ANALOG ELECTRONICS & LINEAR IC

OF 4TH SEMESTER

FOR ELECTRONICS & TELECOMMUNICATION ENGINEERING COURSE

LECTURE NOTE

PREPARED BY

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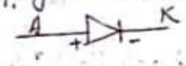
S. No.	Date	Title	Page No.	Teacher's Sign / Remarks

WORKING PRINCIPLE OF DIODE:-

→ It's function is to let electric current flow in one direction but to prevent flow in the opposite direction.

→ This is a very useful and important property. This function is similar to hydraulics.



CURRENT EQUATION OF DIODE:-

→ The diode current equation expresses the relationship between the current flowing through the diode as an function of the voltage applied across it.

$$I = I_0\left(e^{\frac{qV}{\eta KT}} - 1\right) \text{------} (1)$$

Where,

I is the current flowing through the diode

I_0 is the dark saturation current,

q is the the charge on the electron

V is the voltage applied across the diode,

η is the (exponential) ideality current.

$K = 1.38 \times 10^{-23}\ JK^{-1}$ is the Boltzman Constant

T is the absolute temperature in Kelvin.

→ In this equation, two parameters requires to be discussed in quite detail.

→ They are I_0, the dark saturation current and η, the (exponential) Ideality factor.

→ Dark saturation current (I_0) indicate the leakage current density flowing through the diode in the absence of light (hence, dark).

→ This parameter is the characteristics of the diode under consideration and indicates the amount of recombination which occurs within it.

→ That is, I_o will be larger for a diode in which recombination rate is higher and vice-versa. Further, its value is also seen to be directly proportional to the absolute temperature and inversely proportional to the material quality.

η, the (expotential) Ideality Factor

→ η, the (expotential) Idality factor indicates the nearness with which the considered diode behaves with respect to the ideal diode.

→ That is, if the diode under consideration behaves exactly that of an ideal diode, then η will be 1(one). Its value increase from 1 as the difference between the behaviors of the ideal diode and diode under consideration increases greater in the deviation, greater is the value of η.

→ The value of η is typically considered to be 1 for germanium diodes and 2 for sillicon diodes.

→ However, its exact value for the given diode depends on various factors like electron drift, diffusion, carrier recombination which occurs within the depletion region, its doping level, manufacturing technique and the purity of its materials.

→ In addition to, its value is also seen to vary with the value of voltage and current levels. Nevertheless, in the most of the cases, its value is found to be within the range 1 to 2.

→ In forward biased condition, there will be a large amount of current flow through the diode. Thus the diode current equation (equation 1) becomes

$$I = I_o e^{\frac{qV}{\eta KT}}$$

→ On the other hand, if the diode is reverse biased, then the exponential term in equation (1) becomes neglegible. Thus we have

$$I = -I_o$$

SPECIFICATION AND USE OF P-N JUNCTION DIODE:-

→ The material the diode is made of:-

This could be sillicon or Germanium or Selerium or any other semiconductor materials. This is important because the cut in voltage depends upon the material the diode is made of. For example, in Ge diodes the cut-in voltage is around 0.3V, whereas in sillicon diodes the cut-in voltage is around 0.7V.

→ Maximum safe reverse voltage:-

It is denoted as V_R or V_r that can be appllid across the diode. This is also known as Peak-inverse-voltage or PIV. If a higher reverse voltage than the rated PIV is applied across the diode, it will become defective permanently.

→ Maximum average forward current:-

I_F or I_f, that a diode can flow through it without getting damaged.

→ Forward voltage drop V_F or V_f:-

That appears across the diode when the maximum average current, I_f flows through it continuously.

→ Maximum reverse current:-

I_{vr} that flows through the diode when the maximum reverse voltage, PIV is applied

→ Maximum forward surge current:-

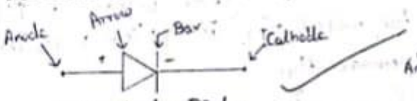
I_s that can flow through the diode for a defined short period of time.

→ The above specifications go with all rectifier diodes. As all the specifications cannot be printed on physical small sized diodes, the diodes are printed with a type of number instead

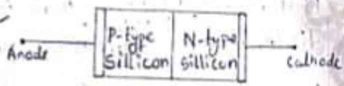
When this type of number is refered to in the manufacturer's manual the detailed specifications for a particular type number of the diode can be obtained.

→ **Uses of Diodes:-**

- The Junction which is the p-n junction diode can be use as a photo diode, the diode which is sensitive to the light when the configuration of the diode is reverse-biased.
- It can be used as a solar cell.
- When the diode is forward-biased, it can be used in LED Lighting application.
- We can see that it is also used as a rectifier in many electric circuits. and as a voltage controll oscillator in Varactors.



Semiconductor Diodes

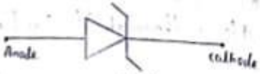


P-N Junction diode

ZENER DIODE:-

INTRODUCTION:-

→ A zener diode is a special type of diode that is designed to operate in the reverse breakdown region.



Zener diode

→ The ordinary rectifier and small signal diodes are never intentionally operated in the break down region because they may be damage them.

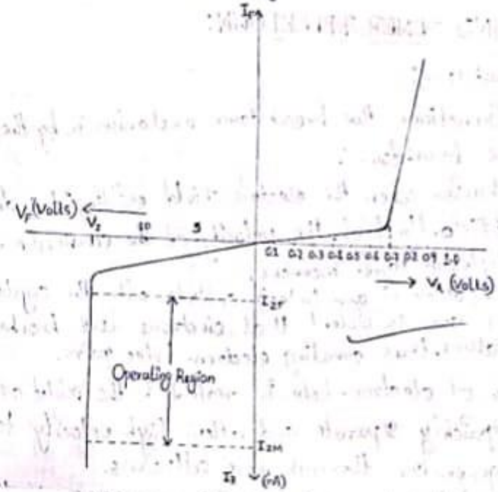
→ On the other hand, zener diodes are only operated in the breakdown region. There fore, zener diodes are cryptically designed to have a sharp breakdown voltage as shown in the figure below.

→ By varying the doping level of sillicon diode, a manufacterer can prodcece zener diodes with breakdown voltage from

2 to 200V.

→ The figure above shows schematic symbol of a zener diode: It is similar to the ordinary crystal diode except that it's bar is just turned into z-shape.

→ It is a specially designed sillicon diode which is optimised to operate in the breakdown region.



V.I. Characteristics of a zener diode.

CHARACTERISTIS OF A ZENER DIODE:-

The V.I characteristics of a zener diode are shown in the above figure.

(i) It's characteristics are similar to the ordinary rectifier diode with the exception that it has a sharp or distinct breakdown voltage called "zener break down voltage" V_z.

(ii) It can be operated in any of the three regions i.e forward, Leakage or breakdown. But usually it is operated in breakdown region.

(iii) The voltage is almost constant (V_Z) over the operating region.
(iv) Usually the value of the V_Z at the particular test current I_{ZT} is specified in the data sheet.
(V) During operation it will not burn as long as the external circuit limits the current flowing through it below the burnout value i.e I_{ZM} (the maximum rated zener current).

AVALANCHE AND ZENER BREAKDOWN:-

Avalanche Breakdown:-

→ For thicker junctions the breakdown mechanism is by the process of "avalanche breakdown".
→ In this mechanism, when the electric field existing in the depletion layer is sufficiently high, the velocity of the carriers (minority carrier) crossing the depletion layer increses.
→ These carriers (electrons and holes) collide with the crystal atoms. Some collisions are so violent that electrons are knocked off the crystal atoms, thus creating electron-holes pairs.
→ As the pair of electron-hole is created in the midst of the high field, they quickly separate and attain high velocity to cause further pair generation through more collisions.
→ This is a cumulative process and as we approach the breakdown voltage, the field become so large that chain of collisions can give rise to an almost infinite current with very slight additional increase in voltage. This process is known as "avalanche breakdown".
→ Once this breakdown occurs the junction can not regain it's original position. Thus the diode is said to be burnt-off.

Zener Breakdown:-

→ Zener breakdown takes place in a very thin junction ie, when both side of the junction are heavily doped and consequently the depletion layer is narrow.
→ In the zener breakdown mechanism, the electric field becomes as high as 10^7 V/m in the depletion layer with only a small applied reverse biased voltage.
→ In this process it becomes possible for some electrons to jump across the barrier from the valence band in p-material to some of the unfilled conduction band in n-material. This process is known as "zener breakdown."
→ In this process, the junction is not damaged. The junction regains to it's original position when the reverse voltage is removed. This process is used in the zener diodes.
→ However, if the number of the electrons jumping across the barrier (i.e flow of current) increases beyond the rated capacity of the zener diode, then avalanche breakdown takes place which destroys the junction.
→ Thus, it is concluded that zener break down does not result in the destruction of diode, as long as current through the diode is limited by the external circuit to a level with in it's power handling capabilities, whereas, the avalanche breakdown destroys the diode.

USE OF CRYSTAL DIODE IN RECTIFIERS:-

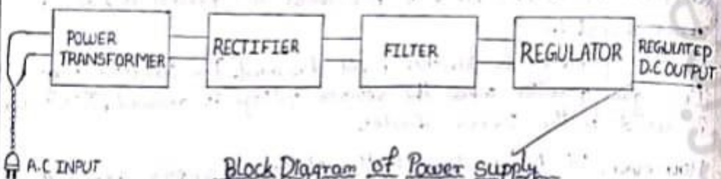
→ The electrical power is generated, transmitted and distributed as A.C for economical reasons.
→ As such an alternating voltage is available at the mains. But most of the electronic circuits needs d.c voltage for their operation.
→ Therefore, now-a-days almost all electronic equipment include a circuit that converts a.c voltage of mains supply into d.c voltage. This part of the equipment is called "power supply."

Power Supply:-

→ The block diagram of a power supply is shown in the figure below.

→ Generally, at the input point of the power supply, a transformer is used to step down the voltage as per need and known as "power transformer." It is allowed by a diode circuit called "rectifier."

→ The pulsating d.c output of a rectifier is fed to the filter circuit which removes the pulsation and smooth it out. At the end a regulator is used to obtain regulate d.c at the output.



Block Diagram of Power supply

→ The rectifier circuit is the heart of a power supply. The following two rectifier circuits are generally used:-

(i) Half-wave rectifier

(ii) Full-wave rectifier

HALF-WAVE RECTIFIER:-

→ In half-wave rectification, when a.c supply is applied at the input, only positive half cycle appears across the load, whereas, the nagative half cycle is suppressed.

Circuit:-

→ For half wave rectification, only one crystal diode is used. It is connected in the circuit as shown in the below.

→ The a.c supply to the rectified is generally given through a tranformer. The transformer is used for step-down or step-up the mains supply voltage as per requirement.

→ It also isolates the rectifier circuit from power line and thus reduces the risk of electric shock.

Operation:-

→ When a.c supply is switched on, the alternating voltage (Vin) appears across the terminals AB at secondary winding

→ During positive half cycle, the terminal A is positive with regard to B and the crystal diode is forward biased.

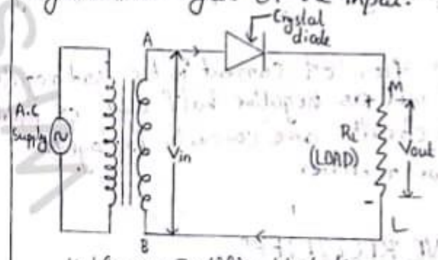
→ Therefore, it conducts and current i flows through the load register R_L. This current varies in magnitude as shown in wave diagram in fig(b).

→ Thus the positive half cycle of output voltage ($V_{out} = iR_L$) appears across the load register (R_L) as shown in fig (c).

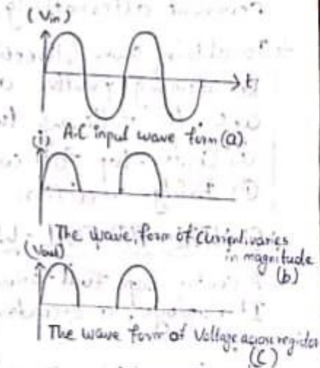
→ During negative half cycle, the terminal A is negative with regard to B and the crystal diode is reverse biased.

→ Under this condition the diode does not conducts and no current flows through the circuit.

→ Therefore, no voltage appears across the load register R_L in the negative half cycle of the input.



Half wave Rectifier block diagram



Peak Inverse Voltage:-(PIV)

→ During nagative half cycle, when the diode is reverse biased, the maximum value of the voltage coming across the diode is called peak inverse voltage.

→ The diode must have higher PIV rating than the voltage which is coming across it.

→ As current flow through the load registe R_L only in one direction i.e from M to L.

→ Hence, d.c. output is obtained across R_L which is pulsating in nature. How ever, the pulsations in the output can be removed with the help of filter circuits.

Disadvantages:-

(i) The output is low because a.c supply delivers power only half the time.

(ii) The output contains more alternating components (ripples), therefore, it needs heavy filter circuit to smooth out the output.

FULL-WAVE RECTIFIERS:-

→ In full wave rectification, when a.c supply applied at the input, during both the half cycles (i.e positive as well as negative) current flows through the load in the same direction.

→ This can be achieved by using atleast two crystal diodes, conducting current alternatively.

→ To obtain same direction flow of current in the load register R_L during positive as well as negative half cycle of input a.c, the following two circuits are commonly employed:-

(i) Centre-tap full wave rectifier

(ii) Bridge rectifier.

CENTRE-TAP FULL-WAVE RECTIFIERS:-

→ A centre-tap full-wave rectifier circuit is shown in the fig below. It employs, a secondary winding 'AB' tapped with the centre point 'C'.

→ The two diodes D_1 and D_2 are connected in the circuit so that each one of them uses one half cycle of input a.c voltage.

→ The diode D_1 utilizes the a.c voltage appearing across the upper half (AC) of secondary winding of rectification while

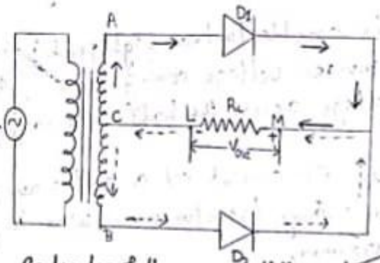
D_2 uses the lower half (CB) of secondary winding.

Operation:-

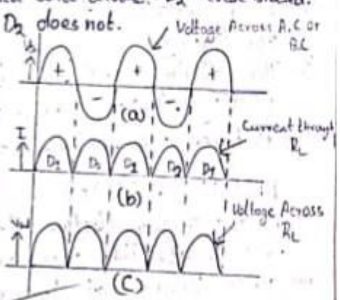
→ When a.c supply is switched on, the alternating voltage V_{in} appears across the terminals AB secondary winding of transformer.

→ During positive half cycle at secondary voltage, the ends A become positive, and end B negative.

→ This makes the diode D_1 forward biased and diode D_2 revese biased. There fore, diode D_1 conduct while diode D_2 does not.



Centre-tap full-wave rectifier



Wave forms

→ Thus the current (i) flows through diode D_1, load register R_L (from M to L) and the upper half of the secondary as shown in the figure above by bold arrow heads.

→ During negative half cycle, the end B becomes positive and end A becomes negative.

→ This makes diode D_2 forward biased and D_1 reverse biased. There fore diode D_2 conducts while diode D_1 does not.

→ Thus, current (i) flows through diode D_2, load register R_L (from M to L) and the lower half of the secondary as shown in the figure above by dotted arrows.

→ It may be seen that the current flows through the load register R_L in the same direction (i.e from M to L) during positive as well as negative half cycle of input a.c voltage.

→ There fore, d.c output voltage ($V_{out} = iR_L$) is obtained across the load register R_L.

Advantages:-

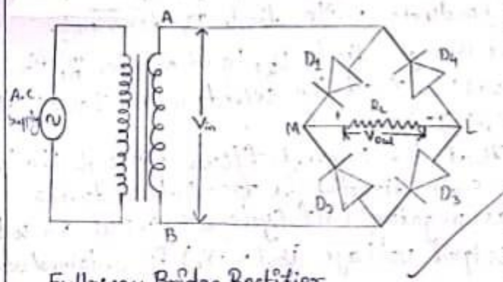
(i) The output and efficiency is high because a.c supply delivers power during the both the halves.

Disadvantages:-

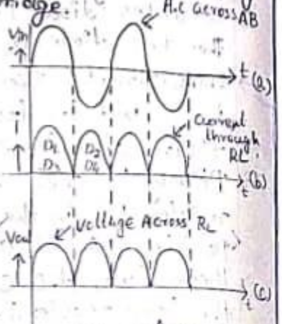
(i) The d.c output is small because each diode utilises only one half of the voltage developed in the transformer secondary.
(ii) It is difficult to locate the centre on the secondary winding for tapping.
(iii) The diode used must be capable to bear high peak inverse voltage. Because peak inverse voltage coming across each diode is twice the maximum voltage across the half-secondary winding.

BRIDGE RECTIFIER:-

→ In the figure below shows the circuit of a full-wave bridge rectifier. In this case, an ordinary transformer is used in place of a center-tap transformer.
→ This circuit contains 4 diodes D_1, D_2, D_3 and D_4 connected to form a bridge.
→ The a.c supply to be rectified is applied to the diagonally opposite end of the bridge.
→ Whereas, the load register R_L is connected across the remaining two diagonally opposite ends of the bridge.



Full-way Bridge Rectifier



Wave form

Operation:-

→ When a.c supply is switched on, the alternating voltage V_{in} appears across the terminal AB of the secondary winding of transformer which needs rectification.
→ During positive half cycle of secondary voltage, the end A becomes positive and end B negative.
→ This makes forward biased to the diode D_1 and D_3 and diode D_4 and D_2 reverse biased. Therefore diodes D_1 and D_3 while diodes D_2 and D_4 do not.
→ Thus, current (i) flows through diode D_1, load resistor R_L (from M to L), diode D_3 and transformer secondary as shown in the figure(A) below.
→ The wave shape of output current is shown in the figure (b).
→ During negative half cycle, the end B becomes positive and end A becomes negative. This brings diodes D_2 and D_4 under forward bias and diode D_1 and D_3 under reverse bias.
→ Therefore, diodes D_2 and D_4 conduct while D_1 and D_3 do not. Thus, current (i) flows through Diod D_2, load resistor R_L (from M to L), diode D_4 and the transformer secondary as shown in the figure(B) below.
→ The wave form of current is shown in the above (b).

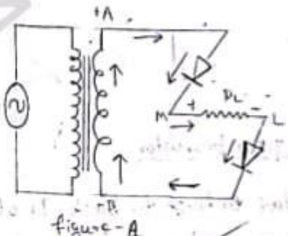
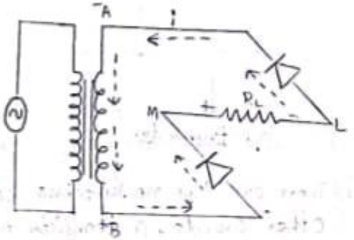


figure - A



figur - B

→ It may be noted that current flows through load register R_L in the same direction (M to L) during both the cycle.

→ Hence, d.C output voltage V_{out} is obtained across the load resistor R_L. The wave shap of output voltage is shown is shown in the above figure.

TRANSISTOR :-

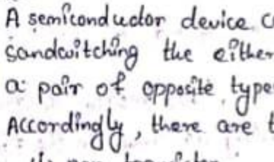
→ A semiconductor device consisting of two pn junction formed by sandwitching the either p-type or n-type semiconductor between a pair of opposite types is known as "transistor."

→ Accordingly, there are two types of transistor namely:-

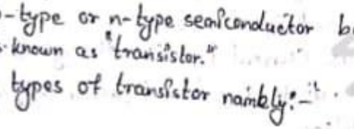
(i) npn transistor
(ii) PNP transistor

(i) NPN Transistor:-
A transistor in which two blocks of n-type semiconductor are separated by a thin Layer of p-type semiconductor is known as "npn transistor."

(ii) PNP Transistor:-
A transistor in which two blocks of p-type semiconductor separated by a thin layer of N-type semiconductor is known as "pnp transistor."



npn transistor



PNP transistor

(i) There are two pn junctions connected back to back. In other other words, a transistor may be regarded as two crystal diodes connected back to back. The diode on the left called emitter-base diode or simply emitter diode. Whereas, the diode on the right is called collector-base diode or the collector diode on the right

These names are given as per the names of the terminals.

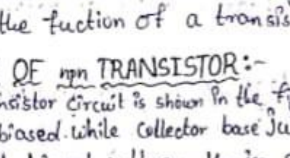
(ii) Transistor has three terminals, taken from each type of semiconductor.

(iii) The middle section is made of a thin layer. This is the most important factor in the fuction of a transistor.

WORKING OF npn TRANSISTOR:-

→ An npn transistor circuit is shown in the figure below. The emitter base junction is forward biased while collector base junction is reverse biased.

→ The forward biased voltage V_{EB} is quite small, whereas, voltage V_{CB} is considerably high.



Flow of majority carriers in npn transistor

→ As the emitter base junction is foward biased, a large no. of electrons (majority carriers) in the emitter (n-type) are pushed towards the base. This continues the emitter current I_E.

→ When these type of electrons enter the p-type material (base), they tends to combine with holes.

→ Since base is lightly doped a very thin only a few electrons (less than 5%) combine with holes to constitute base current I_B.

→ The remaining electron (more than 95%) diffuse across the thin base region and reach the collector base charge layer.

→ These electron then comes under the influence of the positively biased n-region and attracted and collected by the collector. This constitutes collector current I_C.

→ Thus it is seen that almost the entire emitter current flows into the collector circuit.

→ However, to be more precise, the emitter current is the sum of collector current and base current i.e $I_E = I_C + I_B$.

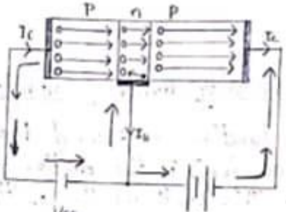
WORKING OF pnp TRANSISTOR:-

→ A pnp transistor circuit is shown in the figure below. The emitter base junction is forward biased while collector base junction is reverse biased.

→ The forward biased voltage V_{EB} is quite small, whereas, the reverse biased voltage V_{CB} is considerably high.

→ As emitter base junction is foward biased, A large no of holes (majority carriers) in the emitter (p-type semiconductor) are pushed towards the base. This constitutes the emitter current I_E.

→ When these holes enters the n-type material (base), they tend to combine with electrons.



Flow of majority carriers in pnp transistor

→ Since the base is lightly doped and very thin, only a few holes (Less than 5%) combine with electrons to continue base current I_B.

→ The remaining holes (more than 95%) diffuse across the thin base region and reach the collector space charge layer.

→ These holes then comes under the influence of negatively biased P-region and attracted or collected by the collector. This constitutes collector current I_C.

→ Thus, it is seen almost the entire current flows into the collector circuit. However, to be more precise, the emitter current is sum of the collector current and base current i.e $I_E = I_C + I_B$

TRANSISTOR CONNECTIONS:-

→ A transistor has three leads, namely emitter, base and collector. However to handle input and output, four terminal are needed (two for input two for output).

→ Therefore, to connect transistor in the circuit, one lead or terminal is made common.

→ The input is fed between common and one of the remaining terminals whereas output is connected between the common and other terminal of the transistor.

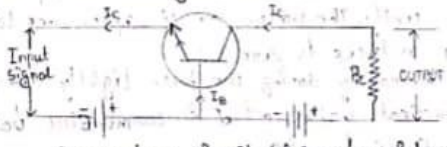
→ Accordingly, a transistor can be connected in the circuit in the following three way:- (1) Common base connection (CB configuration)
(2) Common emitter connection (CE configuration)
(3) Common Collector connectio (CC configuration)

(i) COMMON BASE CONNECTION (OR CB CONFIGURATION):-

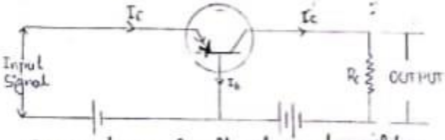
→ The common base circuit arrangement for npn transistor and pnp transistor is shown in the figure below.

→ In this case, the input is connected between emitter and base while output is taken across collector and base.

→ Thus, the base of the transistor is common to both the input and output circuits and hence the name Common base connection or Common base configuration.



Common base circuit of npn transistor



Common base circuit of pnp transistor

Current amplification factor(α):-

→ The ration of Output Current to Input is known as Current amplification factor.

→ In common base connection the output current I_C whereas the input Current Current is emitter current I_E.

→ Thus, the ratio of change in collector current to the change in emitter current at constant collector base voltage V_{CB} is known as Current amplification factor of transistor in common base configuration.

→ It is generally represented by Greek letter α (alpha).

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \quad \text{(at constant } V_{CB})$$

→ Where ΔI_C is the change in collector current and ΔI_E is change in emitter current at constant V_{CB} Now,

$$I_E = I_C + I_B$$

or, $$\Delta I_E = \Delta I_C + \Delta I_B$$

or, $$\frac{\Delta I_E}{\Delta I_E} = \frac{\Delta I_C}{\Delta I_E} + \frac{\Delta I_B}{\Delta I_E}$$

Or, $$1 = \alpha + \frac{\Delta I_B}{\Delta I_E}$$

→ It is clear that the value of Current amplification factor is less than unity. The value of α approaches to unity if the value of I_B reduces to zero.

→ This can be eachieved by doping the base lightly and making very thin. The practical value of α in commercial transistors varies from 0.95 to 0.99.

COMMON BASE CONFIGURATION CHARACTERISTICS:-

→ The complete behavior of transistor can only be described by their characteristics.

→ These characteristics are a graphical representation of transistor behavior.

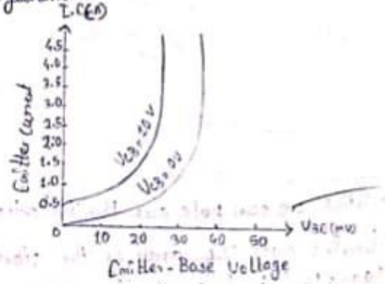
→ We can easily understand what will happen with transistor when a voltage is applied across transistor by their characteristics.

→ Here take input characteristics of common base configuration and output characteristics of common base configuration of transistor.

INPUT CHARACTERISTICS:-

→ Input characteristics is a Curve of emitter base voltage (V_{EB}) with respect to emitter current (I_E) at constant base collector voltage (V_{BC}). Emitter base voltage is shown in x axis of characteristics.

→ The figure shows the input characteristics of common base configuration.



→ By above figure we can note this following points:-

(1) You can see that the Emitter current (I_E) increases rapidly with the small increase in emitter base voltage (V_{EB}). that means input resistance is very small.

(2) With the all Collector-base voltage (V_{BC}) shape of graph remain same that means emitter current is totally independent of base collector voltage. This leads to the conclusion that the emitter current independent of collector voltage.

Input Resistance:-

→ The Input resistance of the transistor is the ratio of change in emitter-base voltage (V_{eb}) to change in emitter current (I_e).

Input Resistance = (Change in V_{be} / change in I_e) at constant V_{cb}

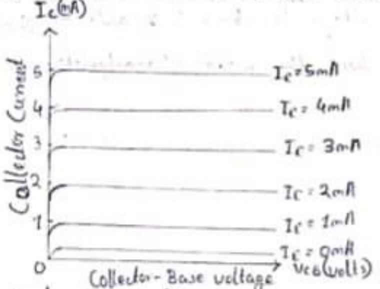
OUTPUT CHARACTERISTICS:-

→ Output characteristics is a graphical representation of transistor output.

→ Output characteristics is curve between base voltage (V_{cb}) at Constant emitter current (I_e).

→ Here collector current is shown on y-axis and collector base voltage is shown on the x-axis.

→ Characteristics of the Common base transistor below figure.



→ By the output characteristics we can note out the following points:-

(1) The collector current varies with V_{cb} only on the starting or when the collector base voltage (V_{cb}) is below 1V. Transistor never operated below this voltage.

(2) After voltage increases to 1-2 V or above, you can see collector current (I_c) becomes a straight horizontal line. That means Collector current becomes constant above 1-2 V. It means collector current is independent of collector base voltages and depends upon the emitter current only. This proves that the emitter current almost flows to collector current. The transistor is always operated on this region.

(3) The large change in collector base voltage there is a small change in collector current. That means output resistance of the circuit is very high.

Output Resistance:-

→ Output resistance is a ratio of change in collector base voltage (V_{cb}) to change in collector current (I_c).

→ The output resistance (R_o) = $\dfrac{\text{change in collector base voltage} (V_{cb})}{\text{Change in collector current} (I_c)}$

At constant emitter current (I_e)

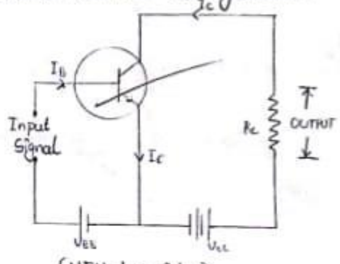
Output resistance is very high in terms of megaohm. This is because of collector current not change with the collector base voltage.

COMMON EMITTER CONNECTIONS OR (CE CONFIGURATION):-

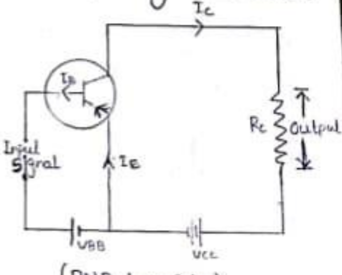
→ In common emitter type configuration, emitter terminal; emitter terminal is common between input and output circuit of transistor.

→ Hence, it names Common type transistor configuration. In common emitter type transistor configuration input is applied between base-emitter Junction. The output is taken from a collector-emitter Junction.

→ Common emitter Configuration can be applied on both the transistor, PNP transistor and NPN transistor. Here specially talk about Common emitter Configuration.



(NPN transistor)



(PNP transistor)

Base Current amplification factor:-

→ For common emitter connection, the input current is base current (I_b) and the output current collector current (I_c).

→ Base amplification factor is generally the ratio of output current to the input current.

→ For emitter connection, the base amplification factor is the ratio of change in collector current ΔI_c to change in base current (ΔI_b).

$$\text{Current amplification factor}(\beta) = \frac{\Delta I_c}{\Delta I_b}$$

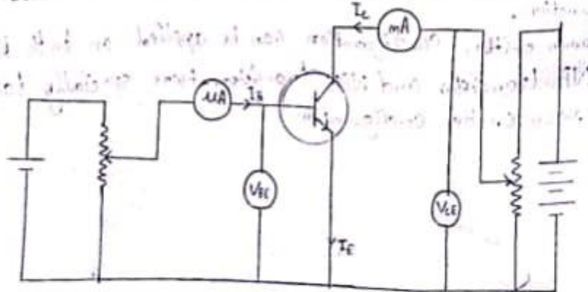
→ In generally any transistor base current is almost 5% of total current. So, the value of current amplification is greater than 20. Value of β is between 20 to 500.

Characteristics of common emitter transistor:-

→ Characteristics of common emitter transistor present the behavior of transistor for some input and output in a graphical way.

→ By the understanding characteristics, we can easily understand about the behavior of common emitter transistor.

→ Here we look into the input and output characteristics of the transistor.



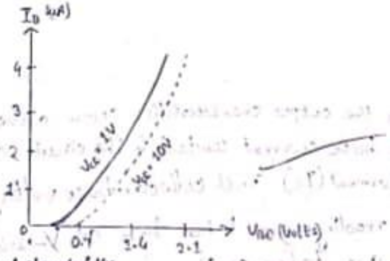
Circuit diagram

Input Characteristics:-

→ Input characteristics is a curve between base current (I_b) and base emitter voltage (V_{eb}) at a constant collector-or emitter voltage (V_{cb}).

→ You can see the input characteristics in the figure. Base current is taken on the y-axis and base-emitter is taken on the x-axis.

→ Here we take the reading of base current and base-emitter current at a constant collector-emitter voltage (V_{cb}) = 1V and then after 10V.



of characteristics

→ The curve looks like the same as forward diode characteristics. So, we can say that the base emitter section works as a forward biased diode.

→ In this characteristics as you can see base current is increased with base-emitter voltage.

Input Resistance:-

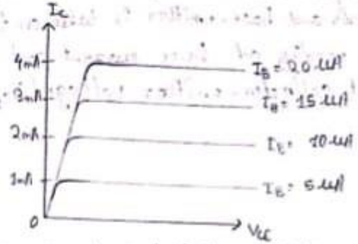
→ For common base connections, the input resistance of a transistor is the ratio of base-emitter voltage to base current (I_b).

$$\text{Input resistance}(R_i) = \frac{\Delta V_{eb}}{\Delta I_b}$$

→ The value of this input resistance is in order of hundred ohms.

Output Characteristics:-

→ Output characteristics is a graphical representation of output current and output voltage. For common emitter output characteristics, it curves between collector current (I_C) and collector-base voltage (V_{cb}) at a constant base current (I_b).



→ As you can see the output characteristics curve above. This curve we can draw by keeping base current constant in the circuit and take a reading of collector current (I_c) and collector-base voltage (V_{cb}).

→ Then collector readings are taken here on Y-axis and collector-base voltages are taken on x-axis,

→ As you can see above figure first we take take readings of collector-current and base collector voltage at constant base current (I_b) = 5uA and then we take readings on various base current values.

→ By the figure we can see that collector current only varies in below 1V base-collector voltage. After that collector current becomes constant and independent of base-collector voltage. At a value of voltage in which current becomes constant this voltage is known as knee voltage. Transistor always operated above knee voltage.

→ Above knee voltage, Ic is going to be constant so after that, there is small I_c increases with Vce increase. This proves that output resistance is going to high as compared to input resistance.

→ For any value above the knee voltage of $I_c = \beta \times I_b$.

Output resistance:-

→ Output resistance is generally the ratio of output voltage and output current.

→ Here for common emitter configuration output current is I_c and output voltage is V_{cb}.

→ So, for common emitter connection, Output resistance (R_o) = $\frac{\text{Change in Vce}}{\text{change in Ic}}$

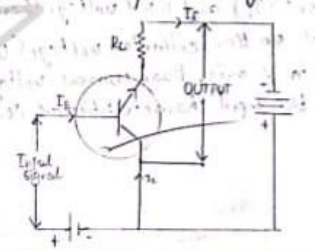
$$\text{Output resistance} = \frac{\Delta V_{cb}'}{\Delta I_c} \text{ at constant base current.}$$

COMMON COLLECTOR CONNECTION (OR CC CONFIGURATION):-

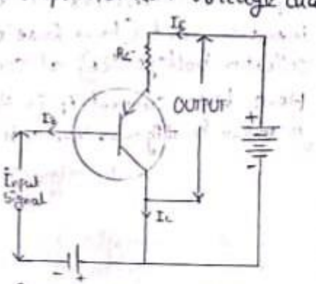
→ Two terminals are needed for input and output. Transistors have three terminals, so one terminal have to be taken as common terminal for both input and output.

→ In common collector configuration collector terminal is taken as common. So input is applied between base and the collector terminals and output is taken from emitter and collector terminals.

→ The common collector configuration is also called emitter-follower or voltage-follower because the output emitter voltage always the base input voltage.



(Common collector circuit of npn transistor)



(Common collector circuit of pnp transistor)

Current amplification factor(γ) :-

→ The current amplification factor is the ratio of change in output current to change in input current.

→ Here for common collector circuit, the input current is base current (I_B) and output current is emitter current (I_e).

→ So, for CC connection the current amplification factor is the ratio of change in emitter current (I_e) to change in base current (I_b).

$$\text{Current amplification factor}(\gamma) = \frac{\Delta I_e}{\Delta I_b}$$

An expression for collector current:-

→ We know,

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = I_B + I_C = I_B + (\alpha I_E + I_{CBO})$$

$$I_E(1-\alpha) = I_B + I_{CBO}$$

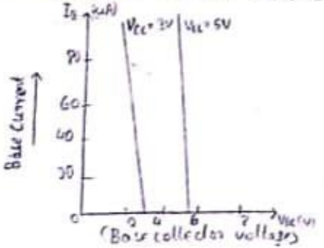
$$I_E = \frac{I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha}$$

$$\therefore I_C ; I_E = (\beta+1) I_B + (\beta+1) I_{CBO}$$

Input characteristics:-

→ Input characteristics of Common collector circuit is curve between input current (here base current = I_b) and input voltage (here base-collector voltage = V_{cb}) at constant emitter-collector voltage (V_{ec}).

→ Here base current I_b is shown in Y-axis. Base current voltage V_{cb} is shown in x-axis. You can see the input characteristics of CC below.

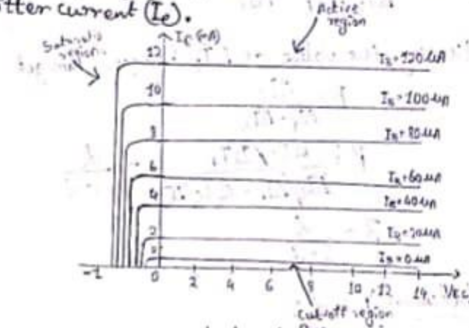


→ First here we take reading of base current (I_b) and base-collector voltage (V_{bc}) on constant V_{ec} = 3V. After that we take V_{ec} = 5V and take reading as same in previous reading.

Output Characteristics:-

→ Output characteristics is a curve between output current (here emitter current I_e) and output voltage (emitter-current voltage V_{ec}) at a constant base current I_b.

→ Here emitter current I_e is shown on Y-axis. Emitter collector I_b constant and take readings. By taking constant I_b we increase V_{ec} and note down emitter current (I_e).



Output characteristics

→ You can see output characteristics in the above figure. Here we take a reading of I_e and V_{ee} at a constant base current (I_b) = 0 µA. After that we repeat this process for higher different constant base voltage (I_b = 20µA, 40µA, 60µA, 80µA, 100µA, 120µA).

→ In CC circuit, if the input current is zero then output current is also zero. So that there is no current flow in the transistor circuit. This region we can call as a cut-off region where $I_b = 0$ so that is also zero.

→ When the base current I_b increases collector current I_c also increases. This we can say that the transistor now falls into the active region. When base current is increased up to its limitation collector current also increases up to its last value. This region is called as Saturation region.

Relation between β & α :-

The relation betⁿ β & α can be derived as:-

we know, $\beta = \frac{\Delta I_C}{\Delta I_B}$ ------ (i)

$\alpha = \frac{\Delta I_C}{\Delta I_E}$ ------ (ii)

Now, $I_E = I_C + I_B$

or, $\Delta I_E = \Delta I_C + \Delta I_B$.

or, $\Delta I_B = \Delta I_E - \Delta I_C$

Substituting the value of ΔI_B in equⁿ(i), we get

$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

$$\beta = \frac{\Delta I_C/\Delta I_E}{\Delta I_E/\Delta I_E - \Delta I_C/\Delta I_E} = \frac{\alpha}{1-\alpha}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

Relation between γ & α :-

We know $\gamma = \frac{\Delta I_E}{\Delta I_B}$ ------ (i)

$\alpha = \frac{\Delta I_C}{\Delta I_E}$ ------ (ii)

Now, $I_E = I_C + I_B$

$\Delta I_E = \Delta I_C + \Delta I_B$

$\Delta I_B = \Delta I_E - \Delta I_C$

Substituting the value of ΔI_B in equation(i) we get

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C} = \frac{\Delta I_E/\Delta I_E}{\Delta I_E/\Delta I_E - \Delta I_C/\Delta I_E} = \frac{1}{1-\alpha}.$$

$$\gamma = \frac{1}{1-\alpha}$$

What is Transistor Biasing?:-

→ To achieve the desired switching or amplification effect a transistor must be supplied with the controled amounts of voltages and current through it. This type of technique is known as "transistor biasing".

→ If the transistor is not biased appropriately, it may be lead to poor amplification of the signal resulting in the gain being very slow. Hence to obtain an intended outcome biasing plays a major role.

Types of Biasing:-

→ The most commonly preffered methods for biasing of transistors are

(1) Base resistor

(2) Collector to base

(3) Biasing with a collector feedback resistor

(4) voltage-divider

→ Above all the methodes follow the same principle to obtain required amount of base and collector currents from Vcc in zero signal conditions.

Base Resistor:-

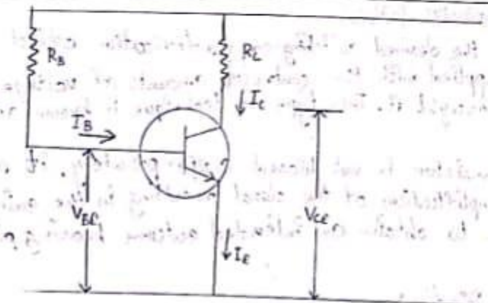
→ The terminal base of the transistor is connected with a high value of base resistor.

→ The transistor used in the circuit is of N-P-N type so that the other end of the resistor will be connected to the positive side of the supply.

→ Through Vcc the required amount of zero signal currents at the base is supplied which will be flowing through the base resistor.

→ This makes the Junction base-emitter to be forward biased and the terminal base will be positive in comparison to the emitter terminal.

→ By the selection of the proper values of the base resistor, the required amounts of currents at the base and collector are made to pass.



Base resistor Transistor Biasing:-

→ The value of the base resistor can be calculated by applying KVL

$$R_B = V_{CC} - V_{BE} / I_B$$

→ Due to fixed value of V_{CC} and selectively used I_B the value of the R_B can be easily found. Hence this method can also be reffered to as a fixed bias method.

Advantages:-

→ Circuit design and calculation are simple.

→ Due to the absence of the resistor at the junction of the base-emitter, there is no chance of occurance of the loading effect.

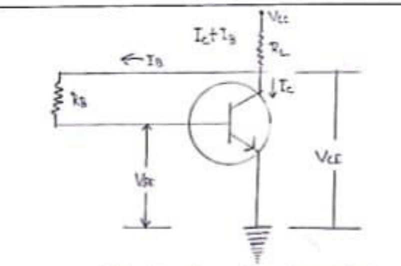
Disadvantages:-

→ Due to the developement of heat, the stabilization criterion of the circuit gets degraded.

→ As the value of the stability factor gets high results to thermal runaway.

Collector Biasing Methode:-

→ This circuit consists of a base-resistor that is feed back to the terminal collector instead of V_{CC}. In this way this circuit is slightly different from the method of the base resistor.



Collector base Transistor Biasing

→ From V_{CC}, the current supplied flows through R_L then it reaches the resistor at the present at the base. This indicates that the voltage is shared among the base and collector terminals.

→ If the current at the collector tends to increase the voltage at the load resistor gets increased. This result is an increase in the value of the voltage at the collector-emitter terminal and the current at the base get reduced.

Advantages:-

→ The change of Q-point is less when compared to the base bias method.

Disadvantages:-

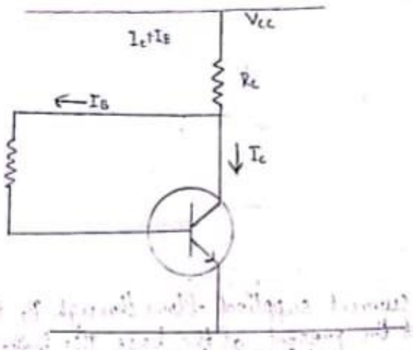
→ If the RL becomes short circuited the value of stability gets large.

→ The negative path of feedback followed the voltage gain smaller

Transistor Biasing with Collector-Feedback resistor:-

→ This method has a resistor on it's base such that one end of it is connected to the terminal base whereas the other end will be connected to the collector.

→ The value of the zero signal of the current at the base can be determined by the voltage applied at the junction in between terminal collector and base (V_{CB}) instead of V_{CC}. Due to V_{CC}, the junction at the base-emitter gets forward biased.



Collector Feedback Resistor

Advantages:-

→ The circuit is very small in terms of design because fewer resistors are required.

→ Stabilization is provided if there are fewer changes.

Disadvantages:-

→ Negative feedback is followed by the circuit.

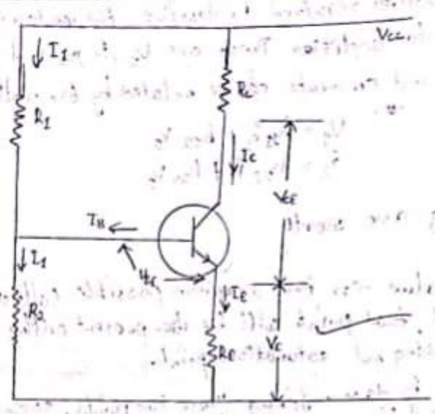
Voltage - vider Method:-

→ Among the existing methods, this type of bias is widely preffered one. It consists of two Resistors R1 and R_2.

→ This circuit of biasing is beneficial in terms of providing stabilization due to the emitter present at the emitter.

→ The drop of voltage at the resistor R_2 makes the junction of the base-emitter to operate in forward bias.

→ Let us assume the value of current flows through the R_2 is I_1. As the current at the base is small the current flows through the resistor R_2 is the same as that of R1 that is I_1.



Voltage Divider Bias

Advantage:-

→ More than one type of voltage divider circuit can be incorporated by making use of this bias.

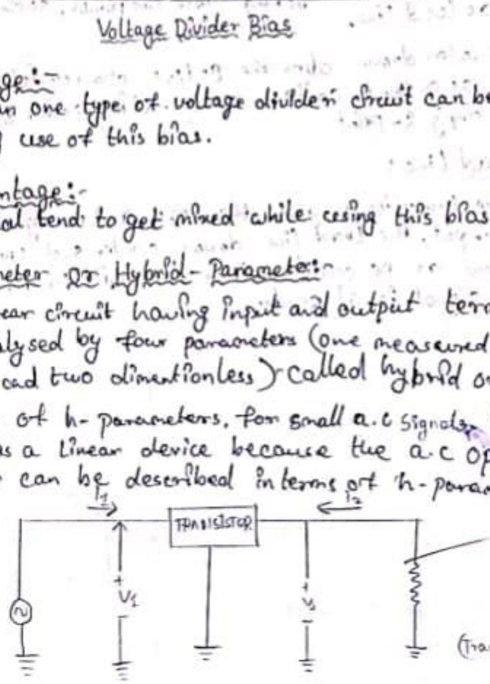
Disadvantage:-

→ The signal tend to get mixed while using this bias in the circuits.

H-parameter or Hybrid-Parameter:-

→ Every linear circuit having input and output terminals can be analysed by four parameters (one measured in ohm, one in mho, and two dimentionless) called hybrid or h parameters.

→ In terms of h-parameters, for small a.c signals the transistor behaves as a linear device because the a.c operation of the transistor can be described in terms of h-parameters.



(Transistor amplifier circuit)

→ These 4 quantities required to describe the external behaviour amplifier. v_1, i_1, v_2 and i_2.

→ These voltages and currents can be related by the following sets of equations:- i.e. $V_1 = h_{11} i_1 + h_{12} V_2$

Load Line:-

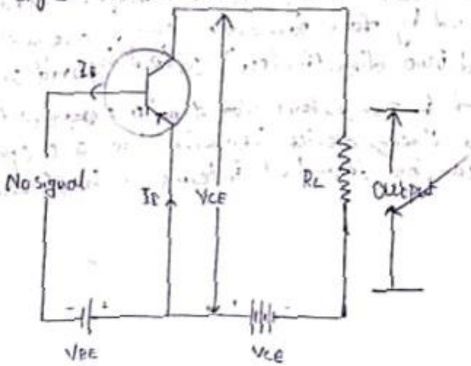
→ When the value for the maximum possible collector current is considered, that point will be present on the Y axis, which is nothing but saturation point.

→ When a line is drawn joining these two points, such as line can be called as load line.

→ This line, when drawn over the output characteristics curve, makes constant at a point called as operating point or quiescent point or simply Q-point.

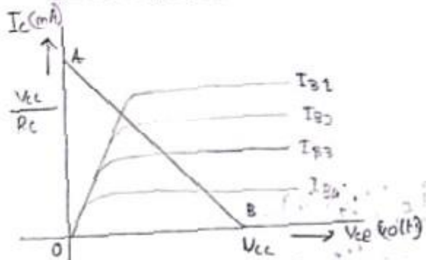
D.C Load Line :-

→ When the transistor is given the bias, and no signal is applied at it's input, the load line drawn under such conditions, can be understood as DC condition. Here there will be no amplification as the signal is abseent.



→ The value of the collector voltage at the given time will be

$$V_{CE} = V_{CC} - I_C R_C$$



→ To obtain the load line the two end points of the straight line are to be determined. Let those two points be A and B.

*Î*Dgb@ n A :-

→ r emitter voltage $V_{CE} = 0$, the collector current is

$$0 = V_{CC} - I_C R_C$$
$$I_C = V_{CC} / R_C$$

• To obtain B :-

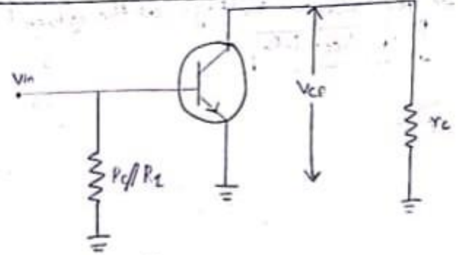
→ the collector emitter current $I_C = 0$, then the collector emitter voltage is maximum and will be equal to the V_{CC}. This gives the maximum value of I_C.

$$V_{CE} = V_{CC} - I_C R_C$$
$$\Rightarrow V_{CC}$$

A.C Load Line :-

→ The D.C Load Line discussed previously. Whereas the A.C load line gives peak-to peak voltage on the maximum possible outp swing for an given amplifier.

→ We shall consider A.C equivalent circuit of a CE ampli for our understanding.



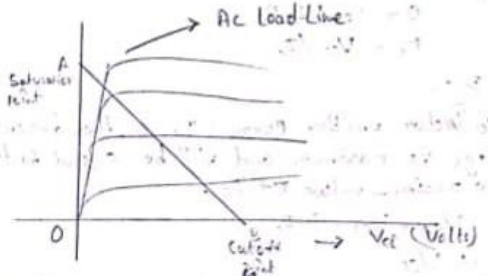
$V_{ce} = (R_c // R_1) \times I_c$

$r_c = R_c // R_1$

→ The quiescent point is so chosen in such a way that the maximum input signal excursion is symmetrical on both negative and positive half cycle.

Hence, $V_{max} = V_{CEQ}$ and $V_{min} = -V_{CEQ}$

where V_{CEQ} is the emitter-collector voltage at quiescent point.



From the graph above, the current I_c at the saturation point is: $\boxed{I_c = I_{CQ} + (V_{CEQ} / r_c)}$

The voltage V_{CE} at the cutoff point is

$\boxed{V_{CE} = V_{CEQ} + I_{CQ} r_c}$

Hence maximum current for the corresponding $V_{CEQ} = V_{CEQ} / R_c // R_1$ is

$I_{CQ} = I_{CQ} \times (R_c // R_1)$

COUPLING:-

→ The process of transferring energy between circuits is known as coupling.

→ There are various types ways to coupling signals in to and out of amplifier circuits.

RC Coupled Amplifier:-

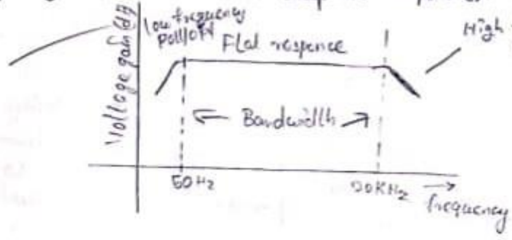
→ When an AC input signal is applied to the base of first transistor, it gets amplified and appears at the collector load R_c which is then passed through the coupling capacitor C_c to the next stage.

→ This becomes the input the next stage, whose amplified output again appears across it's collector load. Thus the signal is amplified in stage by stage action.

→ As we consider a two stage amplifier here, the output phase is same as input. Because the phase reversal is done two times by the two stage CE configuration amplifier circuit.

Frequency Response of RC Coupled Amplifier:-

→ Frequency response curve is a graph that indicates the relationship between voltage gain and function of frequency response of a RC coupled amplifier



→ From the graph, it is understood that the frequency roll off or decreases for the frequencies below 50 Hz and for frequencies above 20 KHz. Whereas, the voltage gain for the range of frequencies between 50 Hz and 20 KHz is constant.

We know that

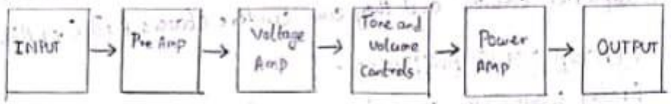
$$X_C = \frac{1}{2\pi f C}$$

→ It means that the capacitive reactance is inversely proportional to the frequency.

POWER AMPLIFIER:-

→ A power amplifier is an electronics device that is designed to increase the magnitude of power of a given input signal. The power of the input signal is increased high enough to drive loads of output devices like speaks, headphones, RF transmitters etc.

→ Unlike voltage or current amplifiers, a power amplifier is designed to drive loads directly and is used as a final block in an amplifier chain.



BLOCK DIAGRAM OF AN AUDIO AMPLIFIER

TYPES OF POWER AMPLIFIER:-

→ Depending upon the type of output device that is connected, power amplifiers are divided into three types:-

(1) Audio Power Amplifier
(2) RF Power amplifier
(3) DC Power amplifier

DIFFERENCE BETWEEN VOLTAGE AMPLIFIER AND POWER AMPLIFIER:-

Voltage Amplifier	Power Amplifier
→ It raises the voltage level.	→ It provides increase in the power level
→ It is known as small signal amplifier.	→ It is known as large signal amplifier.
→ It has a small magnitude input signal.	→ It has comparatively large magnitude input signal.
→ It is uses R.C coupling.	→ It is uses Transfor coupling.
→ The physical size of transistor is small	→ The physical size of transistor is generally large.
→ It has less heat dissipation	→ It has more heat dissipation
→ The base region of transistor is thin.	→ The base region of transistor is comparatively thicker.

POWER AMPLIFIER CLASSES:-

→ There are multiple ways of designing a power amplifier circuit. The operation and output characteristics of each of the circuit configurations differs from one another.

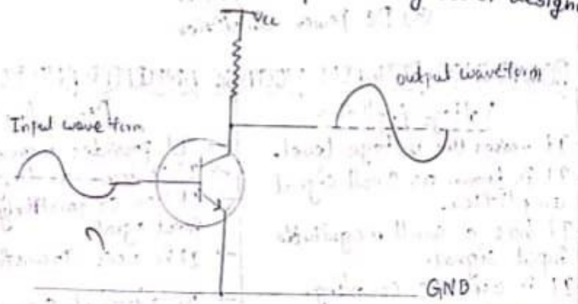
→ To differentiate the characteristics and behaviour of different power amplifier circuits, power amplifier classes are used in which, letter symbols are assigned to identify the method of operation.

→ The most commonly used power amplifiers are the ones used in audio amplifier circuits and they come under classes A, B, C or AB.

CLASS-A POWER AMPLIFIER :-

→ Analog waveforms are made up of positive highs and negative lows. In this class of amplifiers, the entire input wave-form is used in the amplification process.

→ A single transistor is used to amplify both the negative and positive halves of the wave form. This makes their design simple and makes class A amplifiers a most commonly used type of power amplifiers. Although this class of power amplifiers are superseded by better designs.

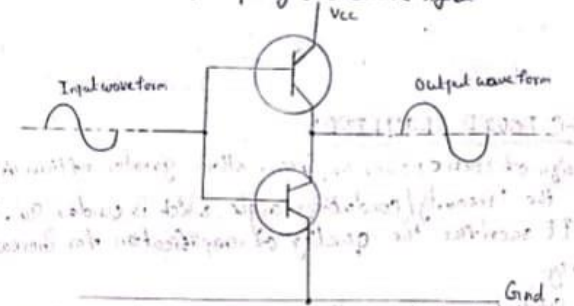


→ In this class of amplifiers, the active elements (the electronic components used for amplifying, which is transistor in this case) is in use all the time even if there is no input signal.

CLASS-B POWER AMPLIFIER:-

→ Class B power amplifier are designed to reduce the efficiency and heating problems present in the class A amplifiers. Instead of a single transistor to amplify the entire waveform, this class of amplifiers use two complementary transistors.

→ One transistor amplifies the positive half of the wave-form and the other amplifies the negative half of the wave form. So each active device conducts one half (180°) of the waveform and two of them, when combined, amplify the entire signal.

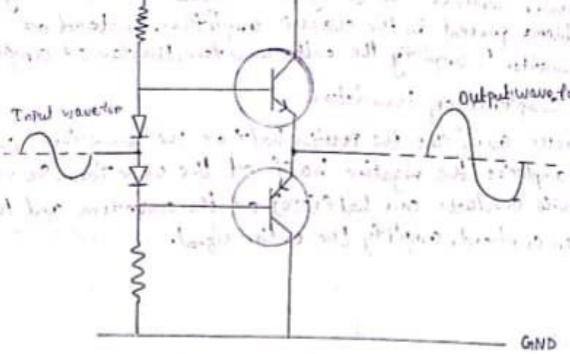


→ The efficiency of class B amplifiers is improved alot over class A amplifier because of two transistor designs. They can reach a theoretical efficiency of about 75%.

CLASS-AB POWER AMPLIFIERS:-

→ Class AB amplifiers are a combination of class A and class B amplifiers. This class of amplifiers are designed to reduce the less efficiency problem of class A amplifiers and distortion of signal at crossover region in class B amplifiers.

→ It maintains high frequency responce like in class A amplifiers and good efficiency as in class B amplifiers. A combination of diodes and resistors are used to provide little bias- Voltage which reduce the distortion of waveform near the crossover region. There is a little drop in efficiency (60%) because of this.

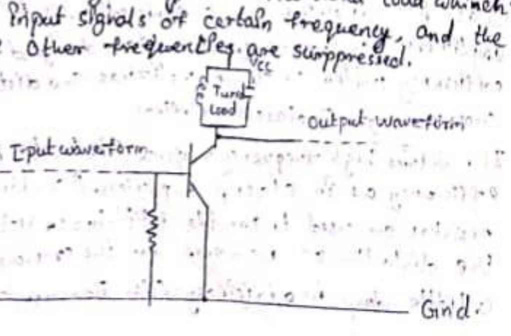


CLASS-C POWER AMPLIFIER:-

→ The design of class C power amplifiers allows greater efficiencies but reduces the linearity/ conduction angle, which is under 90°. In other words, It sacrifies the quality of amplification for increase in efficiency.

→ Lesser conduction angle implies greater distortion and so this class of amplifiers are not suited for audio amplification. They are used in high frequency oscillators and amplification of radio frequency signals.

→ Class C amplifiers generally contain a tuned load which filters and amplifies input signals of certain frequency, and the wave-forms of other frequencies are suppressed.



→ In this type of power amplifier, the active element conducts only when the input voltage is above a certain threshold, which reduces power dissipation and increases efficiency.

OTHER POWER AMPLIFIER CLASSES:-

→ Power amplifier classes D, E, F, G etc. are used are used to amplify PWM modulated digital signals. They come under the category of switching power amplifiers and turn the output either constantly ON or constantly OFF without any other levels in between.

→ Because of this simplicity, power amplifiers falling under the above-mentioned classes can reach theoretical efficiencies of up to (90-100%).

CLASS-B PUSH PULL AMPLIFIER:-

→ Though the efficiency of class B power amplifier is higher than class A amplifier, as only one half cycle of the input is used, the distortion is high.

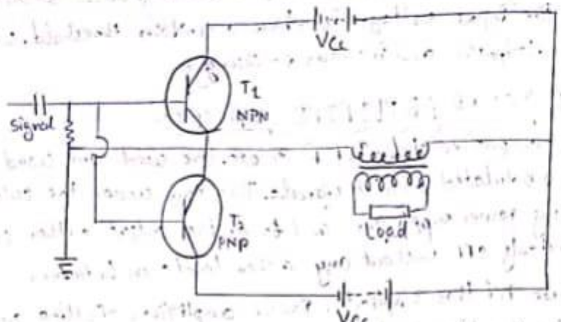
→ Also, the input power is not completely utilized. In order to compensate these problems, the push pull configuration is introduced in class B amplifier.

Construction:-

→ The circuit push-pull class B power amplifier consist of two identical transistors T_1 and T_2 whose bases are connected to the secondary of the centre tapped input transformer T_{r1}.

→ The emitter are shorted and the collectors are given the Vcc supply through the primary of the output transformer T_{r2}.

→ The circuit arrangment of class B push pull amplifier, is same as that of class A push-pull amplifier except that the transistors are biased at cutoff, instead of using the biasing resistors. The figure below gives the detailing of the construction of a push pull class B amplifier.



Working Principle:-

→ When the input signal is applied during the positive half cycle of the input signal, the NPN transistor conducts and the PNP transistor cuts off. During the negative half cycle, the NPN transistor cuts off and the PNP transistor conducts.

Advantages:-

The advantages of complementary symmetry push-pull class B amplifier are as follows.

- As there is no need of centre tapped transformers, the weight and cost are reduced.
- Equal and opposite input signal voltages are not required.

Disadvantages:-

The disadvantages of complementary symmetry push pull class B amplifier as follows

→ It is difficult to get a pair of transistor (NPN) and PNP that have similar characteristics.

→ We require both positive and negative supply voltages.

FIELD EFFECT TRANSISTOR (FET):-

→ The Field effect Transistor, FET is a three terminal active device that uses an electric field to control the flow and it has a high input impedance which is useful in many circuits.

→ There are two types of Field effect transistors, they are:-

(1) Junction Field Effect Transistor (JFET)

(2) Metal oxide semiconductor Field effect transistor (MOSFET)

JUNCTION FIELD EFFECT TRANSISTOR (JFET):-

→ Construction:-

→ The functioning of junction field effect transistor depends upon the flow of majority carriers (electrons or holes) only. Basically, JFETs consist of an N type and P type silicon bar containing PN Junctions at the sides.

→ Following are some important points to remember about FET:-

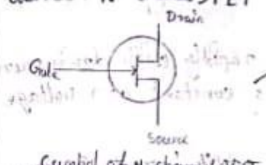
(1) Drain:- It is the exit point for majority carriers through which they enter into the semiconductor bar.

(2) Source:- It is the entry point for majority carriers through which leave the semiconductor bar.

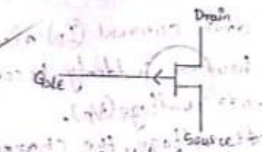
(3) Gate:- By using diffusion or alloying technique, both sides of N type bar are heavily doped to create PN Junction. These doped regions are called Gate.

(4) Channel:- It is the area of N-type material through which majority carriers pass from the source to drain.

→ There are two types of JFETs commonly used in the field semiconductor device: N-Channel JFET and P-channel JFET.



Symbol of N-channel JFET



Symbol of P-channel JFET

WORKING PRINCIPLE:-

→ The two PN Junctions at the sides form two depletion layers. The current conduction by charge carriers (i.e free electrons in this case) is through the channel between the two depletion layers and out of the drain.

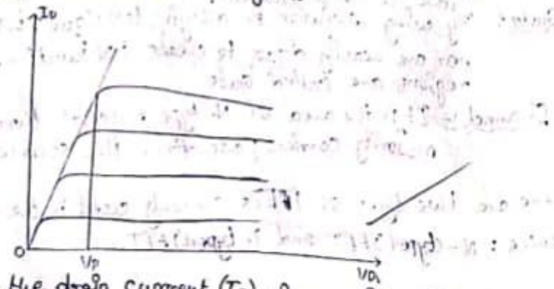
→ The width and hence resistance of the channel can be controlled by changing the input voltage V_{GS}. The greater the reverse voltage, the wider will be the depletion layers and narrower will be the conducting channel.

→ The narrower channel means greater resistance and hence source to drain current decreases. Reverse will happen should V_{GS} decrease.

→ Thus, JFET operates on the principle that width and hence resistance of the conducting channel can be varied by changing the reverse voltage V_{GS}. In other words, the magnitude of drain current (I_D) can be changed by altering V_{GS}.

OUTPUT CHARACTERISTICS OF JFET:-

→ The output characteristics of JFET are drawn between drain current (I_D) and drain source voltage (V_{DS}) at constant gate source voltage (V_{GS}) as shown in the figure.



→ Initially, the drain current (I_D) rises rapidly with drain source voltage (V_{DS}) however suddenly becomes constant at a voltage known as pinch-off voltage (V_P).

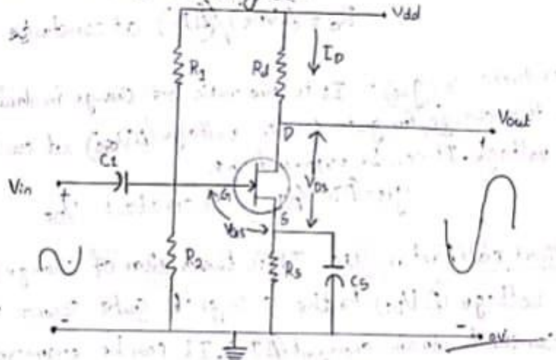
→ Above pinch-off voltage, the channel width becomes so narrow that it allows very small drain current to pass through it.

→ Therefore, drain current (I_D) remains constant above pinch-off voltage.

COMMON SOURCE JFET AMPLIFIER:-

→ The designe of the amplifier's circuit depends on a JFET. To create this amplifier first of all you should search a proper Q-point for exact biasing of the JFET amplifier with a single arrangement of Common-source (CS).

→ For this interpretation look at the circuit diagram, in this circuit we are using N-channel JFET which is connected in a common source arrangement.



Common Source JFET Amplifier

→ The voltage at gate of JFET is supplied by a potential divider system which is created by a resistance R_1 and Resistance R_2 and it (gate) is biased to work in its saturation region. That is equal to the energetic (active) region BJT.

→ The JFET reckipts practically no current at gain letting the gate to be work like an open circuit.

PARAMETERS OF JFET :-

→ The main parameters JFET are -
(1) AC drain resistance
(2) Transconductance
(3) Amplification factor

A.C drain resistance:- It is the ratio of change in the drain source voltage (ΔV_{DS}) to the change in drain current (ΔI_D) at constant gate-source voltage. It can expressed as,

$$R_d = (\Delta V_{DS}) / (\Delta I_D) \text{ at constant } V_{GS}$$

Transconductance (g_{fs}):- It is the ratio of change in drain current (ΔI_D) to the change in gate source voltage (ΔV_{GS}) at constant drain source voltage. It can be expressed as,

$$g_{fs} = (\Delta I_D) / (\Delta V_{GS}) \text{ at constant } V_{DS}$$

Amplification Factor:-(μ):- It is the ratio of change in drain-source voltage (ΔV_{DS}) to the change in gate source voltage (ΔV_{GS}) constant drain current (ΔI_D). It can be expressed as,

$$\mu = (\Delta V_{DS}) / (\Delta V_{GS}) \text{ at constant } I_D$$

Difference between JFET & BJT :-

JFET	BJT
→ The current flow is due to the flow of majority charge carriers.	→ The current flow is due to flow of majority charge carriers
→ The JFET construction is comparatively difficult.	→ BJT construction is comparatively easier.
→ It is a voltage controlled device.	→ It is a current controlled device
→ The JFET biasing is a litt difficult.	→ The BJT has very simple biasing
→ JFET has a comparatively low gain.	→ BJT has a very high gain
→ The output impedance is very low thus low gain.	→ The output impedance is very high thus high gain.

Relation Among JFET PARAMETER:-

The relationship among JFET parameters can be established as under:

$$\text{We know } \mu = \frac{\Delta V_{DS}}{\Delta V_{GS}}$$

Multiplying the numerator and denominator on R.H.S by ΔI_D, we get

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

$$\mu = r_d \times g_{fs}$$

amplification factor = a.c drain resistance × transconductance

METAL OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTER (MOFET):-

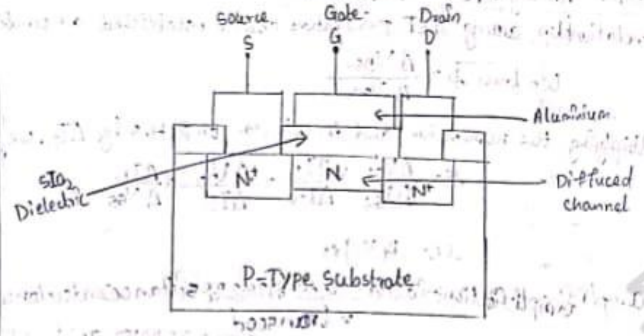
→ The MOSFET is a four-terminal device with source (S), gate (G), drain (d), and body (B) terminals. The main part of MOSFET is connected by source (S). This is how the other 3 terminal devices form the field effect transistor. MOSFET is a type of transistor used in both analog and digital circuits.

→ It is insulated from a channel near an extremely thin layer of metal oxide. The MOS capability that exists in the device is the critical section where the whole operation is holistic.

Construction :-

→ The power MOSFET is shaped like a rectangular box with a vertical 4 layer. In which the p-type layer is in the middle part as the main part. This is n-layer exit layer which is kept slightly lower than the drain and source level. The breakdown of the power MOSFET determines the width of the voltage drift level

→ Both the first and last levels are N+ levels. The first layer is the source layer and the last layer is the drain layer. A P-channel MOSFET structure has the opposite doping profile.



Construction of MOSFET

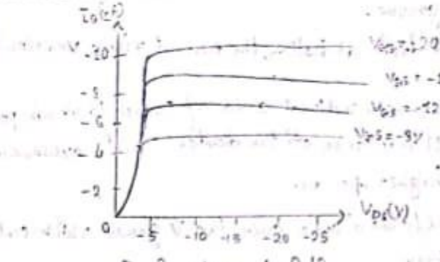
→ The layer of of metal oxide acts as a dielectric layer between the metal and the semiconductor. This creates a MOS capacitance at the input of MOSFET. This capacitance is large. The oxide layer provides a good insulating property by providing a SiO_2 layer that separates the gate terminal from the body layer.

Working principle of MOSFET :-

→ The main principle of the MOSFET device is that the voltage and current between its source and drain terminal can be easily controlled. The function of the MOSFET device is similar to that of a normal switch. The functionality of the MOSFET device depends upon the capacitor of the MOS. The capacitor of MOS is an important part of MOSFET.

Drain characteristics:-

→ The drain characteristics of a MOSFET are drawn between the drain current (I_D) and the drain source voltage V_{DS}. The characteristic curve is as shown below. for different values of input.

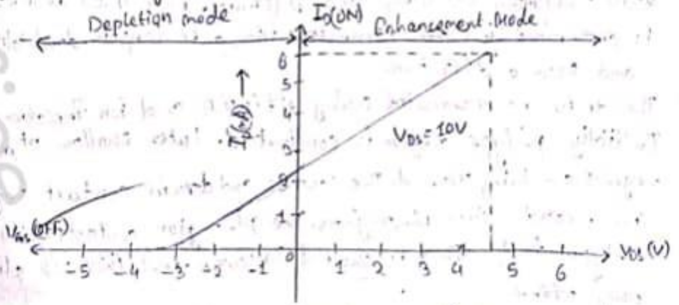


Drain characteristics

→ Actually when V_{DS} is increased, the drain current I_D should increase, but due to the applied V_{GS}, the drain current is controlled at a certain level. Hence the gate current controls the output drain current.

Transfer Characteristics :-

→ Transfer characteristics define the change in value of V_{DS} with the change in I_D and V_{GS} in both depletion and enhancement modes. The below transfer characteristic curve is drawn for drain current versus gate to source voltage.



Transfer Characteristics of MOSFET

VERTICAL METAL OXIDE SILLICON (VMOS):-

→ The VMOS stands for Vertical metal oxide sillicon, The device has V-shaped gate region. The device are used for applications required minimum powers such as powe amplifiers and switching.

→ It consist of $_{at}$ shaped groove.
→ Due to source at top and drain at bottom, the current flows vertically rather than horizontally.
→ V shaped gate makes cross-sectional area of source to drain path larger. Hence lower ON resistance of the device can be achieved which allows much higher power.
→ The gate consists of metallised area over the V groove which controls current flow in P-region.
→ VMOS structure is more complex compare to traditional FET device. This makes it more expensive.

LDMOS:-

→ LDMOS is an assymetric power MOSFET device. It is designed for applications requiring lower on-resistance and higher blocking voltage.
→ In LDMOS channel current is being controlled by vertical electric field (E). This E-field is included by gate and literal field which exists between S (source) and D (Drain). In LDMOS device, channel is determined by three parameters viz. gate length, drain diffusion and source diffution.
→ The device is fabricated using diffusion and ion implation processes. Initially p-type region is constructed. Later shallow p^+ and n^+ regions are being formed. The source and drain contact regions are created from n^+ regions. The p^+-region contacts with the p-type body. This is shorted to source part. this will eliminate body effect.

INTRODUCTION:-

→ Historically, an operational amplifier (OP-Amp) was designed to perform such such Substraction, Integration and differentiation. Hence, the name operational amplifier.
→ An operational amplifier is a multistage amplifier and consist of a differential amplifier stage, a high gain CE amplifier stage and class B push pull emitter follower.
→ A operational amplifier (OPAMP) is an integrated circuit and and is widely used in computers, as audio and video amplifiers in communication electronics. Because of their multipurpos use.
→ All the components of an OP-Amp (e.g transistors, registors etc) are fabricate on a single chip called integrated circuit.
→ OP-Amps are used in all branches of electronics, both digital and linear circuits. In this chapte we shall discuss the various aspects of operational amplifiers.

Block diagram of Operational Amplifier:-

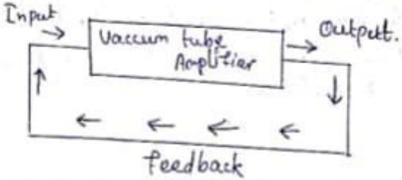
• An operational amplifier (OP-Amp) is a circuit that performs such mathematical operations such as addition, subtraction, integration and differentiation.

Block diagram of OP-Amp

→ The figure shows the block diagram of an operational amplifier. Note that OP-Amp is a multi stage amplifier. The three stages are: differential amplifier input stage followed by a followed by a high-gain CE amplifier and finally the output stage.
→ The key electron circuit in an OP-Amp is the differential amplifier. A differential amplifier (DA) can accept two input signals and amplifies the difference between theses two ~~signal~~ input signals.

What is feedback Amplifier:-

The feedback amplifier can be defined as an amplifier which has feedback lane that exist between output and input. In this type of amplifiers, feedback is the limitation which calculates the sum of feedback given in the following amplifier. The sum of feedback given in the following amplifier. The feedback factor is the ratio of the feedback signal and the input signal.



Types of feedback amplifier:-

The procedure of introducing some device's output energy faction from back to the i/p is termed as feedback. This is mainly used to reduce noise as well as make the operation of an amplifier is constant. The amplifier is classified in two types based on feedback signal helps such as Positive & negative feedback amplifier.

Positive feedback Amplifier:-

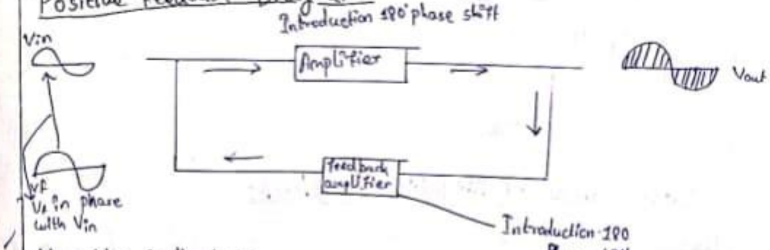
The positive feedback can be defined as when the feedback current otherwise voltage is named as positive feedback generates unnecessary distortion: it is not often used in amplifier. But it amplifies the original signal power and can be used in oscillator circuits.

Negative-Feedback Amplifier:-

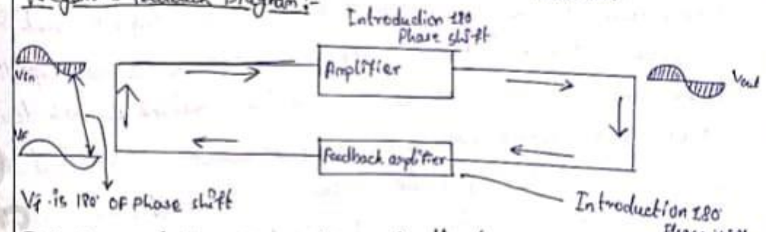
The negative feedback can be defined as if the feedback current otherwise can be applied for reducing the amplifier i/p, then it is called as negative feedback. Inverse

feedback is another name of this negative feedback. This kind of feedback is regularly used in amplifier circuits.

Positive feedback Diagram.



Negative feedback Diagram:-



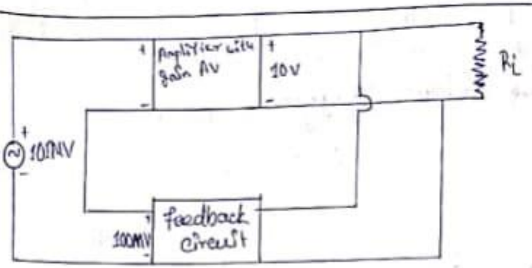
Principle of Negative Voltage feedback amplifier:-

A feedback amplifiers has two parts Vin an amplifier and a feedback circuit usually consists of resistors and returns a fraction of output energy back to the input in figure. as shows the principle of negative voltage feedback in an amplifier. Typical values have been assumed to output i.e 100 mV is feedback to the input where it is applied in series with the input signal of 101 mV. As the feedback is negative therefore, only 1mV appears at the input terminals of the amplifier.

Gain of amplifier without feedback $A_v = \frac{10V}{1mV}$

fraction of output voltage feedback $= 10000 = \frac{100mV}{10V} = 0.01V$

Gain of amplifier with negative feedback $A_f = \frac{10V}{101mV} = 100V$



Classification of Negative feedback:-

Negative feedback in an amplifier is the method of feeding a portion of the amplified output to the input but in opposite phase. The phase opposition occurs at the amplifier provides 180° phase shift whereas the feedback network doesn't while the output energy is being appeared to the input, for the voltage energy to be taken as feedback. The current energy to be taken as feedback., the output is taken in shunt connection. and for the current energy to be taken as feedback the output is taken in series connection. There are two main types of negative feedback circuits

They are :- * Negative voltage feedback
- Negative current feedback

Negative voltage feedback:-

In this method the voltage feedback to the input of amplifier is proportional to the output voltage.

This is further classified into two types

* Voltage - series feedback
* Voltage - shunt feedback

Negative current feedback

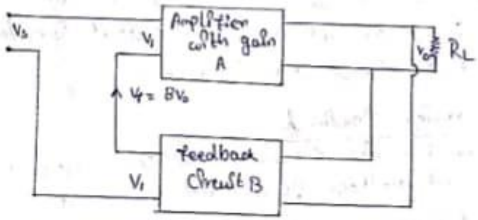
In this method, the voltage feedback to the input of amplifier is proportional to the output current. This is further classified into two types.

* Current - series feedback
* Current - shunt feedback

Voltage - series feedback :-

In the voltage series feedback circuit a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as shunt - driven series - fed feedback i.e a parallel series circuit.

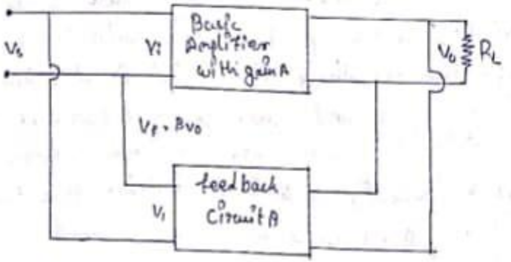
The following figure shows the block diagram of voltage series feedback, by which it is evident that the feedback circuit is placed in shunt with the output but in series with input.



As the feedback circuit is connected is shunt with the output, the output impedance is decreased and due to the series connection with the input, the input impedance is increased.

Voltage-shunt feedback :-

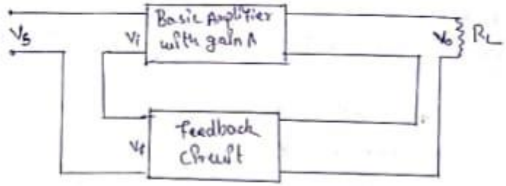
In the voltage shunt feedback circuit. a fraction of the output voltage is applied in parallel with the input voltage through the feedback network. This is also known as shunt-driven, shunt-fed feedback i.e a parallel-parallel prototype.
The below figure shows the block diagram of voltage shunt feedback, by which it is evident that the feedback circuit is placed in shunt with the output and also with the input.



As the feedback circuit is connected in shunt with the output and the input as well, both the output impedance and the input impedance are decreased.

Current-series-feedback:-

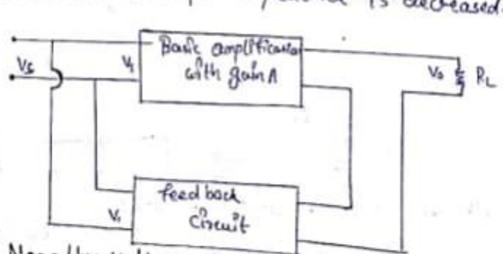
In the current series feedback circuit, circuit a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as series driven series fed feedback i.e a series-series circuit.
The following figure shows the block diagram of current series feedback, by which it is evident that the feedback circuit is placed in series with the output and also with the input.



As the feedback circuit is connected in series with the output and the input as well, both the output impedance and the input impedance are increased.

Current-shunt-feedback:-

In the current shunt feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as a series driven shunt fed feedback i.e a series parallel circuit.
The below figure shows the block diagram of current shunt feedback circuit which it is evident that the feedback circuit is placed in series with the output in parallel with the output, the output impedance is increased and due to the parallel condition with the input impedance is decreased.



Gain of Negative Voltage feedback Amplifier:-

The negative voltage feedback amplifier shown in figure. The gain of the amplifier without feedback is a negative feedback is then applied by feeding a fraction m_v of the output voltage to back to amplifier input. Therefore the actual input to the amplifier is the signal voltage eg minus feedback voltage

$m_v e_o$ ie Actual input to amplifier = $e_g - m_v e_o$
The output e_o must be equal to the input voltage $e_g\ m_v e_o$ multiplied by gain A of the amplifier.

$$(e_g - m_v e_o) A_v = e_o$$

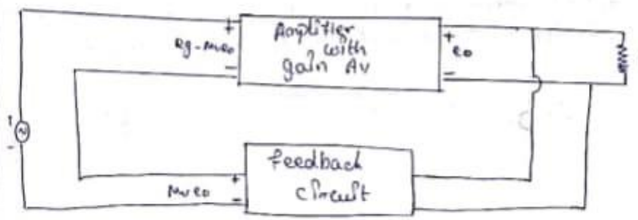
$$A_v e_g - A_v m_v e_o = e_o$$

$$\frac{e_o}{e_g} = \frac{A_v}{1 + A_v m_v}$$

But e_o/e_g is the voltage gain of the amplifier with feedback is

$$A_{vg} = \frac{A_v}{1 + A_v m_v}$$

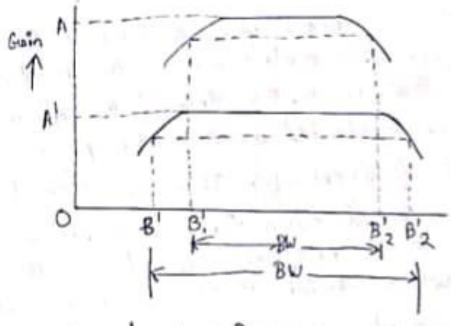
It may be seen the gain of the amplifier without feedback A_v, However, when negative voltage feedback is applied the gain is reduced by a factor $1 + A_v m_v$, it may be noted that negative voltage feedback does not affect the current gain of circuit.



Bandwidth and Gain - bandwidth product:-

Each of higher and lower cut-off frequencies will improve by a factor of $(1 + A\beta)$, However, gain- bandwidth product remains constant. An important piece of information that can be obtained from a frequency curve response is the bandwidth of the amplifier. This refers to the band of frequencies for which the amplifier has a useful gain. Outside this useful Band the gain at the centre of the Bandwidth.

The bandwidth specified for the voltage amplifiers is the range of frequencies for which the amplifiers gain than 0.707 of the output to input voltage. The useful bandwidth will be described as extending to those frequencies at which the gain. 3dB down compared to the gain at the mid- band frequency.



Input and output impedance:-

The output and input impedance will also improve by a factor of $(1+A\beta)$, based on feedback connection sometimes the circuit component doesn't behave in the same way when it is by itself versus when it's connected to another compound. To understand how the circuit will behave we have must consider the input and output impedances of the different parts. The output impedance refers to the impedance or opposition of current flow of the component that often bears an electrical source to drive a load component meanwhile, the input impedance refers to the load components, and opposition to current flowing from the electrical source. In many cases, you will bound to have a high input impedance relative to output impedance and you will see why in the following section.

Gain stability:-

An important advantage of negative voltage feedback is the resultant gain of the amplifier can be made independent of transistor parameters or the supply voltage variations.

$A_f = A/(1+A\beta)$

for negative voltage feedback in an amplifier to be effective the designer deliberately makes the product $A\beta$ much greater than unity. Therefore, in the above reaction, '1' can be neglected as compared to $A\beta$ and the expression becomes $A_f = A/(1+A\beta) = 1/\beta$ It may be seen that the gain now depends only upon feedback fraction β. i.e on the characteristics of feedback circuit. As feedback circuit usually a voltage divider therefor, it is unaffected by changes in temperature, variations in transistor parameters and frequency. Hence the gain of the amplifier is extremely stable.

Distortion:-

A power amplifier will have non-linear distortion because of large signal variations. The negative feedback reduce the non linear distortion. It can be proved mathematically that

$D_f = D/(1+A\beta)$

where D = distortion amplifier without feed-back
D_f = " " in amplifier with negative feedback

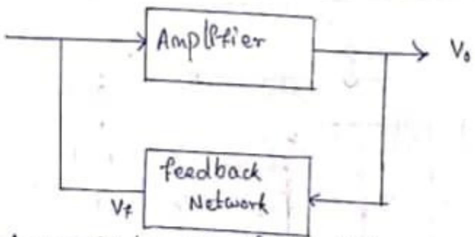
Noise:-

There are no. of source of noises in an amplifier. The noise N can be reduce by the factor of $(1+A\beta)$, in a in a similar - manner to non-linear distortion, so that the noise with feedback is given by $N_f = N/(1+A\beta)$

Oscillator:-

A oscillator is a mechanical or electronic device that works on the principle of oscillation. A periodic fluctuation between two things based on changes in energy. Computers, radios, clocks, watches, and metal detectors are among the many devices that use oscillators. A clock pendulam is a simple type of mechanical oscillators. The most accurate timepiece in the world is the atomic the atomic clock keeps time, according to the oscillations within atoms. Electric oscillators are used to generates signals in computers, wireless recievers and transmitters, audio-frequency equipment particularly music synthesizers. There are many types of electric oscillators, But they all are operate according to the same basic principle. An oscillator always employees a sensitive amplifier whose output is feedback to the input inphase. Thus the signal regenerates and sustains itself.

BLOCK Diagram of Sinwave Oscillators:-



OP-Amp oscillators are circuits that are unstable-not the type that are sometimes unintentionally designed or created in the Lab - ones that intentionally designed to remains in an unstable or in oscillator state. Oscillators are useful for generating uniform signals that are used as a reference in such application as audio function generators, digital system, and communication system.

Barkhausen Criteria:-

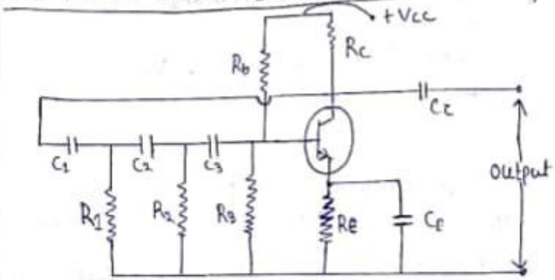
Conditions which are required to be satisfied to operate the circuits as an oscillator are called as "Barkhusen criteria" for sustained oscillation.

The Barkhusen criteria should be satisfied by an amplifier with positive feedback to ensure the sustained oscillations.

For an oscillation circuit there is no input signal "V_s" hence the feedback signal V_f itself should be sufficient to maintain the oscillation.

The Barkhusen criterion state that: The loop gain is equal to unity in absolute magnitude that is $|BA| = 1$ and the phase shift around the loop is zero or an integer multiple of 2π radiation (180°) i.e $\angle B'A = 0$

RC Phase shift Oscillator:-

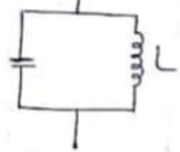


The collector resistor RC limits the collector current of the transistor, resistor R_b and R_3 (nearest to the transistor) from the voltage divider network while the emitter transistor RE improves the stability. Next the capacitor CE and cc are the Emitter by pass capacitor and the output DC decoupling capacitor respectively.

Further the circuit also shown three RC networks exployed in the feedback path.

LC Oscillator :-

Basically an oscillator uses positive feedback and generate an O/P frequency without using an input signal. Thus these are self supporting circuits. that generates a periodic O/P waveform at an exact frequency. LC Oscillator is a kind of oscillator where a tank circuit (LC) is used to give the required positive feedback for maintaining the Oscillation.

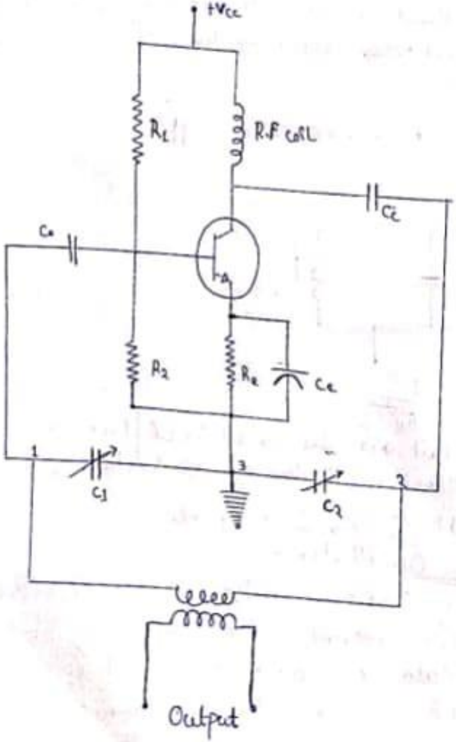


$$f = \frac{1}{2\pi\sqrt{LC}}$$

This circuit ais also called as LC tuned or LC resonant circuit. These Oscillators can understand with the help of FET, BJT, OP-Amp, MOSFET etc.

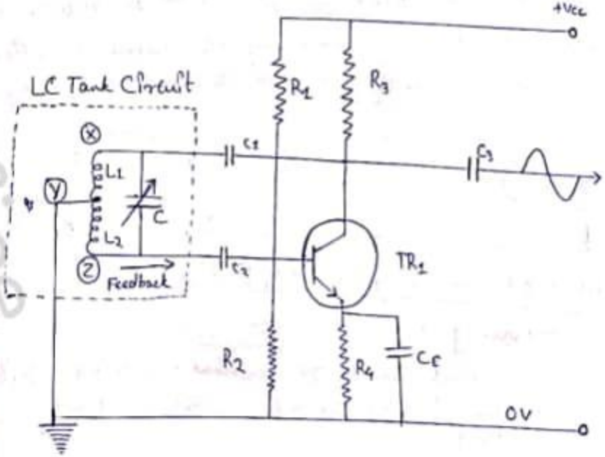
Colpits Oscillator:-

When the collector supply is given, transient current is produced in the oscillatory or tank circuit. The Oscillatory current in the tank circuit produced a.c voltage across C_1 which are applied to the base emitter junction and appear in the amplified form in the collector circuit and supply losses to the tank circuit if terminal is at positive potential with respect to terminal 3 at any instant, then terminal 2 will be at negative potential with respect to 3 at that instant because terminal 3 is grounded. Therefore points 1 and 2 are out of phase by 180°. As the CB configures to transistor it provides 180° phase shift. it makes 360° phase shift between the input and voltage.



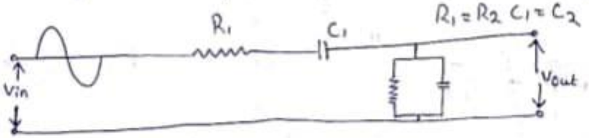
Hartley Oscillator:-

The Hartley oscillators design uses two inductive coils in series with a parallel capacitor to form it's resonance tank circuit producing sinusoidal oscillation. One of the main disadvantages of the basic LC oscillator circuit we looked at that they have no means of controlling the amplitude of the oscillators and also it is difficult to tune the oscillator to the required frequency. If the cumulative electromagnetic coupling between L_1 and L_2 is too small there would be insufficient feedback and the oscillation would eventually die away to zero.



Wien Bridge Oscillator

The wien bridge oscillator uses two RC network connected together to produce a sinusoidal oscillator. In the RC Oscillator we saw that a no of resistors and capacitors can connected together with an inverting amplifier to producing an oscillator circuit. One of the simplest sin wave oscillator uses RC network ~~in circuit~~ in the place of the conventional LC tuned tank circuit to produce a ~~stead~~ sinusoidal output wave form, is called a wien bridge oscillator. The wien bridge oscillator is called because the circuit is based on a frequency selective form of the wheatstone bridge circuit. The wien bridge oscillator is a two way RC coupled amplifier circuit that has good stability at ~~its~~ resonant frequency.



Evolution of frequency of Oscillation:-

The frequency $f = 1/T = \omega/2\pi$

The motion gives the no. of ~~oscillator~~ complex oscillations per unit time. It measured in unit of Hertz. ($1 Hz = 1/s$)

Frequency stability:-

Frequency stability represents the variation of output frequency of a crystal oscillator due to external conditions like temperature variation, voltage variation, output load variation and frequency aging. Frequency stability is typically expressed in parts per million (PPM) or parts per billion (PPb) which can be represented in the form of frequency (usually in Hz).

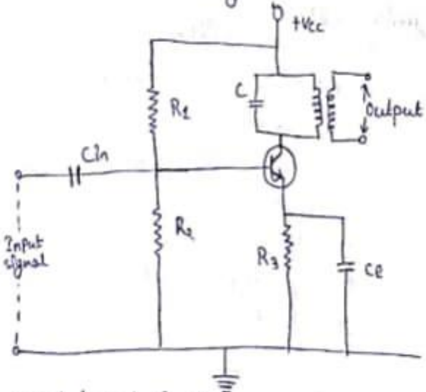
$$\text{Variation in Hz} = \frac{f \times PPM}{10^6}$$

Where f = centre frequency in Hz

PPM = frequency variation in PPM.

What is Tuned amplifier:-

Tuned amplifiers are the amplifiers that are employed for the purpose of tuning. Tuning means selecting among a set of frequencies available. If there occures a need select a particular frequency, while rejecting all the other frequencies, such a process is called selection. This selection done by using a circuit called tuned circuit. When a amplifier circuit has it's load replaced by a tuned circuit. Such as amplifier is called as a tuned amplifier circuit. The basic tuned amplifier circuit looks as shown in fig.



Types of tuned circuits:-

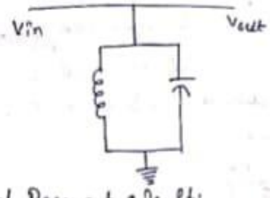
A tuned circuit can be series tuned circuit (series resonant circuit) or parallel tuned circuit (Parallel resonant circuit) according to it's type of it's connection to the main circuit.

Series Tuned circuit:-

The inductor and capacitor connected in series make a series tuned circuit, as shown in the following circuit diagram.

Parallel Tuned circuit:-

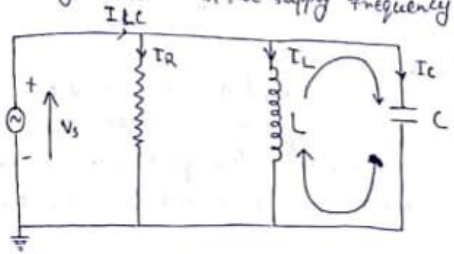
The inductor and capacitor are connected in parallel tuned circuit; as shown in figure below.



Parallel Resonant Circuit:-

Parallel Resonance occurs when the supply frequency creates zero phase difference supply voltage and current producing a resistive circuit.

In many ways a parallel resonant circuit is exactly the same as the series resonance. The circuit we locked at has 3- elements of networks that contains two reactive components making them a second order circuit both are influence by variation in the supply frequency.

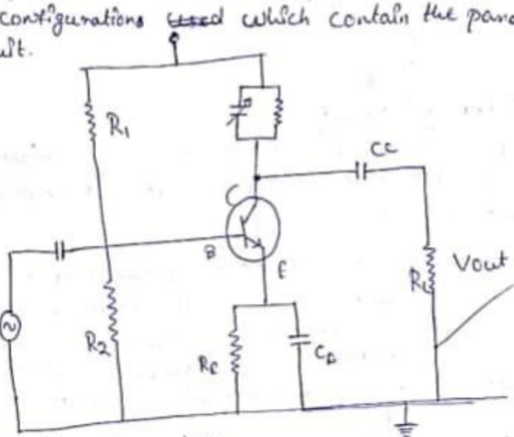


Sharpness of resonance:-

The quantity (ω₀/2Δω) is regarded as a measure of the Sharpness of the resonance. The smaller the Δω, the sharper or narrower is the resonance. Here, ω₀ is the resonant frequency, 2Δω is the bandwidth.

Single tuned amplifier:-

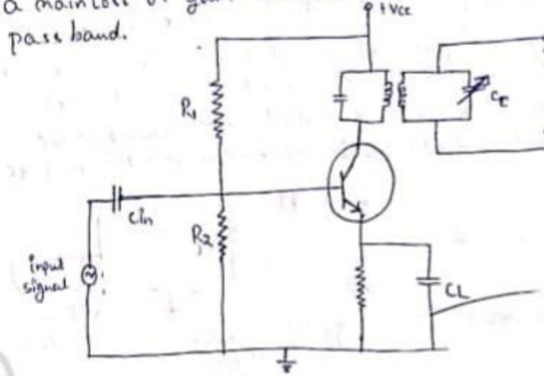
The single tuned amplifier is a multistage amplifier which uses a parallel tuned circuit like a load. But the LC circuit and tuned circuit in every stage are necessary to be selected to the same frequencies. The configuration used in this amplifier is CE amplifier. non configurations which contain the parallel tuned circuit.



Double tuned Amplifier

This is one kind of tuned amplifier that uses the coupling of transformer among the two stages like inductance of both the windings. The tuning of these winding can be done separately across a capacitance. For the transformer

there is critical values of co-efficient where the amplifier's frequency responce can be even maximize within the passband. The gain of this can be highest at the resonant frequency. The coupling can be used by the designe which is greater that over coupling to get a level wider BW at the expenditures of a main loss of gain while the middle of this pass band.

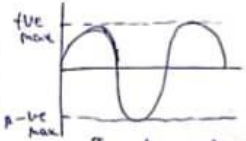


What is clipper circuit?:-

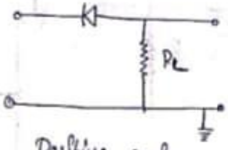
An electronic device that is used to exceed the output of a circuit to go beyond the preset value (voltage level). without varing the remaining part of the input waveform is called a clipper circuit. An electronic alter the positive peak or negative peak of the input signal to a define value by shifting the entire signal up or down to obtain the output signal peaks at the desired level is called Clamper circuit.

Positive diode clipper :-

In a positive clipper, the positive half cycle of the input voltage will be removed. The circuit arrangement for a positive clipper are illustrated in figure below. The diode is kept in series with the load, During the positive half cycle of the input wave form, the diode 'D' is reverse biased which maintains the output voltage at 0 volts. This causes the positive half cycle to be clipped off During the negative half cycle of the input the diode is forward biased and so the negative half cycle appears across the output.



Input waveform

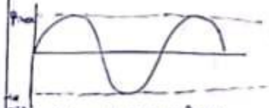


Positive series clipper

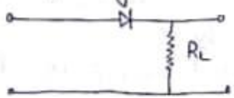
output wave form

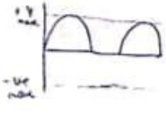
Negative Diode clipper

The negative clipper circuit is almost the same as the positive Diode clipping circuit, with only one difference. If the diode on figure (a) and (b) is connected with reverse polarity the circuit the circuit will become a negative series clipper and a negative shunt clipper respectively



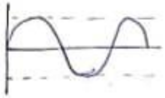
Input waveform



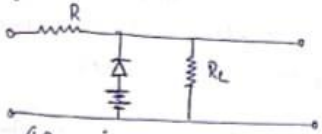


Biased positive clipper and Biased Negative Clipper :-

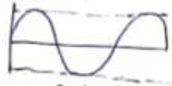
A biased clipper comes in handy when a small portion of ~~positive of~~ positive or negative half cycles of the signal voltage is to be removed when a small portion of the negative half cycle is to be removed, it is called a biased negative clipper. The circuit diagram and wave form is shown in the figure below.



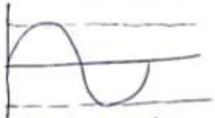
Input wave form



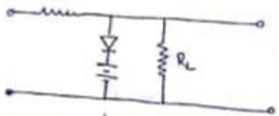
(biased negative clipper)

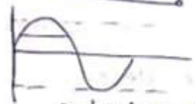


Output wave form



Input wave for





Output wave form

Clamper Circuit :-

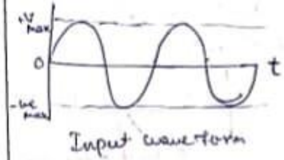
A clamper circuit can be defined as the circuit that Consist of a diode, a resistor and a capacitor that shifts the wave forms to a desired D.C level without changing the ~~act~~ actual appearance of the applied signal

Types of Clamper Circuit :- Positive clamper
Negative clamper

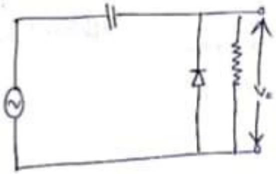
Positive clamper circuit :-

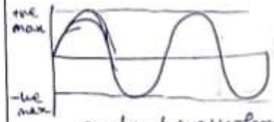
A clamping circuit restores D.C level. When a negative peak of the signal is raised above to the zero levels then the signal is said to be positively clamped.

A positive clamper circuit is one that consist of a diode, a resistor and a capacitor and that shifts the output signal to the portion of the input signal. the figure below explains the construction.



Input waveform

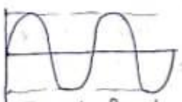




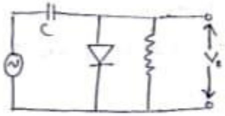
output wave-form

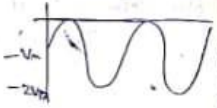
Negative clamper :-

A negative clamer circuits is one that consist of a diode, a resistor and a capaciter and that shifits the output signals to the negative portion of the input signal. The figure below explains the construction of a negative clampers circuit.



Input signal





During the positive half cycle the capacitor gets charged to it's peak value Vm The diode is foward biased and conducts. during the negative half cycle the diode get reverse biased and gets open circuited. The output of the circuit at this moment will be

$$V_o = V_i + V_m.$$

Integrator :-

An integrator in measurement and control applications is an element whose output signal is the time integral of it's input signal. I accumulates the input quantity over a defined time to produce a representative output.

Integration is an important part of many engineering and scientific applications. Mechanical integrators are the oldest application, and are still used in such metering of water flow or electric power. Electronic analogue integrators are the basis of analog computers and charge amplifiers. Integration is also performed by digital computing algorithms.