DS}).

DRAIN CHARACTERISTICS of n-channel JFET

It is the graph drawn between the drain source voltage (V_{DS}) and drain current (I_D) for constant values of (V_{GS}).



The graph can be divided into 3 regions:

Ohmic region: the drain current increases proportionally with the drain source voltage, it is represented by OA

Pinch offregion: it is marked byBC. The drain current remains constant and maximum

Breakdown region: the region CD is called breakdown. The drain current increases rapidly due to break down.

Transfer characteristics

It is the graph plotted between the drain current (I_D) and gate source voltage (V_{GS}) for constant V_{DS}. The transfer characteristics can be determined by keeping the drain source voltage V_{DS} constant, drain current ID is observed by changing the gate source voltage. So it is observed that when the gate source voltage V_{GS} is increased in the negative region the drain current ID decreases.

JFET PARAMTERS:

The important parameters fromthe characteristics curves are

DC drain resistance (R_{DS}): It is defined as the ohmic resistance given by the ratio of V_{DS} to the current I_D for a constant value of V_{GS} expressed in ohm.

i.e. $R_D = \frac{VDS}{I_D}$ Ω

V_{DS}

AC drain resistance (r_d): It is defined as the ratio of small change in V_{DS} to the corresponding change in I_D for a constant V_{GS}. This known as dynamic drain resistance expressed in ohm.

i.e. $R_D = \frac{\Delta V_{DS}}{\Delta I_D}\Big|_{V_{GS}}$ Ω

Trans conductance (g_m): It is defined as the ratio of small change in I_D to the corresponding change in V_{GS} for a constant V_{DS}. It is also called as forward trans conductance expressed in Siemen (S).

i.e. $g_m = \frac{\Delta V_{DS}}{\Delta V_{GS}}\Big|_{V_{DS}}$

Amplification factor(μ): it is defined as the ratio of small change in V_{DS} to the corresponding change in V_{GS} for a constant drain current I_D.

i.e. $\mu = \frac{\Delta V_{DS}}{\Delta V_{GS}}\Big|_{I_D}$

AMPLIFICATION FACTOR μ IN TERMS OF r_d and g_m.

We know that

$$\mu = \frac{\Delta V_{DS}}{\Delta V_{GS}} \quad (1).$$

Multiply and divide by ΔI_D to the equation (1), $\mu = \frac{\Delta V_{DS}}{\Delta V_{GS}} \times \frac{\Delta I_D}{\Delta I_D}$

Rearranging the different terms in the above equation we get

$\mu = \frac{\Delta V_{DS}}{\Delta I_D} \times \frac{\Delta}{\Delta V_{GS}}$

Since $r_d = \frac{\Delta}{\Delta I_D}$, $g_m = \frac{\Delta I_D}{\Delta V_{GS}}$ we get

$\boldsymbol{\mu} = r_d \times g_m$

COMPARISION BETWEEN BJT AND FET

Sl. No.	FET	BJT
1.	It is a unipolar device.	It is a bipolar device.
2.	Current conduction is only by majority charge carriers i.e., either holes or electrons	Current conduction is by both the charge carriers (majority & minority carriers) i.e., both holes and electrons.
3.	It is a voltage controlled device.	It is a current controlled device.
4.	In put resistance is very high in the order of several mega ohm.	Input resistance is very low compared to FET i.e., in the order of few kilo ohm.
5.	It has high switching speed.	It has low switching speed.
6.	Less noisy.	More noisy compared to FET.
7.	Fabrication is simpler in IC.	Comparatively difficult to fabricate in IC.

Chapter 2 **TRANSISTOR BIASING**

What is transistor biasing?

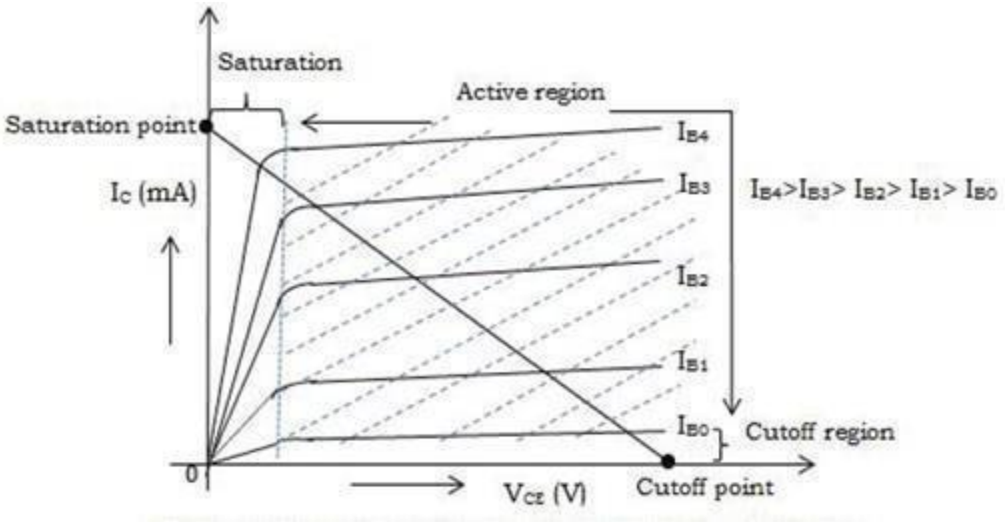
The application ofa suitable dc voltage across the transistor terminals is called as transistor biasing.

Need for biasing

- The operating point should be at the center of the active region, so that on applying the input signal, the operating point does not shift either towards the saturation region or towards the cut off region.
- Stability of the collector current against temperature variations.
- The operating point should not shift when the transistor is replaced by another of the same typein the circuit.

DC load line

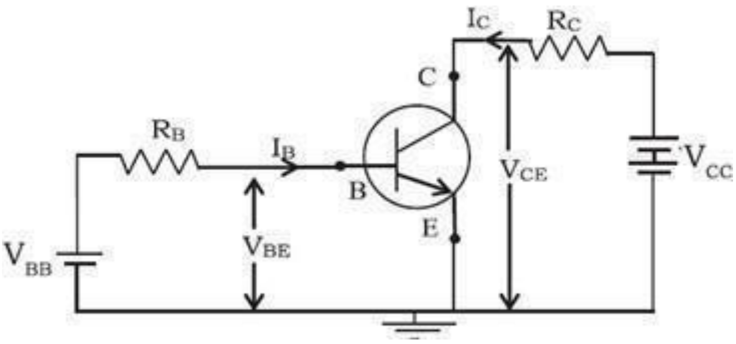
It is a straight line drawn on the output characteristics of a transistor connected in CE mode joining the saturation and cut off points.



Since the values of current and voltage are fixed for the applied dc source, the straight line drawn joining these points is called DC LOAD LINE.

TO FIND THE END POINTS OF THE LOAD LINE:

Consider the circuit in CE mode with two sources VBB and VCC as shown in figure. This graph can be used to find the end points pf the load line. the circuit consists of npn transistor along with batteries and two resistors. RB and RC. VBE and VCE are the input and output voltage drops and IB and IC are the input and output currents .



Applying KVL to the base circuit we get,

$$V_{BB} = I_B R_B + V_{BE}$$

$$I_B = \frac{[V_{BB} - V_{BE}]}{R_B}$$

Similarly, applying KVL to the collector circuit we get,

$$V_{CC} = V_{CE} + I_C R_C \text{ ....} (1)$$

$$V_{CE} = V_{CC} - I_C R_C \text{ ....} (2)$$

Therefore, $I_C = \frac{[V_{CC} - V_{CE}]}{R_C}$ . . . . (3)

or, $I_C = [\frac{-1}{R_C}] V_{CE} + \frac{V_{CC}}{R_C}$

i.e. the above equation is in the form y= mx + c which represents the straight line.

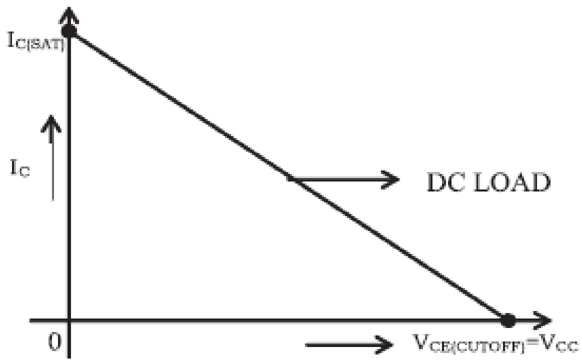
The end point onthe X-axis is found by applying $I_C = 0$ in the equation (2).

i.e. $V_{CE(Cutoff)} = V_{CC}$ .... (4)

The end point onthe Y-axis is found by applying $V_{CE} = 0$ in the equation (3).

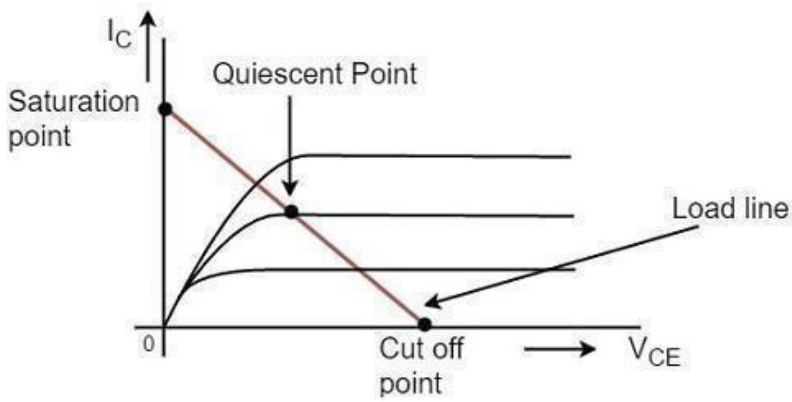
i.e. $I_{C(Sat)} = \frac{V_{CC}}{R_C}$ . . . . (5)

ST.CLARET PRE UNIVERSITY COLLEGE



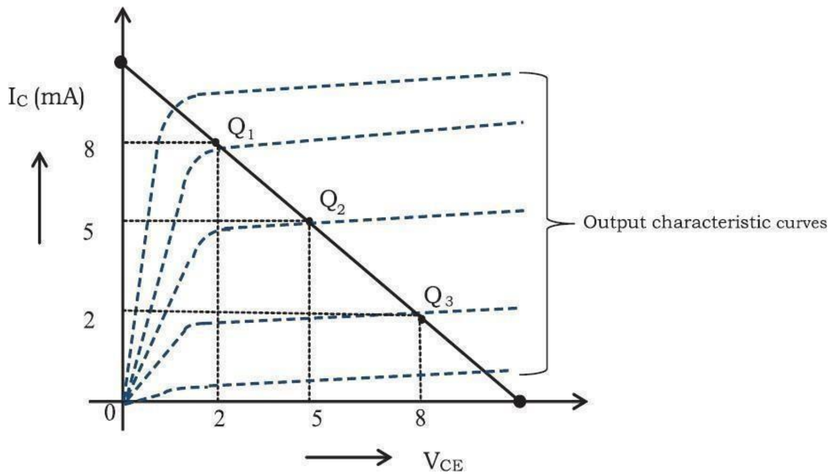
Q point or operating point or Quiescent point:

- q point is the operating point ofthe transistor.
- it is given by the (V_{CE}, I_C).
- it is the point of intersection of the load line and the output characteristics of the transistor. By the location of the point q, we say in which region the transistor operates (active / cut / saturatio



SELECTION OF OPERATING POINT ON DC LOADLINE:

- If the transistor is made to operate as a switch, then the operating points are chosen are saturation region (closed switch) and at cutoffregion (open switch).
- If the transistor is made to operate for amplification purpose then the operating point should be chosen at the center ofthe load line for faithful amplification.



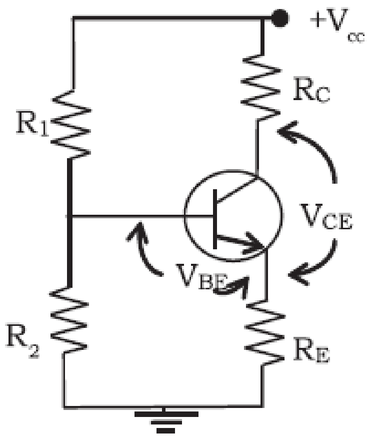
The operating points Q_1, Q_2 and Q_3 are at the Saturation, Active and Cut-offregions respectively

Different biasing circuits

- Fixed bias
- Emitter feedback bias
- Voltage divider bias

VOLTAGE DIVIDER BIAS:

Consider the below circuit used for biasing of a transistor. It is universally accepted biasing circuit. It consists of npn transistor along with the resistors for fixing the operating point .



In the voltage divider biasing circuit, the biasing is provided by the proper selection of the resistors R_1, R_2 and R_E. The name voltage divider is derived from the fact that the resistors R_1 and R_2 form the potential divider across the DC supply V_{CC}. The voltage drop across R_2 forward biases the emitter base junction of the transistor. The emitter resistor R_E provides the stability for the operating point. If the collector current I_C increases due to change in the temperature, consequently the value of β also changes. The emitter current I_E increases with the increase in I_C, thus voltage drop across R_E also increases reducing the voltage drop across base and emitter, V_{BE} decreases the base current I_B and hence collector current I_C also decreases. This reduction in the collector current I_C compensates for theoriginal change in I_C.

Circuit analysis:

Let V_2 be the voltage drop across R_2. Applying voltage divider rule to the base circuit we have,

$$V_2 = \frac{V_{CC} R_2}{R_1 + R_2}$$

Applying KVL to the base circuit we get

$$V_2 = V_{BE} + V_E$$

$$V_2 = V_{BE} + I_E R_E$$

$$\therefore \quad I_E = \frac{V_2 - V_{BE}}{R_E} \qquad \text{. . . . (1)}$$

Since $\cong I$

$$I_C = \frac{V_2 - V_{BE}}{R_E} \qquad \text{. . . . (2)}$$

Similarly, byapply KVL to the collector circuit we have

$$V_{CC} = I_C R_C + V_{CE} + V_E$$

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

$$V_E = I_E R_E$$

Since $I_C \cong I_E$

$V_{CC} = I_C R_C + V_{CE} + I_C R_E$
$V_{CC} = V_{CE} + I_C(R_C + R_E)$

$\therefore \quad V_{CE} = V_{CC} - I_C(R_C + R_E)$......................(3)

Therefore from the above circuit analysis, the factor β does not appear in any of the equations. This operating point does not shift its position due to either rise in the temperature or the transistor of different β. Therefore the circuit provides excellent stabilization.

Expression for the end points of DC load line and for the Q point from approximate analysis.

Consider the equation

$V_{CE} = V_{CC} - I_C(R_C + R_E)$................................(1)

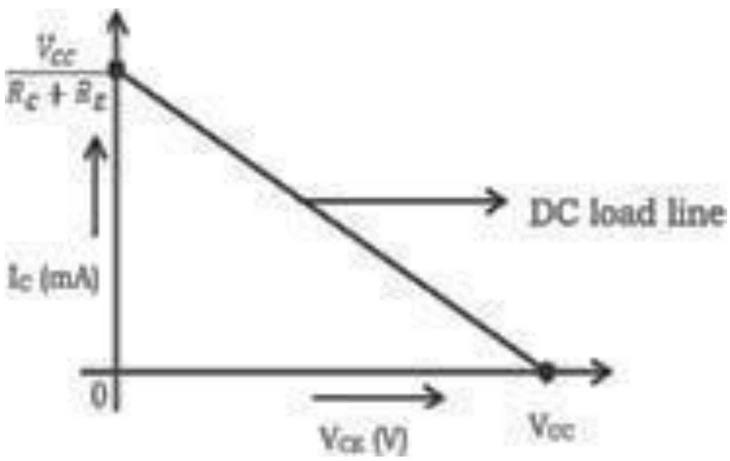
To plot the point on x-axis, substitute $I_C = 0$ in the equation (1) we get

$V_{CE} = V_{CC}$..(2)

To plot the point on y-axis, substitute $V_{CE} = 0$ in the equation (1) we get

$I_C = \frac{V_{CC}}{R_C + R_E}$ . . . . (3)

A straight line called DC load line is drawn from the end points and plotted as shown in figure 2.1.10.



Q-POINT ANALISIS:

We know that byapplying KVL to the base circuit of figure 2.1.9, the voltage across R_2 is given by

$V_2 = V_{BE} + I_E R_E$

$I_E = \frac{V_2 - V_{BE}}{R_E}$

Since $I_E \cong I_C$

$\therefore \quad I_E = I_C = \frac{V_2 - V_{BE}}{R_E}$

Where $V_2 = \frac{V_{CC} \times R_2}{R_1 + R_2}$

Similarly by applying KVL for the collector circuit we have

$$V_{CC} = V_{CE} + I_C R_C + I_C R_E$$

$$V_{CC} = V_{CE} + I_C(R_C + R_E) \qquad \because \qquad I_E \cong I_C$$

$$\therefore \qquad V_{CE} = V_{CC} - I_C(R_C + R_E)$$

$$\therefore \qquad V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E)$$

V_{CEQ} and I_{CQ} defines the operating point or Q point.

Advantages of voltage divider bias:

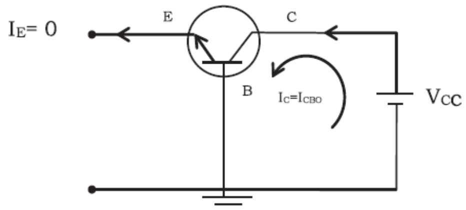
- Q point does not shift, offers excellent stabilization since the stabilization factor does not depend on β.
- This circuit is used in almost all amplifier circuits.
- Voltage divider bias circuit provides better amplification when it is used in amplifiers.

Leakage currents in transistor

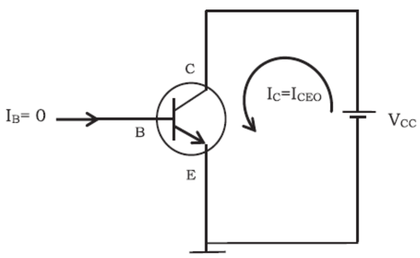
- The flow of current through the transistor due to the motion of minority charge carriers under reverse bias conditions is known as leakage current.
- Leakage currents are highly temperature dependent

Types of leakage currents

- There are mainly two leakage currents that can be measured in a transistor:
- Collector to base leakage current (ICBO): the collector current flowing when emitter base terminal is open is ICBO. It is measured in CB mode.



- Collector to emitter leakage current (ICEO): the collector current flowing when Emitter to base terminal is open is called ICEO. It is measured in CE mode.



Thermal Runaway

The self-destruction of the transistor due to increase in temperature and leakage currents is known as thermal runaway.

Stability factor

It is defined as the ratio of change in collector current to the change in leakage current at constant values of beta and VBE.

Stability factor $S = \frac{\Delta IC}{\Delta I_{CO}}$ β, V_{BE} = Constant

Heat Sink

It is a device which absorbs excess heat generated in a transistor, radiates to surroundings and protects it. Normally, a copper conductor with different shapes is connected to the device as heat sink.

Chapter 3 **TRANSISTOR AMPLIFIERS**

INTRODUCTION

- An amplifier is an electronic device that increases the power ofa signal.
- The process of increasing the strength ofan input signal is referred to as amplification.
- Amplification ofa small signal without change in its shape is known as faithful amplification, as shown in the figure

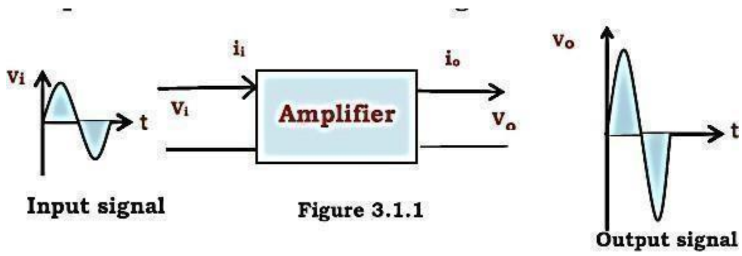
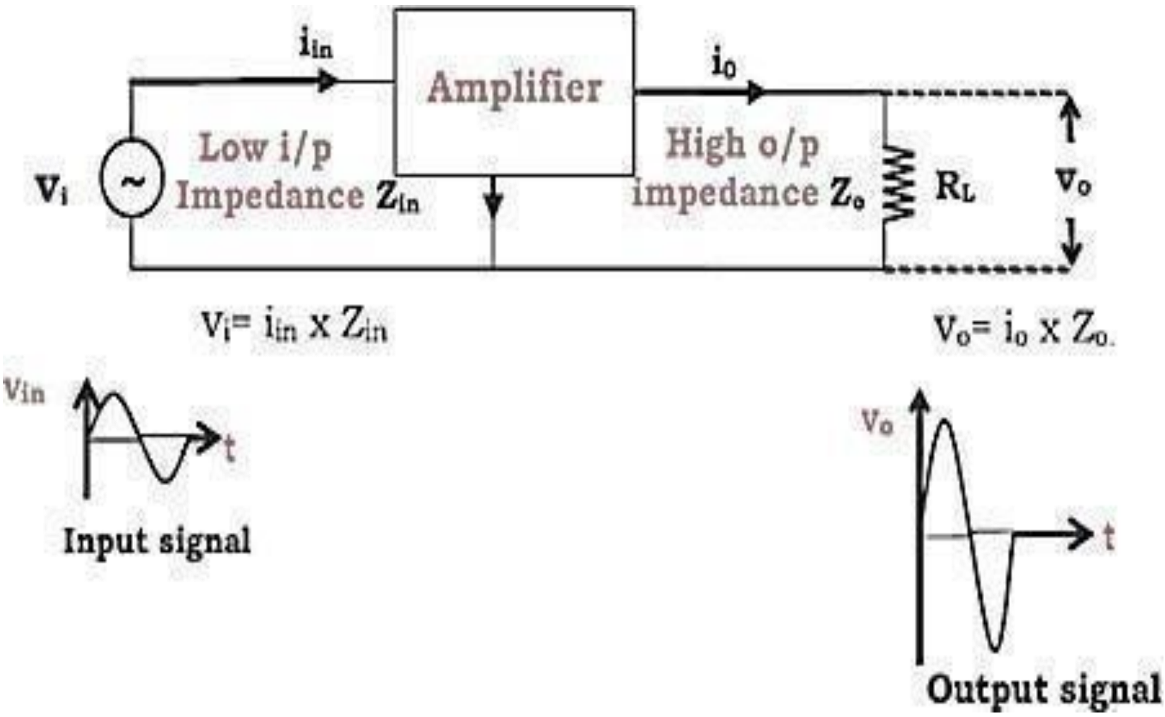


Figure 3.1.1

Concept of working of an amplifier

Consider an amplifier block diagram in figure 3.1.2 with low put impedance and high output impedance. The DC bias is not shown in the figure because our interest is to show the actual amplification only.

When ac signal is applied at the input ofan amplifier, ac flows through small impedance Z_{in}. Thus $v_i = i_{in} \cdot z_{in}$. On the other hand current of nearly same magnitude or even of little lesser value flowing through a high output impedance produces a larger voltage $v_o = i_o \cdot z_o$. Thus small signal applied in the input appears in the amplified form in the output circuit.



Classification of amplifiers and their applications

Different criteria	Classification	Applications
1. Input signal	Small signal amplifier	Voltage amplifiers
	Large signal amplifier	Power amplifiers
2. Nature of output	Voltage amplifiers	Voltage amplifications
	Power amplifiers	Power amplifications
3. Frequency range	AF amplifiers	Audio equipment's
	IF amplifiers	Radio circuits
	RF amplifiers	AM broadcasting
	VHF amplifiers	FM broadcasting
	UHF amplifiers	TV, Military communications like mobiles, radar
	SHF amplifiers	Satellite communication
4. Operating point	Class A	Voltage amplifications
	Class B	Power amplifications
	Class C	Power amplifications
5. Configuration	CE amplifier	Audio amplifiers
	CB amplifier	High frequency applications
	CC amplifier	As an impedance matching circuit.
6. Coupling	RC coupled	Multistage AF applications
	Transformer coupled	RF amplifier
	Direct coupled	DC amplifiers
7. Stages	Single stage amplifier	Audio amplifiers
	Multistage amplifier	Communication systems
8. Band width	Wideband amplifiers	Video amplifiers
	Narrow band amplifiers	Communication systems

Decibel Gain:

The voltage gain, current gain and power gain of an amplifier can also be expressed in decibels (i.e. in dB) as shown below.

The voltage gain in decibel is $A_v(dB) = 20 \log_{10} A_v$

The current gain in decibel is $A_i(dB) = 20 \log_{10} A_i$

The power gain in decibel is Ap(dB) = 10 log10 Ap

3dB frequency

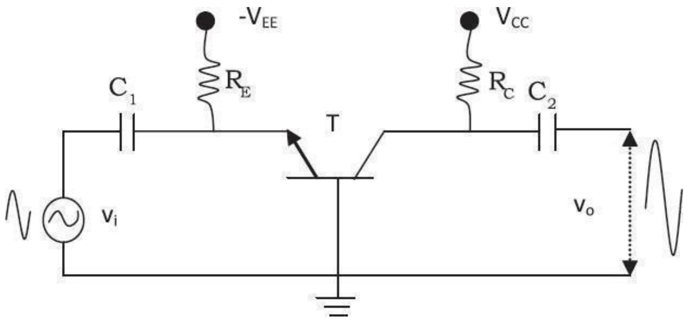
The 3dB destination comes from the fact that the voltage gain at the frequencies is 3dB below the max frequencies

Need for measurement of gain dB:

The unit dB is a logarithmic unit. Our ear response is also logarithmic i.e. loudness of sound heard by ear is not according to the intensity of sound but according to the log of intensity of sound. T Hence, this unit tallies with the natural response of our ears.

Single stage transistor amplifier

Common-Base amplifier CB Amplifier:



Working:

Positive half-cycle of the ac input signal,

- Net forward bias voltage V_{BE} is decreases.
- As a result emitter current (I_E), Base current (I_B) and also collector current is decreased.
- This decreases the voltage drop across R_C which is $I_C R_C$. The voltage across the output terminal (V_O) is increased as per equation
  $V_O = V_{CC} - I_C R_C$
- Hence, an amplified positive half – cycle is produced at the output.
- Reverse will happen during negative half-cycle of the ac input signal. As a result an amplified negative half-cycle is produced .

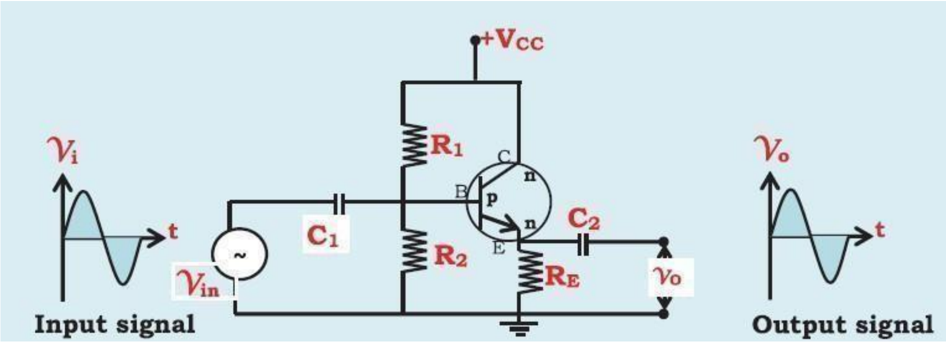
Characteristics of CB – Amplifier:

- Very low input resistance 30Ω to 150Ω
- Very high output resistance upto 500KΩ
- Low current gain (< 1)
- Very high voltage gain about 1500
- Moderate power gain up to 30dB
- No phase reversal between input and output signals

Applications:

- CB amplifier is used to match low input impedance circuit with that of high impedance load.

Common – Collector amplifier (CC-Amplifier or Emitter Follower)



Working:

Positive half-cycle ofthe ac input signal

- The forward bias between emitter base junction increases.
- The base current IB increases.
- Hence IE increases because IE= (1+β)IB
- Voltage drop across RE also increases
- Hence in the positive half cycle ofthe input signal we get a positive half cycle at the output.
- Reverse will happen during negative half-cycle of the ac input signal.
- Since emitter is output terminal, it can be noted that the output voltage from a CC-amplifier circuit is the same as its input voltage. Hence the voltage gain is almost equalto 1.
- As the emitter voltage (output voltage) follows the input voltage Vin, it is also called as voltage follower or emitter follower.

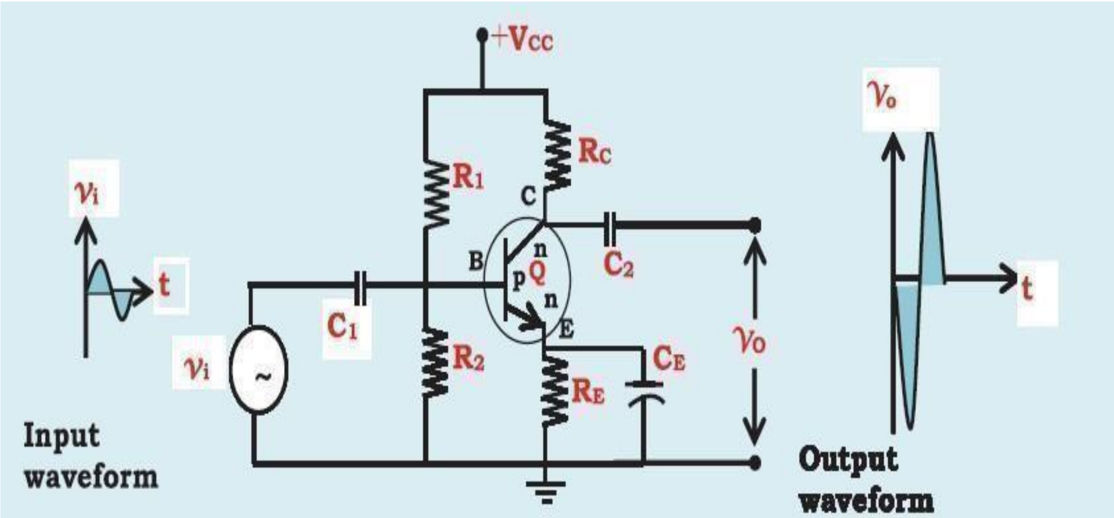
Characteristics:

- Input impedance is high
- Output impedance is low
- Current gain is very high
- Voltage gain is less than 1
- No phase reversal

Applications

- Used for impedance matching
- Used in power amplifiers
- Used in current amplifiers

Common-Emitter Amplifier (CE-Amplifier)



working:

Positive half-cycle ofthe ac input signal

- The forward bias on the base emitter junction increases.
- Consequently i_B is increased.
- This increases i_C because $i_C = \beta\, i_B$.
- Thus voltage drop across R_C i.e. $i_C R_C$ is increased.
- Hence output voltage V_{CE} i.e. V_O is decreased because ofthe equation
- $V_{CE} = V_{CC} - i_C\ R_C$. Therefore we get negative half cycle at the output.
- Reverse will happen during negative half-cycle ofthe ac input signal.
- Thus for a transistor amplifier in a CE – configuration, the input and output signals are 180o out of phase with each other.

Characteristics of CE-Amplifier:

- Input and output impedances are moderate
- High current gain
- Very high voltage gain
- Very high power gain
- Input and output signals are 180o out of phase

Applications

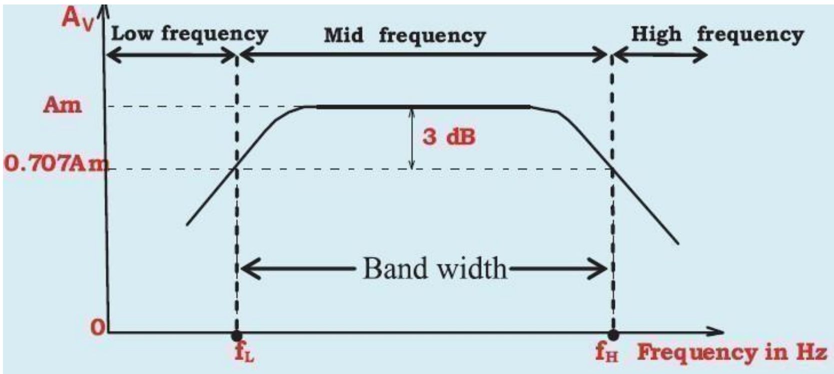
- Communication systems
- RF amplifiers
- AF amplifiers
- Signal generators etc.

Comparison of three amplifier configurations

Amplifier Parameters	Types of amplifiers		
	CE	CB	CC
Current gain	High (β)	Less than 1	Highest (1 + β)
Voltage gain	High	Moderate	Low (≈ 1)
Power gain	Highest	Moderate	Moderate
Phase shift	180°phase shift	No phase shift (0°)	No phase shift (0°)
Input impedance	Moderate	Low	High
Output impedance	Moderate	High	Low
Bandwidth	Narrow	Wide	Wide

Frequency response of a single stage CE-amplifier

The frequency response ofa CE-amplifier is as shown



At Low frequency range:

In the low frequency region, the voltage gain is low, because at low frequencies the reactance of coupling and bypass capacitors are large enough to dropto some ofthe signal voltage and consequently gain decreases.

At mid – frequency range:

At mid frequency range, the coupling and bypass capacitors acts as short circuit , Hence in the mid band frequency region there is no capacitance effect present. As a result gain is uniform or constant. High frequency range:

At high frequency range, the reactance of the junction capacitance of the transistor and wiring capacitance becomes low. Hence the voltage gain decreases at high frequencies

Bandwidth of an amplifier:

The range of frequencies lying between the two cut-off frequencies is called bandwidth ofan amplifier i.e. Bandwidth $BW = f_H - f_L$

DC and AC equivalent circuit of a CE-Amplifier

DC equivalent circuit of a CE – amplifier:

To draw dc equivalent circuit

1. Reduce all the AC sources to zero
2. Open all the capacitors.

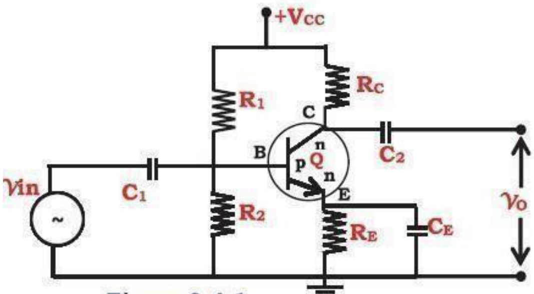


Figure 3.4.1

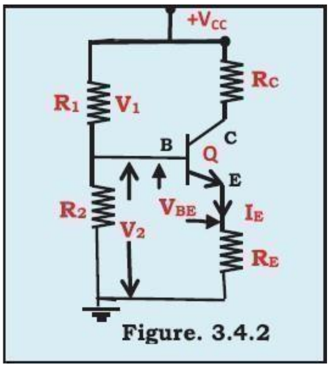


Figure. 3.4.2

AC equivalent circuit of a CE amplifier:

To draw the AC equivalent circuit,

(A) Reduce all DC sources to zero

(B) Short circuit all the capacitors

The AC equivalent circuit for CE amplifier is shown in figure and is also called r_c' model.

The first step to draw ac equivalent circuit is given in figure .

The second step is to replace transistor also with its ac equivalent circuit thus

a. Replace emitter and base junction with ac resistance.
b. Replace collector and base junction with constant current source.

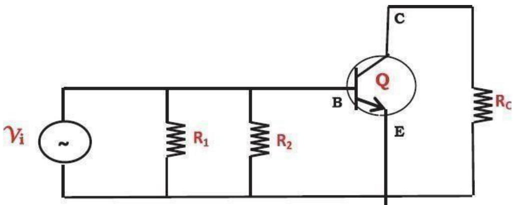


Figure 3.4.3

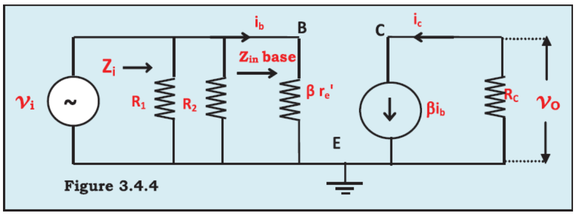


Figure 3.4.4

Input impedance (Z_i):

The input impedance is defined as the ratio of the input voltage to the input current. The input impedance of the amplifier is given by $Z_i = \frac{v_{in}}{i_{in}}$

This is the total input impedance Z_{in} includes the biasing resistors and the impedance looking into the base of the transistor.

$$Z_{in} = R_1 \,||\, R_2 \,||\, _{(base)}$$

The impedance looking directly into the base is given by

$Z_{in(base)} = V_T$/(Input DC base current)

$= V_T/I_B = V_T\,\beta/I_C$ (because $I_C = \beta I_B$)

Since I_C approximately equal to I_E

$_{(base)} = V_T\,\beta/I_E = \beta\, r_e'$

Strictly speaking $_{(base)} = (1 + \beta)\, r_e'$ but approximately we take $\beta e'$

$_{(base)} = \beta r_e'$

Total input impedance $Z_{in} = R_1 = \| R_1 \| \beta r_e' \approx \beta r_e'$

Expression for Output Impedance z_o:

The output impedance of the CE amplifier is defined as the ratio of the output voltage to the output collector current.

Output impedance $z_o = \frac{v_o}{i_o} = \frac{R_C i_c}{i_c} = R_C$

Note: If R_L is the load resistance, then the output impedance equalto

$$z_o = R_C \,\|\, R_L$$

Expression for Voltage gain (A_v)

Voltage gain ofan amplifier is the ratio ofthe output voltage to the input voltage.

$$A_v = -\frac{v_o}{v_i} = -\frac{i_c \times z_o}{i_c \times r_e'} = -\frac{i_c \times z_o}{\beta \times i_b \times r_e'}, \text{ Since } i_c = \beta i_b$$

$$A_v = -\frac{Z_o}{r_e'} = -\frac{R_C}{r_e'}$$

Expression for Current gainA_i: Current gain ofan amplifier is defined as the ratio ofoutput collector current to the input base current.

$$A_i = \frac{i_C}{i_b} = \beta$$

Power gain: Power of an amplifier is defined as the ratio of output power to the input power, $A_P = \frac{p_o}{p_i}$

Power gain of an amplifier is also equal to the product of voltage gain and current gain. $A_P = A_i \times A_v$

Multistage amplifiers:

The cascaded arrangement oftwo or more amplifier stages is called multistage amplifier.

Gain of multistage amplifiers:

Multistage amplifiers are used when the gain from a single stage amplifier is inadequate for the intended application.

In multistage amplifier system, the output ofthe preceding stage is connected as input to thesucceeding stage.The overall numerical voltage gain of the N cascaded stages can be given by the product of the individual stage voltage gains

$A_V = A_{V1} \times A_{V2} \times \ldots\ldots\ldots\ldots\ldots \times A_{VN}$

The overall voltage gain of an amplifier can be expressed in decibel as

(dB) = 20 log A_V

A_V (dB) = A_{V1} (dB) +----------------------- + (dB)

This shows that the overall decibel voltage gain of N- cascaded stages is equal to the sum of the individual stage decibel voltage gains.

$G_V = G_1 + G_2 + G_3 + \ldots + G_N$

$20\ log_{10}\ A_V = 20 log_{10}\ A_{V1} + 20\ log_{10}\ A_{V2} + 20\ log_{10}\ A_{V3} + \ldots. + 20\ log_{10}\ A_n$

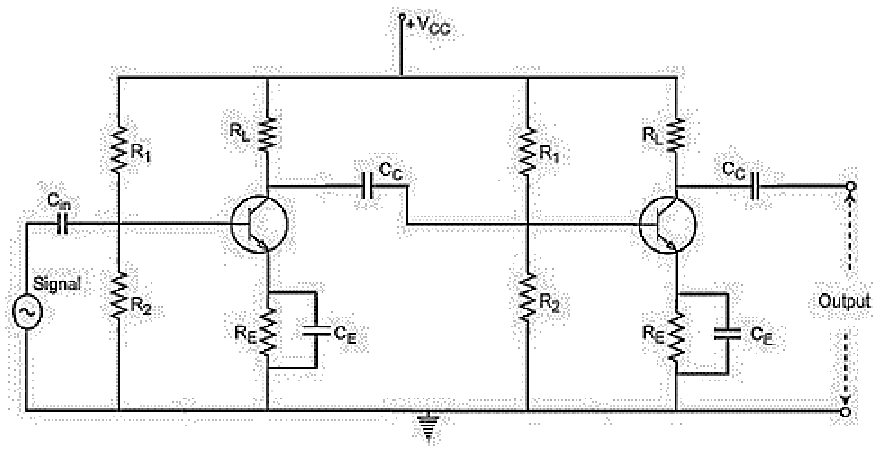
Coupling:

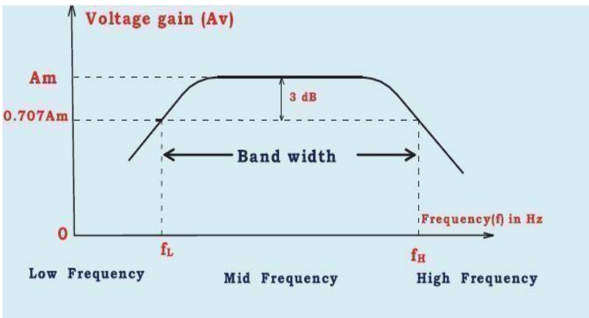
The technique of connecting output of one amplifier stage to the input of the next amplifier stage (such that impedance of the stages are matched enabling maximum transfer of signal from one stage to other)is known as coupling. The main object of coupling is to transfer ac output of one stage to the input of the next stage and to isolate the dc conditions from one stage to the next stage.

Commonly used multistage amplifiers are:

- Direct coupled amplifier
- R-C Coupled amplifier
- Transformer coupled amplifier

Two stage RC- coupled amplifier:



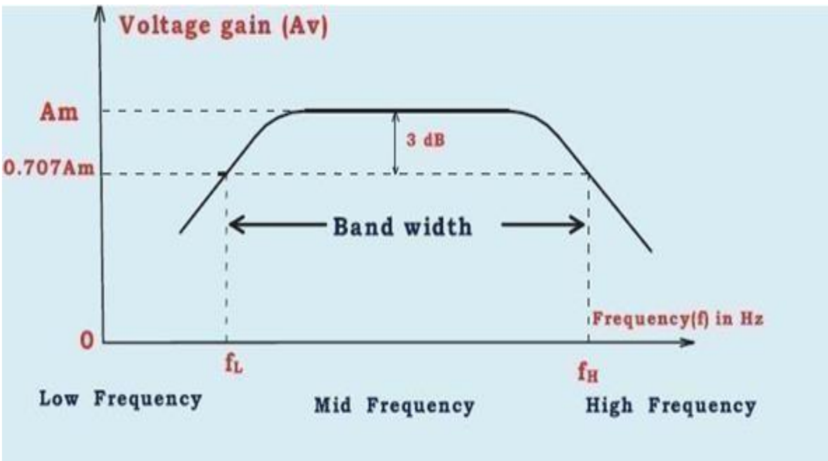


A typical two stage RC-coupled transistor amplifier is as shown. Here, a small AC signal is applied to base of the first-stage and the output signal of first-stage is coupled to the input of the next stage through coupling capacitor Cc and resistor RL at the output terminal of first stage. As the coupling from one stage to the next stage is achieved by the coupling capacitor followed by a connection to shunt resistor, hence the name RC-coupled transistor amplifier.

When an AC signal V_{in} is applied to the base of first stage the amplified and phase inverted signal appears at the collector of transistor T_1. This output signal of the first stage coupled to the base of the second stage. The second stage further amplifies this signal. As a result an amplified and phase inverted signal appears at the collector of transistor T_2. The final output signal Vout across the load resistor RL is in-phase with the input AC signal V_{in}. This is due to the fact that each stage inverts the phase of the signal by 180 degree. Therefore, two stages invert the signal by 360 degree, equivalentto 0 degree. This is how, the two stage RC-coupled amplifier amplifies the signal and overall voltage gain is considerably increased.

i.e. $A_V = A_{V1} \times A_{V2}$

Frequency response of two stage RC-coupled amplifier



At very low frequency:

At very low frequencies of the input signal, reactance of coupling and emitter by pass capacitors are very high. As a result, there is reduction in the output voltage and gain.

At veryhigh frequency:

At veryhigh frequencies gain drops off because ofoverloading effect caused by the capacitances acting as short circuit.

At mid frequency:

At mid frequency range, coupling and bypass capacitors acts as short circuit whereas wiring and transistor junction capacitances act as open circuit. Hence in the mid band frequency region there is no capacitance effect present. As a result gain is uniform or constant.

Advantages of RC-coupled amplifier:

i. The cost of RC-coupled amplifier is verycheap

i. ii. They are very light in weight and occupy less space

ii. Its frequency response is excellent over the AF range

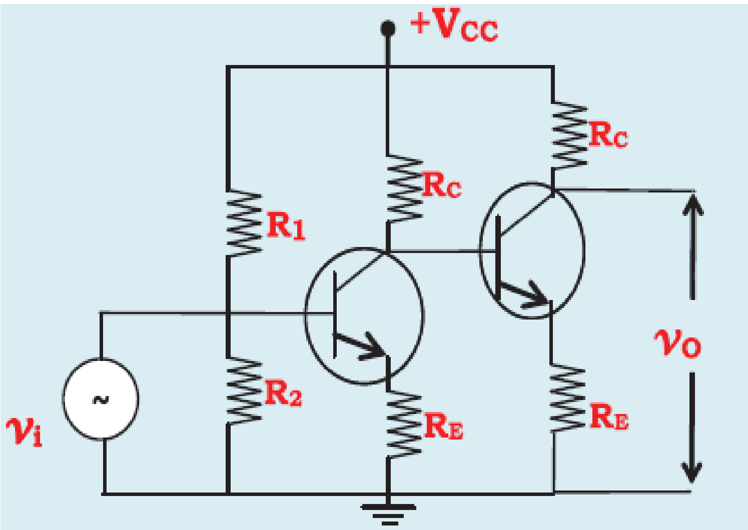
Disadvantages of RC-coupled amplifier:

- The gain ofthese amplifiers are comparatively small.
- The impedance matching is poor and power consumption is high.
- It becomes noisy with age

Applications:

RC-coupled amplifiers are used in all audio small signal amplifiers used in record players, tape recorders, public addressing (PA) systems, radio and TV receivers.

Two Stage Direct –Coupled Amplifier

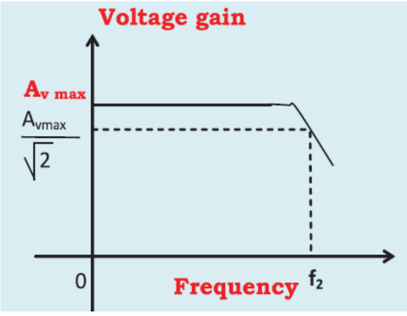


The circuit arrangement of a two stage direct coupled amplifier is shown. In this method of coupling the output ofone stage is fed directly to the input ofnext stage, hence the name direct coupled amplifier. No coupling device like capacitor or transformer is used.

Working:

When a small input signal (V_{in}) of very low frequency (< 10Hz) is applied to base of the first stage transistor, the amplified signal appears across the collector resistor R_c. This amplified signal is directly fed to the base of the second stage transistor for further amplification. In this way, direct coupled amplifier increases the strength of weak signal.

Frequency response curve:



The figure shows the frequency response of Direct coupled amplifier. Here the gain at the lower frequency is constant, due to the presence of coupling capacitors

Advantages:

1. The circuit is very simple
2. Quite inexpensive since it uses minimum components
3. Amplifies both dc and low frequency signals.
4. No coupling / bypass capacitors to cause drop in gain at low frequencies.

Disadvantages:

1. It cannot amplify high frequency signals
2. Operating point is shifted due to temperature variations.

Applications:

Direct coupled amplifiers must be used for low frequencies such as

1. Regulator circuits ofelectronic power supplies.
2. Computer circuitry
3. Differential amplifiers
4. Pulse amplifiers

Power Amplifiers:

The amplifier circuits we have studied so far are voltage or small signal amplifiers. These amplifiers are designed to give large undistorted output voltages from small input voltages. While these do produce small amounts of power in their collector loads, this would be insufficient to operate, for example, a loudspeaker or motor or transmitting antenna in case of transmitting circuits. A power or large signal amplifier is then required which generates large swings of output current and voltages (i.e. large a.c. power) and needs a large alternating input voltage. Actually, the power amplifier is an essential part of every electronic system and used as a last stage (before loudspeaker) in the multistage amplifier systems.

Efficiency ofa power amplifier(η):

It is defined as the ratio of a.c power delivered to load to the d.c power taken from supply battery and is expressed in percentage.

Efficiency= $P_o/P_i \times 100\%$

Classification of power amplifiers:

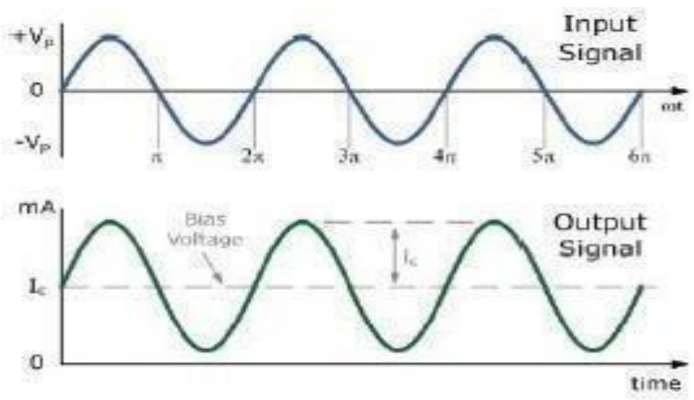
Class A amplifiers

Class B amplifiers

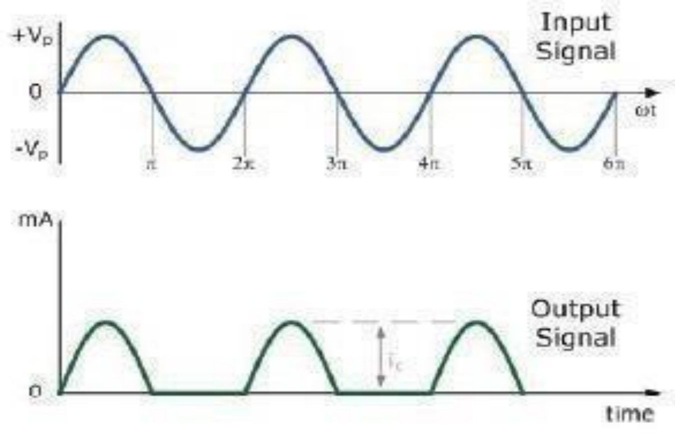
Class C amplifiers

Class AB amplifiers

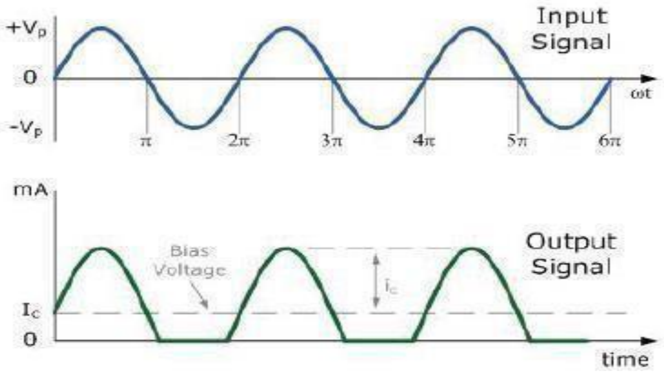
Class A – The amplifier operates in Class A, when the Q-point is located exactly at the centre of the linear amplifying region of the characteristics. The current in the output circuit flows for full cycle of the input signal



Class B – In Class B the quiescent operating point is located at the cut off region. The output current will flow for only half the cycle of the input signal.

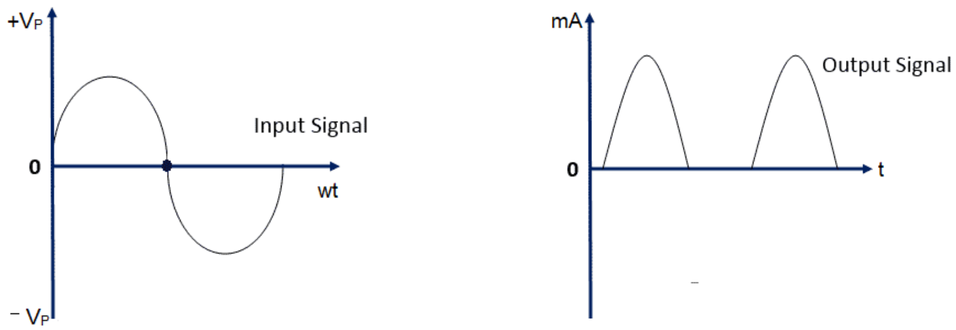


Cass AB – In Class AB, the Q-point is located in between the x-axis and the center of load line.



Class C – In Class C, the Q-point is located beyond the cut-off region or below x-axis. The output current flows for less than half of input signal.

Class C output waveform



Voltage Amplifiers	Power Amplifiers
• It is meant to rise the voltage level of a signal • It is used in the initial stage	• It is meant to boost the power level of a signal • It is used in the final stage

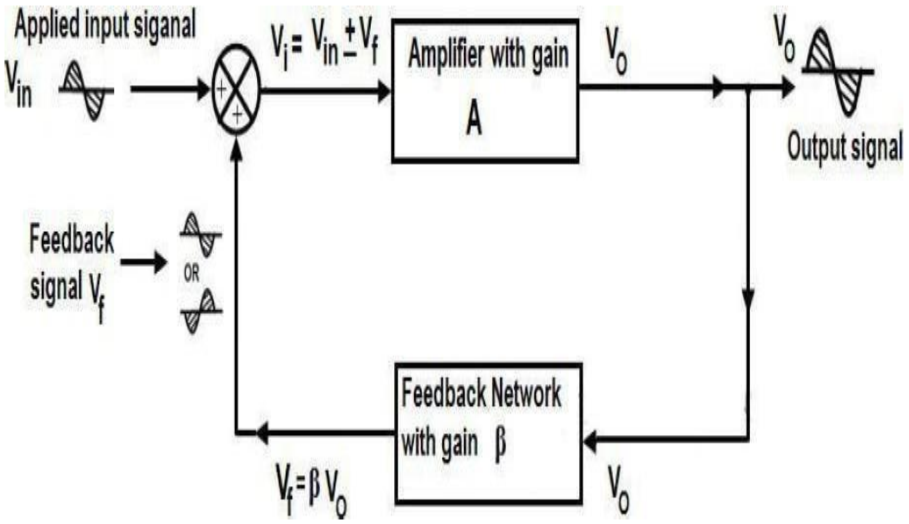
Need for feedback circuit

- An amplifier circuit simply increases the signal strength. But while amplifying, it just increases the strength of its input signal whether it contains information or some noise along with information.
- Therefore, every high gain amplifier tends to give noise along with signal in its output, which is veryundesirable.
- The noise level in the amplifier circuits can be considerably reduced by using feedback circuit done by injecting a fraction ofoutput in phase opposition to the input signal.

FEEDBACK:

- Feedback is the process of taking a part of the amplifier output and feeding (or combining) it back to the input.

The block diagram below shows the amplifier connection with a feedback circuit.



Parameters:

Open Loop Gain:

It is the gain of the amplifier without the feedback network.

A = V_{out}/V_{in}

Closed loop Gain:

It is the gain ofthe amplifier with the feedback network.

$A_f = V_o/V_i$

Feedback factor(β)

It is the ratio of feedback voltage to output voltage.

$\beta = V_f/V_o$

Loop Gain:

The product of open loop gain and the feedback factor.

Parameters:

Open Loop Gain:

It is the gain of the amplifier without the feedback network.

A = V_{out}/V_{in}

Closed loop Gain:

It is the gain ofthe amplifier with the feedback network.

$A_f = V_o/V_i$

Feedback factor(β)

It is the ratio of feedback voltage to output voltage.

β= V_f/V_o

Loop Gain:

The product of open loop gain and the feedback factor.

Loop gain = A. β

Classification of feedback (Types of feedback):

- 1. Positive feedback
- 2. Negative feedback

Positive feedback:

When the original input signal and feedback signal both are in-phase with each other, this feedback is called positive feedback. It is also known as direct feedback or regenerative feedback

Advantages:

The positive feedback increases the output voltage and hence the gain ofan amplifier.

Disadvantages:

It has the disadvantage of increased distortion, Noise and instability.

Therefore, positive feedback is never used in amplifiers.

Applications:

Positive feedback increases the gain of the amplifier therefore it is used in oscillators.

Negative feedback:

When the original input signal and feedback signal both are 180o out-of- phase with each other, the feedback is called negative feedback. It is also known as inverse or degenerative feedback.

- Advantages:
- Stability ofgain is improved
- Distortions in the amplifier output are reduced.
- Increases the input resistance for certain feedback configuration.
- Reduces the output resistance for certain feedback configuration.
- Improves the frequency response

Disadvantage:

The only disadvantage of negative feedback is that it reduces the gain of the amplifier.

Applications:

Negative feedback is frequently used in amplifiers.

Four types negative feedback connections:

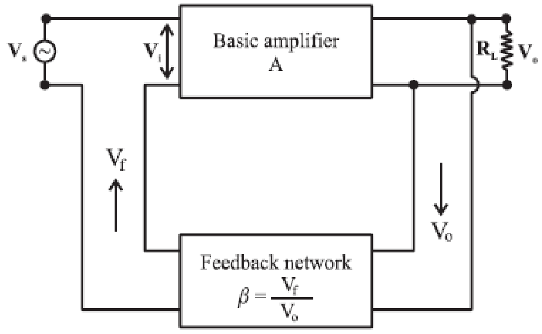
The negative feedback amplifiers can be classified on the basis of electrical quantity (i.e. voltage or current) to be feedback to the input and the type of connection used for feedback (i.e. shunt or series).

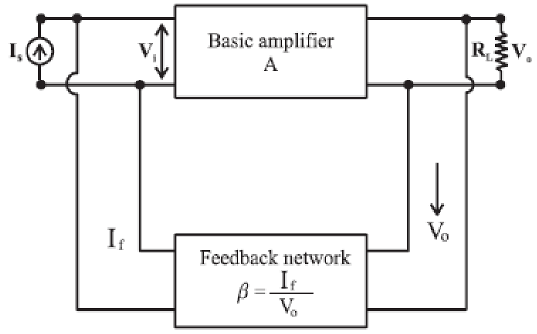
- Voltage – series feedback
- Voltage – shunt feedback
- Current – series feedback
- Current – shunt feedback

The block diagrams of the four types of feedback are shown in the following figures:

Voltage series negative feedback:

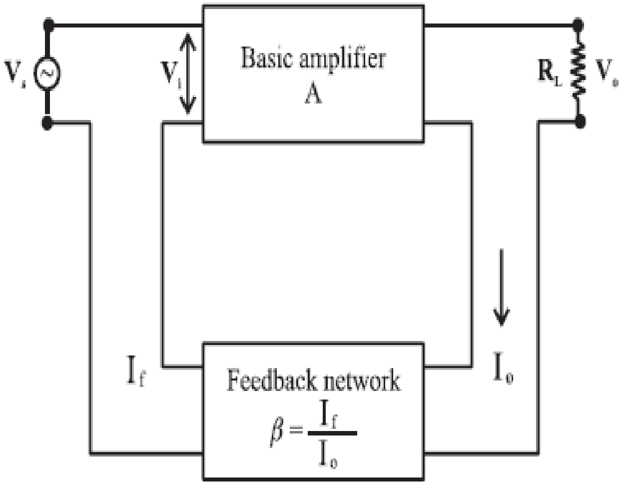
Voltage shunt negative feedback :

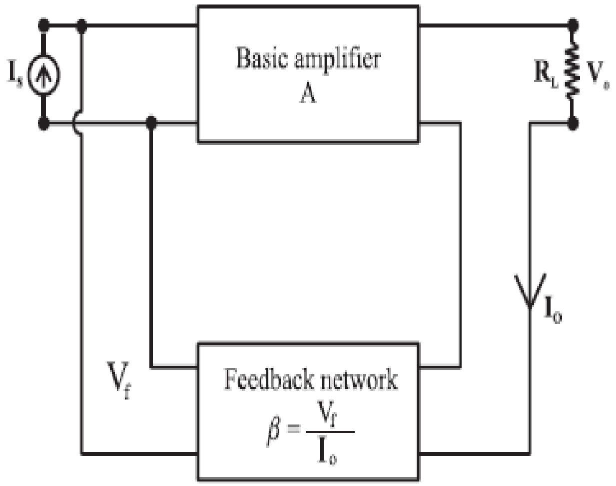




Current series negative feedback:

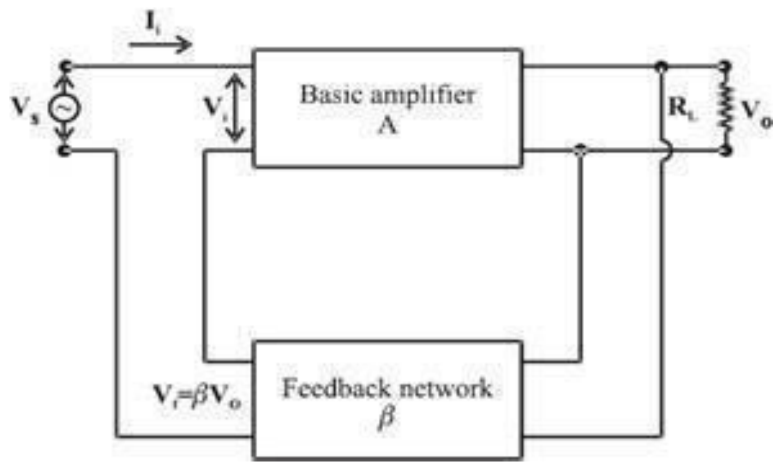
Current shunt negative feedback:



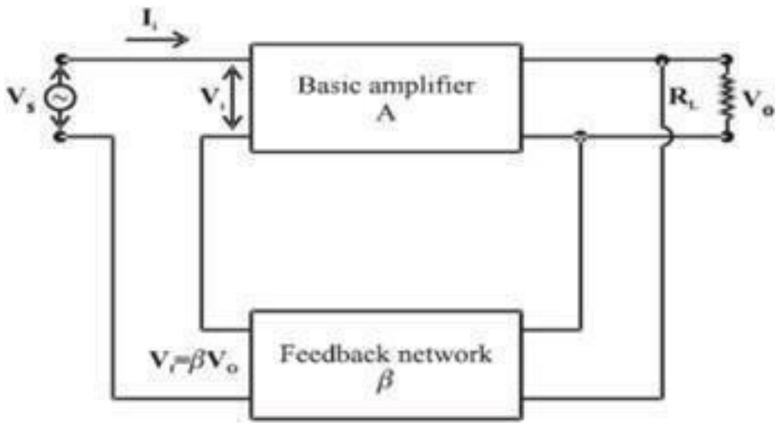


Increase in Input Impedance:

It is desirable to have high input impedance for an amplifier. Then it will not load the preceding stage or the input voltage source. Such a desirable characteristic can be achieved with the help of voltage series negative feedback.



Increase in Input Impedance:



Let I_i be the input current, V_i be the input voltage to the basic amplifier, V_s be the input voltage to the basic amplifier, V be the feedback voltage and V_o be the output voltage.

The input impedance of basic amplifier is

$Z_i = \frac{V_i}{I_i}$ . . . (1)

Let Z_{if} be the input impedance of amplifier with feedback and is given by

$Z_{if} = \frac{V_s}{I_i}$ . . . (2)

Input voltage to the basic amplifier with negative feedback is

$V_i = V_s - V_i$

$= V_s - \beta V_o$ [because $V_f = \beta V_o$]

$= V_s - \beta A V_i$ [because $V_o = \beta V_f$]

$V_s = V_i + A\beta V_i$

$V_s = V_i (1 + A\beta)$ . . . (3)

Substitute equation (3) in equation (2) we get

Z_{if} = Z_{if} = (1 + Aβ) [from equation (1)]

Thus the input impedance with negative feedback increases bya factor of 1 + Aβ.

Decrease in output impedance

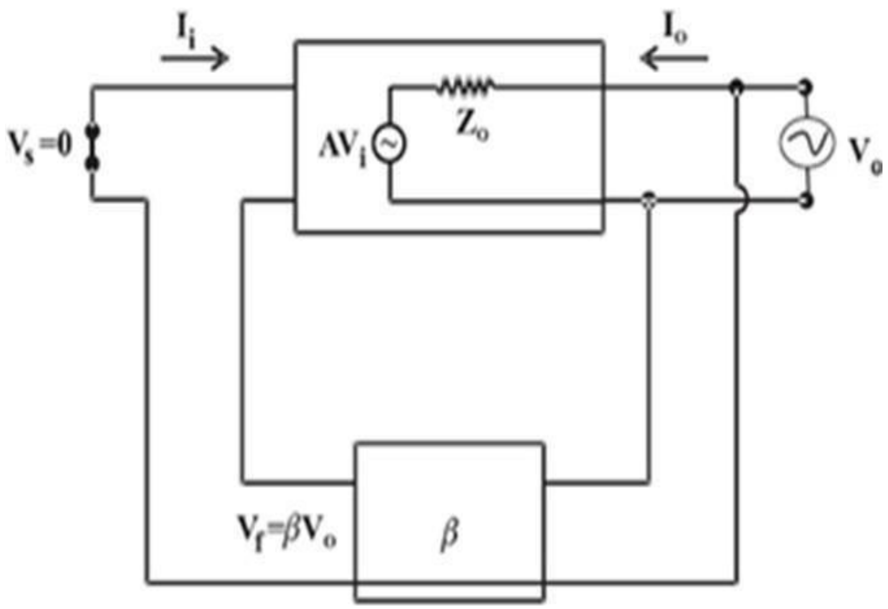
An amplifier with low output impedance is capable of delivering voltage or power to the load without much loss. Such a desirable characteristic is achieved by employing voltage series negative feedback in the amplifier.

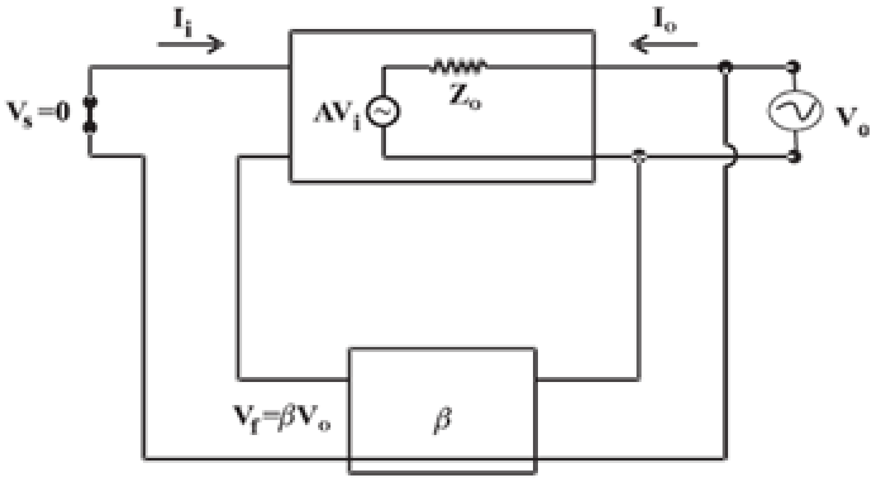
Output impedance of feedback amplifier is the ratio of output voltage to output current with input shorted. Let Z_o be the output impedance of basic amplifier and Z_{of} be the output impedance of feedback amplifier. A hypothetical source of voltage V_o is applied at the output, as shown in

Decrease in output impedance:

The impedance with feedback is given by

$$Z_{of} = \frac{V_o}{I_o} \quad \text{. . . (1)}$$





By applying KVL to the output loop in figure 4.4.3, we get

$V_o =$ $+ AV_i$ . . . (2)

The input to the basic amplifier with negative feedback is

$V_i = V_s - V_f$

But $V_s = 0$ because input is short circuited.

$V_i = - V_f$

Substitute V_i in equation (2), we get,

$V_o = I_o Z_o + AV_f$

$V_o = I_o Z_o + A\beta V_o$ [since $V_f = \beta V_0$]

$V_o = A\beta V_o = I_o Z_o$

$(1 + A\beta) = I_o Z_o$

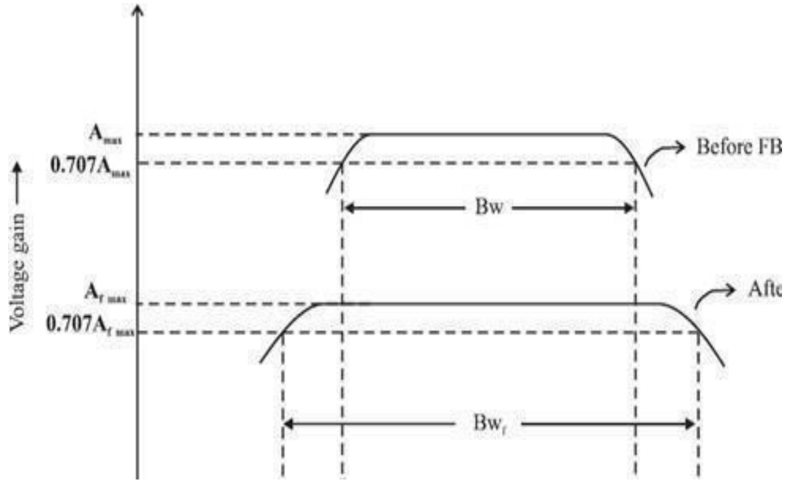
$\frac{V_o}{I_o} = \frac{Z_o}{(1+A\beta)}$ or

$Z = \frac{Z_o}{}$ [from equation (1)]

of $(1+A\beta)$

Thus output impedance of amplifier with negative feedback decreases by a factor of $(1 + A\beta)$

Frequency response of negative feedback amplifier:



The bandwidth (BW) of an amplifier without feedback is equal to the separation between the 3dB frequencies f_1 and f_2.

If A is the gain, then gain-bandwidth product is A × BW.

When negative feedback is applied, the lower cut off frequency decreases by a factor of (1 + Aβ) and upper cut off frequency increases by a factor of (1 + Aβ)

i.e., $f_1' = \frac{f_1}{(1+A\beta)}$ and $f_2' = f_2(1 + A\beta)$

The bandwidth with feedback is $BW_f = f_2' - f_1'$

The relation between BW ofan amplifier with an without feedback is

BW_f = BW(1 + Aβ)

Since gain bandwidth product remains same in both cases.

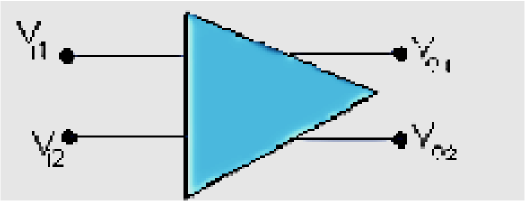
A × BW = × BW_f

OPERATIONAL AMPLIFIERS (OP-AMP)

An operational amplifier, often referred as op-Amp, is a high-gain, directly coupled, negative feedback, differential amplifier designed, to amplify both DC and AC signals gain can be controlled by using feedback. It is used to perform mathematical operations such as addition, subtraction, inversion, differentiation, integration etc. Hence the name operational amplifier or in short op-amp.

Differential (or) Difference amplifier:

A differential amplifier is a circuit which amplifies the difference between two input signals. The symbolic representation of differential amplifier is shown



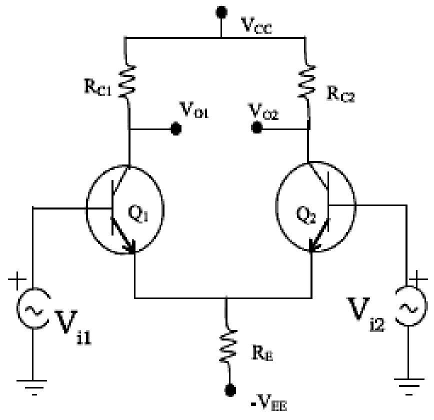
Different configurations of the differential amplifier:

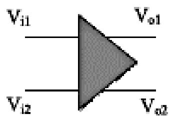
Depending on the number of input signals used and the manner in which the output is taken there are four possible configurations of the differential amplifiers.

The four differential amplifier configurations are following:

- Dual input, balanced output differential amplifier.
- Dual input, unbalanced output differential amplifier.
- Single input balanced output differential amplifier.
- Single input unbalanced output differential amplifier

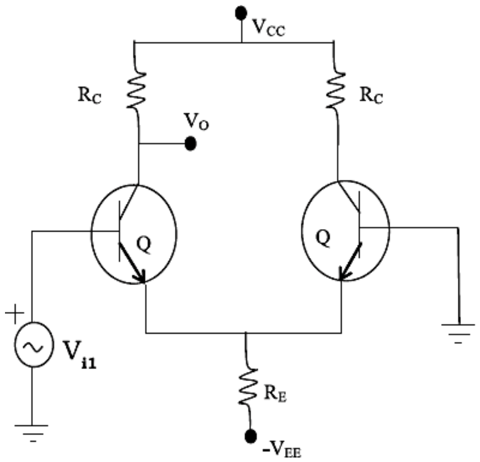
Dual input and balanced output differential amplifier.

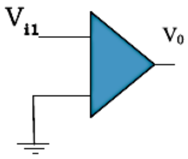




Block diagram

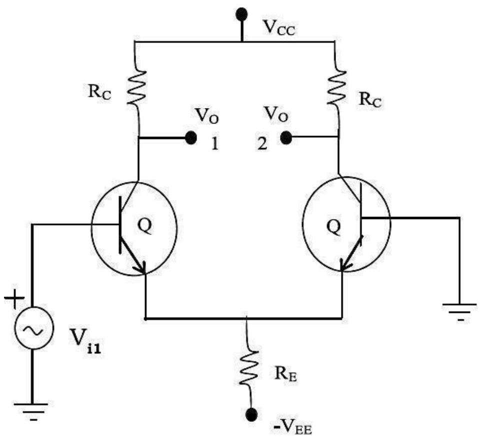
Single input and unbalanced output differential amplifier

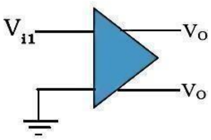




Block diagram

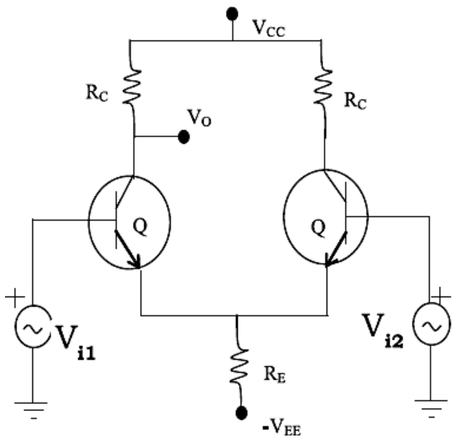
Single input and balanced output differential amplifier

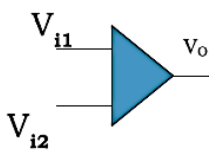




Block diagram

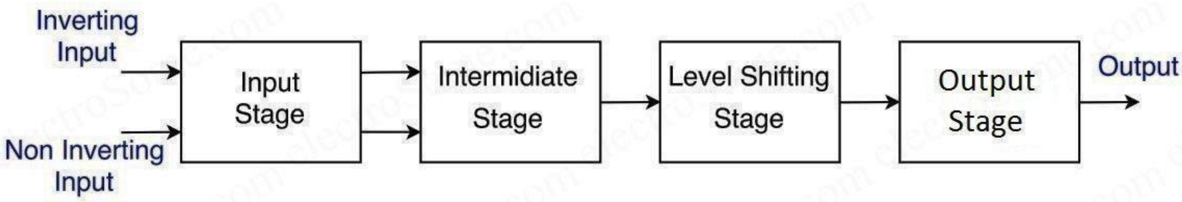
Dual input and unbalanced output differential Amplifier





Block diagram

Block diagram of op-amp:



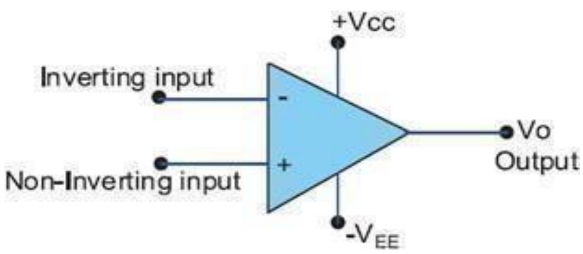
Input stage: The input stage is a dual input, balanced output differential amplifier. The function of this stage is to provide most of the voltage gain to op-amp. It also establishes the high input resistance of the op-amp.

Intermediate stage: The intermediate stage is used to provide some additional gain.

Level shifting stage: Since Op amp is basically DC amplifier and no capacitor is used, the Quiescent voltages shift every stage. To bring it to the original level, Emitter follower is used as DC level shifter

Output stage: The output stage is generally push-pull amplifier and it is used to provide low output resistance and final output.

The circuit symbol of op amp is as shown below:



Allthe Op-Amp have following five terminals:

- An inverting input
- A non-inverting input
- An output
- Apositive power supply, $+V_{CC}$
- A negative power supply, $-V_{EE}$

Characteristics of an ideal op-Amp:

An ideal op-amp has the following characteristics:

- Open loop voltage gain (A_V) = infinity
- Input impedance (Z_{in}) = infinity
- Output impedance (Z_{out}) = 0
- Bandwidth (B.W) = infinity

- CMRR (P) =infinity
- Slew rate = infinity
- Input Offset Voltage=0

Common-mode Rejection ratio [CMRR]:
Common mode rejection Ratio (CMRR) is the ratio of the differential mode gain (ADM) to the common mode gain (ACM). Ideal value of CMRR is ∞. But practically CMRR value is very large.

Slew rate
Slew rate ofan op-amp is the maximum rate ofchange ofoutput per unit time. It represents how quickly the output of an amplifier can change in response to the input. In simple words, it represents the speedof an amplifier. Slew rate is usually represented in V/μS and the equation is
SR = dV_o/dt.

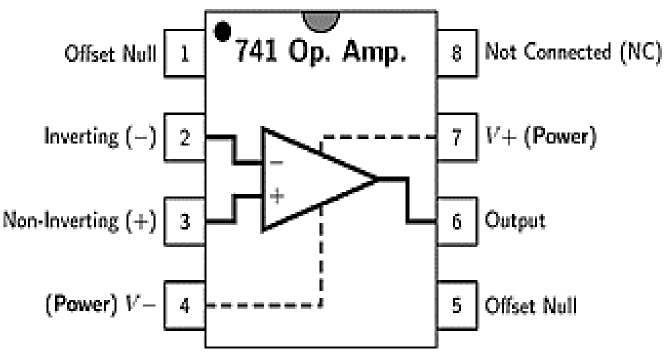
Input offset voltage: this is the small voltage that must be applied between 2 input terminals to make the output voltage 0.

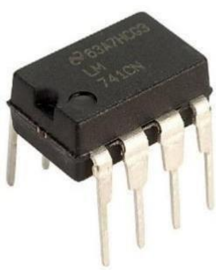
O**utput offset voltage:** when the inputs of the Op amp are grounded the output must be '0' but there is a small error voltage at the output dueto difference in VBE value of input transistor.

Applications of op-Amp with negative feedback:
Applications of op-Amp are innumerable. Some ofthe important applications are:

- Inverting amplifier
- Non-inverting amplifier
- Adder or summing amplifier
- Subtract or and Difference amplifier
- Integrator
- Differentiator
- Comparator

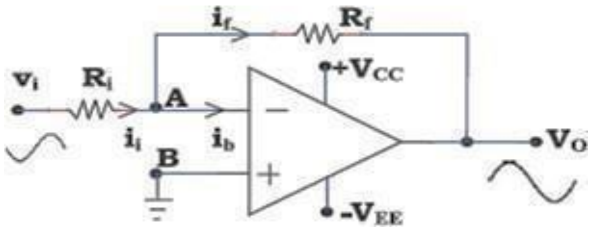
Pin configuration of IC 741:





Concept of virtual ground

It is the situation in which the inverting input of an op-amp is at ground potential even though it is not physically connected to ground. Therefore, even though the inverting terminal is not grounded, there exists zero voltage.



Consider anideal Op-Amp circuit with negative feedback as shown inthe figure. Let V_i = input voltage, V_o = output voltage, i_i = input current, i_f = current through the feedback resistorR_f, i_b = currentflowingintotheop-amp,
R_f = Feedback Resistor, R_i = Input Resistor, V_A = Voltage at the inverting terminal, V_B = Voltage at the non-inverting terminal

For an Ideal Op=amp, open loop gain A = ∞ and input impedance $Z_i = \infty$

$\Longrightarrow$ A $= \frac{VO}{V_B - V_A} = \infty$

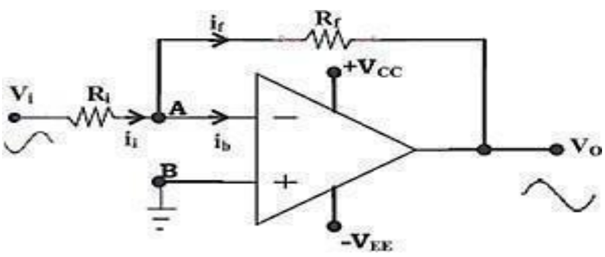
$\Longrightarrow$ $V_B - V_A$ = O

$\Longrightarrow V_A = V_B$

As $V_B = 0$ $\Longrightarrow$ $V_A = 0$

$Z_i = \infty \Longrightarrow$ current into the Op-amp = 0 i.e., $i_b = 0$

Inverting Amplifier: An amplifier whose output is out of phase by 180° with respect to the input is known as an inverting amplifier. Consider an ideal operational amplifier. The circuit of an inverting amplifier is shown in figure below.



The input signal V_i is applied to the inverting terminalofop-amp through a resistorR_i. The non inverting terminal is grounded. R_f is the feedback resistor connected between the output and inverting terminal ofop-amp.

Let i_i and i_f be the input current and output current flowing through R_i and R_f respectively as shown in figure.

For an Ideal op-amp, open loop gain A = ∞ and Input Impedance, $Z_i = \infty$.

Or $V_B = V_A = 0$ (virtual ground concept)

Since input impedance $Z_i = \infty, \Longrightarrow i_b = 0$

Applying KCL at (A),

$i_i = i_b + i_f$

$i_i = i_f$ (since $i_b = 0$)

$\frac{(V_B - V_A)}{R_i} = \frac{(V_A - V_0)}{R_f}$

$\frac{V_i}{R_i} = \frac{(-V_0)}{R_f}$ . . . . since $V_A = 0$

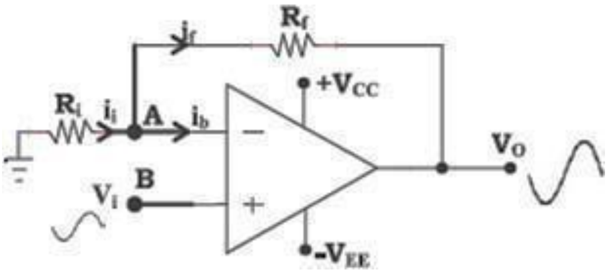
or, $V_o = -\left(\frac{R_f}{R_i}\right) V_i$

or voltage gain, $V = \frac{V_O}{V_i} = -\frac{R_f}{R_i}$

Op-Amp as a non-inverting amplifier:

An amplifier whose output is in phase with the input is called the non-inverting amplifier. Consider an ideal operational amplifier. The circuit diagram of non-inverting op-amp is shown in figure below. The input signal V_i is applied to the non- inverting terminal. The inverting terminal is grounded through resistor R_i. The feedback resistor R_f is connected between the inverting and output terminals of op- amp. Here the output is in phase with the input.

For an ideal op-amp, open loop gain A = ∞ and input impedance, $Z_i = \infty$



$\Longrightarrow$ $A = \frac{V_0}{V_B - V_A} = \infty$

$\Longrightarrow$ $A = V_B - V_A = 0$

or, $V_B = V_A = V_i$

Since input impedance Z = ∞ $\Longrightarrow$ $i_b =$ 0

Applying KCL at (A),

$i_i = i_b + i_f$

$i_i = i_f$ (since $i_b = 0$)

$\frac{(0 - V_A)}{R_i} = \frac{(V_A - V_0)}{R_f}$

Since $V_A = V_i$,

$\frac{(-V_i)}{R_i} = \frac{(V_i - V_0)}{R_f}$

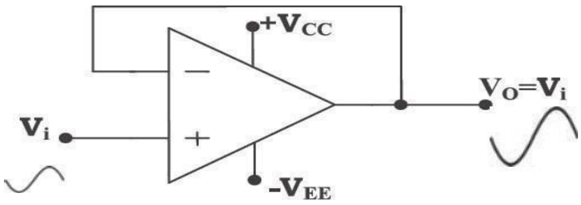
$\frac{V_0}{R_f} = \frac{V_i}{R_f} + \frac{V_i}{R_i}$

$V_0 = R_f \left(\frac{V_i}{R_f} + \frac{V_i}{R_i}\right)$

$V_0 = V \left(1 + \frac{R_f}{R}\right)$

or Voltage Gain, $A_V = \frac{V_0}{V_i}$ is given as $A_V = 1 + \frac{R_f}{R_i}$

Op amp as a buffer (Voltage follower):



An amplifier in which output is equal to the input both in magnitude and phase is known as buffer or voltage follower or unity gain amplifier.

The output voltage V_0 ofnon-inverting op-amp is given by,'

$$V_0 = V_i\left(1 + \frac{R_f}{R_i}\right)$$

$= (1 + 0)$

$= V_i$

i.e. $V_0 = V_i$

or Voltage Gain which is $A_V = \frac{V0}{V_i}$ is equal to 1.

Features of buffer amplifier:

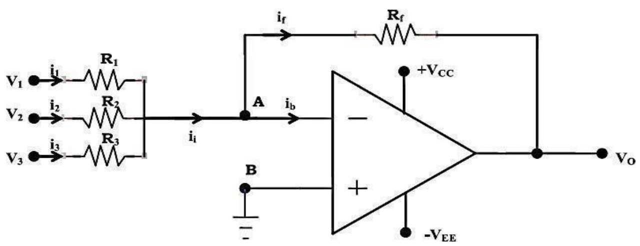
- It has very high input impedance.
- It has very low output impedance
- The output voltage is exactly equal to the input both in magnitude and phase.

Applications of buffer amplifier:

- Buffer amplifier can be used for impedance matching purposes.
- It is veryuseful in isolating any circuit from a load.

Op-amp as a summing amplifier (or) an adder:

The op-amp circuit in which output voltage is equal to sumof the input voltages is called an adder. Fig shows summing amplifier in inverting configuration with three inputs V_1, V_2 and V_3. Depending on the relation between R_1, R_2, R_3, and R_f the circuit can be used as a summing amplifier.



For an ideal op-amp, open loop gain A = ∞ and Z_i = a

By virtual ground concept, $V_B = V_A = 0$

Since input impedance $Z_i = \infty \Longrightarrow i_b = 0$

Appling KCL at A

$i_i = i_b + i_f$

$i_i = i_f$ (since $i_b = 0$)

$i_1 + i_2 + i_3 = i_f$ (as $i_i = i_1 + i_2 + i_3$)

$$\frac{V_1-V_A}{R_1} + \frac{V_2-V_A}{R_2} + \frac{V_3-V_A}{R_3} = \frac{V_A-V_0}{R_f}$$

$V_A = 0$,

$$\frac{V_1-0}{R_1} + \frac{V_2-0}{R_2} + \frac{V_3-0}{R_3} = \frac{0-V_O}{R_f}$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{-V_O}{R_f}$$

$$V_O = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

If $R_1 = R_2 = R_3 = R_f = R$,

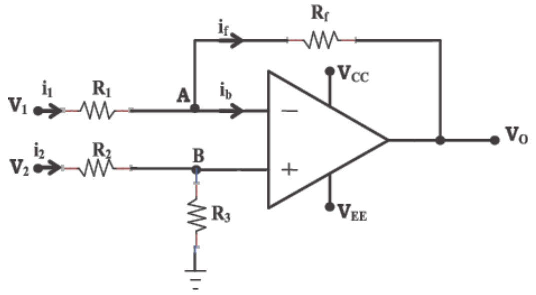
then $V_O = -(V_1 + V_2 + V_3)$

Thus the output voltage is the negative sum of input voltages. So under this condition summing amplifier is also called op-amp inverting adder.

OP-amp as a difference amplifier and subtractor:

Difference amplifier:

A circuit that amplifies the difference between the two input signals applied at the two inputterminals of an op-amp is called difference or differential amplifier. Figure shows the op-amp circuit with two input voltage V_1 and V_2 applied to inverting and non-inverting input terminals respectively. Depending on the relation between R_1, R_2, R_3 and R_f the circuit can be used as a difference amplifier and also subtractor.



Considering V_1 alone and V_2 grounded, the subtractor acts like an inverting amplifier. Therefore,

$V01 = \frac{-R_f}{Ri} V$ → output of an inverting amplifier

Considering V_2 alone and V_1 grounded, the subtractor acts like a non-inverting amplifier with input V_B at the non-inverting terminal.

$V02 = (1 + \frac{R_f}{R_i})\, VB$ → output ofa non-inverting amplifier.

But V_B is the voltage drop across R_3. Therefore,

$V_{02} = \left(\frac{V_2}{R_2+R_3} \right) R_3$

$V_B = \frac{2-3}{R_2+R_3}$

Substituting for V_B, we get,

Bysuperposition theorem,

$V_0 = V_{01} + V_{02}$

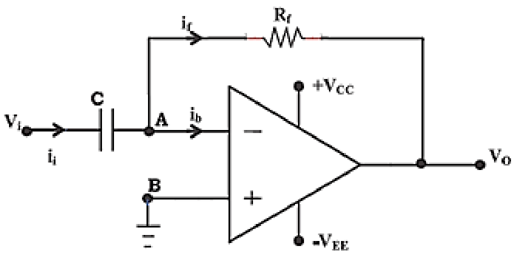
If $R_1 = R_2 = R_3 = R_f = R$

then $V_0 = V_2 - V_1$

Op-Amp as a differentiator

A circuit whose output is proportional to the derivative of its input voltage is known as differentiator. The circuit diagramof a differentiator using an op-amp is shown in figure.

The input voltage V_i is applied to the inverting terminal through a capacitor of capacitance C. The non-inverting terminal is grounded. The feedback resistor R_f is connected between the output and inverting terminals. Since the input impedance of op-amp is infinite no current flows through it.



For an Ideal Op-Amp, open loop gain A = ∞ and input impedance $Z_i = \infty$,

$V_B = V_A = 0$ (virtual ground concept)

Since input impedance $Z_i = \infty, \implies i_b = 0$

Applying KCL at junction A,

$i_i = i_b + i_f$

$i_i = i_f$ (since $i_b = 0$)

The charging current i_i can be expressed in terms ofthe charge Q acquired bythe capacitor C, as

$$\frac{dQ}{dt} = \frac{(V_A - V_0)}{R_f}$$

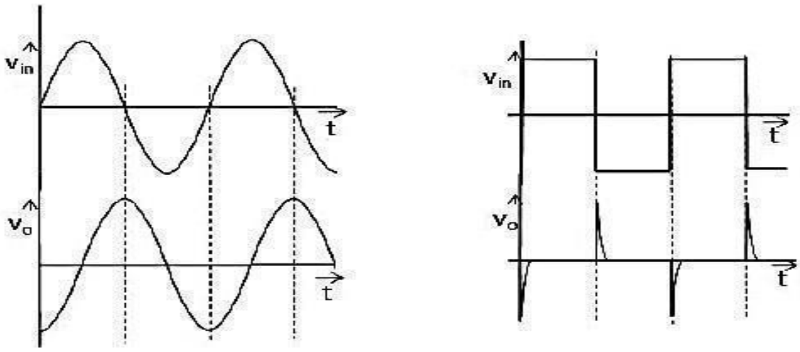
Substituting for Q in terms of Capacitance and potential difference across the capacitor,

$$\frac{d}{dt}[C(V_i - V_A)] = \frac{(V_A - V_0)}{R_f}$$

Since $V_A = 0$

$$V_O = -R_f C \frac{d}{dt}(v_i)$$

Thus the output voltage is proportional to the derivative of the input voltage.

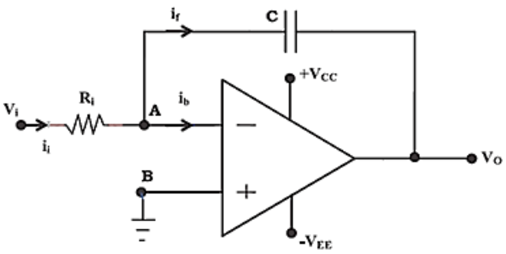


When the input is Sine wave the output of the differentiator is a Cosine wave. When the input is Square wave the output of the differentiator is a Spike wave, as shown in the figure.

Op-Amp as an integrator

A circuit whose output is proportional to the integral of its input is referred to as an integrator. The circuit diagram of an integrator using op-amp is shown in figure below.

The input voltage V_i is applied to the inverting terminal through a resistor R_i. The non-inverting terminal is grounded. The capacitor C (feedback) is connected between the inverting and output terminals of op-amp. As the input impedance of op-amp is infinite, no current flows through it.



For an ideal op-amp, open loop gain A = ∞ and input impedance $Z_i = \infty$,

$V_B = V_A = 0$ (virtualground concept)

Applying KCL at junction A,

$i_i = i_b + i_f$

$i_i = i_f$ (since $i_b = 0$)

The charging current i_i can be expressed in terms of the charge Q acquired by the capacitor C, as

$$\frac{(V_i - V_A)}{R_i} = \frac{dQ}{dt} = \frac{d}{dt}[C(V_A - V_0)]$$

Since $V_A = 0$,

$$\frac{V_i}{R_i} = C\frac{d}{dt}(-V_0)$$

Integrating on both sides with respect to time,

$$\int \frac{V_i}{R_i} dt = \int C \frac{d}{dt}(-V_0) dt$$

$$\int \frac{V_i}{R_i} dt = -CV_0$$

$$-\frac{1}{R_iC}\int V_i\, dt = V_0$$

or,

$$V_0 = -\frac{1}{R_iC}\int V_i\, dt$$

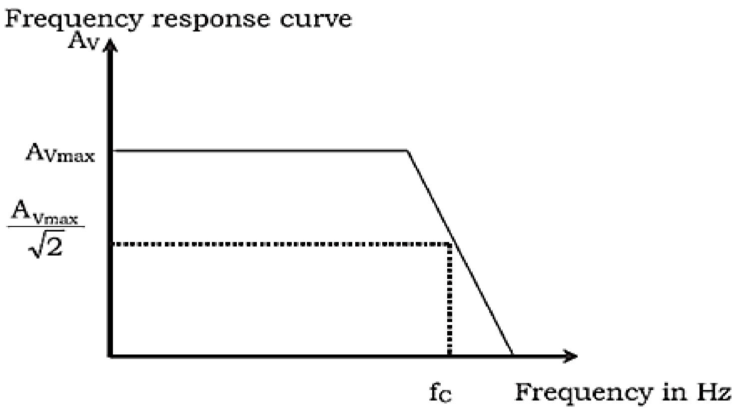
Thus the output voltage is proportional to the integral of the input voltage.

Band pass filter:

A filter designed to pass all frequencies that fall between its cut-off frequencies (fC1 and fC2).

First order active low-pass filter

- The input is applied across the resistor and the output is taken across the capacitor.
- At low frequency: the capacitor acts as an open circuit. Therefore all the input voltage appears across the output.
- At high frequency: the capacitor acts as a short circuit. Therefore the output becomes zero

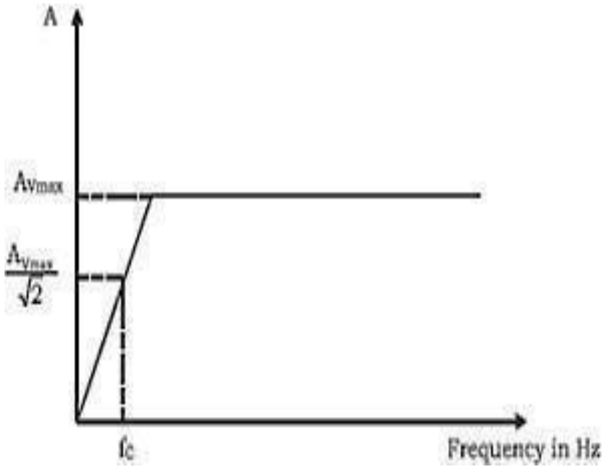


First order active high-pas filter

- The input is applied across the capacitor and the output is taken across the resistor.
- At low frequency: the capacitor acts as a open circuit . Therefore all the output becomes zero.
- At high frequency: the capacitor acts as a short circuit. Therefore all the input voltage appears across the output.

$f_c = \frac{1}{2\pi R_1 C_1}$ and $A_v = 1 + \frac{R_f}{R}$

Frequency response curve:



Comparator:

- Comparator is a circuit which compares two voltages and provides an output voltage that indicates which of the two input voltages is larger in magnitude.
- A comparator in its simplest form is nothing but an open-loop op-amp, with two inputs and one output.
- It compares a signal voltage applied to one input of the op-amp, with a known voltage called the reference voltage (V_{ref}) applied to the other input. The output of a comparator is either positive or negative maximum voltage ($\pm V_{max}$), depending on which input is larger.

Working:

- The operation ofthe circuit is as follows:
- As long as the input voltage V_{in} is less than V_{ref}, the non-inverting terminal is at higher potential than the inverting terminal. Therefore the differential input voltage V_{id} is positive andthe op-amp output will swing to $+V_{sat}$ volts as shown in fig.
- When V_{in} is greater than V_{ref} the inverting terminal is at higher potential than the non- inverting terminal. Therefore the differential input voltage V_{id} is negative and the op-amp output will swing to $-V_{sat}$ volts as shown in fig.

Zero Crossing Detector (ZCD):

Here a time varying signal is applied to the non-inverting terminal and the inverting terminal is grounded.

If $V_i > 0$ then $V_0 = +V_{sat}$ If $V_i < 0$ then $V_0 = -V_{sat}$

i.e. Every time V_i cross '0' level Vo switches its state. Hence the name Zero crossing detector. The same circuit can be used to convert a Sine wave to a square wave.

Chapter 6 **OSCILLATORS**

Oscillators:

Oscillators are electronic circuits that generate an output signal without the necessity of an input signal.

Oscillator is an electronic circuit that receives d.c energy and changes it into a.c energy of any desired frequency.

Oscillators are used in radio, TV transmitters, TV receivers, radar, computers and other electronic devices.

Classification of oscillators:

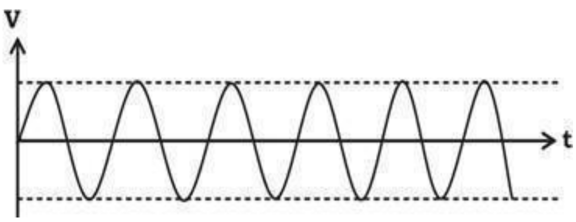
Based on the shape of waveforms they generate, oscillators are classified into:

- Sinusoidal oscillator
- Non-sinusoidal oscillator.
- Based on the components used in the feedback circuit sinusoidal oscillators are further classified into:
-
- LC oscillators
- RC oscillators
- Crystal oscillators

Sinusoidal oscillator or Harmonic oscillator:

When the oscillator output is a sinusoidal waveform, such an oscillator is called sinusoidal oscillator.

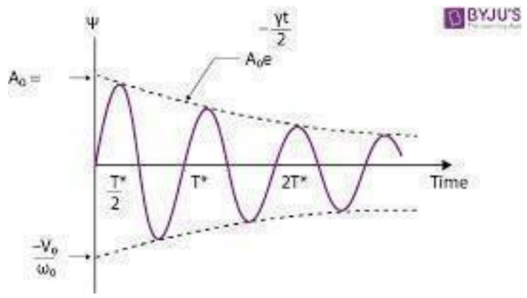
The sinusoidal wave form is as shown in figure.



Non sinusoidal oscillator:

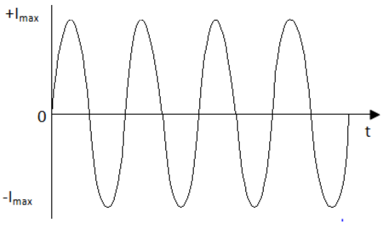
When the oscillator output is non-sinusoidal (triangular, square, saw-tooth etc.), such an oscillator is called as a non-sinusoidal oscillator. The different types of non-sinusoidal waveforms are as shown in figure.

Damped oscillations:



The electrical oscillations whose Amplitude decreases with times are known as damped oscillations.

Undamped Oscillations:



The electrical oscillations whose amplitude does not decrease with time are known as undamped oscillations.

Basic Principle of oscillator

The open loop ofthe amplifier

A = $\frac{V_0}{V_i}$

After applying the positive feedback, the gain becomes

$A_f = \frac{V_0}{V_s}$

Since the feedback voltage is in phase with the signal voltage, We get,

$V_i = V_s + V_f$ . . . (1)

Feedback voltage

$V_f = \beta V_0$ . . . (2)

Substituting (2) in (1),

$V_i = V_s + \beta V_0$

$V_s = V_i - \beta V_0$ . . . (3)

$A_f = \frac{V_0}{V_s}$

$A_f = \frac{V_0}{V_i - \beta V_0}$

Dividing both numerator and denominator by V_i,

$A_f = \frac{\frac{V_0}{V_i}}{\frac{V_i}{V_i} - \beta\frac{V_0}{V_i}}$

Since A = $\frac{V_0}{V_i}$

Voltage gain with positive feed back A_f = $\frac{A}{1-A\beta}$

Where A_f = Voltage gain with feedback

A = Voltage gain without feedback

β = feedback ratio

Aβ is known as Loop gain.

If Aβ = 1, $A_f = \infty$.

As $A_f = \infty$ there is an output without any input. In other words, the amplifier becomes an oscillator.

Barkhausen's Criteria and condition for sustained Oscillations:

- Loop gain Aβ= 1
- Feedback should be positive

(OR)

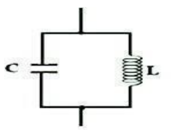
The net phase shift around the loop is 0^0or 360^0 or 2Π radians.

Tank circuit (or) LC circuit (or) oscillatory circuit:

A circuit that Produces electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit.

Fig. shows a simple tank circuit which contains a capacitors C and an inductor L connected in Parallel. The frequency of oscillations produced by this oscillatory circuit is determined by the value of C and L is given by

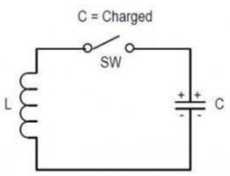
$$f = \frac{1}{2\pi\sqrt{LC}}$$



Simple Tank circuit

Working principle of Tank Circuit

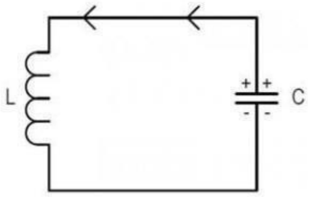
To understand the tank circuit operation, consider the capacitor is already charged from a DC source with polarityas shown in the below figure.



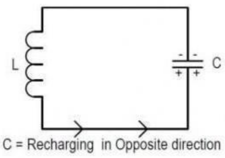
Here the upper plate is positive terminal with respect to lower plate.

It means there is a voltage across the capacitor and it has electrostatic energy.When the switch SW is closed, the capacitor will start to discharge the stored energy through inductor. The current flow is indicated in the below figure.

C = Discharging

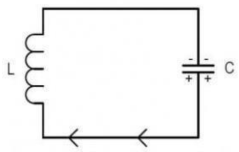


- Due to the nature of inductor, it will not instantly allow the entire current.
- The current will build up slowly towards maximum value.
- This current flow creates the magnetic field around the coil.(ie, developing electromagnetic field).
- Eventually the electrostatic energy stored across the capacitor is converted into electromagnetic energy around the inductor.
- Once the capacitor is fully discharged, the inductor’s magnetic field will start to collapse and produce counter emf. The counter emf will recharge the capacitor in the opposite direction. As shown in the figure.



C = Recharging in Opposite direction

- Hence the capacitor will get charge in opposite polarity. Once the collapsing magnetic field has recharged the capacitor,
- This time the capacitor starts to discharge and the current will flow in opposite direction as shown in the below figure.



C = Discharging in Opposite direction

The sequence of charge and discharge creates the alternating motion of electrons or an oscillating current. The energy is alternately stored in electrostatic field of capacitor and the electromagnetic field of the inductor.

- We know that there is a resistive loss in inductor and dielectric loss in capacitor.
- During each cycle, a small part ofenergy is wasted in these losses.

.

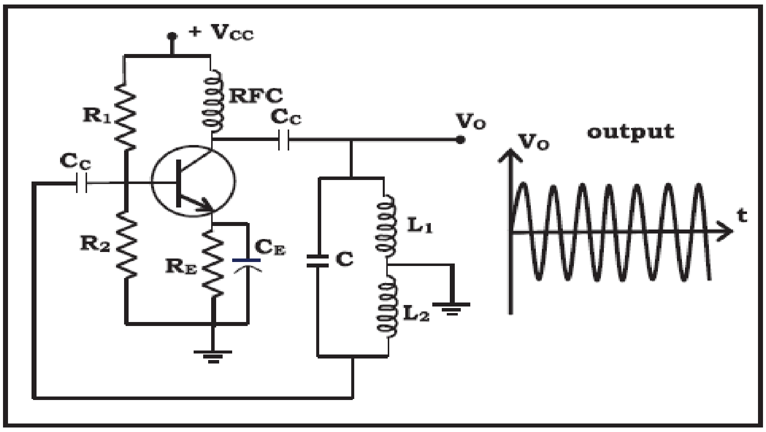
LC oscillators:

The oscillators which use the components L and C to produce oscillations are called LC oscillators. LC oscillator consists of an amplifier and LC tank circuit in the feedback network. According to the nature ofthe feedback process we have two important LC oscillator circuits. They are

- Hartleyoscillator (which uses inductive feedback)
- Colpitts oscillator (which uses capacitive feedback)

LC oscillators are widely used for generating high frequencies. These oscillators are used in RF generators, radio and TV receivers, high frequency heating, etc.

Hartley Oscillator:



The Figure shows the circuit of Hartley oscillator. It consists of a CE-amplifier, tank and feedback circuit. The resistor R1, R2, RE provides the necessary DC bias to the transistor. CE is the bypass capacitor. Cc is the coupling capacitor. RFC is the radio frequency choke, which isolates the DC power supply from the oscillations at the collector. L1, L2 and C forms the tank circuit.

Working:

- When the circuit is switched ON, the collector current charges the capacitor C.
- When the capacitor C is fully charged it discharges through inductors L1 and L2.
- This charging and discharging of the capacitor and inductor alternatively, generates sinusoidal oscillations.
- The oscillations across L1 and L2 are 180°out-of-phase with each other.
- The voltage across L1 is taken as the output voltage.

- The voltage across L2 is the feedback voltage and is fed to the base of CE-amplifier.
- 180^0 phase shift is provided by the amplifier and 180^0 phase shift is provided by the tank circuit. Hence the overall phase shift is 360^0.
- $A\beta = 1$ where $\beta = L2/L1$ and $A = L1/L2$. All Barkhausen's criteria is satisfied so the circuit produces stable oscillations of frequency given by

  $f = \frac{1}{2\pi\sqrt{LC}}$ where $L = L_1 + L_2$

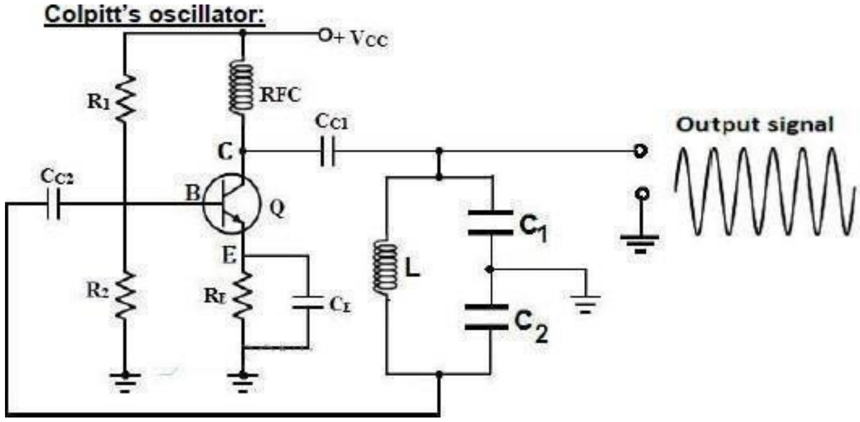
Advantages:

- Suitable for generating high frequency signals
- Easy to obtain a variable – frequency output
- Simple construction

Disadvantages:

- Poor frequency stability.
- Not suitable for generating low frequency signals
- Not possible to fabricate inside an IC.

Colpitt's oscillator:



The Figure shows the circuit of Colpitts oscillator. It consists of a CE-amplifier, tank and feedback circuit. The resistor R1,R2,RE provides the necessary DC bias to the transistor. CE is the bypass capacitor. Cc is the coupling capacitor. RFC is the radio frequency choke, which isolates the DC power supply from the oscillations at the collector. L and C1 and C2 forms the tank circuit.

Working:

- When the circuit is switched ON, the collector current charges the capacitors C1 and C2.
- When theyare fully charged, theystart discharge through the inductor L.
- This charging and discharging of the capacitors and inductor alternatively, generates sinusoidal oscillations.
- The oscillations across C1 and C2 are 180o out-of–phase with each other.
- The voltage across C2 is the feedback voltage and fed to the base of CE-amplifier and appears in the amplified form in the collector circuit with a phase – difference of 180o.
- This is fed to tank circuit to compensate for the energy losses occurring in it.

- If we make A β = 1 The circuit works as an oscillator and produces continuous undamped oscillations of frequency given by

  $f = \frac{1}{2\pi\sqrt{LC}}$ where $C_{eq} = \frac{C_1 C_2}{C_1+C_2}$

Advantages:

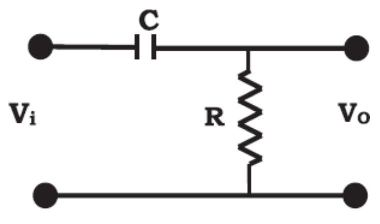
- Suitable for generating high frequency signal.
- The frequency of oscillations is varied bytuning C1 and C2.
- Simple construction
- Disadvantages:
- 1. Poor frequency stability and output waveform
- 2. Not suitable for generating low frequency signals
- 3. Not Possible to fabricate inside an IC

RC Oscillators:

LC oscillators are not suitable for generating frequencies less than 1MHz. To make audio frequency oscillators (< 20 KHz) if LC oscillators are used the LC values required will be too large. Hence, LC tuned circuit (Hartley and Colpitt's oscillators) is not used in audio frequency oscillators. For generating audio frequencies, resistors and capacitors (RC) can be used to provide the necessary phase- shift for positive feedback. Then, the frequencyof oscillation depends on the RC values. Two important types of RC oscillators are.

- RC-Phase shift oscillator
- Wien – bridge oscillator

Principle ofphase shift in RC circuit:



If an AC voltage V_i is applied to this network, then the voltage across R leads the applied voltage by an angle ϕ.

The value of ϕ depends upon the values of R and C. If R = 0, V_0 will lead V_i by 90° i.e. ϕ = 90°. If R = ∞, ϕ = 0°. Therefore, in practice, R is varied to such a value that makes V_0 to lead.

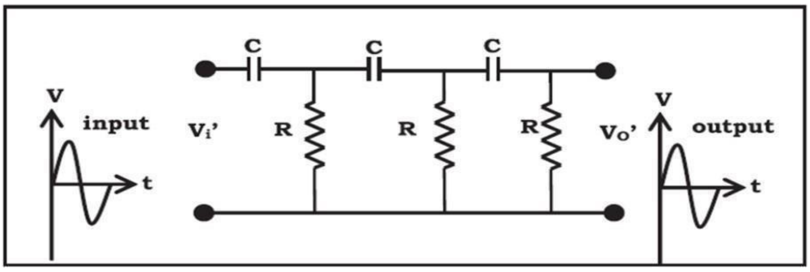


Figure shows the three section of RC network. Each section produces a phase shift of 60°. Consequently, a total phase shift of 180° is produces i.e. voltage V_0' leads the voltage V_i' by 180°.

RC-phase shift Oscillator:

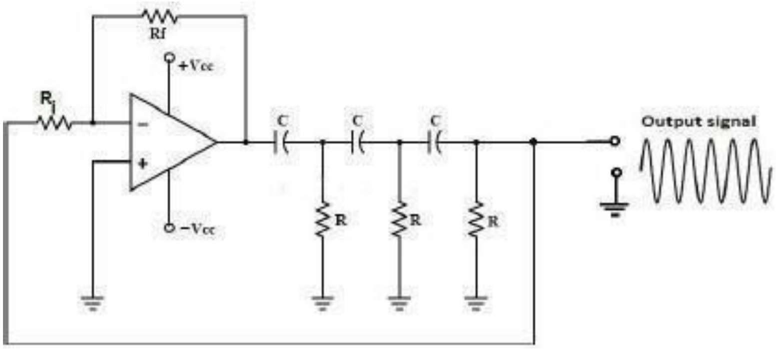


Figure shows a phase-shift oscillator using op-amp, which employs an op-amp as the amplifier and three RC cascaded networks as the feedback circuit.

- When the circuit is switched on, the only signal in the system are noise voltages. Noise voltage contains almost all sinusoidal frequencies of small amplitude.
- All these noise signals are amplified by the inverting op-amp with a phase-shift of 180^0 and appear at its output terminal.
- These amplified noise signals are then fed to three sections RC-network. At one particular frequency depending on the values of R and C each RC section produces a phase-shift of 60^0. As a result the total phase-shift of the feedback network is 60^0 x 3 = 180^0. So a total phase – shift of 360^0 is produced in the entire circuit.
- The other condition to be satisfied for oscillations to occur is that, the loop gain A β =1. To satisfy this condition it can be found that, the value of β should be,=1/29. Therefore the voltage gain of the op amp should be 29.
- Thus all Barkhausen's criteria is satisfied circuit produces continuous undamped oscillation of frequency given by

  $f = \frac{1}{2\pi\sqrt{6}\,RC}$ or $f = \frac{0.065}{\quad}$

- At this frequency, the gain ofan amplifier is $A = \frac{R_f}{R_i} = 29$
- Feedback fraction is $\beta = \frac{1}{29}$

Advantages:

- It does not require transformers or inductors, therefore less bulky.
- Cheap and simple circuit as it contains resistors and capacitors only.
- Suitable for generating low frequency signal (20Hz to 20 KHz)
- It gives pure sine wave output
- The circuit Provides good frequency stability

Disadvantages:

- The circuit is not suitable for generating high frequency signals.
- β = 29 and it is difficult for the circuit to start oscillations.
- It gives only small output dueto smaller feedback
- It is not suited to variable frequency applications.

Wien-Bridge Oscillator:

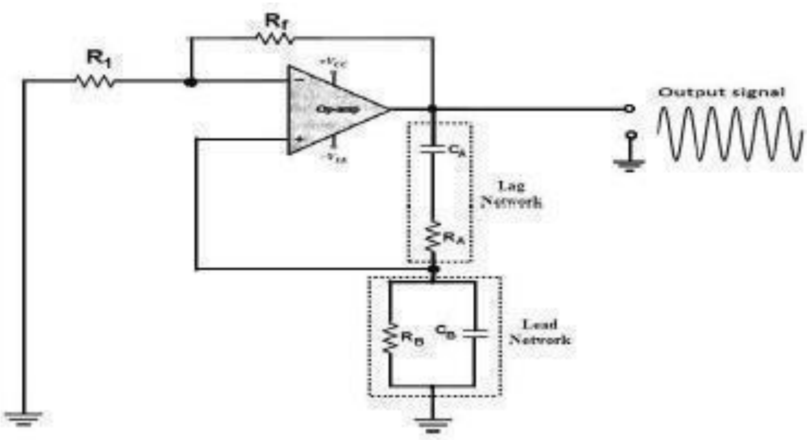


Fig shows the Wien – bridge oscillator using op-amp. It consists of op-amp which works as a non-inverting amplifier and Wien bridge feedback network.

Advantages:

- It gives constant output
- The circuit works quite easily
- Produces good sine wave output
- Provides good frequency stability
- It is a standard oscillator for generating low frequency range signal (i.e. 10Hz to 1MHz).

.

Does not require transformer or inductors, therefore less bulky.

When the circuit is switched on, the only signal in the system is noise voltage. Noise voltagecontains almost all sinusoidal frequencies of small amplitude.

- All these noise signals are amplified by the non inverting op-amp without any phase – shift and appears at its output terminal.
- These amplified noise signals are then fed to the wien bridge feedback network.
- The Wien – bridge network selects only one noise signal frequency at which the bridge is balanced and rejects all other noise signals without introducing any Phase – shift.
- The op-amp output is fed back to both inverting and non-inverting input terminal of the op-amp.
- Resistor Rf provides negative feedback to the amplifier. The purpose of this negativefeedback is to reduce amplitude distortion.
- When the bridge will be balanced and the negative feedback balances out the positivefeedback as result the circuit produces sustained oscillations provided the condition $A\beta=1$ is satisfied.
- To satisfy the condition $A\beta=1$ we have to maintain $\beta=1/3$ and the gain of the amplifier as 3. Barkhausen's criteriia is satisfied and sustained oscillations are produced.

Advantages:

- It gives constant output
- The circuit works quite easily
- Produces good sine wave output
- Provides good frequency stability
- It is a standard oscillator for generating low frequency range signal (i.e. 10Hz to 1MHz).
- . Does not require transformer or inductors, therefore less bulky. Cheap and simple as it contains resistors and capacitors only.

Disadvantages:

- The circuit is not suitable for generating high frequency signals.
- The circuit requires both positive and negative feedback.

Advantages ofwein bridge oscillator over phase-shift oscillators:

Wein – bridge oscillator gives more stable output signal than phase – shift oscillator.

Applications of RC oscillators:

RC oscillators are used in all commercial audio signal generators with a frequency range of 20Hz to 20KHz.

Advantages of RC oscillators over LC oscillators:

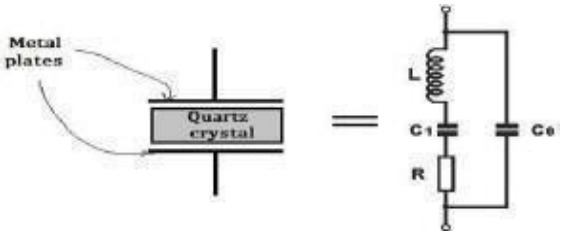
- RC oscillator Provides good frequency stabilityand wave form.
- RC oscillators are suitable for producing low and audio signal frequencies (i.e. 20Hz to 20 KHz)

Limitations of RC and LC oscillators

The LC and RC oscillators have problem of frequency in – stability. The most important reason for the frequency drift (freq change) is the change in values of resistance, capacitance and inductance when temperature changes. causing the circuit to oscillate at the frequency different from the desired frequency.

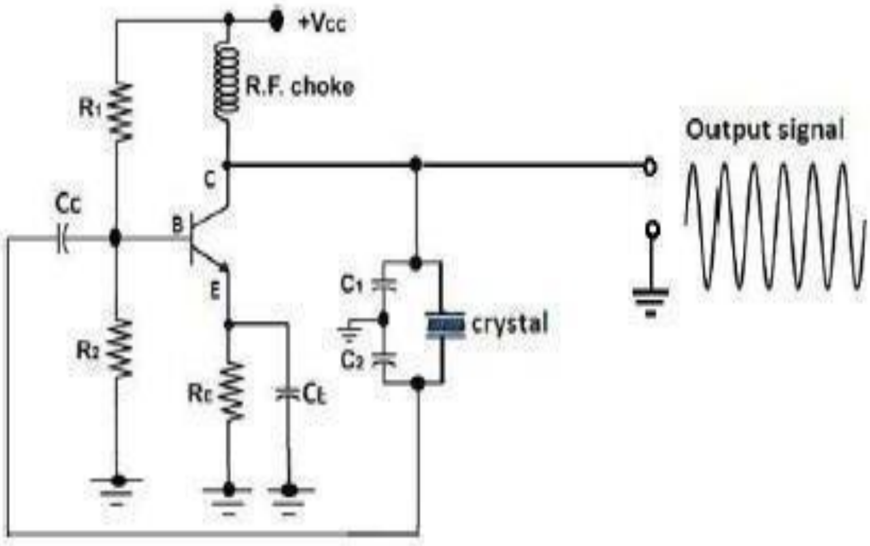
Principle of Crystal oscillator: (OR)Piezoelectric effect of the crystal:
When an a.c voltage is applied to a certain crystal, it starts vibrating at frequencyofthe applied voltage. Conversely, when these crystals are mechanically forced to vibrate, then an a. c voltage is developed across these crystals. These two properties associated with a crystal is known as piezo-electric effect.

Equivalent circuit of a crystal:



- The crystals which exhibit piezoelectric effect are known as piezoelectric crystals.
- The known piezoelectric materials are Rochelle salt, tourmaline and quartz.
- Rochelle salts have the greatest piezo-electric; for a given a.c voltage, they vibrate more than quartz and tourmaline. Mechanically, they are the weakest; they break easily.
- Rochelle salts have been used to make microphones, head sets and loudspeakers.
- Tourmaline shows the least piezo-electric effect; but is the strongest of the three. It is also most expensive. It is occasionally used at very high frequencies.
- Quartz is a compromise between Rochelle salts and tourmaline. Because it is inexpensive and readily available in nature, quartz is widely used for oscillators.
- The natural shape of a crystal is hexagonal prism. But for its practical use it is cut to a rectangular slab.
- This slab is then mounted between the two metal plates, called holding plates.
- The AC equivalent circuit of a crystal is shown in fig. A crystal when not vibrating is equivalent to a capacitor but the same crystalwhen vibrating under the influence ofan AC voltage, behaves like a tuned LCR circuit.

Crystal oscilltor:



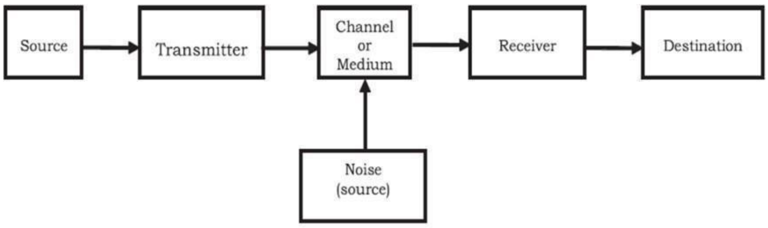
It is a colpitt's oscillator in which the inductor is replaced bythe crystal. As the frequency ofthe crystal oscillator depends on the crystal, which is independent of temperature etc., therefore thecircuit generates a constant frequency and is given f = K/t, Where K is a constant which depends upon the dimensions ofthe crystal, the cut (i.e. X -cut or Y-cut) and its mounting and t is its thickness.

Advantages of crystal oscillator over other types of oscillators:

- Crystal oscillator provides excellent frequency stability
- Crystal frequency is independent ofvoltage, temperature variations.
- Simple circuit as tuned circuit is absent.

Electronic communication system

The block diagram ofa basic communication system is given in figure.



Basic communication system

- Source: The source generates the message which is called information, intelligence, signal or data.
- Transmitter: transmitter is a circuit which processes the information and transmits effectively.
- Channel/medium: the information flows through it.
- Receiver: it receives the signal and processes the information to make it suitable for destination.
- Destination: the end user ofthe information.
- Noise: this is my unwanted electrical disturbance added to the message in the communication channel.

What does noise mean in terms of communication?

Noise is an unwanted signal which interferes with the original message signal and corrupts the parameters of the message signal. This alteration in the communication process, leads to the message getting altered. It is most likely to be entered at the channel

Noise is random in nature; it can be internal or external to a system. Noise can be minimized but cannot be eliminated. Noise can be measured in any system, using parameters like signal-to-noise ratio (SNR), noise figure(NF), noise temperature etc.

Signal-to-noise ratio (SNR): This is defined as the ratio of signal power to noise power at any point in a circuit. Thus,

$$SNR = \frac{Signal\ Power}{Noise\ Power}$$

SNR is ideally infinite and practically between 10-50dB

NOISE RATIO: Noise ratio is defined as the ratio of SNR at the input to the SNR at the out putof a system.

ST.CLARET PRE UNIVERSITY COLLEGE

$$NR = \frac{SNR\ at\ Input}{SNR\ at\ Output}$$

Noise ratio when expressed in decibel is called noise figure (NF

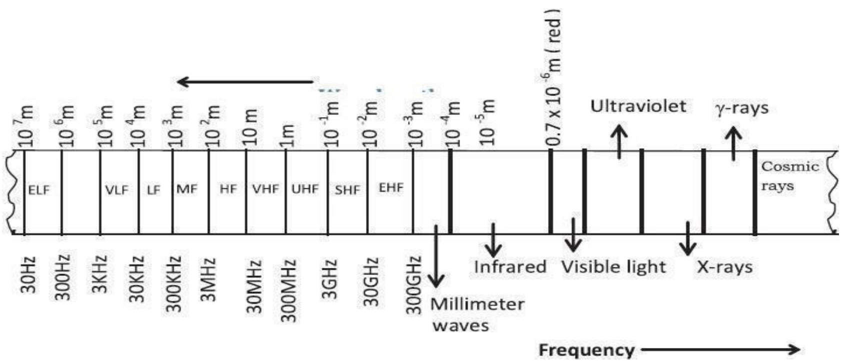
NF = 10 log_{10}(NR) dB

Ideally noise ratio should be 1, if the system is without any internal noise.

FREQUENCY OF RADIO WAVES:

Before it can be transmitted, the information must be converted into electrical signals computable with the medium. Such signals which radiate into space are called ELECTROMAGNETIC WAVES (e.m waves). They are also called RADIO FREQUENCY (RF) waves and can travel long distance in space.

PROPAGATION OF RADIO WAVES:

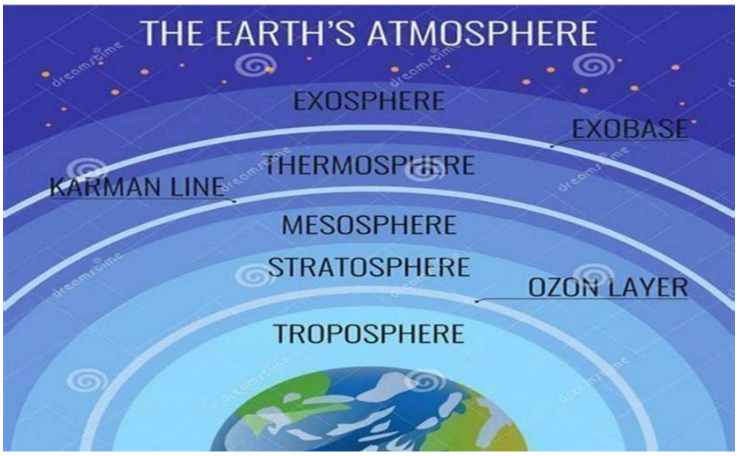


What is radio wave propagation?

Sky wave propagation is one of the radio wave propagation. It is defined as the behaviour of radio waves as they propagate from one point to another or into various parts of the atmosphere. Radio waves propagation can be Classified as follows:

- Ground waves propagation
- Sky wave propagation
- Free space propagation

Frequency	Name of the frequency band	Uses
3 – 30 KHz	Very Low Frequency (VLF)	Long distance point to point communication
30 KHz – 300 KHz	Low Frequency (LF)	Navigation services
300 KHz – 3 KHz	Medium Frequency (MF)	Radio broadcasting, ship to shore communication Police (walkie-talkie)
3MHz – 30 MHz	High Frequency (HF)	International broadcasting, telephone, aviation, all classes of communication
30 MHz – 300 MHz	High Frequency (HF)	RADAR, TV, FM broadcasting, short distance communication
300 MHz – 3 GHz	Ultra High Frequency (UHF)	TV, RADAR, aviation
3 GHz – 300 GHz	Super High Frequency (SHF)	RADAR, satellite communication
30 GHz – 300 GHz	Extreme High Frequency (EHF)	Special purpose communication (Experimental)



Troposphere: Troposphere is the immediate layer on the surface of the earth, which contains about 75% of the total gaseous mass of the atmosphere and practically all the moisture, dust particles and winds exist. This layer is up to an average altitude of 15 km and most of the ground wave and space wave communication occurs in this layer.

The radio waves can be propagates in three different parts

- Ground waves propagation
- Space waves propagation
- Sky waves propagation

Ground waves

- The radio waves transmitted along or reflected from the surface of the earth is called as ground waves
- Ground wave use earth as a transmission line
- These waves exists below the 2 MHz frequency range.
- The LF and MF use ground wave propagation
- They can travel from few 100's -1000's of kilometre
- The strength of these radio signals decreases as it travels over the earths surface, then the electric field is reduced to 0
- Conductivity of the earth surface increases with damping and wetness. Hence these waves are used in marine communication

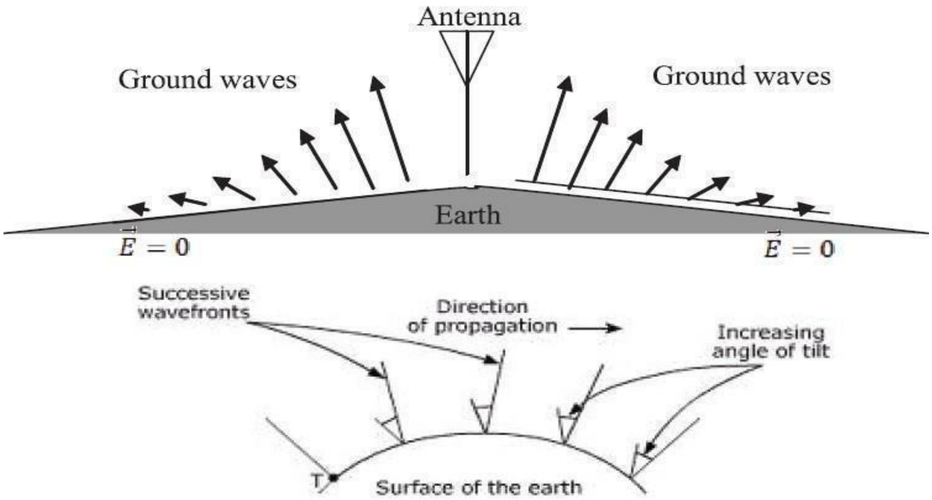
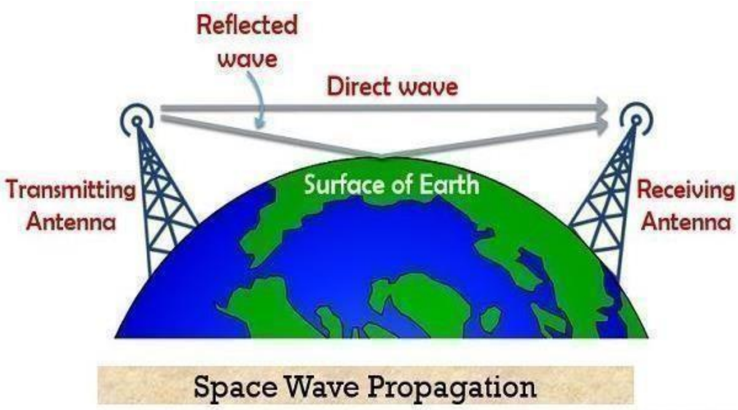


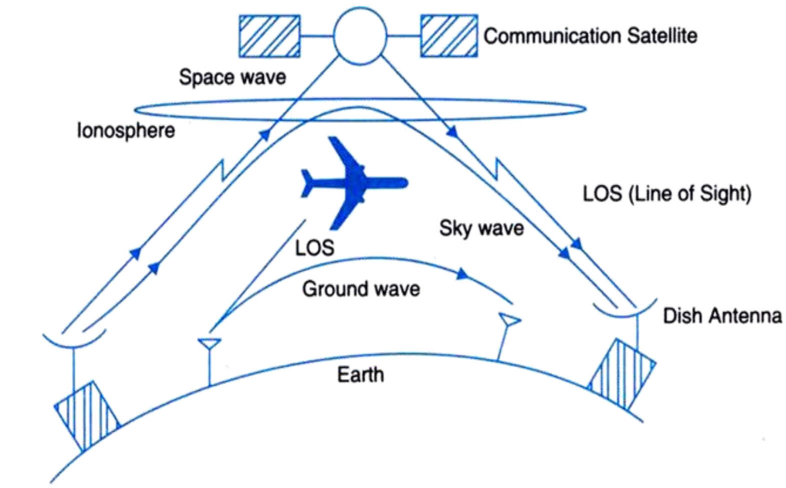
Figure7.3.Ground wave propagation

b. Space waves:

- Space wave propagation is the type of radio wave propagation in which the radio waves are propagated either directly from transmitting antenna to receiving antenna or bygetting reflected from the ground.
- Basically in space wave propagation, direct transmission of the signal is achieved by line of sight communication.
- The transmission of a signal between transmitter and receiver is achieved in the tropospheric region of the atmosphere. Thus space wave propagation is sometimes referred as tropospheric wave propagation.
- This type of radio wave propagation allows the transmission of signals having a very large range of frequencies. The space wave propagation occurs at about 20 km region in the atmospheric zone. Sometimes called the line of sight communication.



c. Sky wave: These are signals that are radiated by an antenna into the upper atmosphere, where it is refracted and/or reflected back to the earth. This bending of signal is caused by a region in the upper atmosphere called ionosphere.

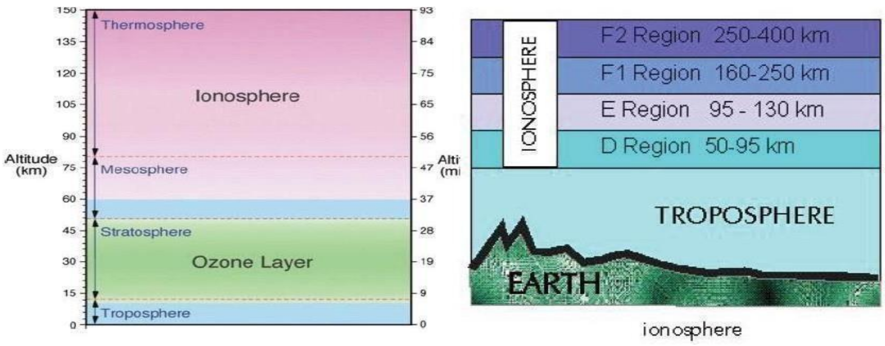


Ionosphere

Ultraviolet radiations from the sun cause the upper atmosphere to ionize, i.e. to become electrically charged. This result in a relatively thick but invisible layer called the Ionosphere extending in the altitudes approximately from 50kmto 400km. The ionosphere supports MF and HF wave propagation.

The ionosphere layer is generally considered to be divided into three basic layers, named as the D, E and F layers. The D and E layers are weakly ionized areas because they are far away from the sun. They exist only during the day time. The F layer is considered to be divided into two layers F_1 and F_2. They are highly ionized; they are far away from the earth and are most effective on the HF signals. The F layer is present both during the dayand night times. A time-altitude graphical

Ionosphere



ionosphere

(a) D layer

- It has an average thickness of 10 kmand extends to an attitude of about 70km.
- It disappears during the night time.
- It reflects VLF and LF waves an absorbs
- MF and HF waves.

(b) E layer

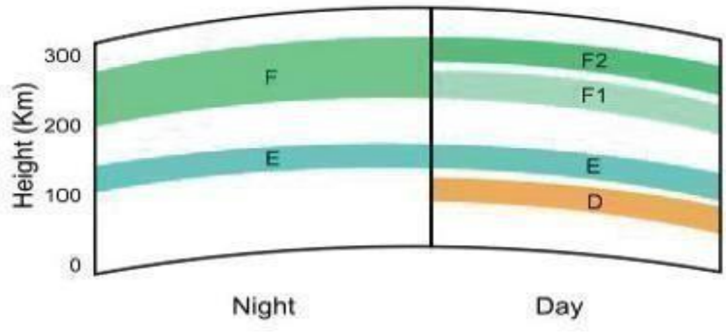
- With an average thickness of 25 km, it is present at an altitude ofabout 100 km.
- This layer considerably diminishes at night.

- It helps MF and partially HF wave propagation.

(c) F layer: The F layer begins from about 150 km an extends up to 400 km. The F layer remains during both day and night time. During day time, it splits into two layers F_1 and F_2, and combines to forma single F layer during night time.

F_1 layer:

- It is located at an average altitude of 200 km. It is also called Kennely-Heaviside layer.
- Its approximately thickness is about 200 km.
- It partially reflects HF waves.

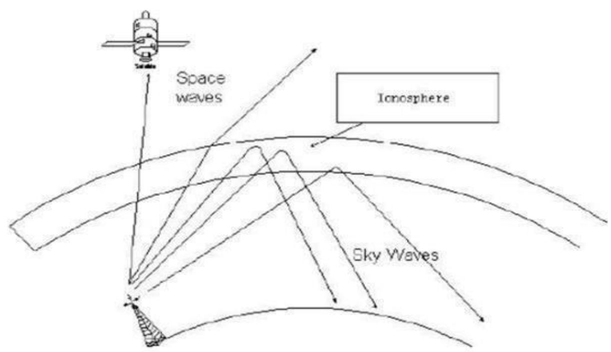


F_2 layer:

- It is located at an average altitude of 300 to 400 km. It is also called Appleton layer.
- The average thickness is around 200 km.
- It is the most useful layer in HF wave propagation.
- The F_2 layer changes its altitude seasonally (according to the revolution of the earth).

SKY WAVE PROPAGATION:

As mentioned earlier, sky wave propagation makes use of the ionosphere to refract and reflect the radio waves for transmission. The ionospheric propagation is represented in the figure.



a Sky wave propagation

Both reflection and refractions occur whenever radio waves enter the ionosphere. The amount of reflection of refraction depends on the ionospheric charge density and the frequency and angle of incidence of the radio wave.

A few important terms used in the ionospheric propagation are described below.

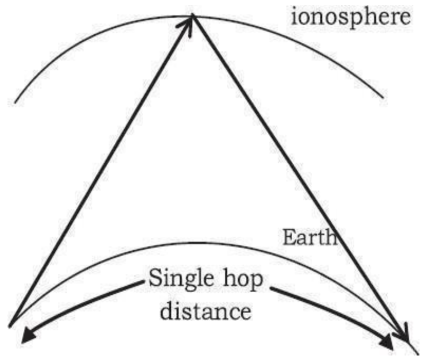
Critical frequency (f_c):

Critical frequency is the highest magnitude of frequency above which the waves penetrate the ionosphere and below which the waves are reflected back from the ionosphere. It is denoted by"fc".

Critical angle (θ_c):

The minimum angle of incidence at which a radio wave of a particular frequency can strike the ionosphere and still be reflected back to the earth.

- **Skip distance (Δ)**: It is the shortest or minimum distance measured between the transmitting antenna and the first receiving antenna measured along the surface ofthe Earth
- **Skip zone or silent zone (δ):** It is the region around the receiving antenna, within the skip distance, where neither the ground wave not skywave is present
- **Single hop distance:** The single hop distance is the maximum distance between transmitting antenna to first receiving antenna measured along the surface of the Earth after ionospheric propagation



- **Multiple hop transmission:** This technique uses repeater stations, to reflect the received ionospheric signals and again transmit them, thus making multiple hops. It is used extensivelyin long distance communication.

Fading: It refers to the fluctuations in the strength of a radio signal. Fading occurs during propagation of waves, which may be due absorption in the layers of atmosphere, loss during refraction, loss due to scattering of signals etc.

Chapter 8 **MODULATION AND DEMODULATION**

Communication svstem using modulation:

Modulation is a process of mixing low frequency signal with high frequency signal. Fig (1) shows how amplitude modulated wave is generated by mixing low frequency modulating and high frequency carrier signal.

The low frequency signal is referred to as the modulating signal (baseband signal) and the high frequency signal is known as the carrier. The resultant signal obtained is called as modulated signal. After modulation, the carrier signal will carry the modulating signal to the destination, however long distance it may be.

Need for modulation:

The various factors responsible for the need of modulation are:

Practical antenna height

Operating range

.Wireless communication

Avoids mixing of signal

Improves quality of reception etc.

Multiplexing

Practical antenna length:

For proper transmission and reception of radio waves the length of the antenna must be atleast one fourth (one quarter) of wavelength of the frequency ofthe transmitted signal.

If I is the height ofantenna, X is the wave length ofthe signal, f is the frequency ofthe signal,and c is the velocity of EM waves 3xl08m/sec

Then the required height of the antenna, according to the rule is:$L = \frac{\lambda}{4}$

Where= $\frac{c}{f}$

So, $l = \frac{c}{4f}$

For 20KHz, $l = \frac{3\times10^{8}}{4\times20\times10^{3}} = 3750m$

and for 1MHz, $l = \frac{3\times10^{8}}{4\times10^{6}} = 75m$

if a carrier of 1 MHz is used to carry the signal, the length of the antenna is only 75 mts, which is quite possible. Thus modulation reduces height of the antenna.

1. operating range:
The energy of any wave dependson itsfrequency. The greater is the frequency of the wave, the greater is the energy possessed by it. Audio signal [20Hz to 20KHz] being low in frequency cannotbe transmitted over large distances, if radiated directly into space. Hence, to cover longer distances, these waves are modulated with high frequency signals (carrier signal).

2. Avoids mixing of signals:
If the signal frequencies (20Hz to 20 KHz) are transmitted directly, all signals from differenttransmitter get mixed together and the receiver cannot separate them from each other. By modulation different messages having different frequencies level can be transmitted simultaneous without any interference. Thus modulation avoids mixing of signals.

3. lmproves duality of reception:
With FM and digital communication techniques like PCM, the effect of noise is reduced to a great extent. This improves quality of reception.

4. Wireless communication:
Transmission is carried without wires and this is a desirable advantage of modulation.

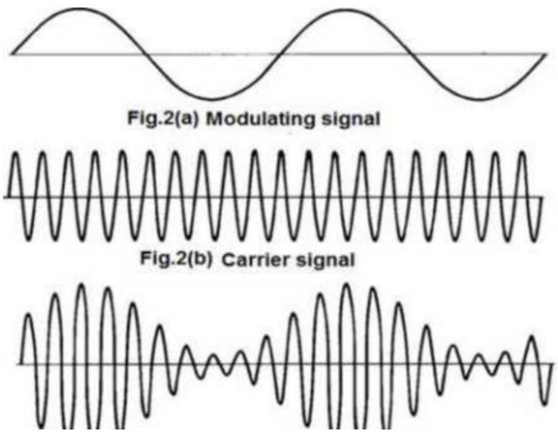
5. Multiplexing:
Multiplexing is technique that allows the simultaneous transmission ofmany baseband signals over a same communication channel.

types of modulation:
Taccordance with the modulating signals giving rise to three types of sine wave modulations they are:

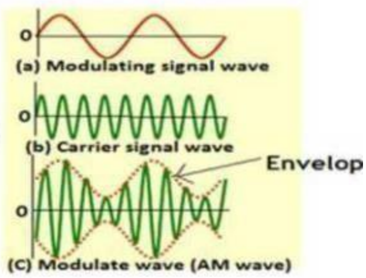
- Amplitude Modulation (AM)
- .Frequency Modulation (FM)
- .Phase Modulation (PM)

Amplitude Modulation (AM):

Amplitude modulation is the process of varying the amplitude of carrier wave in accordance with the instantaneous value of the modulating wave.



(OR)



Modulation Index (or) Depth of modulation in AM:

The modulation index in an AM is defined as the ratio of peak value of the modulating signal to the peak value of the carrier signal.

The modulation index is designated as m_a, where 'a' signifies amplitude modulation. This means Modulation Index = Peak value of modulating signal / peak valueof carrier sigal

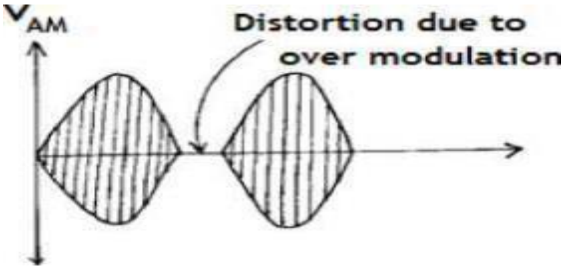
It should be a number between 0 and 1

Percentage modulation (%m_a):

When the modulation index is expressed as percentage, it is called as "Percentage modulation". The percentage modulation is expressed as:

$\% m_a = m_a \times 100\%$

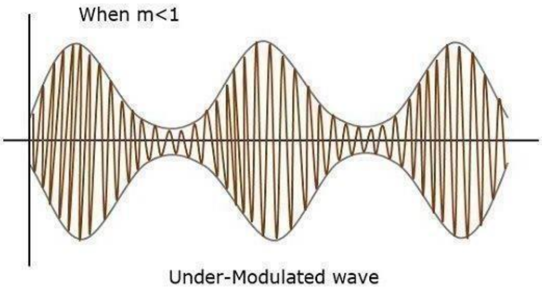
Over modulation: When modulation index ma> 1. The modulation type is known as over modulation.



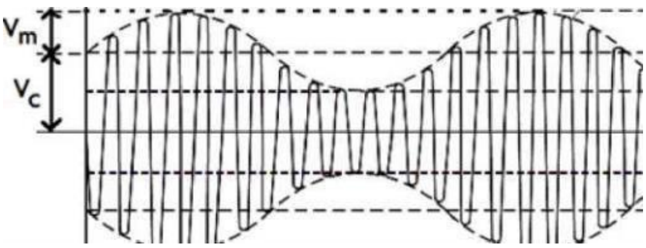
Over modulation results in distortion and also loss of information in the AM wave. Therefore over modulation should be avoided.

Undermodulation:

When modulation index ma<l, the modulation type is known as under modulation. The ma< 1, when the Vm< Vc.



Modulation Index interms of maximum and minimum voltage of AM wave:



in order to calculate modulation index "m_a" which is

$$m_a = \frac{V_m}{V_c}$$

we must express V_m and V_c in terms of V_{max} and V_{min} Referring to fig, we can write $V_{max} = V_c + V_m$ (2)
$V_{min} = V_c - V_m$ (3)

Now eq(2)+eq(3) = $V_{max} + V_{min} = 2V_c$

Similarly eq(2)-eq(3) = $V_{max} - V_{min} = 2V_m$

Substituting in the equation for m_a, we get

$$m_a = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

voltage equation of an AM wave:

The modulating signal can be represented as:

$v_m = V_m \sin\omega_m t$ (1)

And the carrier signal can be represented as:

$v_c = V_c \sin \omega_c t$ (2)

During the process of AM, peak amplitude V_c of the carrier signal is varied in proportional to the instantaneous amplitude ofthe modulating signal v_m.

Amplitude of AM wave= peak amplitude of carrier + instantaneous amplitude of modulating signal

$A = V_c + v_m$

$A = V_c + V_m \sin \omega_m t$

$A = V_c (1+V_m / V_c \sin \omega_m t)$

$A = V_c (1+m_a \sin \omega_m t)$

In AM, the frequency of the carrier wave is unaltered. Therefore, the instantaneous voltage equation ofthe AM wave can be written as:

$V_{am} = A.\sin\omega_c t$

$V_{am} = V_c (1+m_a \sin\omega_m t) .\sin\omega_c t$

$V_{am} = V_c \sin\omega_c t + m_a V_c \sin\omega_m t \sin\omega_c t$

$V_{am} = V c \sin\omega_c t + m_a V_c /2 [\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t]$

$V_{am} = V_c \sin\omega_c t + m_a V_c /2 \cos(\omega_c - \omega_m)t - m_a V_c /2 \cos(\omega_c + \omega_m)t$

$\mathbf{V_{am} = V_c \sin 2\Pi f_c t + m_a V_c /2 \cos(f_c - f_m) 2\Pi t - m_a V_c /2 \cos(f_c + f_m) 2\Pi t}$

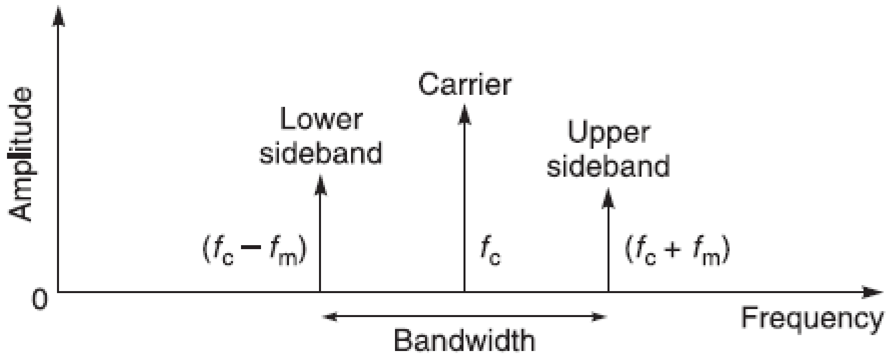
This is the expression for instantaneous value ofan AM wave

Observations:

- first term $V_c \sin 2n f_c t$ is the original carrier signal itself in its unmoldulated form.
- the second term having amplitude $\mathbf{m_a V_c /2}$ **a**nd frequency ($f_c - f_m$) is called ower side band (LSB) signal.
- The third term having amplitude $\mathbf{m_a V_c /2}$ and frequency (fc + fm) is called upper side band (USB) signal
- The unmodulated carrier (first terms) does not contain any information, as it is totally predictable.
- The information is carried only by the two side bands, LSB and USB

Frequency spectrum and Bandwidth of an AM wave:

The amplitude versus frequency plot of the signal is called the frequency spectrum of the signal Fig (5) shows the frequency spectrum of an AM signal.



Bandwidth (BW) of an AM wave:

The total frequency range occupied by the AM wave is known as its bandwidth. In AM wave, the bandwidth is from(fc-fm) to (fc+fm) as shown in fig .Bandwidth = fUSB- fLSB

$BW = (f_c + f_m) - (f_c - f_m)$

$\mathbf{BW = 2f_m}$

Thus in AM, Bandwidth is twice the modulating signal frequency

Power relations in AM wave:

The total power developed by an AM wave across the antenna resistance R is

$P_t = P_c + P_{lsb} + P_{usb}$ (1)

$$= \frac{V_C^2}{R} + \frac{V^2_{USB}}{R} + \frac{V^2_{LSB}}{R}$$

Where $V_{LSB} = V_{USB} = \frac{m_a V_C}{2}$

R is the resistance of antenna.

$$P_C = \frac{V^2 rms}{R} = \frac{(\frac{V_C}{\sqrt{2}})^2}{R} = \frac{V_C^2}{2R}.$$

$$P_{USB} = P_{LSB} = \frac{V^2}{R} = \frac{\left(\frac{\frac{m_a V_C}{2}}{\sqrt{2}}\right)^2}{R}$$

$$= \frac{ma^2 V_C^2}{8R}$$

$$\therefore P_T = P_C + P_{LSB} + P_{USB}$$

$$= \frac{V_C^2}{2R} + \frac{m_a^2 V_C^2}{8R} + \frac{m_a^2 V_C^2}{8R}$$

$$= \frac{V_C^2}{2R} + \frac{m_a^2 V_C^2}{4R}$$

$$P_T = \frac{V_C^2}{2R}[1 + \frac{m_a^2}{2}]$$

$$\therefore P_T = P_C[1 + \frac{m_a^2}{2}].$$

$$P_T = P_C[1 + \frac{m_a^2}{2}]$$

$$I_T^2 R = I_C^2 R[1 + \frac{m_a^2}{2}]$$

$$I_T^2 = I_C^2[1 + \frac{m_a^2}{2}]$$

$$I_T = \sqrt{I_C^2[1 + \frac{m_a^2}{2}]}$$

$$I_T = I_C\sqrt{[1 + \frac{m_a^2}{2}]}$$

Power dissipated in a load in terms of currents:

$P_t = P_c(1+\frac{m_a^2}{2})$ 1

Where,

P_t = total or modulated power

P_c = carrier or unmodulated power

m_a = modulation index

From equation (1), we may write

$$\frac{P_t}{P_c} = 1+\frac{m_a^2}{2}$$

or,

$$\frac{I_t^2 . R}{I_c^2 . R} = 1+\frac{m_a^2}{2}$$

ST.CLARET PRE UNIVERSITY COLLEGE

Power in side bands:

$$P_{SB} = \frac{m_a^2 p_c}{2}$$

Transmission efficiency

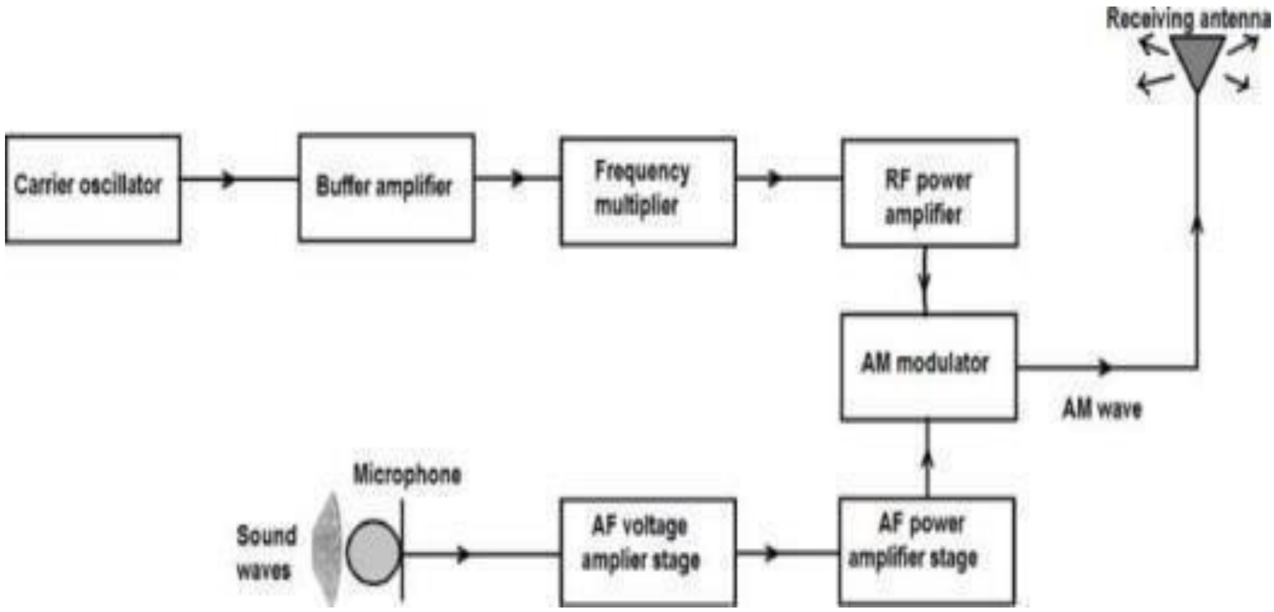
Transmission efficiency of an AM wave is the ratio of the transmitted power which contains the information (i.e. the total side band power) to the total transmitted power of an AM wave. It indicates the percentage oftotaltransmitting power that is converted to useful power.

$$\%\eta = \frac{m_a^2}{2+m_a^2} \times 100\%$$

Equation reveals that the transmission efficiency of an AM transmitter depends on the value of the modulation index ma. It also reveals that the efficiency is proportional to ma. The maximum possible value of ma is 1 at 100-percent modulation. Therefore, the transmission efficiency of the transmitter will be maximum at 100-percent modulation. It proportionally reduces as the value of ma decrease

Transmitters:

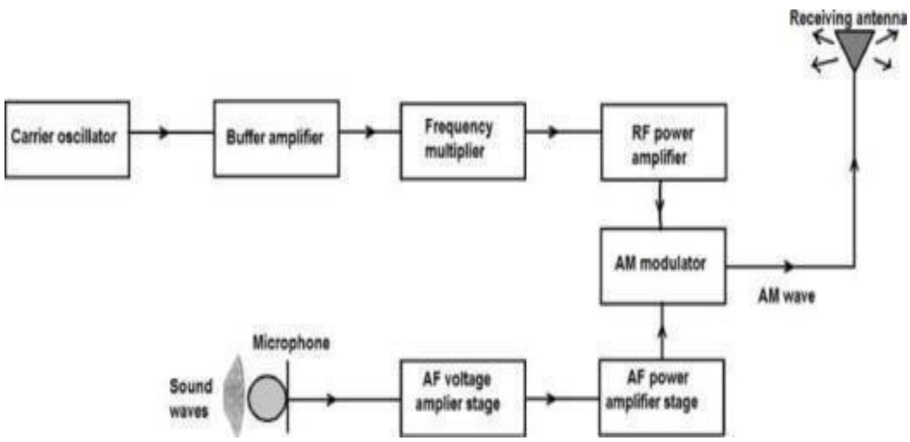
Transmitter is a collection of electronic circuits designed to convert the information from information



source into equivalent electrical signals and make it suitable for transmission.

Block diagram of AM radio Transmitter

An AM transmitter can be divided into two main sections:



- .Audi frequency (AF) section
- .Radio frequency (RF) section

1. AF Section:

The block diagram is divided into two sections . the AF section is explained below

The main blocks of AF section and their function are given as follows:

- Microphone : lt is a transducer which converts sound waves into equivalent electrical signal (modulating or AF signal)
- AF voltage amplifier stage :This stage amplifies the voltage level of AF signal to a desired level.
- AF power amplifier stage:This stage amplifies the power of the AF signal to a desired level. The output of this section is fed to the modulator.

2. RF section:

The main blocks of RF section and their function are given as follows:

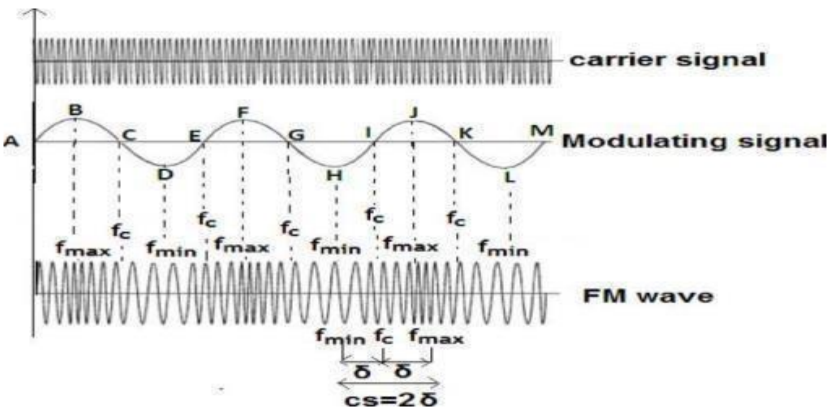
- Carrier oscillator :The carrier oscillator generates the high frequency carrier signal.
- Buffer amplifier:The buffer amplifier matches the output impedance of the carrier oscillator with the input impedance ofthe frequency multiplier
- Frequency multiplier:its main function is to increase (multiply) the frequency of the carrier signal generated bythe carrier oscillator to a desired level.
- Power amplifier:This stage amplifies the power level ofthe carrier signal to a desired level.
- Modulated class C power amplifier(modulator):This is the output stage ofthe AM transmitter.
- Transmitting antenna radiates the AM signal into space for transmission.

Limitations of AM:

- .Noisy reception
- .Poor transmission efficiency
- Poor operating range
- .Poor signal quality

Frequency modulation (FM):

It is a modulation system in which the frequency ofthe carrier wave is varied in accordance with the variations in the amplitude of the modulating signal.



Advantages of FM:

- .Noiseless reception
- Better audio quality(i.e. high fidelity Hi-Fi)
- .High transmission efficiency
- Operating range is quite high

Disadvantages:

- .Smaller area ofreception
- Costly equipments are required
- .Much wide channel is required.

Definition of some important FM terms:

Centre frequency (or) Resting frequency (fr)

It is the frequency of the FM wave when amplitude ofthe modulating signal is zero.

.Frequencv deviation (δ):

The maximum change in frequency either above or below the resting (centre) frequency in FM is called frequency deviation.

Carrier swing (C.S)or frequency swing:

The total variation in frequency from the minimum to the maximum in FM signal is called the carrier swing

Modulation Index

The modulation index of an FM wave is defined as the ratio of the frequency deviation to the frequency of the modulating signal.

$$\text{Modulation Index} = \frac{\text{frequency deviation}}{\text{Modulating signal frequency}}$$

the modulation index (m_f) can be greater than 1 and there is no theoretical limit for it.

Percent modulation (%m_f)

Percent modulation with reference to FM is defined as the ratio of the actual frequency deviation occurred to the maximum frequency deviation allowed for the system.

$$\text{Percent - modulation} = \frac{\text{ual freqyency deviation}}{\text{maximum permitted frequency deviation}}$$

For FM broadcast band (88 to 108MHz) max frequency deviation is fixed and its value is±75KHz .

.

Deviation ratio:

It is defined as the ratio of maximum frequency deviation allowed to the maximum modulating signal frequency allowed for the system

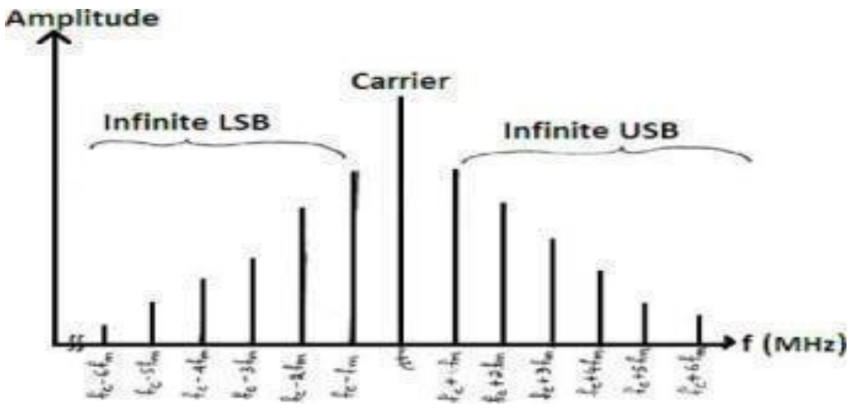
Deviation ratio:

It is defined as the ratio of maximum frequency deviation allowed to the maximum modulating signal frequency allowed for the system.

$$\text{Deviation ratio} = \frac{\text{maximum frequency deviation allowed}}{\text{maximum modulating signal fi'equency allowed}}$$

Where, $m_f = KV_m/\omega_m = KV_m/2\Pi f_m = \delta/f_m$ is known as the modulation index

Frequency spectrum of FM signal:



The following points are observed from this frequency spectrum:

- .FM has a carrier and an infinite (unlimited) number of side bands (both LSB and USB) separated from each other by fm-
- Though theoretically, the number of sidebands are infinite, the strength (amplitude) of higher side bands becomes increasingly so weak that beyond a certain number the higher sidebands may be omitted (neglected) without damaging the quality ofthe transmitted signal.
- .In FM the sideband frequencies are:

1st sideband = f_c+f_m

2nd sideband = $f_{c+} 2f_m$

3rd sideband = $f_c + 3f_m$ and so on

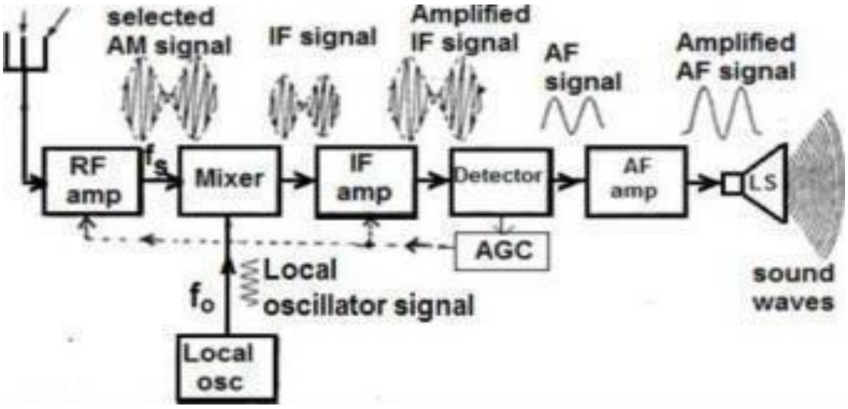
Where f_c is the carrier frequency

f_m is the modulating signal frequency

Bandwidth of an FM:

Theoretically the bandwidth of the FM wave is infinite. But practically it is calculated based on how many number of significant sideband pairs.

AM super heterodyne receiver (SHD radio receiver):



The function of each stage is as follows:

- Receiving antenna: Its function is to receive the signals fromdifferent broadcasting stations.
- RF amplifier: It selects the desired AM station signal and amplifies the selected AM station signal to a desired level.
- Local oscillator : It generates high frequency signal whose frequency is always(fs + 455 kHz).
- Mixer:This circuit produces IF = 455 KHz by mixing fs and f0 signals.
- IF amplifier: It amplifies IF signal to a desired level.
- Detector:It recovers the modulating signal (AF signal) from the IF signal by rectification and filtering action.
- AF amplifier: It amplifies the AF signal to a desired level.
- AGC : lt controls the gains of RF amplifier and IF amplifier to maintain a constant output voltage level even when selected station signal strength varies considerable amount.
- 10 .Loud speaker: It converts amplified AF signals into corresponding sound waves.

Comparison of AM with FM:

Amplitude Modulation (AM)	Frequency Modulation (FM)
1. Amplitude of AM wave will change with the modulating voltage	Amplitude of FM wave is constant.
2. Modulation index should not exceed 1.	There is no restriction on the value of the modulation index.
3.Noise level is high	Noise level is low
4.Bandwidth much less than FM	Bandwidth is larger than AM
5. AM has only 2 side bands	FM has unlimited number (oo) of sidebands.
6. Adjacent channel interference is more.	Adjacent channel interference is hardly present
7. carrier power and one sideband power are useless (most of the transmitted power is not useful)	All the transmitted power is useful

CHAPTER 9 POWER ELECTRONICS AND APPLICATIONS

Power electronics:

It is the branch of electronics which deals with the control and conversion of large amounts of electrical power (AC or DC) with high efficiency using power semiconductor devices

(OR)

The studyof semiconductor power devices and their applications is referred to as power electronics

Important power semiconductor devices:

The important power semiconductor devices are:

- Power Diode
- Power BJT
- Power MOSFET
- Thyristor (SCR)
- .diac
- Triac
- IGBT

Types of power converters:

With the help of power semiconductor devices, power converters have been developed that have the ability to control efficiently the output parameters such as voltage, current and frequency. There are many types of power converters. They can be classified based on the type of power conversion. The classification is shown in table below:

PowerDiode:

Power diode is a two terminal PN Junction diode which has p^+, n', n^+ layer

Constructional details of power diode (Basic structure of power diode):

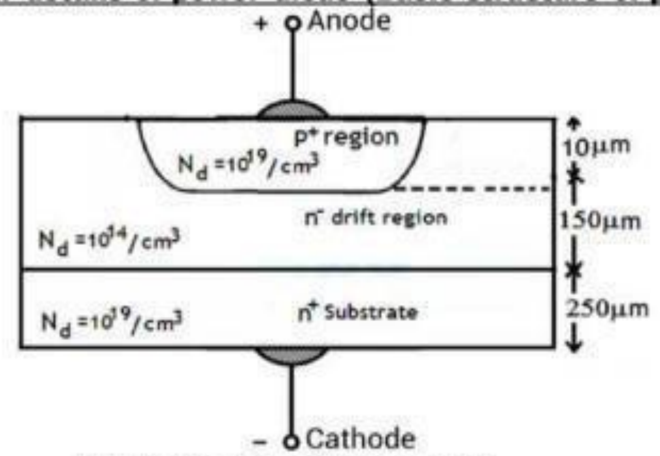


Fig.2 structure of power diode

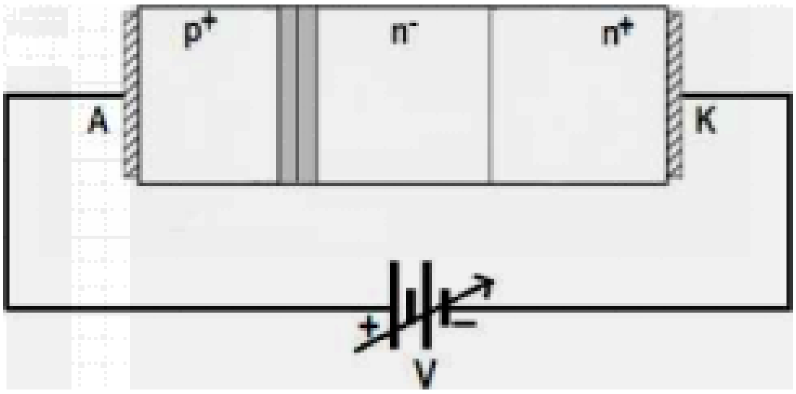
The structure of the power diode is little different than the small signal diodes. Fig. shows the structure of power diode. there is a heavily doped n+ substrate . This substrate forms a cathode of the diode. Onn+ substrate a lightly doped n^- epitaxial layer (this layer is also

Power diode under different forward bias condition:

At forward biased condition:

When the positive terminal of the battery is connected to anode (A) and negative terminal isconnected to cathode (K) of the power diode the diode is said to be forward biased. At low forward bias condition there will be injection of excess p-type carrier from p+ side into the n side. At lowlevel of injection all excess p-type carriers recombine with n- type carriers in the n drift region.

At higher forward bias the holes from p+ region reaches the n n+ junction and attracts electrons from the n+ region. This leads to electron injection into the n drift region from n+ region. As a result, electrons density is equal to holes density across the drift region. This mechanism is called **"double injection".**



Voltage drop of a forward bias power diode:

The voltage drop across a forward biased power diode has two components i.e.

$VAK=V_j+ V_{RD}$ .... (1)

Where Vj is the drop across the p+ n junction.V_{RD} is due to Ohmic drop in the

drift region

non-punch through and punch through power diode:

In power diodes if the depletion layer width is less than the width of the drift layer and doesn't reach the end of the drift layer, such a condition is called non punch through and the diode is called as non- punch through diode.

In non-punch through diodes the electric field is maximum at the P^+ n^- junction and decreases to zero at the end of the depletion region

In power diodes if the width of the depletion layer is almost equal to the width of the drift layer and it makes contact with the n^- region, such a condition is called punch through and the diode is called as punch through diode.

In the punch through construction the electric field strength is more uniform.

V-l Characteristics of power diode:

The V-l characteristics of power diode are shown In fig. In the forward biased condition, anode current increases linearly with voltage. A forward bias of 1V is sufficient to trigger diode into conduction.

When the diode is reverse biased, a very small anode current flows. This current is called leakage current. When the reverse bias is greater than reverse breakdown voltage, anode current starts rising rapidly. Hence, large power dissipation takes place in the diode and it Is damaged.

V-l characteristics of power diode can be expressed by Shockley diode equation as I=Is

$[e^{(qv/KT)} - 1]$

Where

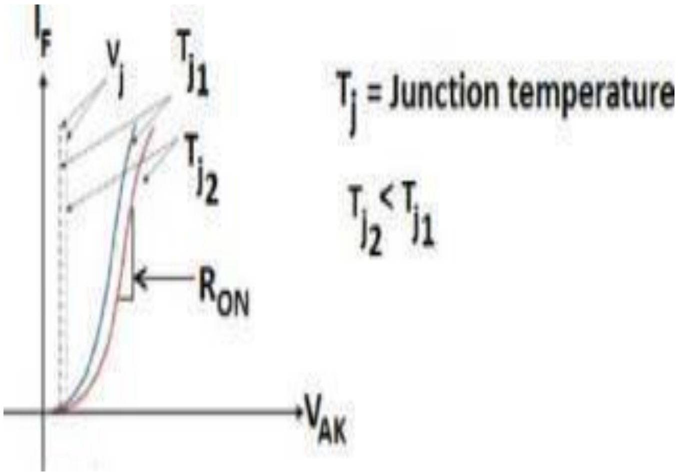
Is is reverse saturation current in amps

q is the charge on an electron

K is Boltzmann's constant which is equal to $1,381 x lO^{-23}$ J/K

T is temperature in Kelvin

V-l characteristics of power diode under forward biased condition for two different temperature is shown blow



Power Diode Applications:

As a rectifier Diode

For Voltage Clamping

For voltage clipping

Power BJT:

A BJT fabricated with high voltage and high current rating are called power transistor. The circuit symbol of power transistor is as shown in fig. below.

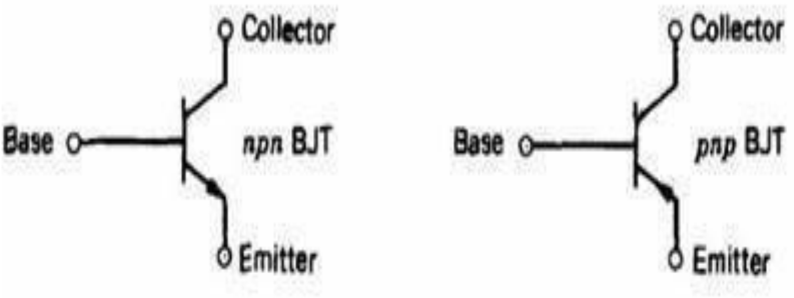
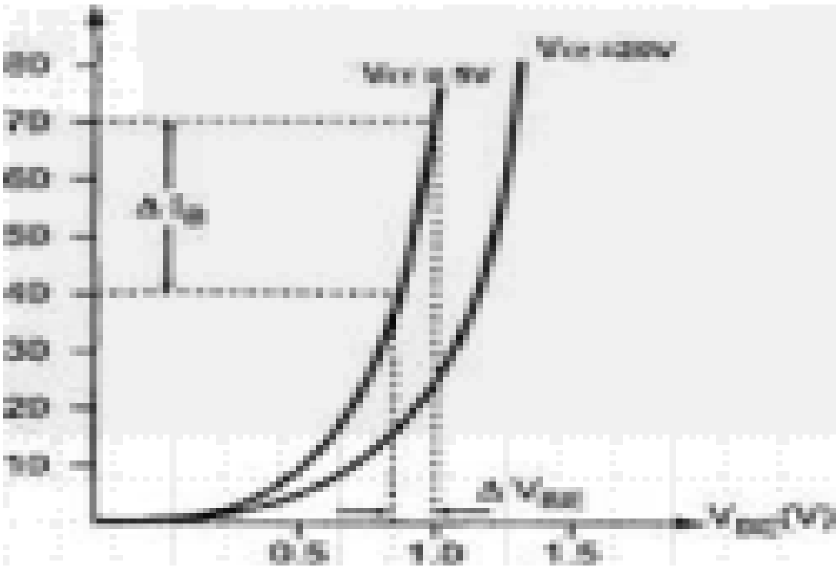


Figure 5.17 Symbol of power BJT

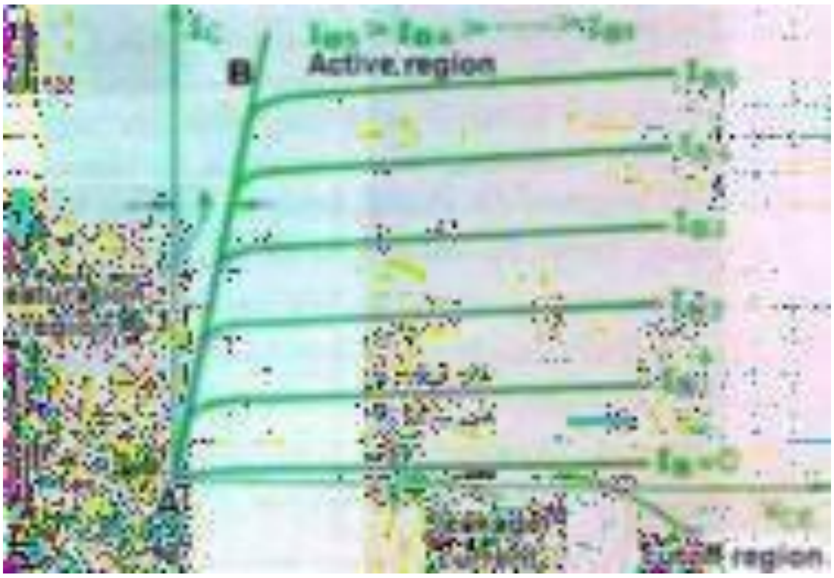
A Power BJT has a four layer structure of alternating P and N type doping as shown in fig. . In the structure there is a heavily doped emitter region having thickness of about 10pm. The base has moderate doping The thickness of the base can vary from 5 to 20pm. The collector is split into two regions as shown in fig. . These two regions are n - region having thickness of 50 to 200pm. The thickness of n - drift region determines the breakdown voltage capability of the power transistor. The n+ region has high doping intensity. It's doping is similar to that of emitter but having thickness of 250pm. The n+ region serves as collector contact for external circuits.

It is a graph that shows the variation of the base current with the base-emitter voltage, for constant collector to emitter voltage



Output characteristics:

it is a graph that shows the variation of the collector current (Ic) with the collectoremitter voltage (Vce), keeping the base current (Ib) constant.



Thyristor (SCR)

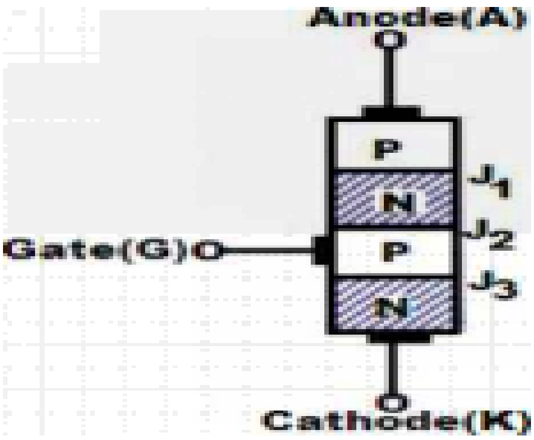
Thyristor is also called as SCR. SCR stands for Silicon Controlled Rectifier. Thyristor (SCR) is a three terminal, three junction power semiconductor device made of four alternative layers of p-type and n-type silicon.

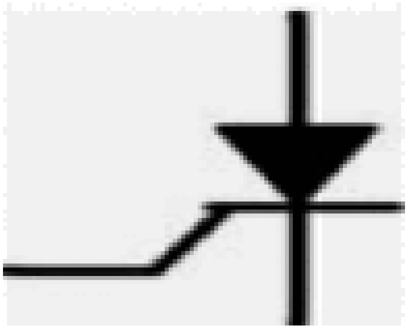
(OR)

It is three terminal, three junctions, four layered, unidirectional, and current controlled power semiconductor

Basic Structure:

Structure and symbol is as shown in figure The three junction of SCR are labeled as Ji, J2 and J3. The device has three terminals labeled as Anode (A), Cathode (K) and Gate (G). The anode and cathode are power terminals and gate is the control terminal. The control signal is applied between the gate and cathode terminal.



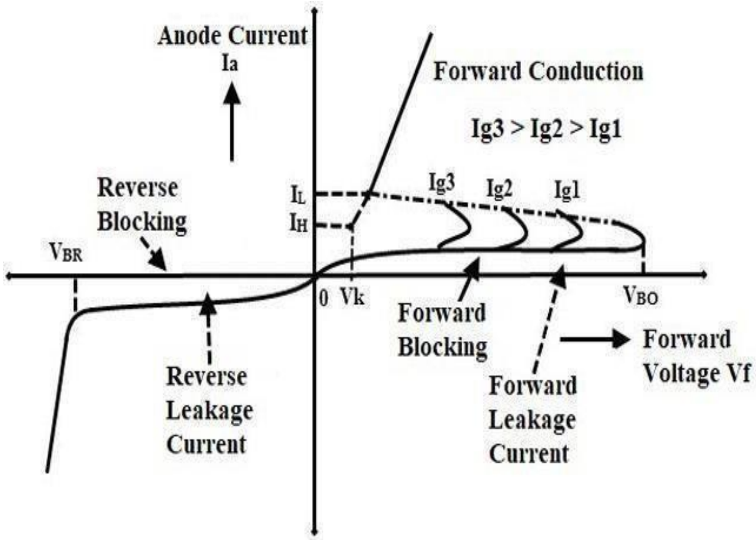


V-l characteristics of SCR:

It is a graph of anode current (I_A) versus anode-to-cathode voltage (V_{Ak}) of SCR for different fixed values of gate current (I_g)

fig. shows the V-l characteristics of SCR. The SCR characteristics can be divided into four regions of operation:

- Forward blocking state (OFF state)
- Forward conducting state (ON state)
- Transition state (unstable state)
- .Reverse blocking mode (OFF state)



Fromthe above graph the following points are obtained.

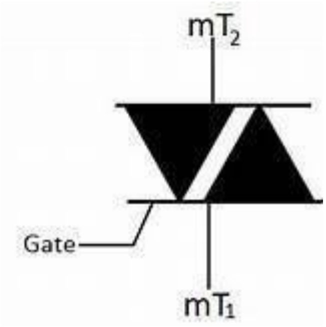
- When the gate current Ig=0 anode-to cathode-voltage ($V_{AK)}$ is increased gradually above zero, a very little anode current called forward leakage current flows and the SCR is said to be in the forward blocking state (OFF state).
- At certain value of anode-to-cathode voltage (V_{AK}) known as the forward break over voltage labeled as V_{FBO}, SCR conducts heavily and current through SCR increases rapidly (and is only limited by external load resistance in the circuit).
- The forward blocking region is lying between points 0 and A. The SCR is OFF in this region. So it blocks the forward anode-to-cathode voltage (V_{AK}).
- Forward conducting region is lying between B and C. The SCR is ON in this region so it conducts heavily..
- A large current associated with VBR gives rise to more losses in the SCR. This may lead to SCR damage as the junction temperature may exceed its permissible temperature rise.

Applications of SCR:

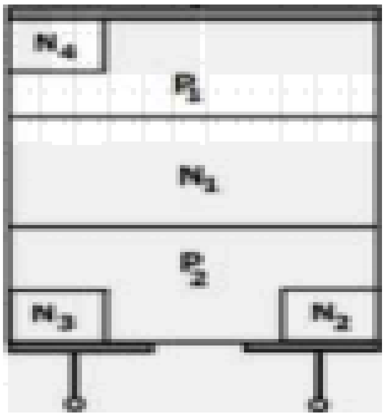
The following are the applications ofthyristors (SCRs) I

- Speed Controllers of AC and DC motors
- DC and AC circuit breakers
- Illumination (light dimmers) and temperature controllers
- Pressure control and liquid level regulators
- Variable voltage AC to DC rectifiers

TRIAC



CONSTRUCTION OF TRIAC



Triac is a three terminal, six doped regions, bidirectional, power semiconductor device. It incorporates two SCRs connected in inverse parallel with a common gate terminal in a single chip device. Traic is basically equivalent to two SCRs connected back to back with common gate terminalas shown .

Triac" is an abbreviation for three terminal ac switch. Tri'-indicates that the device has three terminals and ac' indicates that the device controls alternating current or can conduct in either direction (i.e. bothduring the positive half cycle and negative half cycle ofthe supply voltage).

The basic structure of the triac is shown in figure As seen, it has six doped regions. The gate terminal G makes ohmic contacts with both the N3 and P2 materials. This permits trigger pulse of either polarityto start conduction..

Since the triac is a bidirectional device, the power terminals are designated as main terminal-1 (MT1), and main terminal-2 (MT2) instead of anode and cathode. The control terminal is called the gate (G). The gate terminal is near the terminal MT1.

A traic is bidirectional device hence current can flow in both the directions. Either from MT2 terminal to MT1 terminal or MT1 terminal to MT2 terminal.

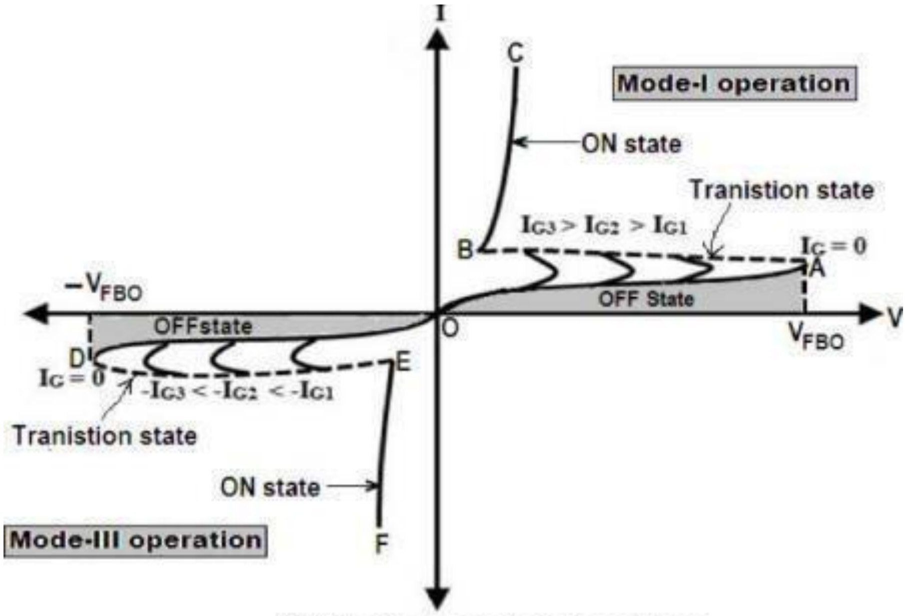
Triac is extensively used in residential lamp dimmers, heater control and for fan motor control.

V-I Characteristics of a triac:

The static characteristics of a triac l are shown in fig . The triac characteristics can be divided into three regions of operation.

- i.Forward blocking state (OFF state)
- i.Forward conducting state (ON state)

Transition state (unstable state)



(27) Static characteristics of triac

Applications of a triac:

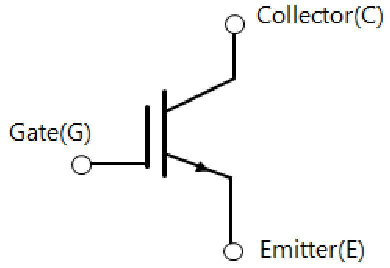
- TRIACs are used for many electrical switching applications:
- •Domestic light dimmers
- •Electric fan speed controls
- •Small motor controls
- •Control of small AC powered domestic appliances

Power MOSFET:

MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor. It is a three terminals, unipolar, bidirectional, voltage controlled, and very fast switching power semiconductor device.

- The collector and emitter terminals are called power terminals and the gate is the control terminal.
- A low voltage is applied across the gate and emitter to turn ON the IGBT.
- In IGBT, whenever a voltage between gate and emitter is applied, current flows from collector to emitter and IGBT is said to be turned ON.
- When the gate-emitter voltage is removed the IGBT turns OFF. Thus gate has full control over the conduction of IGBT.

symbol of IGBT:



V-l characteristics of IGBT:

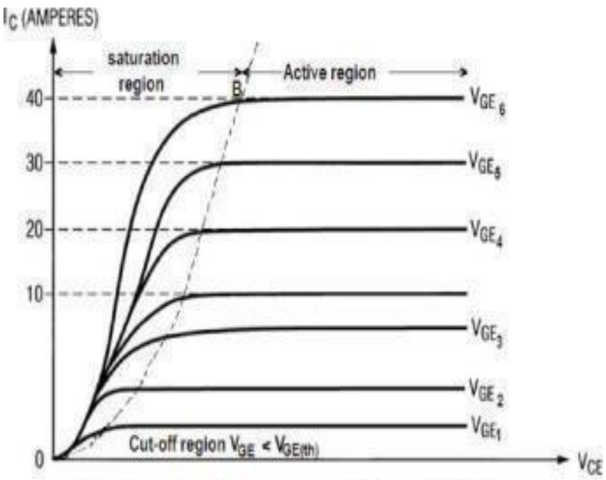


Fig.32 output characteristics of IGBT

It is a graph that shows the variation of the collector current (Ic) with the collector emitter voltage (VCE, keeping the gate-emitter voltage (VGE) constant.

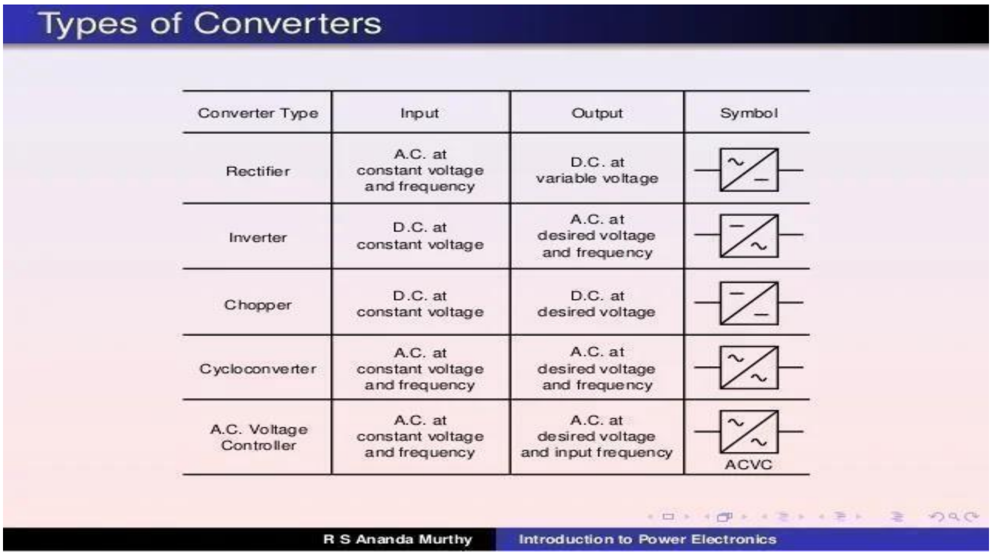
In fig observe that there are three regions in the characteristics: Cut-off region, Saturation region and active region.

Applications of IGBT:

IGBT is used in the following circuits:

SMPS circuits

UPS systems



Types of Converters

Converter Type	Input	Output	Symbol
Rectifier	A.C. at constant voltage and frequency	D.C. at variable voltage	
Inverter	D.C. at constant voltage	A.C. at desired voltage and frequency	
Chopper	D.C. at constant voltage	D.C. at desired voltage	
Cycloconverter	A.C. at constant voltage and frequency	A.C. at desired voltage and frequency	
A.C. Voltage Controller	A.C. at constant voltage and frequency	A.C. at desired voltage and input frequency	ACVC

R S Ananda Murthy Introduction to Power Electronics

Applications of power electronics:

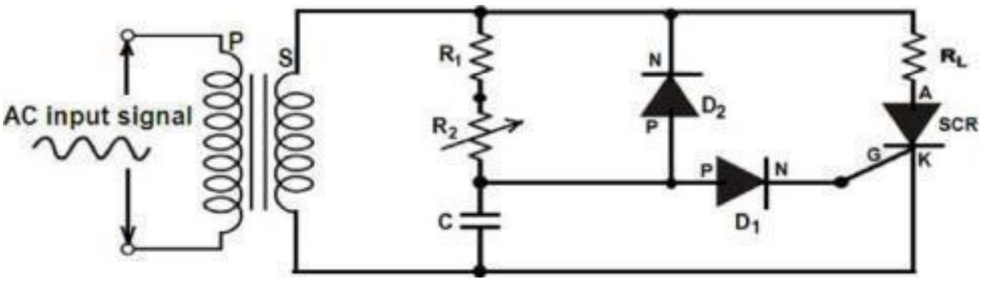
the ability to control efficiently the output parameters such as voltage, current and frequency. There are many types of power converters. They can be classified based on the type of power conversion. The classification is shown in table below

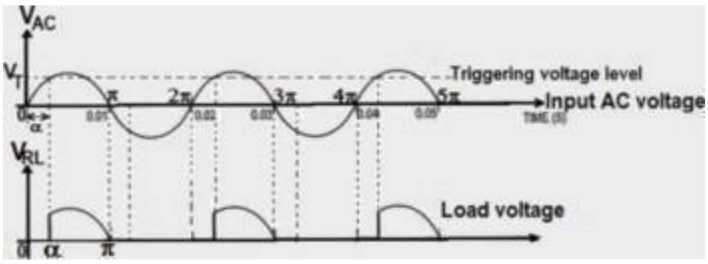
Phase controlled rectifier:

The rectifier circuits in which the rectified output can be controlled by the phase angle of firing are called as phase
controlled rectifier.

SCR half-wave rectifier with RC triggering

Fig shows input and load voltage (output) waveforms of SCR half-wave rectifier with RC triggering with resistive load.





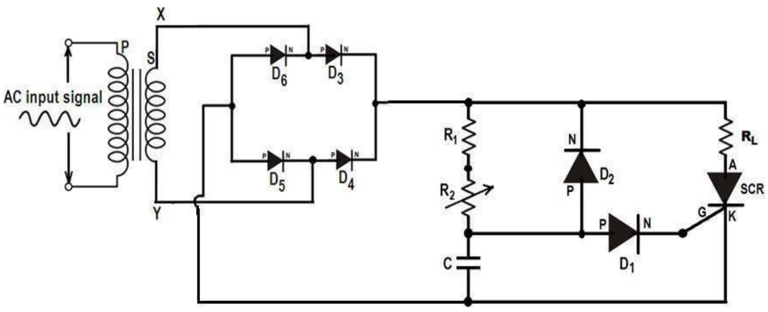
The expression ofaverage load voltage (V_{dC}) and load current (I_{dC}) is given below:

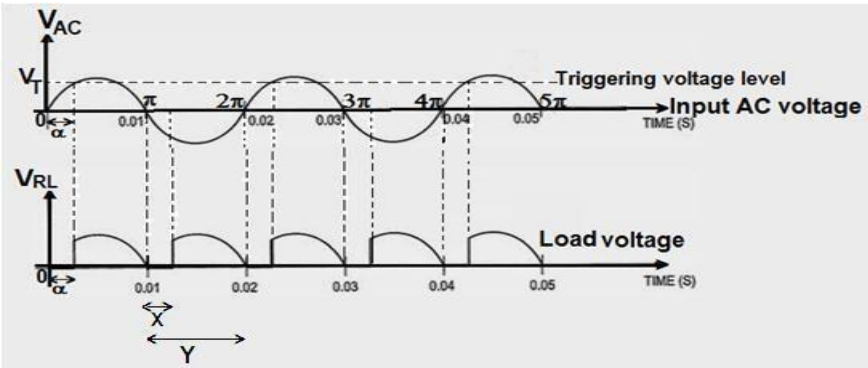
The average load voltage is given by

$$V_{dc} = \frac{V_m}{2\pi}(1 + \cos\alpha)$$

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{V_m}{2\pi R_L}(1 + \cos\alpha)$$

SCR full-wave rectifier by RC triggering circuit:





The average load voltage is given by

$$V_{dc} = \frac{V_m}{\pi}(1 + \cos\alpha)$$

The average load current is given by

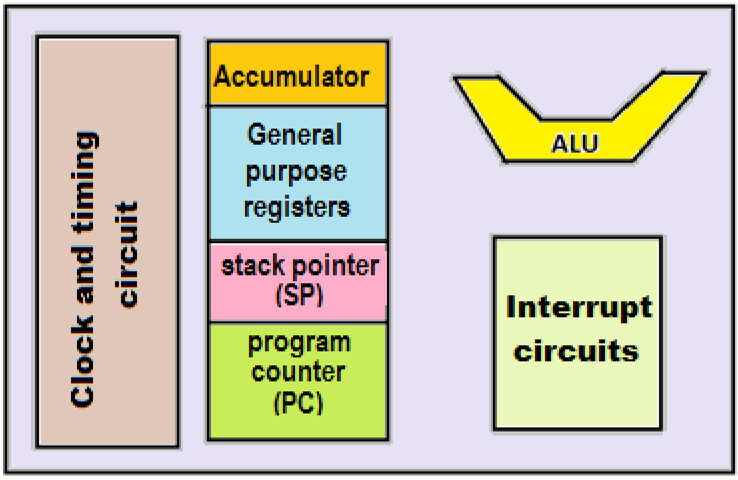
$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{V_m}{\pi R_L}(1 + \cos\alpha)$$

CHAPTER 10 **MICROCONTROLLER**

Microprocessor (μp):

It is basically the entire CPU fabricated on a single chip.

Block diagram of general microprocessor:



Function of each block:

ALU (Arithmetic and Logic Unit):

ALU stands for Arithmetic and Logic Unit. The main purpose of this unit is to perform all arithmetic and logic operations. It can perform arithmetic operations like addition, subtraction, multiplication,

Accumulator:

It is an 8-bit register . It holds one ofthe datato be processed bythe ALU.

General purpose registers (working register):

It is a storage unit within the processor. In this unit there are various registers for storing data temporarily during program execution, .

Program Counter (PC):

It is a 16-bit register that holds the address of the next instruction of the program which is to be fetched and executed

Stack Pointer (SP):

In microprocessor it is a 16-bit register used to store the address of a memory location belonging to the most recent entry in the stack

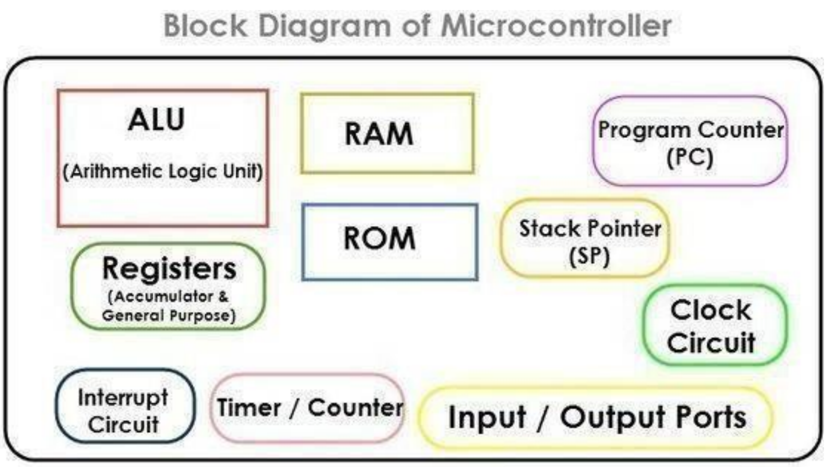
.**Clock circuit:**

It is a circuit which generates clock pulses which is necessary for synchronizing various internal operations or devices in the microprocessor

Interrupt circuit:

It is a device that stops (pause) the current program execution when the interrupt signal is received and forcing the CPU to execute another program immediately

Microcontroller (µc):
It is basically a small computer on a single integrated circuit (IC)



Function of each block:

ALU (Arithmetic and Logic Unit):

ALU stands for Arithmetic and Logic Unit. The main purpose of this unit is to perform all arithmetic andlogic operations. It can performarithmetic operations like addition, subtraction, multiplication,

Accumulator:

It is an 8-bit register . It holds one ofthe data to be processed bythe ALU.

General purpose registers (working register):

It is a storage unit within the processor. In this unit there are various registers for storing datatemporarily during program execution,

Internal RAM:

Memoryunit used to store user programand data while working. It is also known as read/write memory because user can either read the stored contents of memory locations or write new contents into the memory location while working on them. .

It is a built-in memory IC, programmed with specific data when it is manufactured. ROM is used to storethe permanent software programwhich drives the hardware devices that are attached or connected to the microcontroller.

Program Counter (PC):

It is a 16-bit register that holds the address of the next instruction of the program which is to be fetched and executed □

Stack Pointer (SP):

In microprocessor it is a 16-bit register used to store the address of a memory location belonging to the most recent entry in the stack

.**Clock circuit:**

It is a circuit which generates clock pulses which is necessary for synchronizing various internal operations or devices in the microprocessor

Interrupt circuit:

It is a device that stops (pause) the current program execution when the interrupt signal is received and forcing the CPU to execute another program immediately

Timer/Counter:

This unit generates time delays and to count internal or external clock pulses when used in counter mode.

Input/output port (I/O port):

As we know that microcontroller is used in embedded systems to control the operation of machines. Therefore to connect it to other machines, devices or peripherals we

requires I/O interfacing ports in microcontroller. For this purpose microcontroller has input output portsto connect it to other peripherals**.**

Input/output port (I/O port):

to connect it to other machines, devices or peripherals we require I/O interfacing ports in microcontroller. For this purpose microcontroller has inpu output ports to connect it to other peripherals.

ST.CLARET PRE UNIVERSITY COLLEGE

Comparison between Microprocessor and Microcontroller:

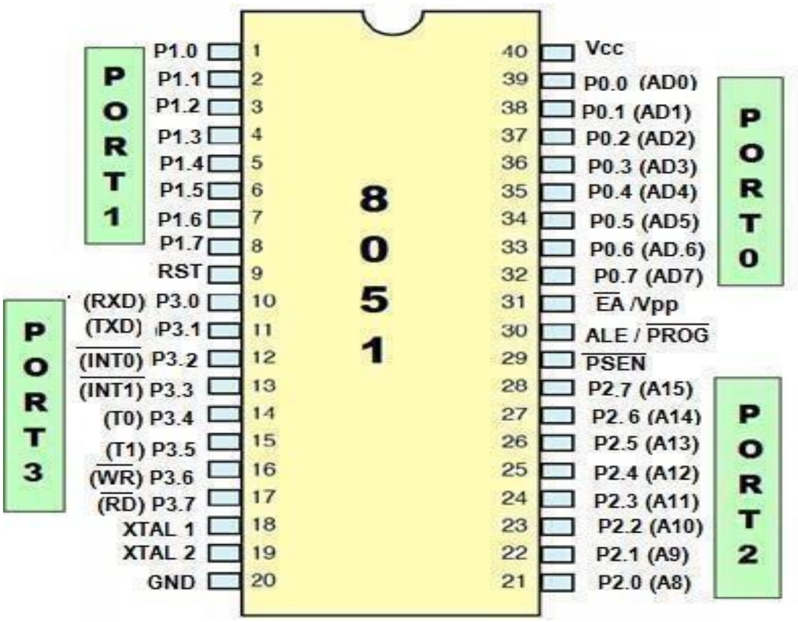
Microprocessor(µp)	Microcontroller(µC)
It is just a processor. Memory and I/O components have to be connected externally	Micro controller has external processor along with internal memory and i/O components
Cannot be used in compact systems and hence inefficient	Can be used in compact systems and hence it is an efficient technique
Due to external components, the entire power consumption is high	Since external components are low, totalpower consumption is less a
Mainly used in personal computers	Used mainly in washing machine, MP3 players

General features of 8051 microcontroller:

- 4 KB on-chip ROM
- 128 bytes on-chip RAM
- 8-bit CPU
- 4 register banks
- Two 16-bit timers
- Two 16-bits registers
- One 8-bit stack pointer
- 5 interrupts
- 4 parallel I/O ports (P0 to P3) each of 8-bits with a total of 32 I/O pins or lines.

Pin-configuration of 8051 microcontroller:

Pin-configuration of 8051 microcontroller:



Addressing modes of 8051 microcontroller:

The term addressing mode refers to how the operand is specified in an instruction along with opcode. the addressing modes are classified as follows:

- ➔ Immediate addressing
- ➔ Direct addressing mode
- ➔ Register addressing mode
- ➔ indirect addressing mode

Immediate addressing mode:

The addressing mode in which, data is present within the instruction itself is known as immediate addressing mode.

Examples:

MOV R1,#60h

MOV A,#0FFh

MOV R0,#50h

Direct addressing mode:

The addressing mode in which, the data is in a RAM memory location whose address is known, and this address is given as a part ofthe instruction is known as direct addressing mode.

Examples:

MOV A, 35H

MOV R1,42H

Register addressing mode:

The addressing mode in which, the operands are specified by registers name is known as register addressing mode

Examples:

MOV A,R0

MOV R2,A

indirect addressing mode:

The addressing mode in which, register R0 or R1 is used to hold the address of the data is called register indirect addressing mode

Examples:

MOV A,@R0 ; move the contents of RAM location whose address is held by R0 register to accumulator

MOV A,@R1 ; move the contents of RAM location whose address is held by R1 register to accumulator

8051 Assembly Language Programming (ALP)

An assembly language program is a sequence of instructions written in mnemonics to perform a specific task. These instructions are selected from the instruction set of the microprocessor/microcontroller being used

The 8051 Instruction Set: Depending onoperation theyperform, all instructions are divided in several groups:

- ➔ Data Transfer Instructions
- ➔ Arithmetic Instructions
- ➔ Branch Instructions
- ➔ Logical Instructions

Data transfer Instructions: The instructions used to copy the content of source operand to Destination operand or used to exchange the contents of source operand to destination operand and vice-versa are called data transfer instructions

examples

MOV A,Rn	Moves the register to the accumulator
MOV A,direct	Moves the direct byte to the accumulator
MOV A,@Ri	Moves the indirect RAM to the accumulator
MOV A,#data	Moves the immediate data to the accumulator
MOV DPTR,#data	Moves a 16-bit data to the data pointer
XCH A,Rn	Exchanges the register with the accumulator

Arithmetic instructions: The instructions used to perform basic arithmetic operations such asaddition, subtraction, multiplication, division, increment and decrement are called arithmetic group of instructions

ADD A,Rn Adds the register to the accumulator

ADD A,direct Adds the direct byte to the accumulator

ADD A,@Ri Adds the indirect RAM to the accumulator

ADD A,#data Adds the immediate data to the accumulator
ADDC A,Rn Adds the register to the accumulator with a carry flag
ADDC A,direct Adds the direct byte to the accumulator with a carry flag
ADDC A,@Ri Adds the indirect RAM to the accumulator with a carry flag
SUBB A,Rn Subtracts the register from the accumulator with a borrow
SUBB A,direct Subtracts the direct byte from the accumulator with a borrow

SUBB A,#data Subtracts the immediate data from the accumulator with a borrow
INC A Increments the accumulator by1
DEC A Decrements the accumulator by1
MUL AB Multiplies A and B
DIV AB Divides A by B

Branch Instructions:

The instructions used to alter or change the normal sequence of program execution either conditionally or unconditionally are called program branching instructions. This group includesjump, call and return instructions

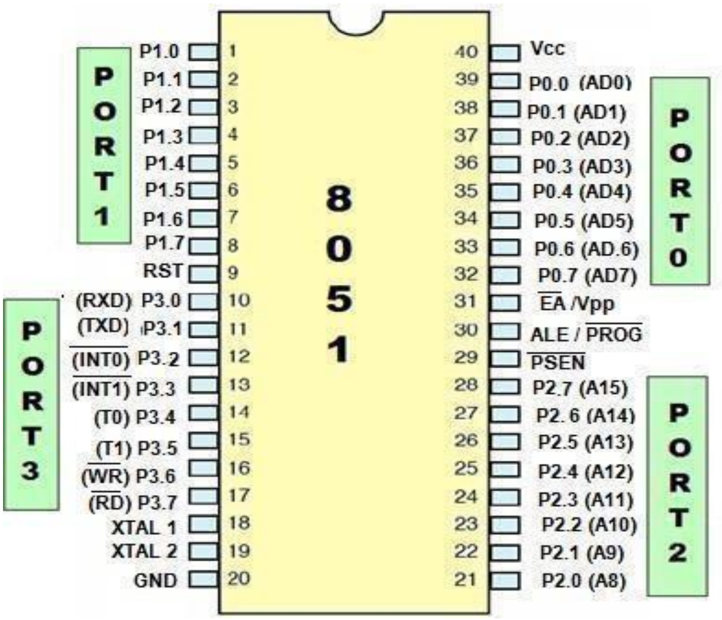
ACALL Absolute subroutine call
LCALL Long subroutine call
AJMP Absolute jump
LJMP Long jump
SJMP Short jump

Logic instructions:

Instructions used for performing logical operations such as „Oring‟, „ANDing‟, „XORing‟, complementing, clearing, bit rotation and swapping nibbles of a byte , etc., are knows as logical instructions.

ANL A,Rn AND register to accumulator
ANL A,direct AND direct byte to accumulator
ANL A,@Ri AND indirect RAM to accumulator
ANL A,#data AND immediate data to accumulator
ANL direct, AND accumulator to direct byte
ANL direct,#data AND immediate data to direct register
ORL A,Rn OR register to accumulator
ORL A, direct OR direct byte to accumulator
ORL A,@Ri OR indirect RAM to accumulator
ORL direct,A OR accumulator to direct byte
ORL direct,#data OR immediate data to direct byte
ORL A,@Ri OR indirect RAM to accumulator
ORL direct,A OR accumulator to direct byte
ORL direct,#data OR immediate data to direct byte
XRL A,Rn Exclusive OR register to accumulator
XRL A,direct Exclusive OR direct byte to accumulator

XRL A,@Ri	Exclusive OR indirect RAM to accumulator
XRL A,#data	Exclusive OR immediate data to accumulator
XRL direct,A	Exclusive OR accumulator to direct byte
XORL direct,#data	Exclusive OR immediate data to direct byte
CLR A	Clears the accumulator
CPL A	Complements the accumulator



CHAPTER 11 **introduction to C- Programming**

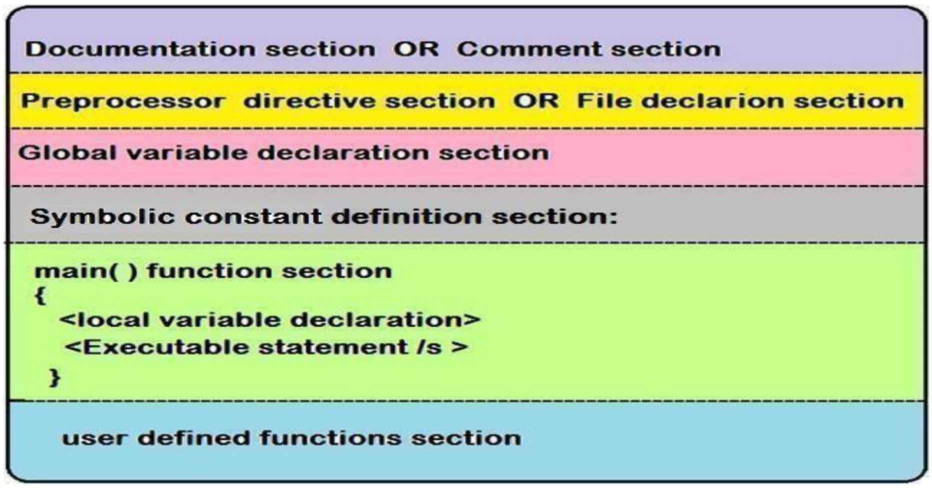
C is a general purpose, structured, middle level programming language. C language is developed in 1972 by Dennis Ritchie at the Bell Telephone Laboratories for use with the UNIX operating system. It was named „C‟ because many of its features were derived from an earlier language called „B‟. C programming is near to machine as well as human so it is called middle level language

Features of C:

The main features of C language are:

- Structured programming language.
- Provides various operators (Arithmetic, Increment, Decrement)
- Helps to develop efficient programs.
- Can be compiled and executed on anycomputer (i.e. it is a portable language).
- Provides various data types (int, float, char, etc.,)
- Allows use ofpointers for array, memory functions etc.
- Provides high level instructions.
- Allows user to make exclusive use of function calls.
- It is a case sensitive language.
- It contains only 32 keywords.

Basic structure of C programming:

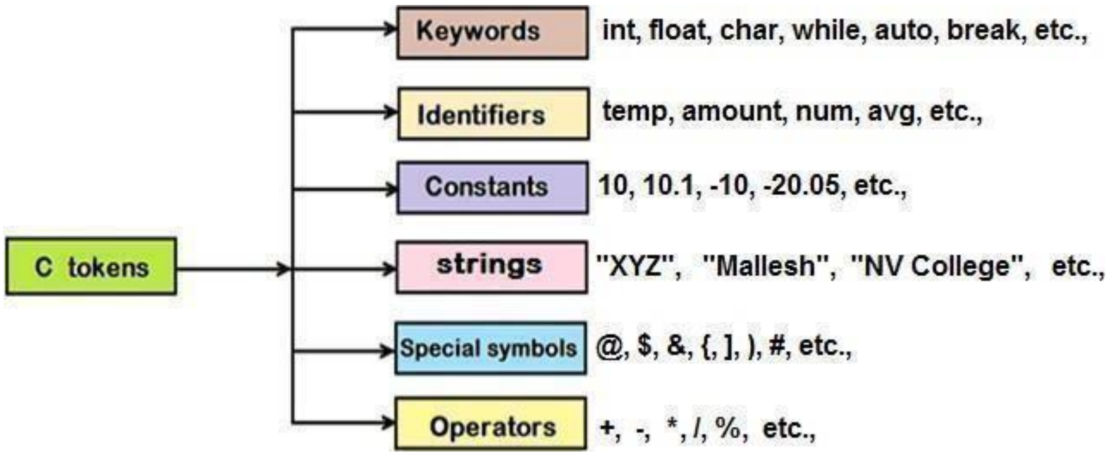


Character set of C language

A character set is a collection of alphabets, digits and special symbols which can be used to represent the information in C programing language

The complete character set of C language is shown in the table below:

Alphabets (upper case)	A, B, C, D,----------X, Y, Z
Alphabets (lower case)	a, b, c, d,---------x, y, z
Digits	0,1,2,3,-------------9
`special symbols	, (comma) / (forward slash) \ (back slash) + (plus) . (period) - (minus) ; (semicolon) ~ (Tilde) * (Asterisk) : (colon) $ (dollar) ^ (carat) ?(question mark) # (Hash) < (less than or opening angle brace) > (greater than or closing angle brace) ’ (apostrophe) % (percentage) ″ (quotation mark) & (ampersand) = (equals to) ‖ (Vertical bar) _ (underscore) [ ] (left/right brackets) ( ) (left/right parentheses) { } (opening and closing curly braces



Keywords (reserved words):

- Keywords are the words whose meaning, purpose and function have already been explained to the C compiler
- No new meaning can be given to the keywords since their meaning is already known to the C compiler.
- Key words cannot be used as variable names, because if we do so we are trying to assign a new meaning to the keyword, which is not allowed by the computer.
- Allthe keywords must be written in lower case.
- There are a total of 32 keywords, whose meaning is already known to the computer.

Various keywords available in C language are shown below**:**

auto	double	int	struct	const	float	short	unsigned
break	else	long	switch	continue	for	signed	void
case	enum	register	typedef	default	goto	sizeof	volatile
char	extern	return	union	do	if	static	while

Identifiers:

An identifier is a name or word (other than keyword) used to identify a variable, function, symbolic constant and so on.

Rules for constructing identifiers:

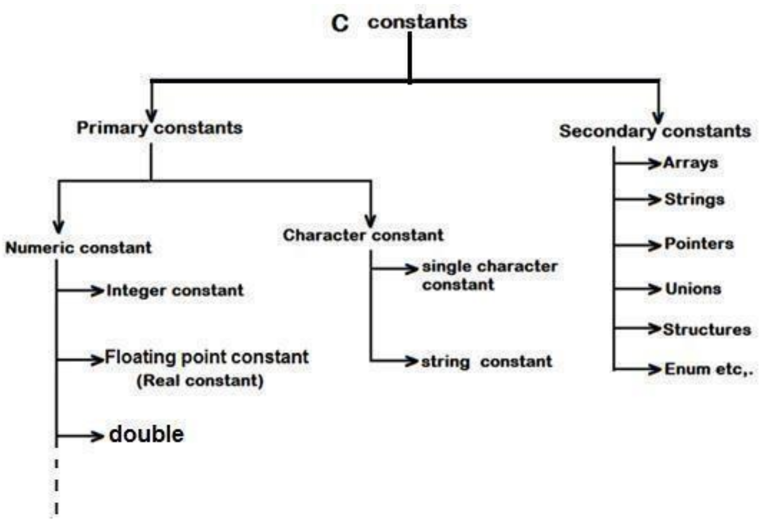
- . Identifiers can be constructed with digits, letters and underscore.
- But the first character in the identifier must be an alphabet or an underscore and then it can have considerable number of digits, letters, underscore.
- Special symbols are not allowed (except underscore).
- Identifiers are also case sensitive in C. for example Total and total are two different identifiers in C.
- Keywords cannot be used as an identifier.
- The first character ofan identifier name cannot be a digit.
- Two successive underscores are not allowed.

Constants :

Constant is fixed value or quantity assigned to a variable which cannot be modified by the program once theyare defined.

The C constants can be divided into two major categories.

- Primary constants
- secondary constants



Integer constants:

Integer constant is a signed or unsigned whole numbers without any fractional part. (OR) Integer constant is a number without decimal point. It can be either positive or negative. It consists of a sequence of digits without a decimal point.

Floating point constant (or) Real constants:

Floating point constant is a number with decimal point.

Character constant:

A character constant is a single character (which may be single alphabet, single digit or single special symbol) enclosed within a pair of apostrophes or single quotation marks. Following are the some of the valid character constants

“a“, “B“, “$“, “_“, “9“, “=“, “ “, “&“, “@“, “?“

String constant:

It is a sequence of characters (single or several alphabets, single or several digits or single or several special symbols or combination ofthese) enclosed within a pair of double quotes

Examples:

Following are the some of the valid string constants

”abc”, ”1234”, ”Mallesh”, ”The sum of numbers=”, ”A”, ” ”, ”hello!”, “a@73”

Variables:

Variable is a name given to memory location where different constants (such as integer, floating point, character constant) may be stored.

Consider the following examples to declare variables in a C program:

int a;
int age;
int a,b,c;
float x;
float weight;
float x,y,z;
double height;

Data types:

A data type in C programing language refers to the type of data being stored in the variable

Built-in data types

16-bit machine				
Data type	Keyword	purpose	Number of bytes allocated	Range of values
Integer	int	To hold an integer constant	2 bytes	- 32768 to +32767 for singed int 0 to 65535 for unsigned int
Floating point	float	To hold a floating point (real) constant	4 bytes	3.4×10^{-38} to $4.3\times10^{+38}$ (or) 3.4e-38 to 4.3e+38
Double precision	double	To hold real constant	8 bytes	1.7×10^{-308} to $1.7\times10^{+308}$ (or) 1.7e-308 to 1.7e+308
Character	char	To hold character constant	1 byte	-128 to +127 for signed char 0 to 255 for unsigned char
Non-specific (no value variable)	void	Non-specific	No memory allocated (0 byte)	It has no range

Operators, operands and expression:

Operators: Operators are symbols that perform specific operations on one, two or more operands, and gives meaningful result.

Operand: Operand is an object (variables or constants) on which an operation is Performed

Unary operator in C:

An operator which acts on only one operand to produce the result is called unary operator**.**

Unary operator	meaning	Examples
-	Unary minus	-7.5, -(x+y)
++	Increment operator	++i or i++
--	Decrement operator	--i or i--
!	NOT or negation operator	!x
~	Tilde (bitwise complement operator)	int x=10; ~x=?

Assignment operators in C:

C operator (=) which is used to assign the value of the expression which is on its right to the left side variable is called assignment operator.

Full form (long form)	Short-hand form	Meaning
a=a+5	a+=5	a+5 is first computed and that result is assigned to a
a=a*k	a*=k	a*k is first computed and that result is assigned to a
a=a-2	a-=2	a-2 is first computed and that result is assigned to a
a=a/3	a/=3	a/3 is first computed and that result is assigned to a
a=a+(b-2)	a+=(b-2)	a+(b-2) is first computed and that result is assigned to a
x=x%100	x%=100	X%100 is first computed and that result is assigned to x
x=x/100	x/=100	x/100 is first computed and that result is assigned to x

Arithmetic operators in C:

Arithmetic operators are binary operators which are used to perform various arithmetical operations (like addition, subtraction, multiplication division andmodulus division operation). +, -, *, / and % are all arithmetic operators.

The valid arithmetical operators supported by C language are given in the table below.

Arithmetic operator	Operation performed (function)	Example	Precedence (Left to Right)
+	Addition	x+y	Lowest
-	Subtraction	x-y	Lowest
*	Multiplication	x*y	Highest
/	Division	x/y	Highest
%	Modulus division(i.e. arithmetic operator used to find remainder of the integer division)	x%y	highest

Relational operators in C:

C operators used for performing (making) comparison are called relational operators.

Relational operator	Operation	Example
>	Greater than	x>y
<	Less than	X<y
>=	Greater than or equal to	x>=y
<=	Less than or equal to	X<=y
= =	Equal to	X==y
!=	Not equal to	X!=y

Logical operators:

Logical operators are binary operators used for performing (making) logical decisions (by comparing two or more relational expressions)

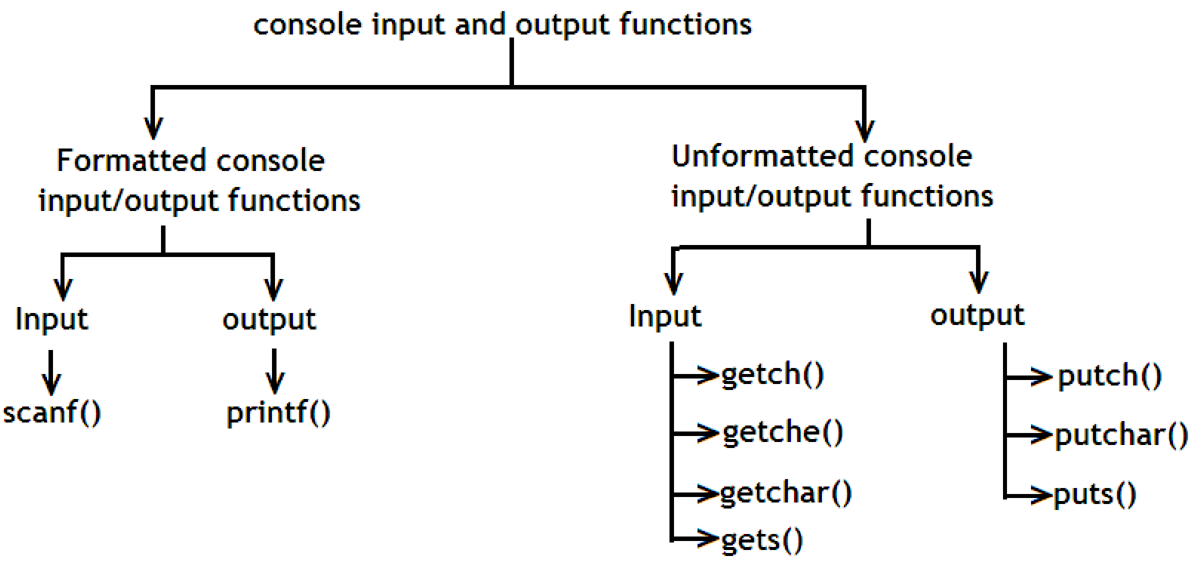
Logical operator	meaning	Operation	Example
!	Exclamation	Logical NOT (It is a logical operator which performs logical NOT operation)	!x
&&	Double ampersand	Logical AND (It is a logical operator which performs logical AND operation)	X&&y
||	Double pipeline	Logical OR (It is a logical operator which performs logical OR operation)	x||y

conditional operator (?:) in C:

The C operator used to check a condition and select a value depending on the value of the test condition is called as ternary or conditional operator.

The syntax of conditional or ternary operator is as given below.

(conditional_expression)?(expression1):(expression2);



Standard input and output device:

The standard input device is usually the keyboard and the standard C input function defined is scanf().

The standard output device is usually the screen and the standard C output function defined is printf().

The syntax of scanf() is as given below.

scanf("list of formate specifiers", list ofthe addresses of variables);

Format specifier	Input type	Data type
%d or %i	Short signed integer	Integer
%u	Short unsigned integer	
%ld	Long unsigned integer	
%lu	Long unsigned integer	
%x or %X	Unsigned hexadecimal integer	
%o	Unsigned octal integer	
%f or %G or %g	Single precision float	Float
%lf	Double precision float	
%e or %E	Float (scientific)	
%c	Signed character	Character
%c	Unsigned character	
%s	Read a string	String

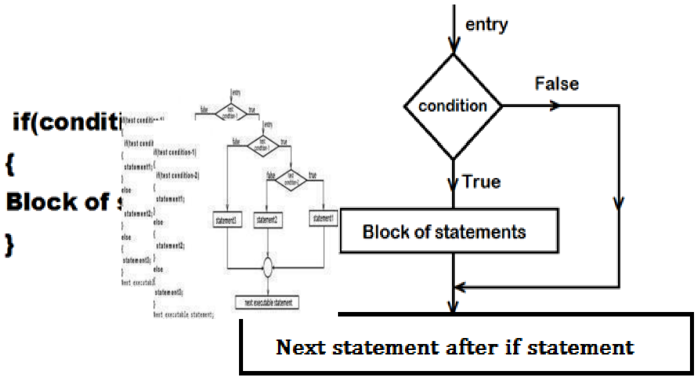
The syntax of printf() statement is as given below.

Printf("control string", list of variables);

getche( ):
It is also an unformatted input function. It is same as getchar() except that it is does not wait for enter key to press after entering the character. The character entered is visible on the screen. getche()function is defined in conio.hstandard input output library header file which we have include at the beginning of our program using preprocessor common #include.
getch():
It is also an unformatted input functions and is used to read a single character. The entered character is not visible on the screen. This function does not wait for enter key to press after entering the characterclrscr( ):
It is a library function. It stands for clear screen. Clrscr() function is used to clear the previous output fromthe console output screen.
getchar():
It is an unformatted I/O functions and is used to read a single character. The entered character is visible on the screen. The function waits for an enter keyto be pressed after entering the character
gets():
gets function is also an unformatted i/o function. It is used to read a line of character. The characters are treated as a single string unless an enter key is pressed or new line character is encountered. This function reads space also
putchar() and putch():
These are unformatted o/p functions these functions are used to display a single character on the screen.
puts():
This is an unformatted output function. This function is used to display a string on the screen. The string can include white spaces.Control statements (or) control instructions (or) control structures in C:

if statement:

- It is a simplest conditional statement. It either executes or ignores a set of statements (or single statement) after a test condition.
- It is also called as one waybranching statement.
- If the test condition is true then block of statements are executed and if the test condition is false then, it ignores block of statements and the control is transfers to next statement that comes after if statement.
- The general syntax and the flowchart ofthe if control construct is given below

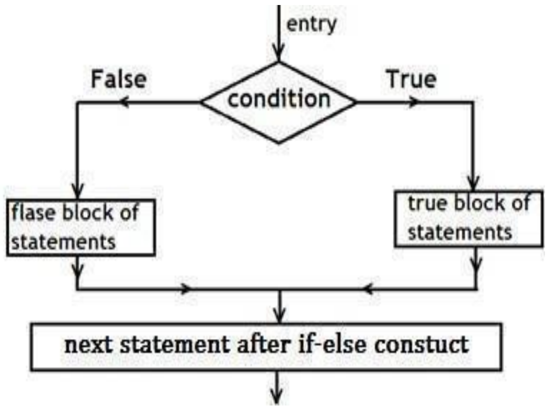


if...else statement:

- It is used to execute one set of statements if the condition is true and another set of statement if the condition is false.
- It is a two waydecision making statement. (i.e. two way branching statements).
- If the condition is true then first block of statement (true block statements) is executed and second block statement (false block statement) is ignored.
- If the condition is false then second block of statement (false block statements) is executed and first block statement (true block statement) is ignored.
- After executing any of the blocks (true block or false block), control is transferred to next statement that comes after if-else structure.

The general syntax and the flowchart of the if...else **control construct is given below**

```
if(condition)
{
true block statements;
}
else
{
false block statements;
}
next statement;
```

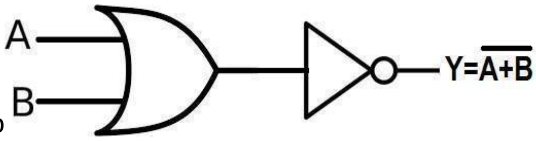


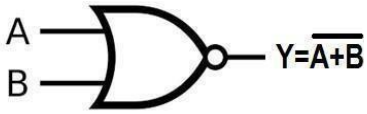
Nested if-else statement:

A if statement within the bodyof another if statement it is known as nested ifelse statement.

NOR – gate:

A NOR – gate is a series combination of OR and NOT gates. It is a universal logic gate in which





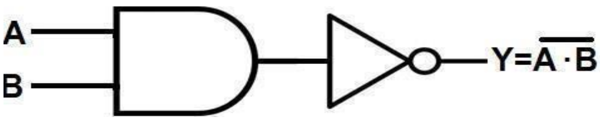
HIGH outp ut occurs only when all the inputs are Low

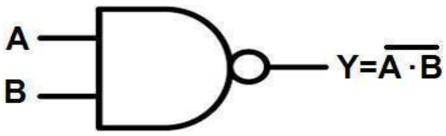
Truth table of NOR-gate

Input		output
A	B	$Y=\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

NAND – gate:

A NAND – gate is a series combination of AND and NOT – gates. Its operation is just complement of AND – gateIt is a universal logic gate in which LOW output occurs only when all the inputs are HIGH.





Truth table of NAND-gate

Input		output
A	B	$Y=\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

XOR – gate:[Exclusive OR-gate]:

It is a 2 – input and one output logic gate. Its output is HIGH (1) when the inputs are different and low (O) when the inputs are same

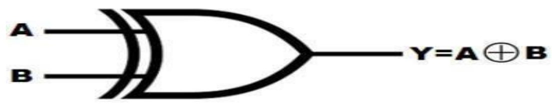
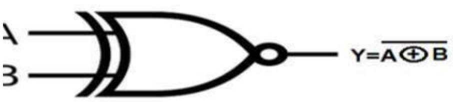


Fig (5) symbol of XOR – gate

Inputs		Output
A	B	$Y = A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

XNOR – gate (Exclusive NOR – gate):

It is a 2 – inputs and one output logic gate. Its output is HIGH (1) when the inputs are same and Low (o) when the inputs are different



ig.(7) symbol of XNOR – gate

Inputs		Output
A	B	$Y=\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

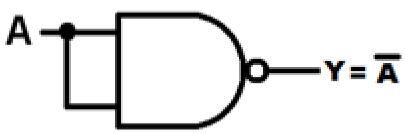
Universal Property of NAND and NOR gates:

NAND and NOR gates are called universal gates because any gate can be implemented (Constructed) byusing either of them (i.e. using only NAND gates or only NOR gates)

NAND – gate as universal gate:

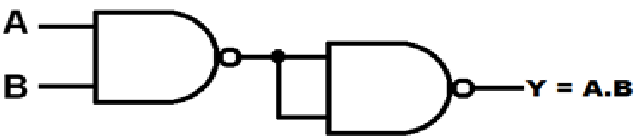
Realization of NOT, AND, OR, XOR and XNOR gates using NAND gates:

1. NAND to NOT Conversion:



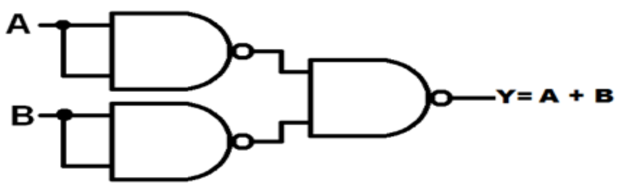
Input	Output
A	$Y=\overline{A}$
0	1
1	0

2. NAND to AND Conversion:



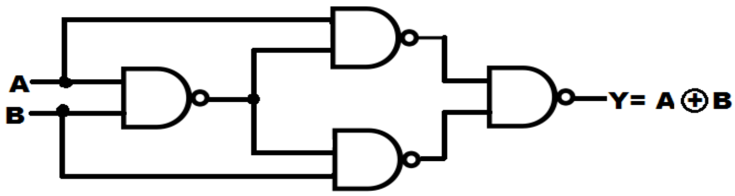
Inputs		Output
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

3. NAND to OR Conversion:



Inputs		Output
A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

4. NAND to XOR conversion:

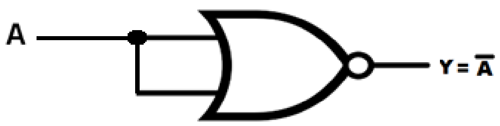


Inputs		Output
A	B	$Y= A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

NOR-gate as an universal gate:

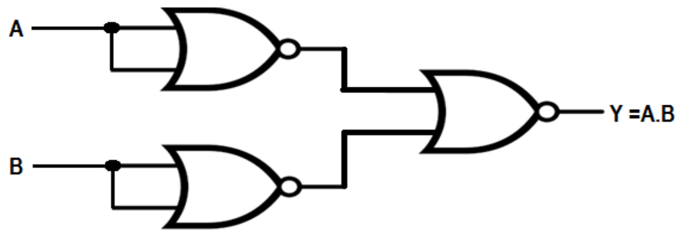
Realization of NOT, AND, OR, XOR and XNOR – gates using NOR-gates:

1. NOR to NOT Conversion:



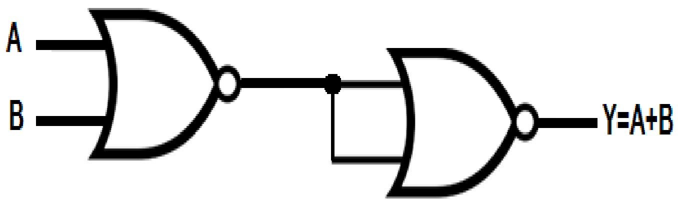
Input	Output
A	$Y=\overline{A}$
0	1
1	0

2. NOR to AND Conversion:



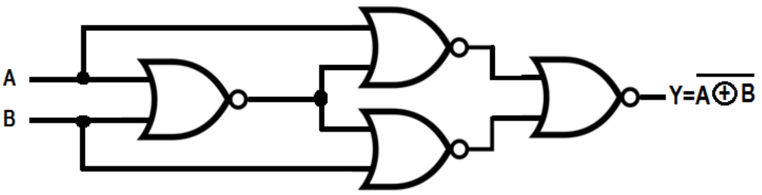
Inputs		Output
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

3. NOR to OR conversion:



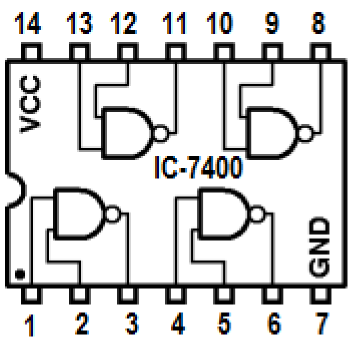
Inputs		Output
A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

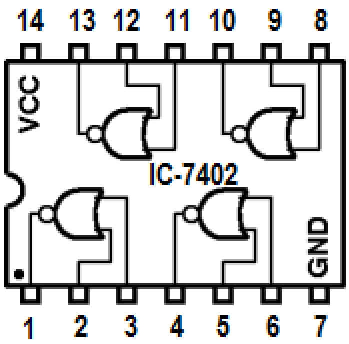
4. NOR to XNOR Conversion



Inputs		Output
A	B	$Y=\overline{A\oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

Pin diagram of NAND IC – 7400 and NOR IC-7402



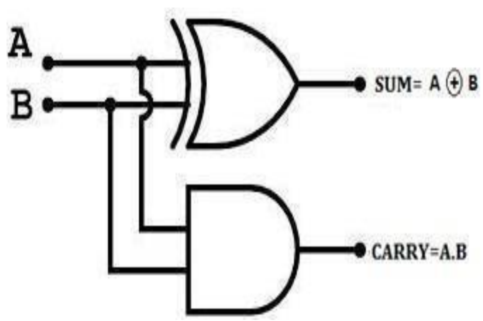


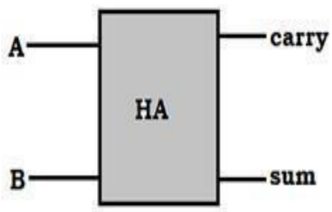
Arithmetic logic Circuits:

Electronic circuits needed to perform the arithmetic operations, Such as addition, subtraction, etc… in the digital computers are termed as arithmetic logic circuit

Half – adder:

It is a combinational logic circuit that can add two bits at a time, Producing SUM and CARRY as two separate outputs.

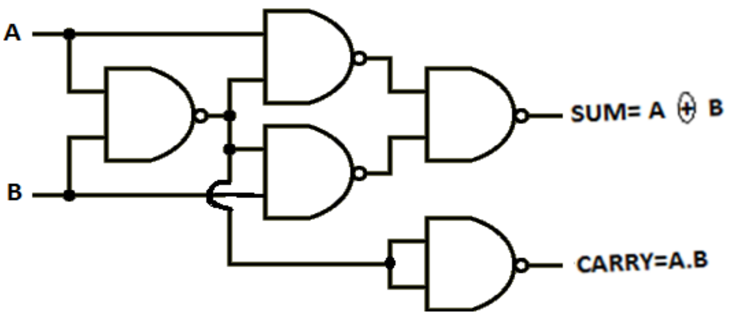




Truth table

Inputs		Outputs	
A	B	CARRY	SUM
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Realization of Half – Adder Using NAND – gates

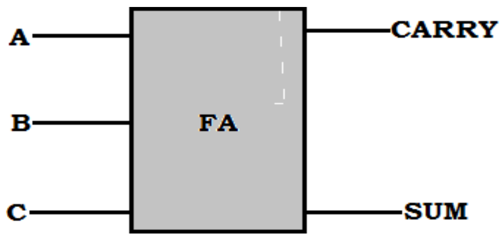


Applications:

- Half-adders are used to form a full – adder.
- It addstwo bits at a time.
- Used in digital computers and calculators.

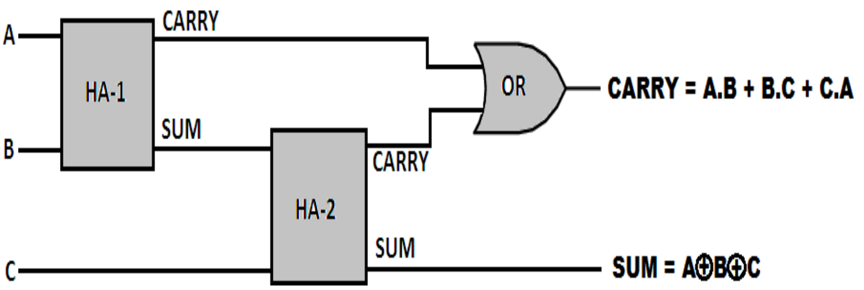
Full – Adder:

It is a combinational logic circuit which adds three bits at a time Producing SUM and CARRY as two separate outputs

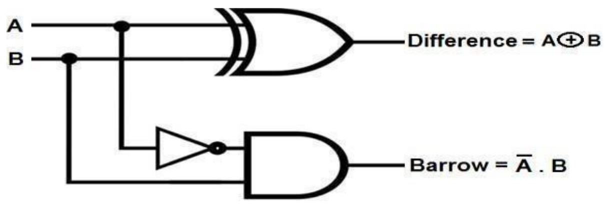


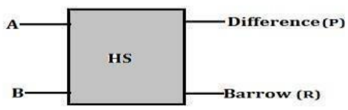
Truth table for a full-adder				
Input			Outputs	
A	B	C	Carry	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Realization of full – adder using two half – adders and OR-gate:

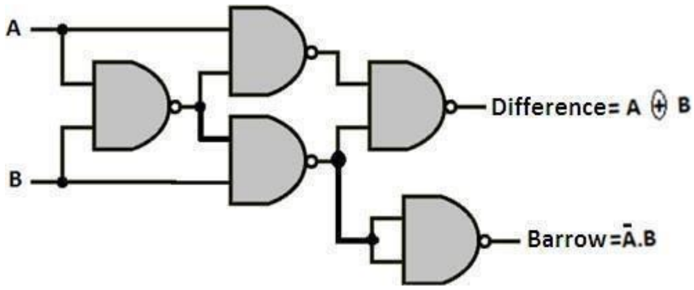


Half-subtractor: It is a combinational logic circuit that can subtract two bits at a time, Producing DIFFERENCE and BARROW as two separate outputs.





Half-subtractor using NAND-gates:



A	B	DIFFERENCE	BORROW
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Meaning of minimization:

The meaning of minimization or simplification is to optimize some engineering criteria such as the minimizing total number of gates, ICs used in the design of digital system etc,. To implement a logic function with a less number of gates we have to minimize literals and the number of terms. Usually, literals and terms are arranged in one ofthe two standard forms

- **Sum of Products form (SOP form)**
- **Product of sums form (POS form)**

Sum of Products (SOP) Expression:

A SOP expression is Boolean expression in which two or more AND function ORed together.

Product of sum (POS) Expression:

A POS expression is a Boolean expression in which two or more OR terms are ANDed together.

Canonical SOP and POS forms: (OR) Standard SOP and POS forms:

If each term in SOP and POS forms contains all the possible literals then these are known as canonical SOP and POS, respectively.

Minterm:

Each individual product terms in a canonical SOP expression is Known as minterm

Maxterm:

Each individual sum term in a canonical POS expression is known as maxterm.

Conversion of a Boolean expression in SOP form to the standard (canonical) SOP form:

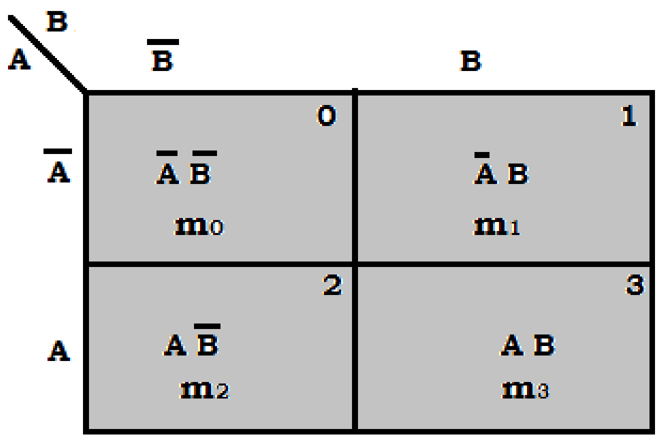
- Find the missing literal in each product term if any
- Multiply each product term having missing literals with a sum term consisting of a missing literal and its complement
- Expand the terms byapplying distributive law
- : Finally, the canonical SOP expression is obtained by neglecting (omitting)

Simplification of Boolean expressions using Karnaugh-map (K- map) technique:

K-map is a technique used to simplify the Boolean expressions. (OR) k-map is a technique of simplifying Boolean expression using graphical representation method.

Howto draw k-map for 2-variables:

A two variable k-map has $2^n = 2^2 = 4$ cells or squares and is shown in fig below



K-map for 3 – variables:

A three variable k-map has $2^n = 2^3 = 8$ cells and is shown in fig bellow

A \ BC	$\overline{B}\,\overline{C}$	$\overline{B}\,C$	$B\,C$	$B\,\overline{C}$
$\overline{A}$	0 $\overline{A}\,\overline{B}\,\overline{C}$ mo	1 $\overline{A}\,\overline{B}\,C$ m1	3 $\overline{A}\,B\,C$ m3	2 $\overline{A}\,B\,\overline{C}$ m2
A	4 $A\,\overline{B}\,\overline{C}$ m4	5 $A\,\overline{B}\,C$ m5	7 $A\,B\,C$ m7	6 $A\,B\,\overline{C}$ m6

K-map for 4 – variables:

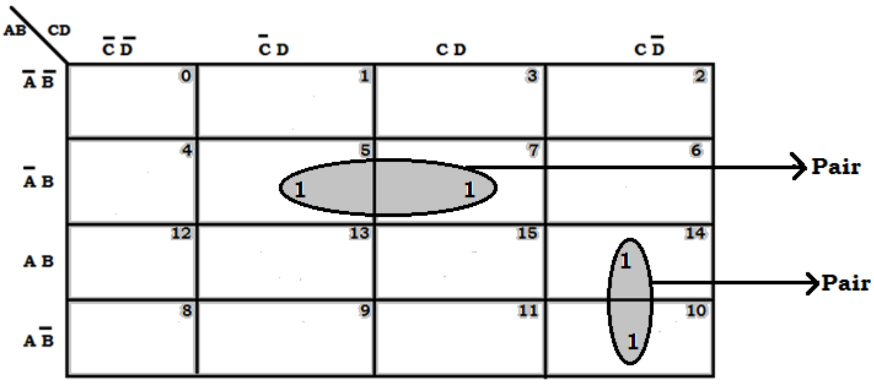
A four variable k-map has $2^n = 2^4 = 16$ cells and is shown fig below:

AB \ CD	$\overline{C}\,\overline{D}$	$\overline{C}\,D$	$C\,D$	$C\,\overline{D}$
$\overline{A}\,\overline{B}$	0 $\overline{A}\,\overline{B}\,\overline{C}\,\overline{D}$ mo	1 $\overline{A}\,\overline{B}\,\overline{C}\,D$ m1	3 $\overline{A}\,\overline{B}\,C\,D$ m3	2 $\overline{A}\,\overline{B}\,C\,\overline{D}$ m2
$\overline{A}\,B$	4 $\overline{A}\,B\,\overline{C}\,\overline{D}$ m4	5 $\overline{A}\,B\,\overline{C}\,\overline{D}$ m5	7 $\overline{A}\,B\,C\,D$ m7	6 $\overline{A}\,B\,C\,\overline{D}$ m6
$A\,B$	12 $A\,B\,\overline{C}\,\overline{D}$ m12	13 $A\,B\,\overline{C}\,D$ m13	15 $A\,B\,C\,D$ m15	14 $A\,B\,C\,\overline{D}$ m14
$A\,\overline{B}$	8 $A\,\overline{B}\,\overline{C}\,\overline{D}$ m8	9 $A\,\overline{B}\,\overline{C}\,D$ m9	11 $A\,\overline{B}\,C\,D$ m11	10 $A\,\overline{B}\,C\,\overline{D}$ m10

Grouping the adjacent cell for simplification:

Pair :

Two horizontal or vertical adjacent 1‟s on a k-map is called a pair. A pair eliminates one variable that changes form



Quad:
Four horizontal, vertical or rectangular adjacent 1‟s on a k-map is called a quad. A quad eliminates two variables which changes form.

Octet:
Eight adjacent 1‟s in a 2 x 4 shape on a k – map is called an octet. An octet eliminates three variables which changes form.

Redundant group:
If all the 1s in a group are already involved (used) in some other groups, then that group is called as a redundant group.

How to use the k-map to simplify logic equations:

- Construct the k-map and enter 1s in the cells correspond to the minterms present in the given Boolean expression and leave the other cells blank or enter 0‟s.
- Encircle the octets, quads, and pairs. Remember to roll and overlap to get the largest groups possible.
- Ifany isolated 1s remain encircle each.
- Eliminate anyredundant group if they exist.
- Write the Boolean expression by ORing (logically adding) the Product terms generated by each encircled group.

Codes (Binary codes):
In digital systems like computer, microprocessor, microcontrollers, etc., are required to handle the data which may be numeric, alphabets or special symbols/characters. As these digital systemsoperating ina binary system and hence the numerals, alphabets and other special characters are to be converted into binary format. This process of converting into binary format is known as coding and combinations ofbinary digits (i.e. binary format) that represent numbers, alphabets or symbols are called as digital codes **Codes are broadly classified as:**

- Weighted codes
- Non-weighted code
- Self complementing codes
- Cyclic (or) reflective codes
- Error detecting and correcting codes
- Alphanumeric codes

Those codes which obey positional weighting principles are called weighted codes**.** *The codes* 8421, 2421, 5421 and 5211 *are examples of weighted codes*

Non-weighted codes:

Those codes which do not obey positional weighting principles are called non weighted codesExcess-3 code and Graycode are examples of non-weighted codes.

BCD or 8-4-2-1 Code:

The Binary Coded Decimal (BCD) is a coding system in which each digit of the decimal number is represented by a nibble.

Decimal to BCD Conversion:

To express any decimal number in BCD, simply replace each decimal digit by a 4- bit binary code (nibble).

Ex:

Write BCD code for a decimal number 34

Soln: Decimal number

34

4 bit binary code

0011 0100

Hence, $(34)_{10}$ = [00110100]

Encode the decimal number 628 into 8421 code

Soln: Decimal number

628

4-bit binary code

0110 0010 1000

Hence, $(628)_{10}$ = (011000101000)

Excess – 3 Code (XS3 code):

Excess – 3 code is a non-weighted code in which 3 is added to each decimal digit and each digit sum is then converted into a nibble (i.e. 4-bit binary form).

For example, the excess – 3 code for the decimal digit 2 is

2 +3

5= *0101 is the excess – 3 code of decimal 2*

Similarly The XS3 code for the decimal digit 9 is

9 +3

12= *1100 is the XS3 code of decimal 9*

The XS3 codes are used in digital computers, especially in the earlier models for performing subtraction operations

Gray code:

Gray code is a non-weighted code, in which only one bit changes between successive numbers. *Gray codes are used in input /output devices and in some types of analog – to – digital converters.*

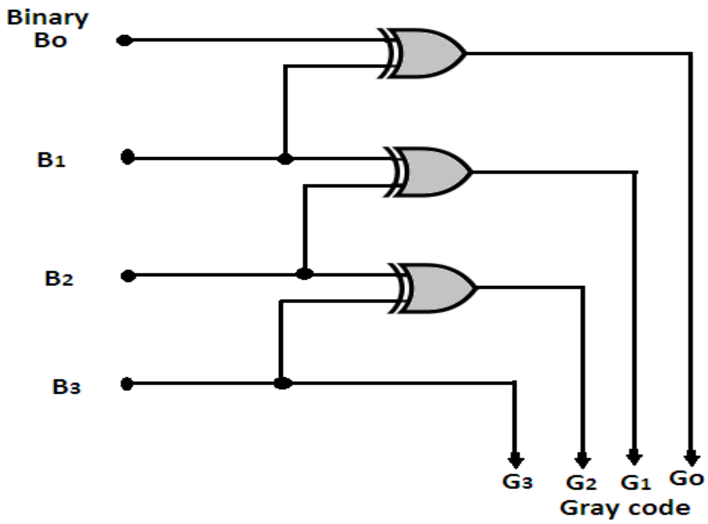
Binary – to – Gray code conversion:

To convert a binary number to its gray code, the following procedure is adopted.

- Write the first binary digit (MSB) as the first graydigit (i.e. MSB digit ofthe graycode).
- Next XOR addition operation is done with each pair of adjacent bits (i.e. first and second, second and third binary bits, and so on) to get next gray digits.

Binary– to – Graycode conversion using XOR – gates:

Fig shows the logic diagram used to convert 4-bit binary –to – gray cod



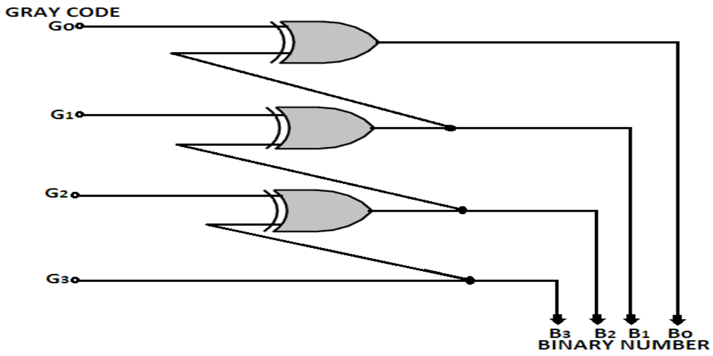
Gray to Binary conversion:

To convert a graycode into binary, the following procedure is adopted.

- Write the first gray digit (MSB) as the first (MSB) binarydigit.
- Next XOR addition operation is done diagonally [i.e. first binary bit is XOR addition with second graydigit, and so on] to get the successive binary digit

Grayto Binary conversion using XOR-gate:

Fig.shows the logic diagram used to convert 4-bit gray code to binary code.



Alphanumeric code:

A code that represents numbers, alphabetic letters, and special symbols are called alphanumeric codes

The two most popular alphanumeric codes are:

a) American Standard Code for Information Interchange (ASCII)

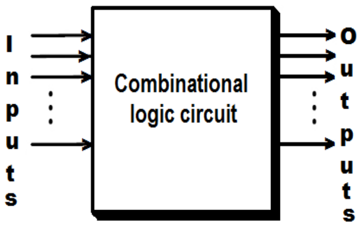
b) Extended Binary Coded Decimal Interchange Code (EBCDIC)

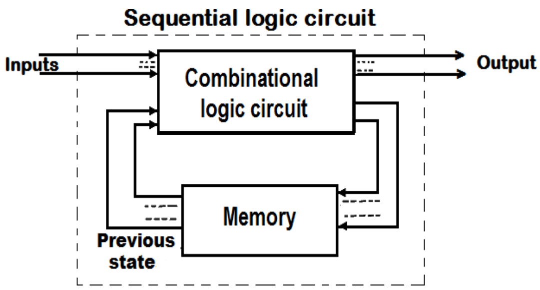
Classification of Logic circuits:

Logic circuits may be classified into two categories

1. Combinational logic circuit.

2. Sequential logic circuit.





.Combinational logic circuit:

The logic circuits whose output at any instant of time depends only on the input signals present at that moment oftime are known as combinational circuits.

Examples of combinational circuits are: Adders, subtractors, comparators, decoders, encoders, code converters, multiplexers, demultiplexers and parity generators/checkers.

.Sequential logic circuit:

The logic circuits whose output at any instant of time depends not only on the present state of inputs but also upon the previous memory condition (i.e. previous history of output or inputs) are called sequential logic circuits.

Examples of sequential logic circuits are: Flip-Flops, counters and registers.

Importance of clock in digital circuits:

The basic timing signal in a digital system is called a clock. (OR) The clock is a square wave signal.It is used in digital circuits for network synchronization (i.e. utilized to co-ordinate actions of digital circuits) and to prevent many timing Problems.

Latches and Flip-flops

Latches and flip-flops are the basic building blocks of the most sequential circuits. The maindifference between latches and flip-flops is that a latch does not have a clock signal, whereas a flip- flop always does have a clock signal.

Flip-Flops:

Flip-flop is a 1-bit memory (storage) device. It can store either a binary „O" or a binary „1". (OR) A flip-flop is the basic building block of sequential circuits which is capable of storing one bit (O or 1) of information.

Triggering of flip-flops:

The term "Triggered" is synonymous with the term „clocked‟, which means the application of a single clock pulse at the clock input ofa flip-flop.

There are two main types of clocking or triggering viz.

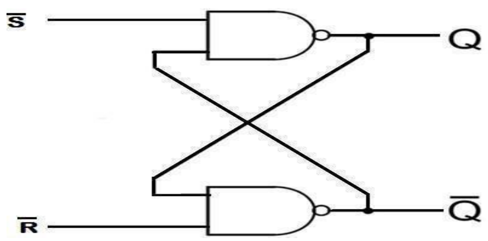
1. Level triggering
2. Edge triggering

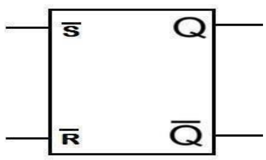
In level triggering the flip-flop changes its state when the level of the clock pulse is 1 (High) or O (Low).

The term edge-triggered means that the flip-flop changes its states either at the positive edge (i.e. rising or leading edge) or at the negative edge

Basic NAND latch

The basic NAND latch (i.e. latch) is as shown in fig. It consists oftwo cross coupled NAND gates the output ofone NAND – gate is connected to other NAND gate input and vice versa.





Working:

Basic operation of latch is as follows:

Case1: When $\overline{S}$ =0 and $\overline{R}$=0:
Under this input condition both outputs Q=1. This is called *INVALID* or *PROHIBITED* condition..

Case2: When$\overline{S}$ =0 and R =1:

Under this input condition, the output Q=1 and $\overline{Q}$ =0. This is called *SET* condition.

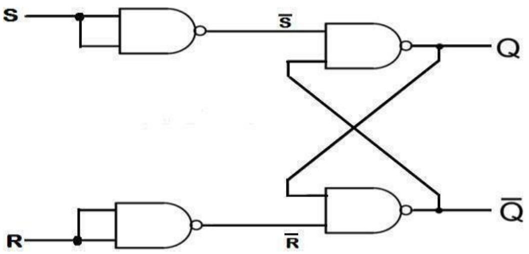
Case3: When $\overline{S}$=1 and $\overline{R}$ =0:

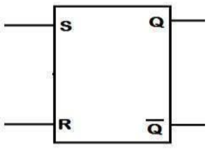
Under this input condition, the output Q=0 and $\overline{Q}$=1. This is called *RESET* condition.

Case4: When$\overline{S}$ =1 and $\overline{R}$ =1:

Under this input condition, the output Q=Q only . Since there is no change in output values, this condition is called *NO CHANGE* or *HOLD* condition.

RS – latch using NAND gates (i.e. latch with Inverted inputs)





Basic operation of S R flip-flop is as follows:

Case1: When S=R=0: the flip –flop output Q=Q only and Q=$\overline{Q}$ only. This condition is called *NO CHANGE or HOLD* condition.

Case2: When S=1 and R=0:

This input condition makes Q =0 and $\overline{Q}$ =1, This condition is called *SET* condition.

Case3: When S=0 and R=1:

This input condition makes Q=1 and $\overline{Q}$ =0 This condition is called *RESET* condition.

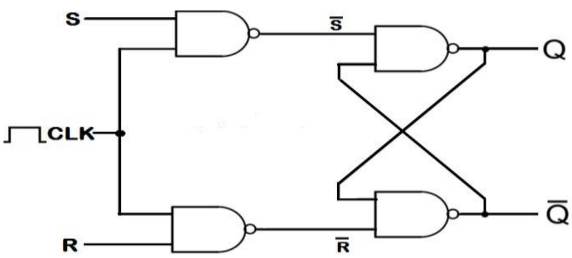
Case4: When S=1 and R=1:

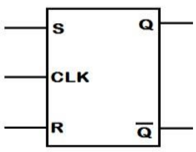
This input condition makes both outputs Q= $\overline{Q}$=1. This condition is called *PROHIBITED* or *INVALID* condition.

the truth table of RS-latch is as shown below

INPUT		**OUTPUT**		**MODE**
S	**R**	**Q**	$\overline{\mathbf{Q}}$	
0	**0**	**Q**	$\overline{Q}$	**NO CHANGE**
0	**1**	**0**	**1**	**RESET**
1	**0**	**1**	**0**	**SET**
1	**1**	**1**	**1**	**INVALID**

Clocked RS-Flip-Flop:





Working:

Basic operation of clocked S R flip-flop is as follows:

Case 1: When CLK=0, S=X and R=X:

When the clock input is low (i.e. CLK=0), the flip-flop is disabled (inactive). Therefore irrespective of the values of S and R inputs the output remains at its previous state. This is called *no change* or *hold* condition.

Case 2: When CLK=1, S=0 and R=0:

When CLK=1, the flip-flop is enabled (i.e. active) and inputs S=0 and R=0 makes the flip-flop remains in its previous state. This is called *NO CHANGE* or *HOLD* condition.

Case 3: When CLK=1, S=0 and R=1:

When CLK=1, the flip-flop is enabled (i.e. active) and inputs S=0 and R=1, the flip-flop produces output Q=0 and Q=1. This is called *RESET* condition

Case 4: When CLK=1, S=1 and R=0:

When CLK=1, the flip-flop is enabled (i.e. active) and inputs S=1 and R=0 makes Q=1 and Q=0. This is called *SET* condition

Case 5: When CLK=1, S=1 and R=1:

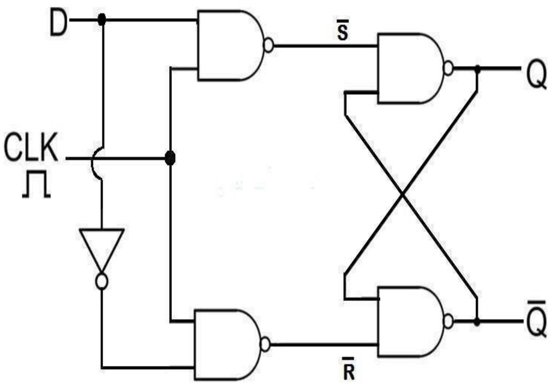
When CLK=1, the flip-flop is enabled (i.e. active) and inputs S=1 and R=1, the flip-flop produces output Q=1 and Q=1. This is called *INVALID* condition.

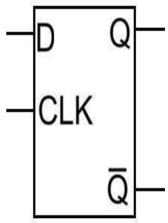
the truth – table of clocked RS – flip-flop is as shown below.

INPUT		**OUTPUT**			
S	**R**	**Q**	$\overline{Q}$	**MODE**	**CLK**
X	**X**	**Q**	$\overline{Q}$	**DISABLED**	**0**
0	**0**	**Q**	Q	**NO CHANGE**	**1**
0	**1**	**0**	**1**	**RESET**	**1**
1	**0**	**1**	**0**	**SET**	**1**
1	**1**	**1**	**1**	**INVALID**	**1**

D – Flip-Flop (Data flip-flop):

It is a single input flip-flop in which the output Q follows the input D. D-flip flop consists of a clocked RS-flip-flop with an inverter (NOT-gate) connected in between the S and R input terminals. It has two complementary inputs and two complementary outputs





Working :

The basic operation of D flip-flop is as follows:

Case 1: When CLK=0 and D=X:

When the CLK=0, the flip-flop is disabled (inactive). As a result there is no change in the output state irrespective of the value of D input.

Case 2: When CLK=1 and D=0:

When CLK=1, the flip-flop is enabled (i.e. active) and D=0 makes S=0 and R=1. Now with S=0 and R=1, the flip-flop output Q=D=0. i.e. output Q follows input D.

Case 3: When CLK=1 and D=1:

When CLK=1, the flip-flop is enabled (i.e. active) and D=1 makes S=1and R=0. Now with S=1 and R=0, the flip-flop output Q=D=1. i.e. output Q follows input D

INPUT		**OUTPUT**	
CLK	**D**	**Q**	**MODE**
0	**X**	**NO CHANGE**	**DISABLED**
1	**1**	**1**	**SET**
1	**0**	**0**	**RESET**

J K FLIP-FLOP:

The JK flip-flop is a type of flip-flop that canoperate in the SET, RESET, HOLD and TOGGLE modes

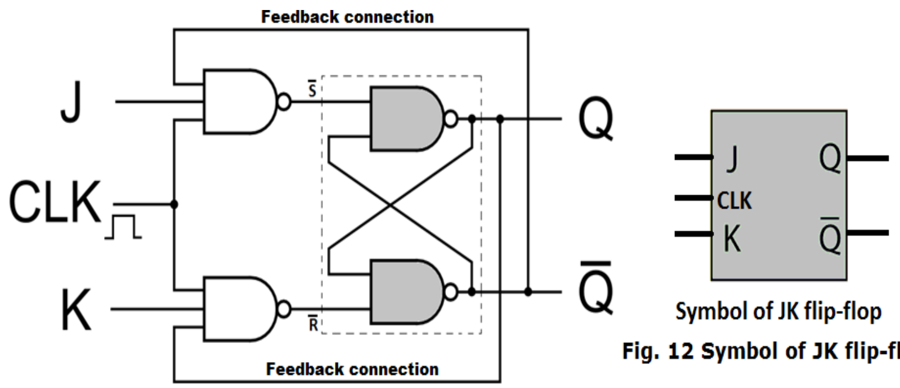


Fig. 12 Symbol of JK flip-flop

Basic operation of J K flip-flop is as follows:

Case 1: When CLK=0, J=X and K=X:

When the clock input CLK=0, the flip-flop is disabled. As a result there is no change in the output state irrespective of the values of J and K input. In the disabled mode, the data inputs J and K have noeffect on the outputs.

Case 2: When CLK=1, J=0 and K=0:

With this input conditions the flip-flop is enabled (i.e. active) and produces the output Q=Q and

$\overline{Q} = \overline{Q}$. i.e. there is no change in the output states. The outputs "hold" the last data present. Thisis called NO CHANGE condition.

Case 3: When CLK=1, J=1 and K=0:

With this input conditions the flip-flop is enabled (i.e. active) and produces the output Q=1 and $\overline{Q}$=0. This is called SET condition

Case 4: When CLK=1, J=0 and K=1:

With this input conditions the flip-flop is enabled (i.e. active) and produces the output Q=0 and $\overline{Q}$= 1. This is called RESET condition.

Case 5: When CLK=1, J=1 and K=1:

With this input conditions the flip-flop is enabled (i.e. active) and produces the output Q= $\overline{Q}$ and

$\overline{Q}$ = Q. i.e. output changes to their opposite state. This is called *TOGGLE* condition.

Truth table and timing diagram of JK flip-flop is as shown below

INPUT		OUTPUT			
J	K	Q	$\bar{Q}$	MODE	CLK
X	X	Q	$\bar{Q}$	DISABLED	0
0	0	Q	$\bar{Q}$	NO CHANGE	1
0	1	0	1	RESET	1
1	0	1	0	SET	1
1	1	Q	Q	TOGGLE	1

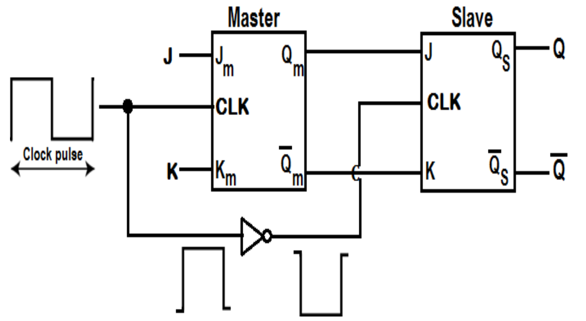
Race around condition: In JK flip flop when J=1, K=1 and clock pulse width is too wide compared to propagation delay time of the flip-flop

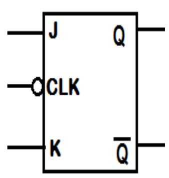
(i.e. TW>>TP),then repeated toggling occurs and results in unpredictable output condition. This is called race around condition.

Race around condition can also be avoided by using a JK master slave flip-flop.

Master Slave JK Flip-Flop:

A master salve flip-flop is a series combination of two JK flip-flops which eliminates race around Problem of JK flip-flop





T – flip – flop(Toggle Flip-flop):

A Flip-flop which operates only in no change and toggle mode is called T–flip-flop**.**

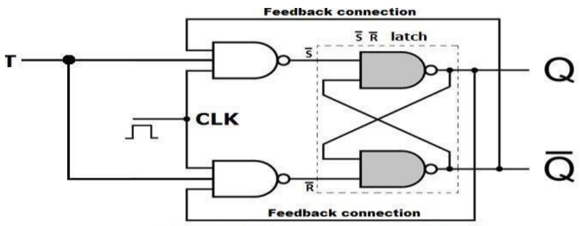


Fig.15 T-flip-flop using JK flip-flop

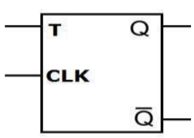


Fig.16 symbol of T-flip-flop

Working:

Case1: When the clock input CLK=0 and T=X:

With CLK=0, the flip – flop is disabled and does not responds to its T input. As a result the output remains unchanged irrespective of the T-input.

Case2: When the clock input CLK =1and T = 0:

With CLK=1, the flip-flop is enabled and T=0 makes J=0 and K=0. As a result the output of the flipflop remains unchanged.

Case3: When the clock input CLK =1and T = 1:

With CLK=1, the flip-flop is enabled and T=1 makes J=1 and K=1. As a result the output of the flipflop *toggles* (i.e. output changes to its opposite state).

Truth-table ofT flip-flop is as follows:

INPUT		**OUTPUT**	
CLK	**T**	**Q**	**MODE**
0	**X**	**NO CHANGE**	**DISABLED**
1	**1**	$\overline{Q}$	**TOGGLE**
1	**0**	**0**	**NO CHANGE**

Mobile communication:

The communication between the moving transceivers is called as mobile communication

Basic components ofcellular communication system:

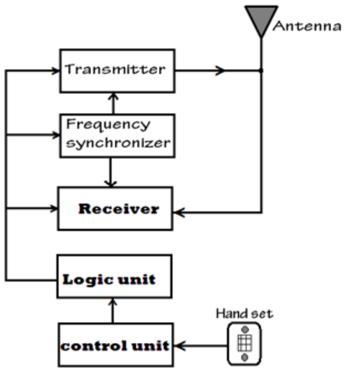
The components of cellular communication system are:

- . Hand set [Mobile unit or mobile station unit]
- . Cell site (or) Base station
- MTSO [MSC]
- PSTN
- . Operating frequencies

. Hand set:

A cell phone hand set is actually a radio transceiver. Using this instrument, even while on move, it can easily get a call or make a call to a land phone or another cell-phone subscriber and converse. Here, all mobile hand sets are having its own individual number so that it can be addressed from any other phone.

The hand set unit consists of five major sections; transmitter, receiver, synthesizer, logic unit, and control unit as shown in fig below.

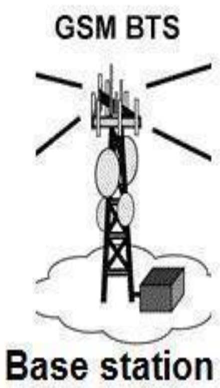


General block diagram of a cellular mobile radio unit

2.Base station (cell site):

In cellular telephone system or mobile system each cell has its own low power transmitter and receiver called a base station.

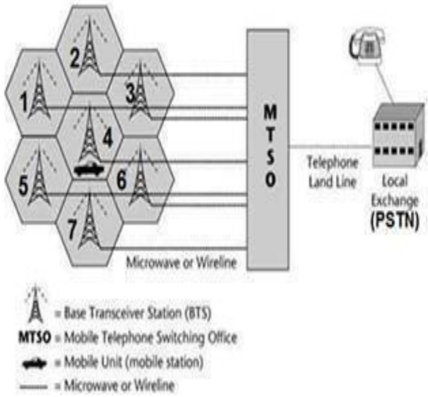
Each base station has low power transmitter and receivers, interface equipments and antenna systems. Antennas for these cell stations are located from where they can operate most effectively. In city areas, they may be put on top of tall buildings. Rural cell sites may be located on large hills or mountains, from where the best radio coverage can be obtained.



Mobile telephone switching office (MTSO):

In mobile communication system the cells (base stations) in a city are connected by a wire or by microwave link to a computer controlled master station called MTSO or MSC.

MTSO is the centre of all operations relating to mobile communication system (i.e. MTSO manages the overall functioning of the system) as shown in fig below. The MTSO controls all the cells and provides the interface (link) between each cell and the main telephone office. It also makes decisions about when to "hand off" the mobile unit (or call) to another cell to maintain optimum signal strength.



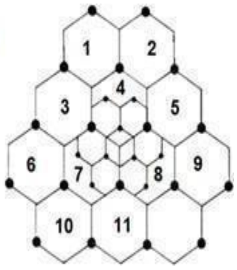
Note: the cell phones communicate with each other through base stations via the MTSO.

Note: In mobile communication system all base stations and the master station are controlled by computers.

2. Cell splitting: The process of subdividing an existing cell into smaller cells is called as cell splitting.

(OR)

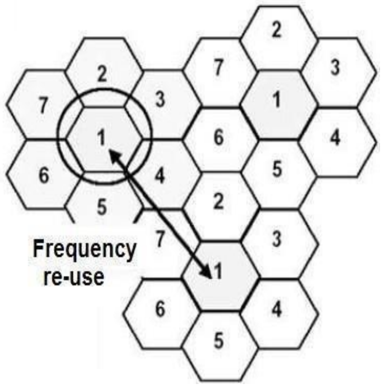
It is the process of subdiving highlty congested (i.e. crowded) cells into smaller cells.



4. Frequency reuse: It is the process in which the same set of frequencies can be allocated to more than one cell, provided the cells are seperated by sufficient distance.

(OR)

It is a process which allows cells within the system to use the same frequency channel.



.Call hand-off (call hand-over or hand-off)

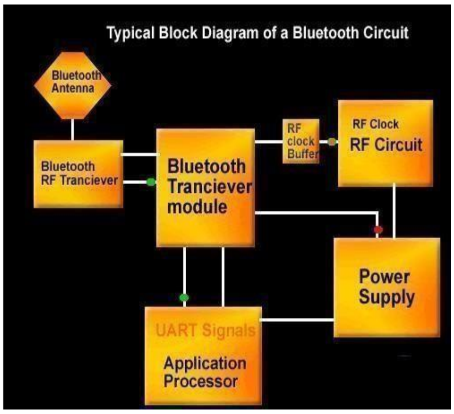
It is the process of transferring mobile call from one base station's control to another base station's control automatically without interrupting the call when a mobile user move into different cell whilea conversation is in progress

Bluetooth: It is a wireless technology to send and receive data between Bluetooth enabled devices within a small area (within 10mts). **OR** Bluetooth is a short-range (~10mts or 30 foots) wireless technology that allows both voice and data to be transmitted between electronic devices.

Block diagram of a Bluetooth circuit:

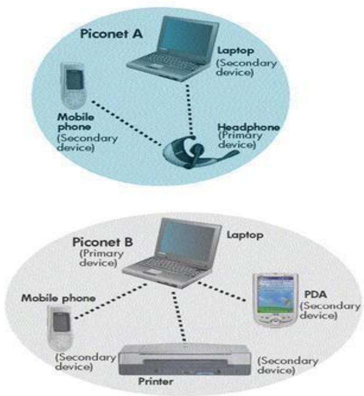
The Bluetooth standard, like WiFi, uses the **FHSS technique** (***Frequency-Hopping Spread Spectrum***), which involves splitting the frequency band of 2.402 to 2.480 GHz into 79 channels (called *hops*) each 1MHz wide, then transmitting the signal using a sequence of channels known to both the sending and receiving stations.

Thus, by switching channels as often as 1600 times a second, the Bluetooth standard can avoid interference with other radio signals.



What is piconet ? How is it related to Bluetooth?

One merit of Bluetooth technology is that it allows more than two devices to be sharing information at the same time. ***In Bluetooth technology when more than two electronic devices enter into the process of sending and receiving data they form a small network like that of a computer network. Such a micro-network of electronic devices is called a Piconet.*** In a piconet, there will be more than two devices. The maximum number of devices that a single piconet can accommodate is seven. Any one of these devices acts as the superior device, or the Master device. It is the master device that initiates the action, or "give the order to begin" the action. The other devices are known as slave units. They act according to the instructions given by the Master unit. A Bluetooth device can either act as the Master or as the Slave, depending upon the situation. A device can enter a piconet and leave a piconet. When more than one piconets join together, it is termed a scatternet.



Wi-Fi:

Wi-Fi is the technology of using broadband internet connection without wires. OR A wireless local area network that uses radio waves to connect computers and other devices to the Internet. OR Wi-Fi is a term for certain types of wireless local area networks (WLAN) that use specifications in the 802.11 family. Products that pass the Wi-Fi Alliance tests for interoperability, security and application-specific protocols are labeled "Wi-Fi CERTIFIED," a registered trademark of the Alliance. Wi-Fi radios transmit signals at 2.4 GHz or 5 GHz. These high frequencies allow the signal to carry more data.

Hotspot:

Places where Wi-Fi connection is available are called hotspots.

Comparison of Bluetooth and Wi-Fi:

	Bluetooth	Wifi
Bandwidth:	Low	High
Hardware requirement:	Bluetooth adaptor on all the devices connecting with each other	Wireless adaptors on all the devices of the network, a wirelessrouter and/or wireless access points
Ease of Use:	Fairly simple to use. Can be used to connect upto seven devices at a time. It is easy to switch between devices or find andconnect to any device.	It is more complex and requires configuration of hardware and software.
Primary Devices:	Mobile phones, mouse, keyboards, office and industrial automation devices	Notebook computers, desktop computers, servers
Range:	10 meters	100 meters
Security:	**More secure than Wifi as it covers shorter distances and has a 2 level password protection**	Less secure. It has all the risks associated with any other network. If someone accesses one part, the rest can also be accessed
Power Consumption:	Low	High
Frequency:	2.4 GHz	2.4 GHz

Satellite communication system:

It is an earthorbiting device (in space) that relays communication signals over long distances.

Communication satellite:

A communication satellite is a microwave repeater station in space that permits (allows) two or more users to deliver or exchange information simultaneously.

Geostationary (OR) Geosynchronous satellite:

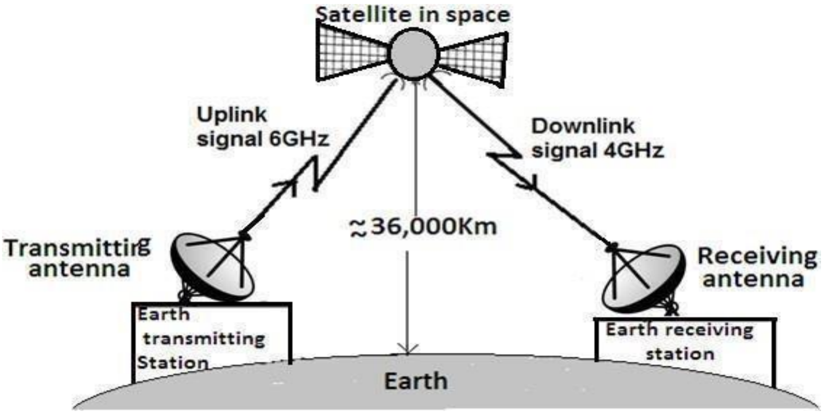
A satellite that takes 24 hours to revolve around the earth and appears to remain fixed for an observer on the earth is called as geostationary satellite

Applications of Geostationary satellite:

Most communication satellites today are geostationary satellites. Various application specific areas ofgeostationary satellites are given below.

- Television broadcasting.
- Regional, national and international global communications.
- Telephone and data circuits.
- Mobile telephone services.

- Militaryapplications.
- Private networks for corporations, government agencies.

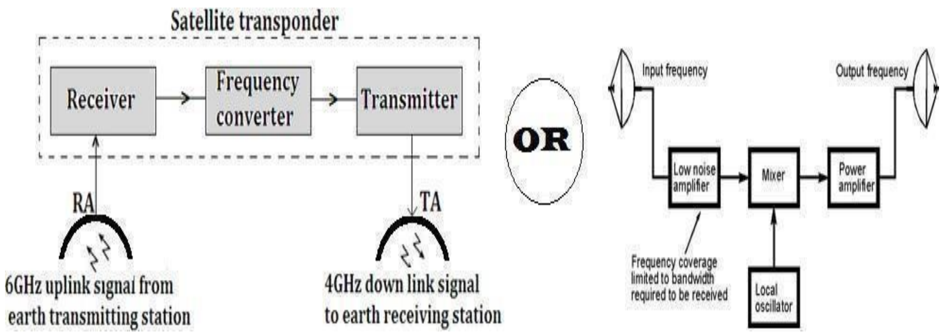


Uplink and downlink system:

The signal transmitted by the transmitting station on earth to satellite is called *uplink signal.* A typical uplink signal frequency is 6GHz.

The signal retransmitted from satellite to the receiving station on earth is called downlink signal. A typical *downlink signal* frequency is 4GHz.

The satellite transponder:



Transponder basically consists of a low noise amplifier, a frequency changer consisting of a mixer and local oscillator, and then a high power amplifier. The satellite transponder receives the 6 GHz uplink transmission from the earth transmitting station, amplifies the weak uplink signals and changes it to another new frequency known as downlink frequency which is 4GHz. This signal after power amplification is transmitted from the satellite back to the earth receiving station for relaying todifferent receiving station**s.**

Types of computer network:

Based on their coverage area (geographical area), networks can be classified into the followingcategories**:**

- **LAN (Local Area Network):**

LAN is a computer network that connects computers located within a small area (such as computers within a building, office, campus etc).

- **MAN (Metropolitan Area Network):** MAN is a computer network that connects computers located in the same geographical area such as a city or a town.
- **WAN (Wide Area Network):**

WAN is a computer network which connects computers located in different geographical area (such as across the country or around the world)

Internet:
A worldwide computer network is called internet.

Uses of Internet:

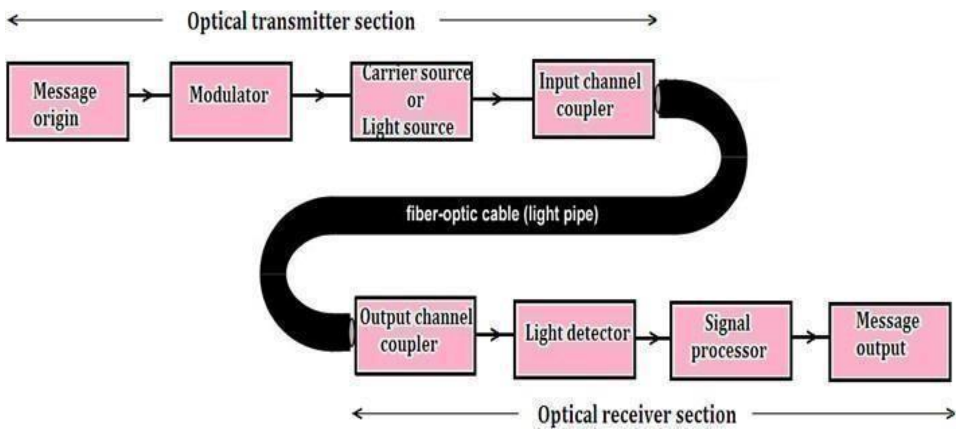
- Internet is used mainly in the following works:
- It is used for sending and receiving e-mails by companies and individuals.
- It is used for finding and circulating information on all subjects.
- It is used for communication, entertainment and playing on-line games.
- It is used for e-commerce (i.e. for advertisement, promoting business, selling and
- buying services and products).
- Used for on-line employment
- Used for videoconferencing, chatting and other such communication activities.
- For on-line ticket reservation.
- For on-line banking (e-banking).

Universal Resource Locator (URL):
URL stands for Universal Resource Locater. It is complete address ofa website on the Internet.
www (web): www stands for world wide web. It is the electronic library on the Internet that provides us with lots of information.

Electronic Mail (E-Mail):
The electronic way of sending and receiving messages (i.e. files or mail) through computer network is known as E-mail.

Fiber optic communication system:
An optical fiber is a solid, flexible, transparent, cylindrical rod made of ultra pure glass (silica) or plastic and is about as thick as human hair. Optical fibers are so constructed that they carry light form a source at one end of the optical fiber to a detector at its other end.

Blockdiagramofoptical fiber communication system



Applications of fiber optic communication:

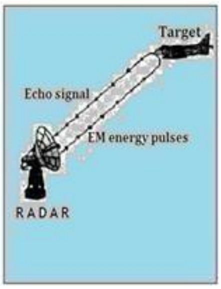
RADAR:

Radar is the short form of Radio Detection And Ranging. It is a complete electronic system used to gather information (such as location, distance, direction, height and speed) about distant objects (target) by transmitting EM signals towards the object and analyzing the received reflected signal (called as echo signal).

Conventional radars operate in upper UHF and microwave ranges (100MHz to 36GHz). But now-a-days, radars operate at frequencies as low as few MHz also, The radars are ezxperimented at millimeter wave i.e. frequencies above 110GHz. In radar system distance is measured in nautical mile or radar mile.

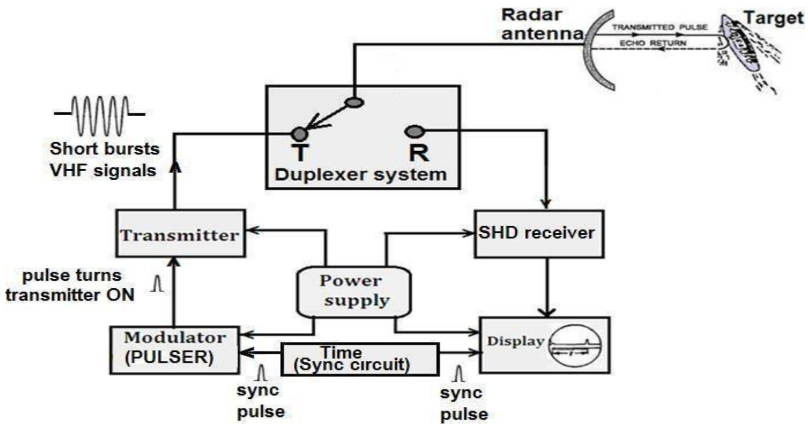
1 nautical mile = 1852 meters
1 radar mile = 6000 feet

* Radar mile is commonly used



$$\text{Distance} = \frac{(\text{Velocity of EM signal}) \times (\text{Two-way time})}{2}$$

Block diagram of basic Radar system:



Applications of radar:

- Aiming guns at ships and aircrafts
- Locating ships
- Giving warning regarding approaching aircraft or ships.
- Landing of planes in bad weather conditions
- Searching submarines
- Safety navigational applications
- Used in defense weapons systems
- Police use radars to detect the speed of passing (moving) vehicles
- Militaryuse these for surveillance and directed guided missiles.
- Geologists use radarsto map the earth and other planets.

Govt of Karnataka

Dept of Pre University EducationII PUC

ELECTRONICS (40)

Blueprint* for Model Question Paper – 2022-23 onwards

Sl. no	**Name of the chapter**	**Knowledge and Understanding**				**Applications and skill**				**Total Marks**
	Marks→	1	2	3	5	1	2	3	5	
1	Field Effect Transistor (FET)	√√		√						**05**
2	Transistor Biasing	√√	√							**04**
3	Transistor Amplifiers	√√	√		√				√	**14**
4	Feedback in Amplifiers	√		√			√			**06**
5	Operational Amplifiers	√			√	√			√	**12**
6	Oscillators	√		√			√	√		**09**
7	Wireless Communication	√		√						**04**
8	Modulation and Demodulation	√√		√	√				√	**15**
9	Power Electronics and its applications	√	√					√		**06**
10	Digital Electronics	√√	√		√	√		√	√	**18**
11	Microcontroller	√	√		√					**08**
12	C Programming	√	√		√					**08**
13	Modern Communication Systems	√	√	√						**06**
Total		**80**				**35**				**115**

Parts	Marks per Question	Total Questions given including choices	Questions to be answered
Part A – I (MCQ) Part A – II (Fill in the Blanks)	1 1	15Q×1M = 15 5Q×1M = 05	15Q×1M = 15 5Q×1M = 05
Part B - III	2	9Q×2M = 18	5Q×2M = 10
Part C - IV	3	9Q×3M = 27	5Q×3M = 15
Part D - V	5	10Q×5M = 50	5Q×5M = 25
		115	70

ST.CLARET PRE UNIVERSITY COLLEGE

II PUC- ELECTRONICS (40) MODEL QUESTION PAPER

Time: 3 Hour 15 min **Max. Marks: 70**

Instructions:

1. **The question paper has four parts A, B, C and D.**
2. **Part - A is compulsory.**
3. **Part - D consists of essay type questions and problems together.**
4. **Circuit diagrams, timing diagrams and truth tables must be drawn wherever necessary.**
5. **Solve the problems with necessary formulas.**

PART A

I. Select the correct answer from the choices given: **15 x 1 = 15**

1. Name a unipolar device.
   a) Diode b) BJT c) FET d) TRIAC
2. For faithful amplification the operating point is chosen at the
   a) Centre of the active region b) Cut off region c) Saturation region d) Inversion region
3. What is the phase difference between input and output of a transistor CB amplifier? a) 0^0 b) 60^0 c) 90^0 d) 180^0
4. What happens to the input impedance of an amplifier when voltage series negative feedback is applied?
   a) Remains same b) Increases c) Decreases d) Oscillates
5. Virtual ground concept relates voltage at the inverting terminal VA to the voltage at non- inverting terminal VB by the relation
   a) VA > VB b) VA - VB = 0 c) VA < VB d) VA - VB = 1
6. Mention the output of an integrator if the sine wave is given to its input.
   a) Cosine wave b) Sine wave c) Square wave d) Triangular wave
7. Mention the high frequency stability oscillator
   a) Crystal oscillator b) Hartley oscillator c) Wein bridge oscillator d) Colpitts oscillator
8. Which layer of the ionosphere is called Kennelly-Heaviside layer?
   a) D layer b) E layer c) F1 layer d) F2 layer
9. How many sidebands present in AM?
   a) 1 b) 2 c) 3 d) ∞
10. A SCR has
   a) Two junctions and three layers b) Three junctions and three layers
   c) Three junctions and four layers d) Four junctions and three layers
11. Gray code is used in shaft position
   a) Multiplexer b) decoder c) encoder d) de-multiplexer
12. the output of XOR gate is HIGH when
   a) both inputs are high b) when anyone input is high c)when both inputs are low d) none of these
13. How many timers are present in 8051 microcontroller?a) 1 b) 2 c) 3 d) 4
14. Size of an integer in C programming is
   a) 1 byte b) 2 bytec) 4 byted) 8 byte
15. Shapes of cells in mobile network operation system is
   a) Octagonalb) Circular c) Oval d) Hexagonal

Fill in the blanks by choosing appropriate answer fromthose given in the bracket: 5×1=5
[a) data b) modulation c) biasing d) impedance e) switching speed]

16. FET has high ……………….
17. Application of suitable voltage across the terminals of a transistor is called ……………
18. CC amplifier is used to match …………
19. Process of changing some characteristics of carrier in accordance with instantaneous value of the signal is called ………
20. Flip-Flops are used to store ………...

PART B

II. Answer any FIVE questions: 5 x 2 = 10

21. Mention any two advantages of voltage divider biasing.
22. Write the steps involved in drawing DC equivalent circuit ofan amplifier.
23. Calculate gain ofa negative feedback amplifier with an internal gain, A = 100 andfeedback factor β= 0.1.
24. Determine frequency of Hartleyoscillator. Given L_1 = 4 mH, L_2 = 2 mH and C =10 nf
25. Compare forward characteristics of power diode for two different junctiontemperatures.
26. Write minterm designation table for two input variables.
27. Write anytwo comparisons between Microprocessor and Microcontroller.
28. Mention any four operators used in C programming.
29. Distinguish between uplink and downlink signals.

PART C

III. Answer any FIVE questions: 5 x 3 = 15

30. Obtainthe relations between FET parameters.
31. Give any three differences between positive feedback and negative feedback.
32. Draw the circuit diagram of phase shift oscillator. Write the expression for its frequencyof oscillations.
33. Determine frequency oftank circuit having L = 1 μH and C = 0.01 μF.
34. Draw the block diagram of basic communication system and explain the function ofeach block.
35. Explain diode detector circuit.
36. Determine V_{dc} and I_{dc} of SCR HWR. Given firing angle is 90^0 and rms voltage of ac inputto the rectifier is 230 V and load is 10 Ω.
37. What is half-adder? Draw the logic diagram of half adder using only NAND gates.
38. What is Internet? Mention the important techniques used for Bluetooth operation.

PART D

IV. Answer any FIVE questions: 5 x 5 = 25

39. With a neat circuit diagram explain the working of two stage RC-coupled amplifier.

40. With the circuit diagram derive an expression for output voltage of three input op-ampadder.

41. Derive an expression for instantaneous voltage equation of AM wave.

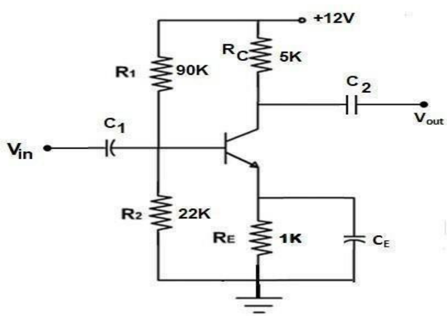
42. Prove the universal properties of the NOR gate.

43. Write an assembly language program to add two numbers 1FH and B4H and store the resultin R0. Verify the result by binary addition.

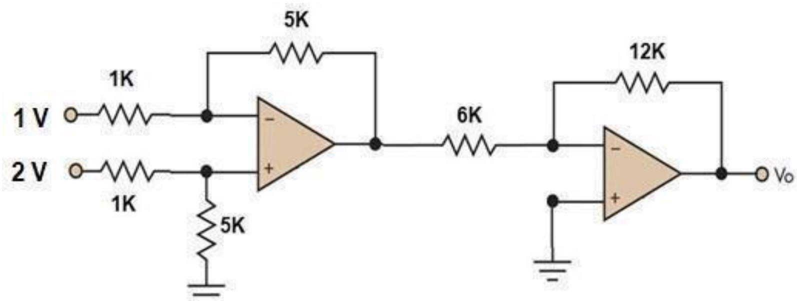
44. Write a c-programto accept the three integers and print the largest amongst them.

45. Calculate the voltage gain, input impedance and output impedance in the circuitgiven below.

Given β = 100 and re' =26mV/IE· .



46. Find the output voltage in the op-amp circuit given.



47. A 10 kW carrier wave is amplitude modulated at 80% depth of modulation by a sinusoidalmodulating signal. Calculate the total power and side band power of the AM wave.

48. Simplify the Boolean expression Y = Σm (1, 3, 5, 7, 13, 15) + Σd (0, 12, 14) usingK- map. Draw the NAND Gate equivalent circuit to realize the simplified equation.

*****

ST.CLARET PRE UNIVERSITY COLLEGE

II PUC- ELECTRONICS (40) MODEL QUESTION PAPER

Time: 3 Hour 15 min **Max. Marks: 70**

Instructions:

6. **The question paper has four parts A, B, C and D.**
7. **Part - A is compulsory.**
8. **Part - D consists of essay type questions and problems together.**
9. **Circuit diagrams, timing diagrams and truth tables must be drawn wherever necessary.**

Solve the problems with necessary formulas

PART – A

I. Select the correct answer from the choices given **1 × 15 = 15**

1. Unitless parameter of JFET is

(A) Drain resistance (B) Trans-conductance

(C) Amplification factor (D) None of these

2. The operating point is also called as

(A) Cut-off point (B) Quiescent point (C) Saturation point (D) Pinch-off point

3. Small signal amplifiers are also called as

(A) Voltage amplifies (B) Power amplifiers

(C) Class B amplifier (D) Buffer amplifiers

4. What happens to the bandwidth of an amplifier when negative feedback is applied?

(A) Remains same (B) Increases (C) Decreases (D) Oscillates

5. Slew rate is expressed in

(A) V/μS (B) μS/V (C) A/mS (D) Ω/μS

6. The feedback component of op-amp differentiator is

(A) Resistor (B) Capacitor (C) Inductor (D) Diode

7. Name the oscillator which does not produce phase shift in feedback path

(A) Phase shift oscillator (B) Wein bridge oscillator

(C) Crystal oscillator (D) Hartley oscillator

8. The layer of atmosphere which reflects the radio waves is

(A) Troposphere (B) Stratosphere (C) Mesosphere (D) Ionosphere

9. The intermediate frequency in AM radio receiver is

(A) 455 Hz (B) 455 KHz (C) 455 MHz (D) 455 GHz

10. Identify bidirectional semi-conductor controlled device

(A) Power Diode (B) Power Transistor (C) SCR (D) TRIAC

11. Gray code is used in shaft position

(A) decoder (B) multiplexer (C) encoder (D) register

12. Logic expression for the output of two input XNOR gate is

(A) $Y = AB$ (B) $Y = A + B$ (C) $Y = \overline{A}$ (D) $Y = \overline{A \oplus B}$

13. Microcontroller chip contain

(A) RAM (B) ROM (C) Timer (D) All of these

14. Size of a float data type in C programming is

(A) 1 byte (B) 2 bytes (C) 4 bytes (D) 8 bytes

15. The data range of Wi-Fi is up to

(A) 100 meter (B) 1 kilometer (C) 500 meter (D) 1000 meter

II. Fill in the blanks by choosing appropriate answer from those given in the bracket **1 × 5 =5**

(current, twice, race around condition, high, stabilization, quad)

16. FET has a_____________switching speed.

17. The process of making the operating point independent of transistor parameters is known as______________.

18. CC amplifier has the highest_____________gain.

19. In Amplitude modulation bandwidth is_____________the modulating signal frequency.

20. ____________is the disadvantage of JK flip-flop.

PART B

III. Answer any FIVE of the following questions **5 × 2 = 10**

21. Mention the biasing conditions for a transistor to operate in active region.

22. Write the steps involved in drawing DC equivalent circuit of an amplifier.

23. Calculate the gain of a negative feedback amplifier with an open loop gain A = 100 and feedback factor $\beta = \frac{1}{10}$

24. A RC phase shift oscillator has $R_1 = R_2 = R_3 = R = 10\ k\Omega$ and $C_1 = C_2 = C_3 = C = 0.047\ \mu F$..Determine frequency of oscillations.

25. Write Shockley's diode equation for current through the power diode and explain its terminology.

26. Write the logic diagram of D flip-flop

27. Briefly explain register addressing mode.

28. Name any four operators used in C programming.

29. Mention the important techniques used in Bluetooth operation

PART – C

IV. Answer any FIVE of the following questions **$5 \times 3 = 15$**

30. Mention the differences between FET and BJT
31. Define the terms open loop gain, closed loop gain and feedback fraction.
32. What is an oscillator? Mention Barkhausen criterion.
33. Determine the frequency of oscillations of a Hartley oscillator when $L_1 = 2$ mH, $L_2 = 4$ mH and C = 10 nF.
34. Draw the block diagram of a communication system and explain the function of each block.
35. Draw the frequency spectrum of an AM wave.
36. Determine V_{dc} and I_{dc} of SCR FWR. Given firing angle is 0° and rms voltage of ac input to the rectifier is 230 V and load is 20 Ω.
37. Convert $(1010)_G$ into binary number using XOR gates.
38. What is RADAR? Mention its two applications.

PART – D

(Section – I)

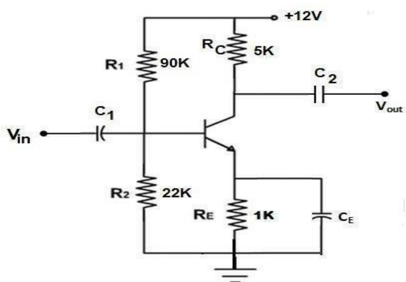
V. Answer any THREE of the following questions **$3 \times 5 = 15$**

39. With circuit diagram explain the working of CB amplifier.
40. Derive an expression for output voltage of op-amp non inverting amplifier.
41. Derive an expression for modulation index for AM in terms of V_{max} and V_{min}
42. What is full adder? Realize full adder using block diagrams of two half adders and an OR gate. Write the truth table of full adder.
43. Write an assembly language program to subtract 35 H from 4 AH and save the result into register RO. Verify the content of RO after executing the program.
44. Write a C program to accept the three different integers and print the largest amongst them.

(Section – II)

VI. Answer any TWO of the following questions **$2 \times 5 = 10$**

45. For the CE amplifier circuit , find (a) DC voltage across 10 kΩ, (b) I_E (c) r_e (d) $Z_{in(base)}$ (e) Z_0. Given $r'_e = \frac{26mV}{I_E}$ and $\beta = 100$,



46. Design an op-amp circuit to realize the output, $V_o = -(3V_1 + 2V_2 + V_3)$. Assume $R_F = 10\ k\Omega$. Determine output voltage when $V_1 = 1$ V, $V_2 = -2$ V and $V_3 = 2$ V.
47. The carrier current of an AM transmitter is 8 A, it increases to 8.65 A when the carrier is amplitude modulated. Find the percentage modulation. Determine the antenna current I. when the depth of modulation is 0.75 if carrier current remains same.
48. Simplify the Boolean expression $Y = \sum m(0, 2, 4, 8, 10) + \sum d(12, 14)$ using K-map: Draw the NAND gate equivalent circuit to realize the simplified equation.