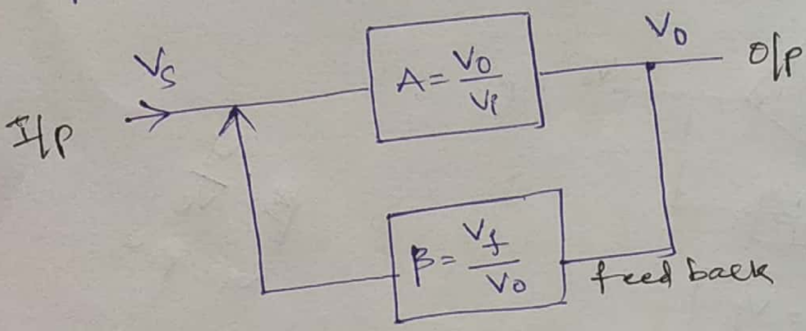
Module-4

Feed back Amplifier

Concept of Feedback Amplifier:

the Feed back amplifier can be defined as an amplifier which as a feed back lone exist between out put to input.



Feedback is defined as the process in which a part of output signal (voltage or current) is returned back to the input.

the amplifier that operates on the principle of feedback is known as feedback amplifier.

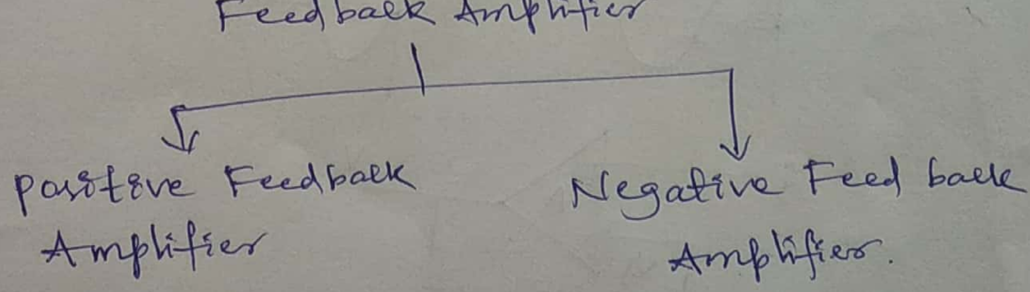
Feed back factor (β):

The feed back factor is the ratio of feed back signal and input signal

$$\beta = \frac{V_f}{V_s}$$

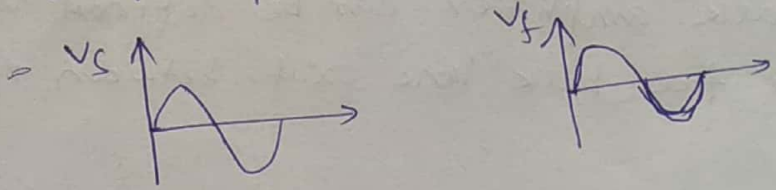
Types of feed back amplifiers:

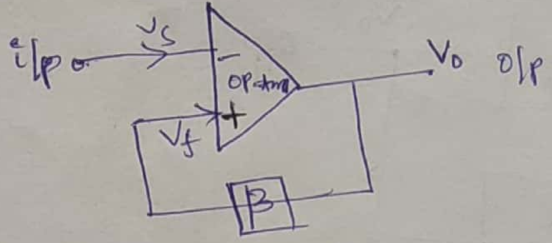
Feed back amplifier are basically classified into two categories. based on the feed back signal.



Positive Feedback Amplifier:

It is a type of an amplifier in which source signal and the feedback signal are in the same phase. Thus, the feedback signal applied increases the strength of the input signal.





$$\beta = \frac{V_f}{V_s}$$

$$V_f = \beta V_s$$

$$\boxed{V_s + V_f = V_i}$$

$$A_f = \frac{V_o}{V_s} = \frac{V_o}{V_i - V_f} = \frac{V_o}{V_i - \beta V_s} \quad \left(\beta = \frac{V_f}{V_s}\right)$$

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

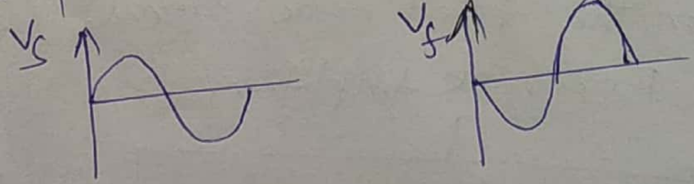
$$= \frac{A V_i}{V_i - \beta A V_i}$$

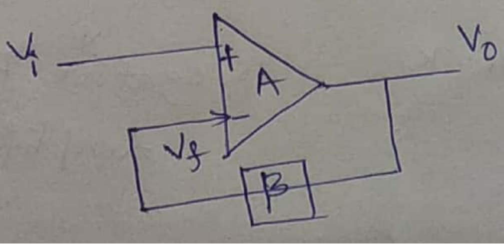
$$= \frac{V_i}{V_i} \times \left(\frac{A}{1 - \beta A}\right)$$

$$\boxed{A_f = \frac{A}{1 - \beta A}}$$

Negative Feedback Amplifier:

In this type of amplifier source signal and the feedback signal are out of phase with each other. thus, the feedback signal applied to decrease the strength of the input signal.





$$V_s - V_f = V_i$$

$$A_f = \frac{V_o}{V_s} = \frac{V_o}{V_i + V_f} = \frac{V_o}{V_i + \beta V_s}$$

$\because \frac{V_f}{V_s} = \beta$

$$= \frac{AV_i}{V_i + \beta A V_i}$$

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

$$= \frac{V_i}{V_i}\left(\frac{A}{1+\beta A}\right)$$

$$A_f = \frac{A}{1+\beta A}$$

Effects of -ve feed back

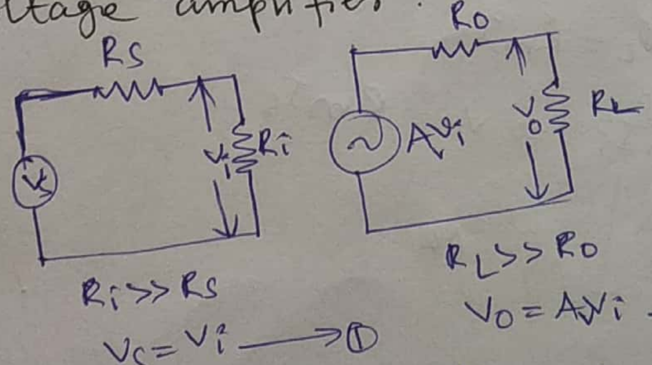
- Increase stability
- Increase Bandwidth
- Less distration
- Decrease Noise
- I/P and O/P impedance can be modified.

I $= \frac{V}{I}$ $= \frac{I}{V} = G$

Basic classification of amplifiers: Depending up on output & input

1. voltage amplifier $\left(A = \frac{V_o}{V_i}\right)$
2. Current amplifier $\left(A = \frac{I_o}{I_i}\right)$
3. Transconductance amplifier $\left(G = \frac{1}{R} = \frac{I_o}{V_i}\right)$
4. Trans resistance amplifier $\left(R = \frac{V_o}{I_i}\right)$

- Voltage amplifier:



= Thevinen's equivalent model → for Voltage

= Nortons equivalent Circuit for current

$R_i >> R_s$

$V_s = V_i \longrightarrow (1)$

$R_L >> R_o$

$V_o = A_V V_i \longrightarrow (2)$

$V_o = AV_i \Rightarrow V_o = A_V V_s$

$$A_V = \frac{V_o}{V_s}$$

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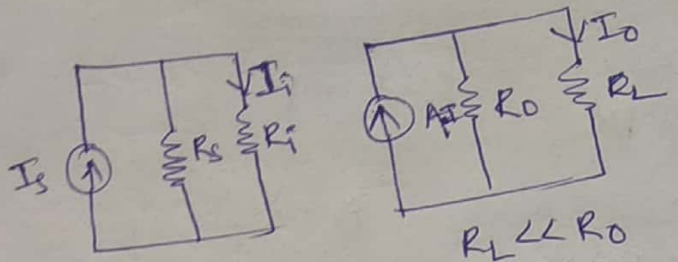
- Current amplifier.



$R_L << R_o$

$R_i << R_s$

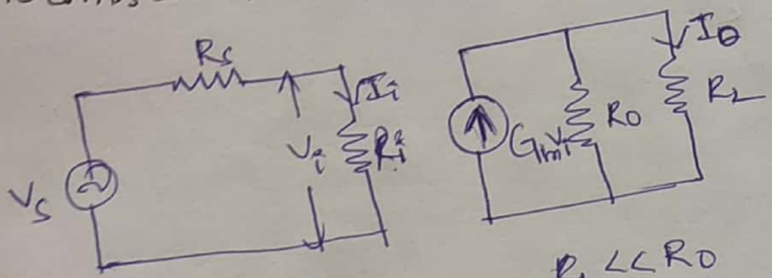
$I_s = I_i \rightarrow ①$

$I_o = AI_i \longrightarrow ②$

$I_o = AI_s$

$$\boxed{A_i = \frac{I_o}{I_s}}$$

- Transconductance



$\frac{1}{R} = \frac{V}{I} \quad \frac{1}{\frac{V}{I}} = \frac{I_o}{V_i}$

$R_L << R_o$

$R_i >> R_s$

$I_o = G_m V_i$

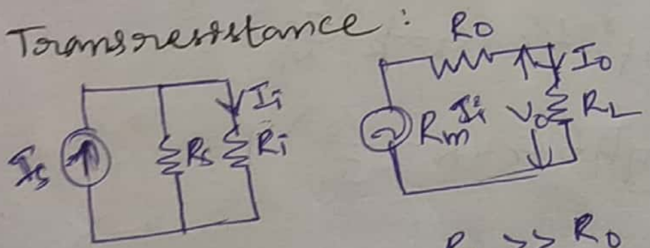
$V_i = V_s$

$I_o = G_m V_s$

$$\boxed{\frac{I_o}{V_s} = G_m}$$

A_G

- Transresistance :



$R = \frac{②}{①}$

$R_L >> R_o$

$R_i << R_s$

$I_s = I_i \rightarrow ①$

$V_o = R_m I_i$

$V_o = R_m I_i \Rightarrow V_o = R_m I_s$

$$\boxed{R_m = \frac{V_o}{I_s}}$$

A_R

Topology of feed back amplifier:

- Voltage series feed back Amplifier - VCVS
- Voltage shunt feed back Amplifier - CCVS
- Current series feed back Amplifier - VCCS
- Current shunt feed back Amplifier - CCCS

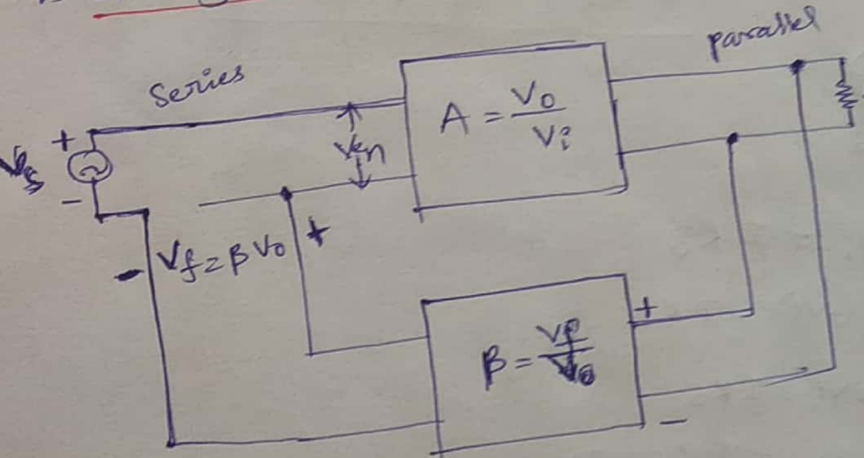
* Voltage Series feed back Amplifiers: (series - parallel)

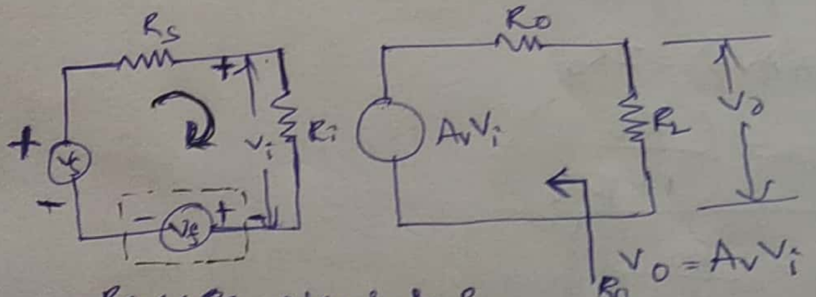
In this type of circuit, a portion of the o/p voltage can be applied to the input voltage in series through the feedback circuit. the block diagram of the voltage series feedback amplifier is shown below, by which it is apparent that the feedback circuit is located in shunt by means of the output although in series by means of the input.

- When the feed back is allied in shunt through the o/p, then the output impedance will be reduced and the i/p impedance is enlarged because of the series connection with the input.

o/p ⇒ V - parallel
I - Series

i/p ⇒ mentioned name





KVL ⇒ $+V_i + V_f - V_s = 0$

$V_i = V_s - V_f$

$R_s << R_i$ Neglect R_s

Apply KVL at input loop

$-V_s + V_i + V_f = 0$

$$\boxed{V_i = V_s - V_f}$$

$$\boxed{\because \beta = \frac{V_f}{V_o} \quad V_f = \beta V_o} \quad A = \frac{V_o}{V_i}$$

$\frac{V_o}{V_i} = AV$

Input impedance:

$V_i = V_s - \beta V_o$

$V_i = V_s - \beta (A_v V_i)$

$V_i + \beta A_v V_i = V_s$ $\qquad V_i = I_i R_i$

$V_i (1+\beta A_v) = V_s$ $\qquad V_i = I_i R_i$

$I_i R_i (1+\beta A_v) = V_s$

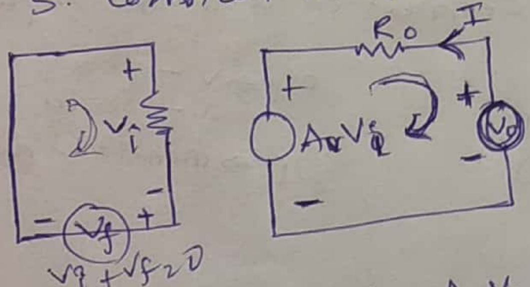
$$\boxed{R_{if} = R_i (1+\beta A_v) = \frac{V_s}{I_i}}$$ input resistance

R.

Output impedance:

1. Remove R_L
2. Make source zero ; if it is voltage source then short circuit and if it is current source then open circuit.
3. Connect a battery at output size

$$\boxed{-A_v V_i + V_o - R_o I_o = 0}$$ from KVL



$V_i + V_f = 0$

$V_i = -V_f$

$V_o - A_v V_i = I R_o$

$V_o - A_v(-V_f) = I R_o$ $\qquad V_f = \beta V_o$

$V_o + A_v V_f = I R_o$

$V_o + A_v \beta V_o = I R_o$

$V_o (1 + A_v \beta) = I R_o$

$\frac{V_o}{I} = \left(\frac{R_o}{1+\beta A_v}\right)$

$$\boxed{R_{of} = \frac{R_o}{(1+\beta A_v)}}$$

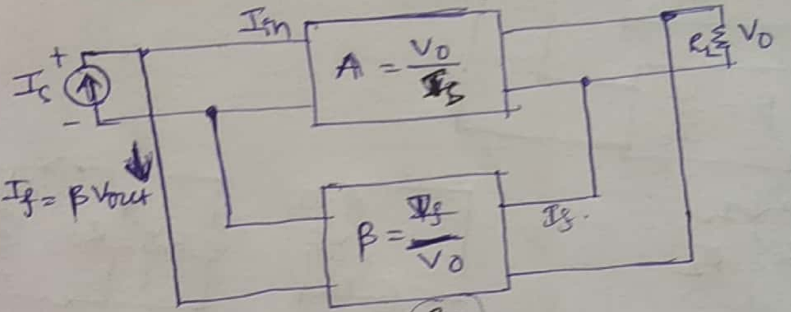
* Voltage shunt feed back amplifier:

In this type of feed back circuit, a portion of the o/p voltage can be applied to the input voltage in parallel with through the feed back circuit.

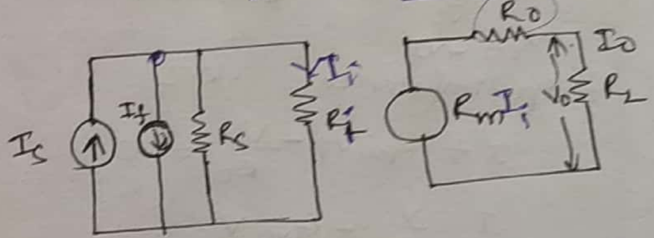
- The block diagram is shown below, by which it is apparent that feedback circuit is located in shunt by means of the o/p as well as the input.

- When the feed back circuit is allied in shunt through the o/p as well as the input, then both the o/p impedance & the i/p impedance will be decreased.

$R = \frac{V}{I}$



Transresistance Amplifier



$R_s >> R_i$

$V_0 = R_m I_i$

$I_i = \frac{V_i}{R_i}$

from KCL

$$\boxed{I_s = I_i + I_f}$$

$I_f = \beta V_0$

input impedance

$I_s = \beta V_0 + I_i$

$I_s = (\beta R_m I_i + I_i)$

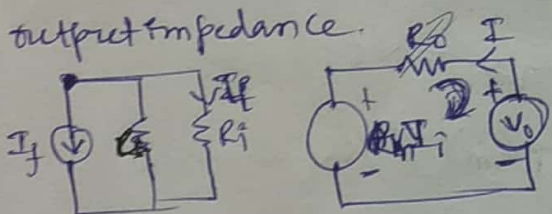
$I_s = I_i(1 + \beta R_m)$

$I_s = \frac{V_i}{R_i}(1 + \beta R_m)$

$R_i = \frac{V_i}{I_s}(1 + \beta R_m)$

$$\boxed{\frac{R_i}{1+\beta R_m} = \frac{V_i}{I_s} = R_{if}}$$

output impedance



$V_0 - R_m I_i$

$V_0 = R_m I_i$

$I_i = -I_f$

output kvr $V_0 - R_m I_i = I R_o$

$V_0 + R_m I_f = I R_o$

$V_0 + \beta R_m V_0 = I R_o$

$V_0(1 + \beta R_m) = I R_o$

$$\boxed{\frac{V_0}{I} = \frac{R_o}{1+\beta R_m} = R_{of}}$$

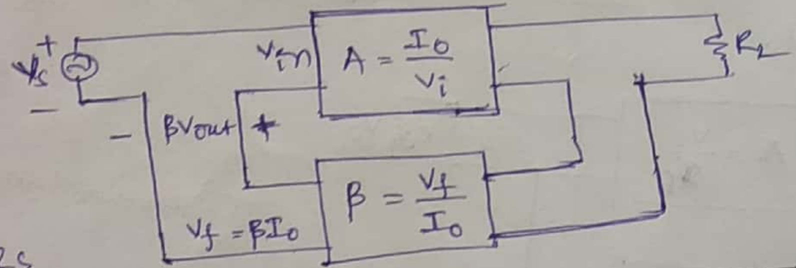
- Current Series feedback Amplifier

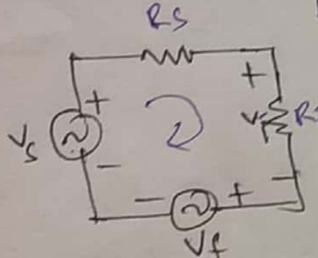
- In this type of feed back circuit, a portion of the o/p voltage is applied to the i/p voltage in series through the feed back circuit.

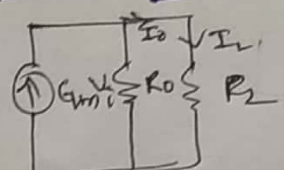
- The block diagram of the current series feed back - amplifier is shown below, by which it is apparent that the feed back circuit is located in series by means of the output as well as the input.

- When the feed back circuit is allied in series through the o/p as well as the input, then both the o/p impedance & the i/p impedance will be increased.

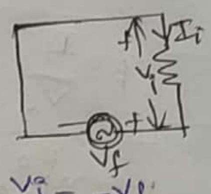
Trans conductance



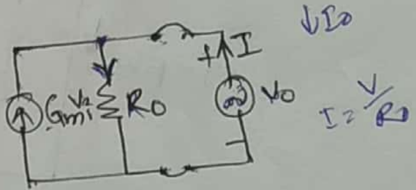




$I_o = G_m V_i$



$V_i = -V_f$



Input impedance:

$V_i = V_s - V_f$ $\quad (V_f = \beta I_o)$

$V_i = V_s - \beta I_o$

$V_i = V_s - \beta G_m V_i$

$V_i + \beta G_m V_i = V_s$

$V_i (1 + \beta G_m) = V_s$

$I_i R_i (1 + \beta G_m) = V_s$

$$\boxed{R_i (1 + \beta G_m) = \frac{V_s}{I_i} = R_{if}} \uparrow$$

Output impedance (KCL)

$I + G_m V_i - \frac{V}{R_o} = 0$

$I = \frac{V}{R_o} - G_m V_i$

$I = \frac{V}{R_o} - G_m(-V_f)$ $\quad (V_f = \beta I_o)$

$I = \frac{V}{R_o} + G_m V_f$

$I = \frac{V}{R_o} + G_m \beta I_o$

$$\boxed{I = -I_o}$$

$I = \frac{V}{R_o} + G_m \beta (-I)$

$I + G_m \beta I = \frac{V}{R_o}$

$I (1 + G_m \beta) = \frac{V}{R_o}$

$$\boxed{R_{of} = R_o (1 + G_m \beta) = \frac{V}{I}} \Uparrow$$

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- **Current shunt feedback amplifier:**

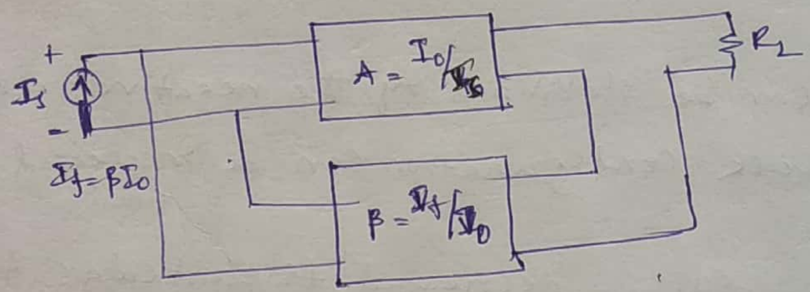
- In this type of circuit, a portion of the o/p voltage is applied to the i/p voltage in shunt through the feedback circuit.

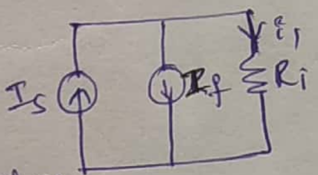
- The block diagram of the current shunt feedback amplifier is shown below, by which it is apparent that the feedback circuit is located in shunt by means of the output as well as the input.

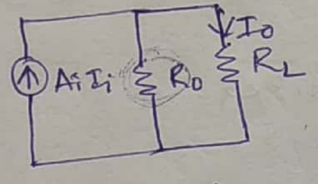
- When the feedback circuit is allied in series through the o/p however in parallel with the input, then the o/p impedance will be increased & because of the parallel connection with the i/p and the i/p impedance decreased.

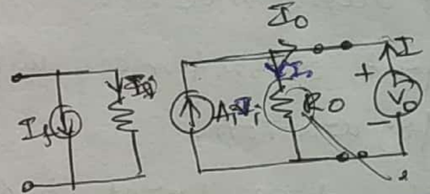
$A_i = \frac{I_o}{I_s}$

Current Amplifier









$V_o = A_i I_i$

I/p impedance

$I_s = I_i + I_f$

$I_f = \beta V_o$

$I_s = I_i + \beta V_o$

$= I_i + \beta A_i I_i$

$= I_i (1 + \beta A_i)$

$I_s = \frac{V_i}{R_i} (1 + \beta A_i)$

$$\frac{R_i}{1+\beta A_i} = \frac{V_i}{I_s} = R_{if}$$

$I_i = -I_f$

$I_f = \beta I_o$

output impedance

$I + A_i I_i - \frac{V_o}{R_o} = 0$

$I = \frac{V_o}{R_o} - A_i I_i = \frac{V_o}{R_o} + A_i(-I_f)$

$I = \frac{V_o}{R_o} + A_i I_f = \frac{V_o}{R_o} + A_i \beta I_o$

but $I_o = -I$

$I = \frac{V_o}{R_o} - A_i \beta I$

$I + A_i \beta I = \frac{V_o}{R_o}$

$I(1 + A_i \beta) = \frac{V_o}{R_o}$

$$R_{of} = R_o (1 + \beta A_i) = \frac{V_o}{I}$$

Amplifier characteristics:

Feedback Topology	Input Resistance	output Resistance
Voltage series	Increases $R_{if} = R_i(1+\beta A_v)$	Decreases $R_{of} = R_o/(1+\beta A)$
Voltage shunt	Decreases $R_{if} = R_i/(1+\beta R_m)$	Decreases $R_{of} = R_o/(1+\beta R_m)$
Current series	Increases $R_{if} = R_i(1+\beta A)$	Increases $R_{of} = R_o(1+A\beta)$
Current shunt	Decreases $R_{if} = R_i/(1+\beta A)$	Increases $R_{of} = R_o(1+A\beta)$

Advantages:

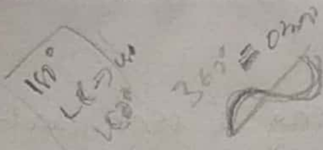
- The amplifier gain can be stabilized by the negative feedback
- The particular feedback configuration can be increased by the input resistance.
- Output resistance will be decreased for particular feedback configuration.
- The operating point is stabilized.

Disadvantages:

- Amplifier is a gain reduction.

Applications:

- Electronic amplifier
- RPS (Regulated power supplies)
- A large bandwidth amplifiers.



Oscillators

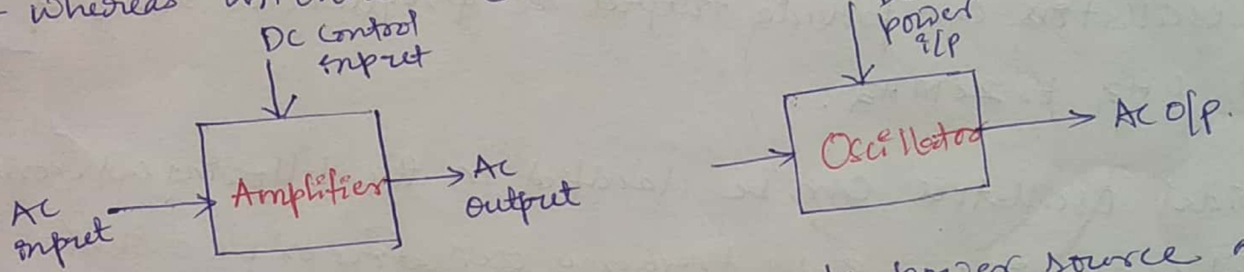
An Oscillators generates output with out any ac input signal.

An electronic oscillator is a circuit which converts dc energy into ac at a very high frequency.

An amplifier with a positive feedback can be understood as an oscillator.

Amplifier Vs Oscillator:

- An amplifier increases the signal strength of the input signal applied
- whereas an oscillator generates a signal with out the input signal



- An amplifier takes energy from dc power source and converts it into ac energy at signal frequency.
- An oscillator produces an oscillating ac signal on its own.
- The frequency, wave form and magnitude of ac power generated by an amplifier, is controlled by the ac signal voltage applied at the input.
- whereas those for an oscillator are controlled by the components in the circuit itself.

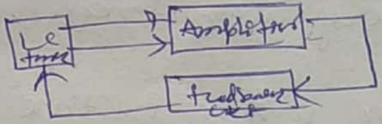
Classification of Oscillators:

Electronic oscillators are classified mainly into the following two categories -

1. Sinusoidal oscillator or Harmonic Oscillator
2. Non - sinusoidal Oscillator or Relaxation Oscillator.

Sinusoidal Oscillators:

- the oscillators that produces an output having a sine waveform are called sinusoidal or harmonic oscillators.
- Such oscillators can provide output at frequencies ranging from 20Hz to 1 GHz.



Non-Sinusoidal Oscillators:

- the oscillators that produces an output having a square, rectangular or sawtooth waveform are called non-sinusoidal or relaxation oscillators.
- Such oscillators can provide output at frequencies ranging from 0 Hz to 20MHz.

Sinusoidal Oscillators can be classified in the following categories:

1. Tuned oscillators: ⇒ Radio frequency oscillators or LC oscillator

- These oscillators use a tuned circuit consisting of inductor(L) and capacitor (C). to generate high frequency signals.
- thus these are known as radio frequency (R.F) oscillators.
- Such oscillators are Hartly, colpitts, clapp-oscillators etc.

2. RC Oscillators: Audio frequency oscillators

- These oscillators use resistors and capacitors, to generate low or audio frequency signals.
- thus these are known as Audio frequency (AF) oscillators.
- Such oscillators are phase-shift and wein bridge oscillators.

3. Crystal Oscillators:

- These oscillators use quartz crystals and are used to to generate highly stabilized output signal with frequencies up to 10MHz.
- The piezo oscillators is an example of a crystal oscillator.

4. Negative - resistance Oscillators:

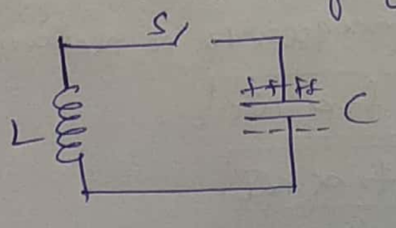
- these oscillators use negative-resistance characteristic of the device such as tunnel devices.
- A tunnel diode oscillator is an example of a negative-resistance oscillator.

Sinusoidal Oscillators:

- An amplifier with +ve feedback produces its output to be in phase with the input and increases the strength of the signal.
- positive feed back is also called as degenerative feedback or direct feedback.
- This kind of feed back a feedback amplifier, an oscillator.
- the use of +ve feedback results in a feedback amplifier having closed-loop gain greater than the open loop gain.
- It results in instability and operates as an oscillatory circuit.
- An oscillatory circuit provides a constantly varying amplified output signal of any desired frequency.

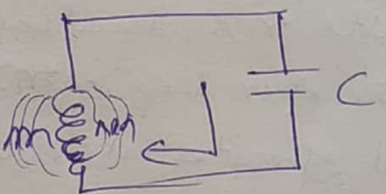
Oscillatory circuit:

- An Oscillatory circuit produces electrical oscillations of a desired frequency.
- They are also called as tank circuits.
- A simple tank circuit comprises of an inductor(L) and capacitor (C) both of which together determine the oscillatory frequency of the circuit.
- To understand the concept of oscillatory circuit let us consider the following circuit.



- The capacitor in this circuit is already charged using a dc source. In this situation, the upper plate of the capacitor has excess of electrons whereas the lower plate has deficit of electrons.
- The capacitor holds some electrostatic energy and there is a voltage across the capacitor.

- When the switch S is closed, the capacitor discharges and the current flows through the inductor.
- Due to the inductive effect, the current builds up slowly towards a maximum value.
- Once the capacitor discharges completely, the magnetic field around the coil is maximum.



- ~~[illegible]~~
- once the capacitor is discharged completely, the magnetic field begins to collapse and produces a counter emf according to Lenz's law.
- the capacitor is now charged with +ve charge on upper plate and -ve charge on the lower plate
- once the capacitor is fully charged, it starts to discharge to build up a magnetic field around the coil.
= this continuation of charging and discharging results in alternating motion of electrons in an oscillatory current.

frequency of oscillations:
- the actual frequency of oscillations is the resonant frequency of the tank circuit

$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$ = resonant frequency or natural frequency.

* capacitance of the capacitor $\boxed{f_0 \alpha 1/\sqrt{C}}$
* self inductance of the coil $\boxed{f_0 \alpha 1/\sqrt{L}}$

1 Tuned Circuit Oscillators.

- Tuned circuit oscillators are the circuits that produces oscillations with the help of tuning circuits.

- These are also known as LC oscillators, resonant circuit oscillators or tank circuit oscillators.

Classification of Tuned Circuit Oscillators:

- Depending upon the way the feed back is used in the circuit, the ~~circuit~~, LC oscillators or Tuned circuit oscillators are divides as the following types.

(a) Tuned collector or Armstrong Oscillator:

- It uses inductive feed back, from the collector of a transistor to the base.

- The LC circuit is in the collector circuit of transistor.

(b) Tuned base:

- It uses inductive feed back. But the LC circuit is in the base circuit.

(c) Hartley Oscillator:

- It uses inductive feed back

(d) Colpitts Oscillator:

- It uses capacitive feed back

(e) Clapp Oscillator:

- It uses capacitive feed back.

Barkhausen stability criterion:

The Barkhausen stability criterion states that:

1. the total phase shift around a loop, as the signal proceeds from i/p through amplifier, feedback network back to input again, completing a loop, is precisely 0° or 360°.

2. The magnitude of the product of the open loop gain of the amplifier (A) and the feedback factor (β) is unity i.e, $|A\beta| = 1$.

Hartley Oscillator:

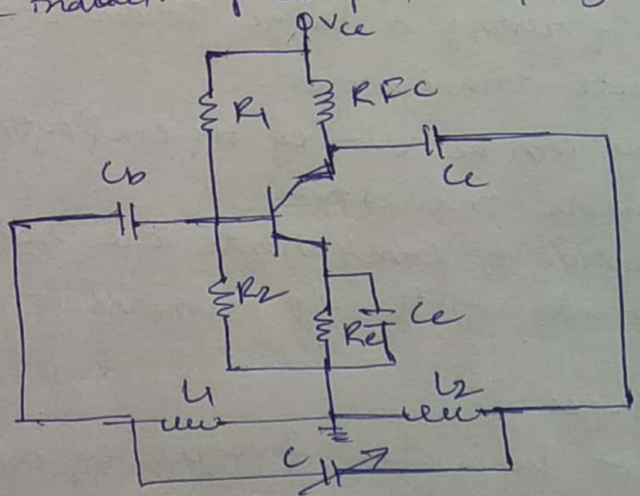
A very popular local oscillator circuit that is mostly used in radio receivers is the Hartley oscillator circuit.

Construction:

- In the circuit diagram of a Hartley oscillator shown below, the resistors R_1, R_2 and Re provides necessary bias condition for the circuit.
- The capacitor Ce provides ac ground thereby providing any signal degeneration. This also provides temperature stabilization
- the capacitors Cc and Cb are employed to block dc and to provide an ac path.
- the radio frequency choke (RFC) offers very high impedance to high frequency currents.
- which means it shorts for dc and opens for ac. Hence it provides dc load for collector and keeps ac currents out of dc supply source.

Tank circuit:

- the frequency determining network is a parallel resonant circuit which consists of the inductors L_1 and L_2 along with a variable capacitor C.
- The Jn of L_1 & L_2 are earthed. The coil L_1 has its one end connected to base via Cc and the other to emitter via Ce; so L_2 is in the o/p circuit
- Both the coils L_1 & L_2 are inductively coupled and together form an Auto transformer.



- The following circuit diagram shows the arrangement of a Hartley oscillator. The tank circuit is shunt fed in this circuit. It can also be a series - fed.

Operation:

- When the Vcc supply is given, a transient current is produced in the oscillatory or tank circuit.
- This oscillatory current in the tank circuit produces ac voltage across L_1.
- The auto-transformer made by the inductive coupling of L_1 & L_2 helps in determining the frequency and establishes the feedback
- As the CE configured transistor provides 180° phase shift, another 180° phase shift is provided by the transformer, which makes 360° phase shift b/w the input & o/p voltages.
- This makes the feedback +ve. which is essential for the condition of oscillations.
- When the loop gain $|\beta A|$ of the amplifier is greater than one, oscillations are sustained in the circuit.
- The frequency of Hartley oscillator is given as.

$$f = \frac{1}{2\pi\sqrt{L_T C}}$$

where $L_T = L_1 + L_2 + 2M$.

Advantages:

- Instead of using a large transformer, a single coil can be used as an auto-transformer.
- frequency can be varied by employing either a variable capacitor or a variable inductor.
- Less number of components are sufficient.
- The amplitude of the o/p remains constant over a fixed frequency range.

Disadvantages:

- It cannot be a low frequency oscillator.
- Harmonic distortions are present.

RC Oscillators:

The different types of RC oscillators as follows:

- RC phase shift oscillator
- twin T - oscillator
- Quadrature oscillator
- Wien bridge oscillator

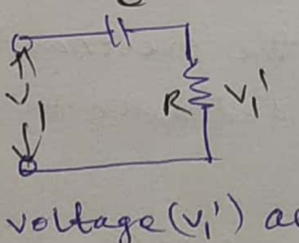
Drawback of LC circuits:

- frequency instability
- Waveform is poor
- Cannot be used for low frequencies
- Inductor are bulky and expensive.

*Note: All the drawbacks of LC oscillator circuits are thus eliminated in RC oscillator circuits. Hence the need for RC oscillator circuits arise. These are also called as phase-shift oscillators.

Principle of phase-shift Oscillators:

- The output voltage of an RC circuit for a sinewave input leads the input voltage.
- The phase angle by which it leads is determined by the value of RC components used in the circuit.
- The following circuit diagram shows a single section of an RC network.



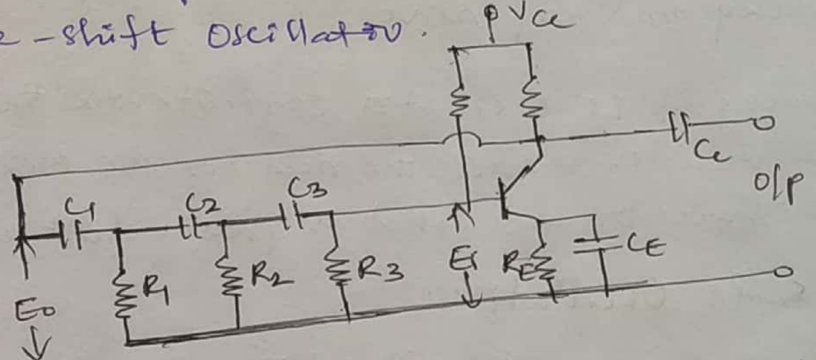
- The output voltage (V_1') across the resistor leads the input voltage by some phase angle $\phi°$. If R were reduced to zero V_1' will leads the V_1 by $90°$ i.e $\phi° = 90°$.
- However, adjusting R to zero would be impracticable, because it would lead to no voltage across R. Therefore, in practice, R is varied to such a value that makes V_1' to lead V_1 by $60°$.

RC phase-shift Oscillator:

The oscillator circuit that produces a sinewave using a phase-shift network is called as a phase shift oscillator circuit.

Construction:

- The RC phase shift oscillator circuit consists of a single transistor amplifier section and a RC phase-shift network.
- The phase shift network in this circuit, consists of three RC sections.
- At the resonant frequency f_0, the phase shift in each RC section is 60° so that the total phase shift produces by RC network is 180°
- The following circuit diagram shows the arrangement of an RC-phase-shift oscillator.



The frequency of oscillations is given by

$$f_0 = \frac{1}{2\pi RC\sqrt{6}}$$

where $R_1 = R_2 = R_3 = R$

$C_1 = C_2 = C_3 = C$.

Operation:

- When Vcc applied oscillates at the resonant frequency f_0. The o/p E_0 of the amplifier is fed back to RC feed back network.
- This network produces a phase shift of 180° and a voltage E_i appears at its output.
- This voltage is applied to the transistor amplifier.

The feed back applied will be.

$$\beta = E_i / E_0$$

- the feedback is in correct phase, where as the transistor amplifier which is in CE configuration, produces a 180° phase shift.
- The phase shift produced by network and the transistor add to form a phase shift around the entire loop which is 360°.

Advantages:

- It doesnot require transformers or inductors
- It can be used to produces very low frequencies
- The circuit provides good frequency stability.

Disadvantages:

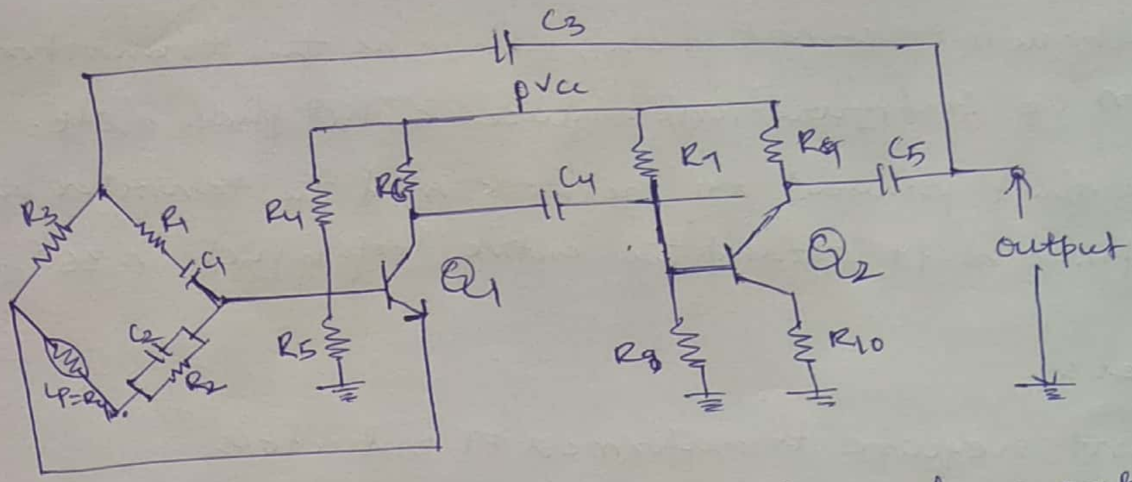
- starting the oscillations is difficult as the feedback is small
- The output produced is small.

Wien Bridge Oscillator:

- It is one of the popular audio frequency oscillator is the wien bridge Oscillator: this is the mostly used because of its important features.
- this circuit is free from the circuit fluctations and the ambient temperature.
- the main advantages of this oscillator is that the frequency can be varied in the range of 10 Hz to about 1MHz where as in RC oscillators, the frequency is not varied.

Construction:

- It is a two-stage amplifier with RC bridge circuit.
- the bridge circuit has the arms R_1C_1, R_2C_2, R_3 and the tungsten lamp (L_p).
- Resistance R_3 and the L_p are used to stabilize the amplitude of the output.
- the following circuit diagram shows the arrangement of a wien bridge oscillator.



- The transistor Q_1 serves as an oscillator and an amplifier, while the other transistor T_2 serves as an inverter.
- the inverter operation provides a phase shift of 180°.
- this circuit provides +ve feedback through $R_1 C_1$, $R_2 C_2$ to the to the transistor T_1 and -ve feedback through the voltage divider to the input of transistor T_2.
- The frequency of oscillations is determined by the series element $R_1 C_1$ and parallel element $R_2 C_2$ of the bridge.

$$f = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$$

- If $R = R_1 = R_2$ and $C_1 = C_2 = C$ then $f = \frac{1}{2\pi RC}$

Operation:

- when the circuit is switched ON, the bridge circuit produces oscillations of the frequency.
- The two transistors produces a total phase shift of 360° so that proper +ve feed back is ensured.
- The -ve feed back in the circuit ensures constant o/p. This is achieved by temperature sensitive tungsten lamp (Lp). Its resistance increases with current.
- If the amplitude of the o/p increases, more current is produced and more -ve feedback achieved.
- Due to this, the output would return to the orginal value.
- whereas, if the o/p tends to decrease, reverse action would take place

Advantages:

- The circuit provides good frequency stability.
- It provides constant ~~frequency~~ output.
- The operation of circuit is quite easy.
- The overall gain is high because of two transistors
- The frequency of oscillations can be changed easily.
- The amplitude stability of the output voltage can be maintained more accurately. by replacing R_2 with a thermistor.

Disadvantages:

- The circuit cannot generate very high frequencies.
- Two transistors and number of components are required for the circuit construction.

Crystal Oscillator:-

- whenever an oscillator is under continuous operation, its frequency stability gets affected.
- There occurs changes in its frequency. The main factor that affects the frequency of an oscillator are,
  - power supply variations
  - Changes in temperature.
  - changes in load or output resistance.

* In RC and LC oscillators the value of resistance, capacitance and inductance vary with temperature, and hence the frequency gets affected.

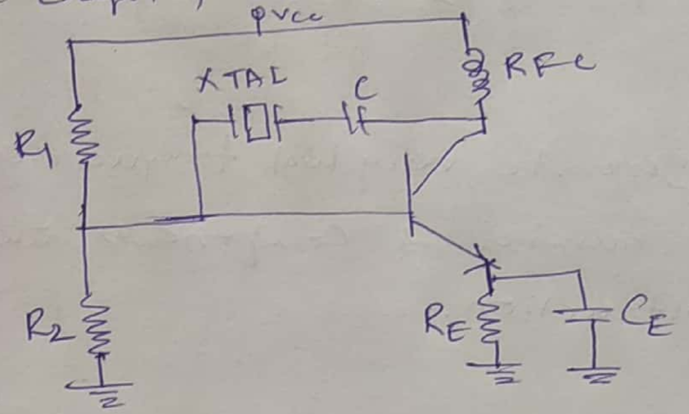
- In order to avoid this problem, the piezo electric crystals are being ~~utilized~~ used in oscillators.
- The use of piezo electric crystals in parallel resonant circuits provide high frequency stability in oscillators. such oscillators are called as Crystal Oscillators.

= The principle of crystal oscillators depends upon the piezo electric effect.

- The natural shape of a crystal is hexagonal. When a crystal wafer is cut perpendicular to X-axis, it is called as X-cut & when it is cut along Y-axis, it is called Y-cut.

Crystal Oscillator Circuit:

The following ckt diagram shows the arrangement of a transistor pierce crystal oscillator.



- In this ckt, the crystal is connected as a series element in the feedback path from collector to the base.
- The resistor R_1, R_2 and R_E provide a voltage divider dc bias circuit.
- The capacitor C_E provides ac bypass of the emitter resistor and RFC coil provides for dc bias while decoupling any ac signal on the power lines from affecting the output signal.
- The coupling capacitor C has negligible impedance at the ckt operating frequency. and it blocks any dc between collector and Base.
- The frequency is given by $f_0 = \frac{1}{2\pi\sqrt{LC}}$.

Advantages:
- They have a high order of frequency stability.
- The quality factor (Q) of the crystal is very high.

Disadvantages:
- They are fragile and can be used in low power circuits.
- The frequency of oscillations cannot be changed appreciably.

POWER Amplifier :

Basic Amplifier :

An amplifier circuit is one which strengthens the signal(i/p). The process of increasing the signal strength is called as Amplification.

Classification of amplifiers :

1. Based on number of stages :
   * Single - stage amplifiers :- This has only one transistor circuit, which is a single-stage amplification.
   * Multi - stage amplifiers :- This has multiple transistor circuit, which provides multi-stage amplification.

2. Based on its output : (voltage & power)
   * Voltage Amplifiers :- The amplifier circuit that increases the voltage level of the input signal.
   * power Amplifiers : The amplifier circuit that increases the power level of the input signal.

3. Based on the input signals : (magnitude)
   * small signal amplifier : when the i/p signal is so weak so as to produce small fluctuations in the collector current compared to its quiescent value, the amplifier is known as small signal amplifier. = Audio amplifiers
   * Large signal amplifier : when the fluctuations in collector current are large i.e; beyond the linear portion of the characteristics, the amplifier is known as Large signal amplifier. = Radio amplifiers.

4. Based on frequency range :
   * Audio Amplifiers : The amplifier circuit that amplifies the signal that lie in the audio frequency range i.e; from 20Hz, to 20kHz.
   * Radio Amplifiers : The amplifier circuit that amplifies the signal that lie in the Radio frequency range i.e; from

5. Based on the Coupling method:

* Rc Coupled amplifier: A multi stage amplifier circuit that is Coupled to the next stage using resistor and capacitor (RC) combination Can be Called as RC Coupled amplifier.

* Transformer Coupled amplifier: A multi-stage amplifier circuit that is coupled to the next stage, with the help of a transformer, can be called as a transformer Coupled amplifier.

* Direct Coupled amplifier: A multi-stage amplifier circuit that is coupled to the next stage directly, can be called as a direct Coupled amplifier.

6. Based on the Transistor Configuration:

* CE amplifier: the amplifier circuit that is formed using a CE configured transistor combination is called as CE amplifier.

* CB amplifier: The amplifier circuit that is formed using a CB configured transistor combination is called as CB amplifier

* CC amplifier: The amplifier ckt that is formed using a CC configured transistor combination is called as CC amplifier

power amplifier:

The power amplifier amplify the power level of the signal. this amplification is done in the last stage in audio applications.

- The operating point of a transistor plays a very important role in determining the efficiency of the amplifier

= the main classification is done based on their mode of operation.

classification Based on mode of operation:

i.e; Angle of conduction, efficiency and position of operating point.
of point.

class A power amplifiers ⇒ At the centre of the active region (360°).

when the collector current flows at all times during the full cycle of signal, the power amplifier is known as class A power amplifier.

class B power amplifier :⇒ at cutoff (180°)

when the collector current flows only during the +ve half cycle of the input signal.

class C power amplifier. ⇒ Below cutoff Less than 180°

when the collector current flows for less than half cycle of the input signal.

class AB power amplifier. ⇒ slightly above cutoff (180° - 360°)

if we combine the class A and class B amplifier so as to utilize the advantages of both.

* Collector efficiency:

$$\eta = \frac{\text{avg ac o/p power}}{\text{avg dc power i/p to transistor}} \times 100 = \boxed{\frac{P_{out}}{P_{dc}} \times 100}$$

* power dissipation capability:

the ability of power transistor to dissipate the heat developed in it.

power Dissipation = DC input power - (DC output + AC output power)

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* Distortion:

The change of o/p wave shape from the input wave shape of the amplifier.

An amplifier that has less distortion, produces a better output and hence considered efficient.

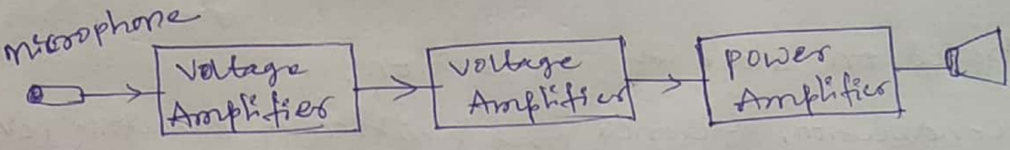
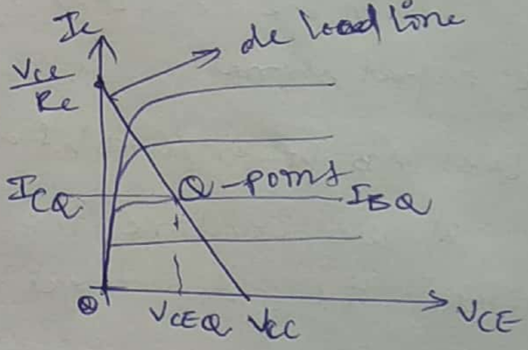


Fig: Multistage amplifier

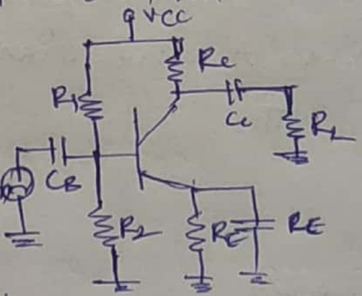
Importance of Q-point:

- Location of Q-point decides the shape of the o/p waveform and in turn efficiency & power dissipation of the transistor
- The location of the Q-point decides conduction angle.
- Q-point is given (V_{CEQ}, I_{CQ} & I_{BQ})
- Q-point decides the region of operation of the transistor (Active/Cutoff/saturation).
- Q-point can be located anywhere on the characteristic curve & DC load line.



- **Load Line:**

Every amplifier has dc equivalent circuit and an ac equivalent circuit



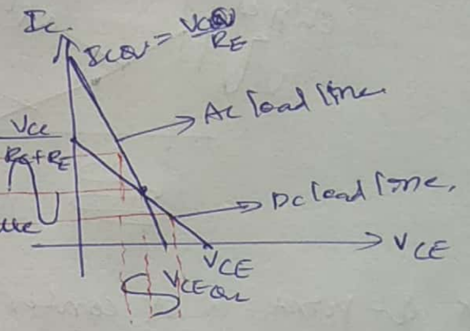
- It has two load lines.
  DC & AC load lines
- Q point calculations are done using DC load line
- AC load line intersects DC load line at the Q point.

Dc load line :

- Maximum value of voltage($V_{CE\,cutoff}$) and maximum value of current ($I_{c\,sat}$) gives us the DC load line.

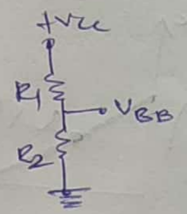
$$V_{CE\,cutoff} = V_{cc}$$

$$I_{csat} = V_{cc}/R_c + R_E$$



- Q point can be moved by changing the value of R_2 on this DC load line.

Q-point calculation :



$$V_{BB} = \frac{R_2}{R_1+R_2} V_{cc}$$

$$V_E = V_{BB} - V_{BE}$$

$$I_E = \frac{V_E}{R_E} \approx I_c \checkmark$$

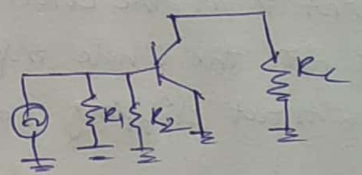
$$V_C = V_{cc} - I_c R_c$$

$$V_{CE} = V_C - V_E \checkmark$$

I_{CQ} & V_{CEQ} gives us the Q point, which can be plotted on dc load line

Ac load line:

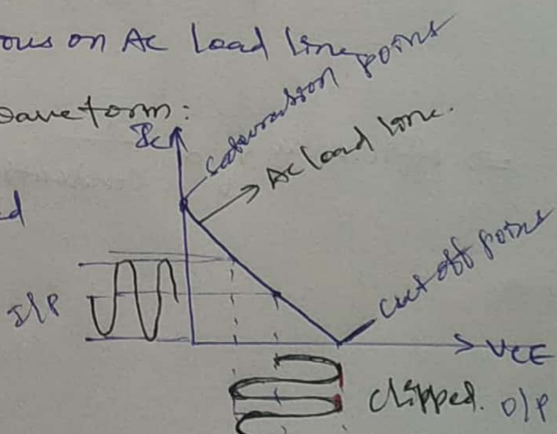
$V_{cc} = 0$ & all the capacitor are shorted.



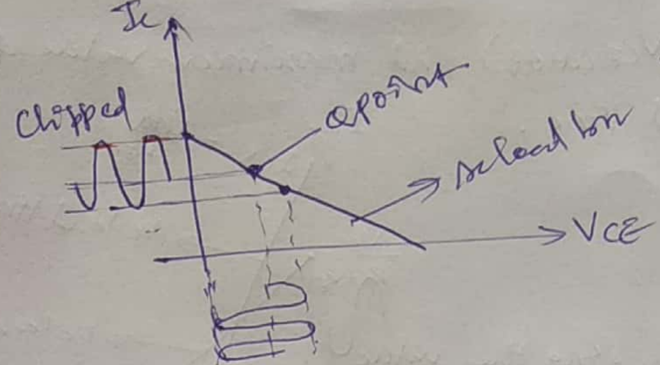
- with the emitter at ac ground, R_E has no effect on the Ac operation
- The instantaneous operating point moves along the Ac load line.
- the peak to peak sinusoidal current & voltage are determined by the Ac load line..
- Instantaneous output signal various on Ac load line points

Effect of Q point on output waveform:

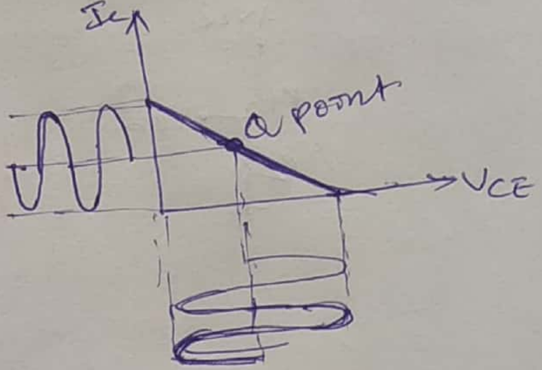
* Q point below the center of load line



* Q-point above the center of the Load line



* Q-point is at center of the load line.



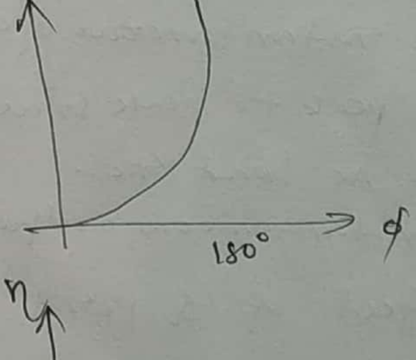
Q point and Conduction Angle:

- Conduction angle is the angle of input cycle for which transistor input cycle for which transistor conducts (Amplifies) - Active region
- If Q point is at the centre of the (load line) Active region, Transistor conducts for the whole input cycle and we get complete cycle at the output without clipping so conduction angle is 360°.

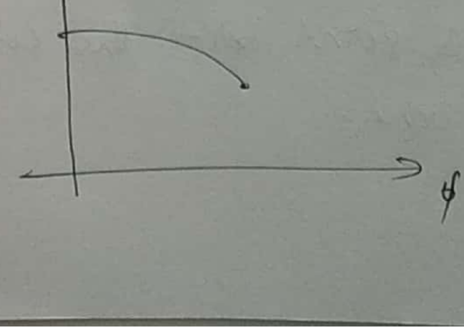
Effect of conduction angle on power amplifier:

$\Rightarrow$ P_D (power dissipation) $\propto \phi$

ϕ = conduction angle

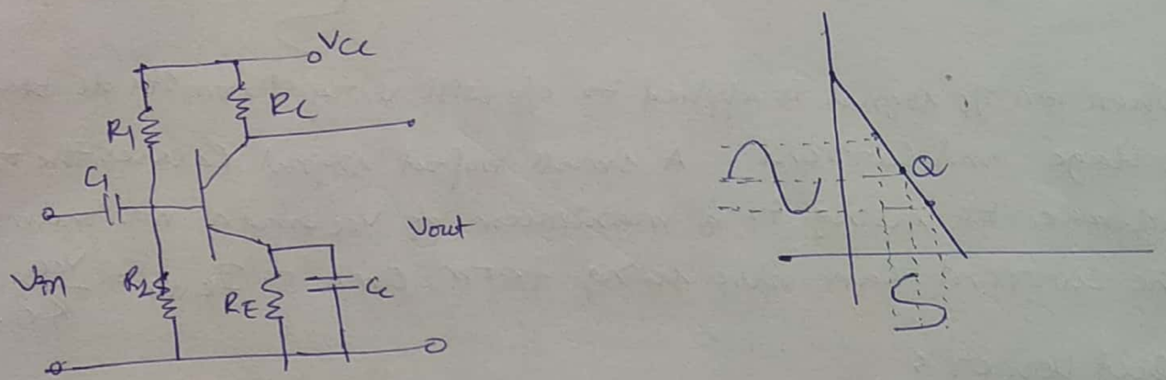


$\Rightarrow$ efficiency $\eta \propto \frac{1}{\text{conduction angle}}$



Class-A Amplifier:

- class A amplifiers are the most common type of amplifier class due to mainly their simple design
- class A, literally means the best class of amplifier due to mainly their low signal distortion levels and are propably the best sounding of all the amplifier classes mentioned here.
- The class A amplifier has the highest linearity over the other amplifier classes and such operates in the linear portion of the characteristics curve.
= Generally class A amplifiers use the same signal transistor connected in common emitter configuration for both halves of the waveform with the transistor always having current flowing through it, even if it has no base signal.
- this means that the output stage whether using a Bipolar, MOSFET or IGBT device is never driven fully into its cut-off or saturation regions but instead has a base biasing Q-point in the middle of its load line. Then the transistor never turns OFF which is one of the its main disadvantages.



= To achieve high linearity and gain, the output stage of a class A amplifier is biased ON all the time.
- Then for an amplifier to be classified as "Class A" the zero signal idle current in the output stage must be equal to or greater than the maximum load current required to produces the largest output signal.

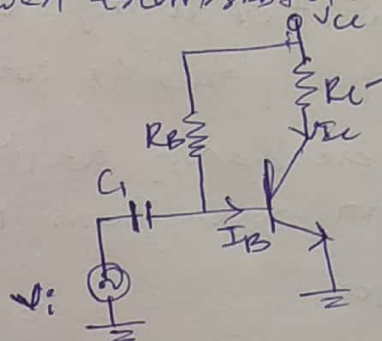
= As a class A amplifier operates in the linear portion of its characteristics curve (o/p), the single output device conducts through a full 360° of the output waveform. Then the class A amplifier is equivalent to a current source.

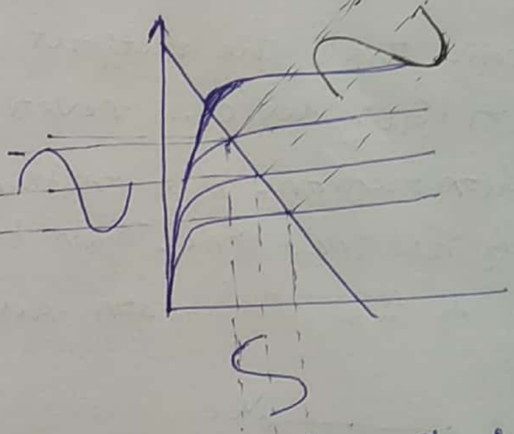
= Since a class A amplifier operates in the linear region, the transistor base DC biasing voltage should be chosen properly to ensure correct operation and low distortion.

= However, as the output device is ON at all times, it is constantly carrying current, which represents a continuous loss of power in the amplifier:

Series fed class A amplifier:

— this is similar to the small-signal amplifier except that it will handle higher voltages. The transistor used is a high power transistor.





- when an i/p signal is applied to o/p will vary from its dc bias operating voltage and current. A small input signal causes the output voltage to swing to a maximum of Vcc and a minimum of 0V. the current can also swing from 0mA to $I_{C\,sat} = \frac{V_{cc}}{R_C}$

Input power:
— the power into the amplifier is from the DC supply, with no i/p signal, the DC current drawn is the collector bias current I_{CQ}.

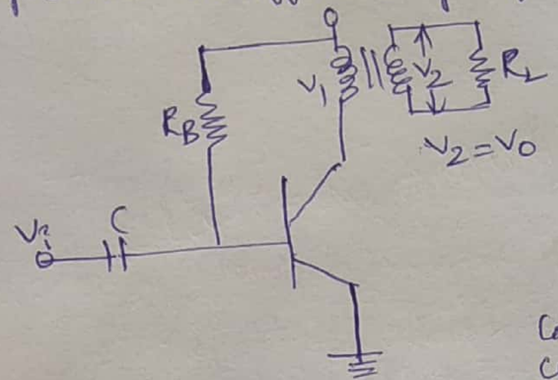
$$P_{in(dc)} = V_{cc} I_{CQ}.$$

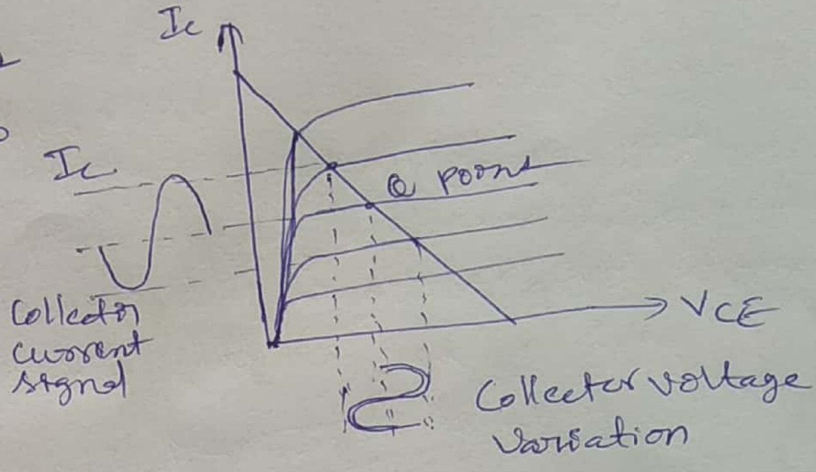
output power $P_{out(ac)} = \frac{V^2_{CE(rms)}}{R_C} = I^2 R_C$

efficiency : $\frac{P_{o(ac)}}{P_{in(dc)}}$, =

Transformer-Coupled Class A Amplifier:

This circuit uses a transformer to couple to the load. This improves the efficiency of the class A to 50%.





DC load line:

As in all class A amplifiers the Q-point is established close to the ~~capacitance~~ midpoint of the DC load line. The dc resistance is small ideally at 0 and a dc load line is a straight vertical line.

AC load line:

The saturation point ($I_{c\,max}$) is at V_{cc}/R_c and the cut off point is at V_2 (the secondary voltage of the transformer). This increases the max^m output swing because the min^m and max^m values of I_c and V_{CE} are spread further apart.

Signal swing and output AC power:

The voltage swing: $V_{CE(PP)} = V_{CE\,max} - V_{CE\,min}$

The current swing: $I_{c(PP)} = I_{c\,max} - I_{c\,min}$

The AC power: $P_{o(ac)} = (V_{CE\,max}\ V_{CE\,min})(I_{c\,max}\ I_{c\,min})$

Power input to the dc source:

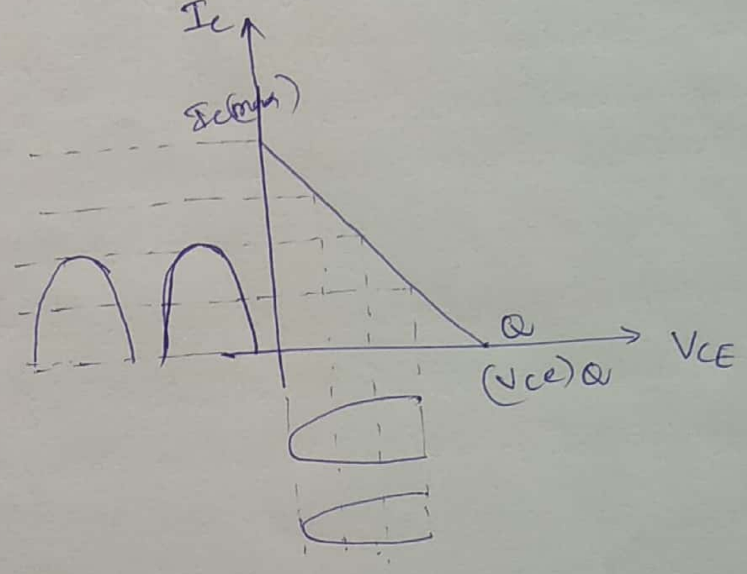
$$P_{i(dc)} = V_{cc}\, I_{CQ}$$

class B Amplifier:

when the collector current flows only during the +ve half cycle of the input signal, the power amplifier is known as class B power amplifier:

operation:

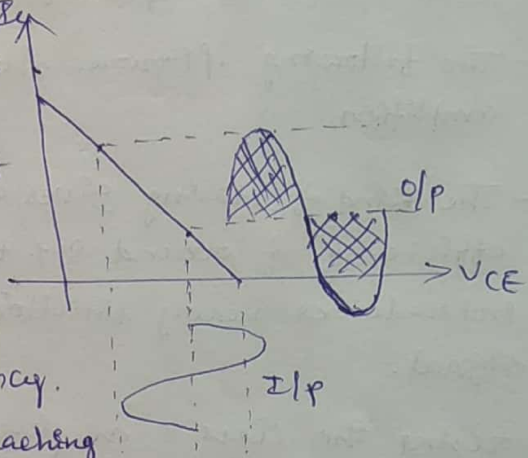
- The biasing of the transistor in class B operation is in such a way that at zero signal condition, there will be no collector current.
- The operating point is selected to be at collector cut off voltage. so, when the signal is applied, only the +ve half cycle is amplified at the output.
- The figure below shows the input & output waveforms during class B operation.



- when the signal is applied, the circuit is forward biased for the +ve half cycle of the input and hence the collector current flows.
- But during the -ve half cycle of the input, the circuit is reverse biased and collector current will be absent. Hence only the +ve half cycle is amplified at the output.
= As the -ve half cycle is completely absent, the signal distortion will be high.
- Also, when the applied signal increases, the power dissipation will be more
→ But when compared to class A power amplifier, the output efficiency is increased.

Class AB power Amplifier:

- As the name implies, class AB is a Combination of class A and class B type of amplifiers.
- As class A has the problem of low efficiency and class B has distortion problem, this class AB is emerged to eliminate these two problems, by utilizing the advantages of both the classes.
- the conduction angle of class AB amplifier is somewhere between 180° to 360° depending upon the operating point selected. this is understood with the help of below figure



- the crossover distortion created by class B is over Come by this class AB, as well as the inefficiencies of class A and B don't effect the Circuit.
- so class AB is good compromise between class A and class B in terms of efficiency and linearity having the efficiency reaching about 50% to 60%.
- The class A, B and AB amplifiers are Called as linear amplifier because the output signal amplitude and phase are linearly related to the input signal amplitude and phase.

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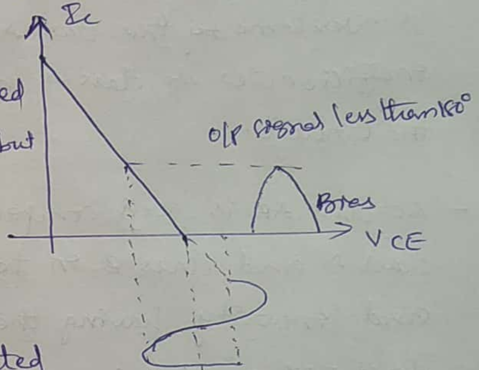
Class C power Amplifier:

- when the collector current flows for less than half cycle of the input signal, the power amplifier is known as class C power amplifier
- The efficiency of class C amplifier is high while linearity is poor.
- The conduction angle for class-C is less than 180°. It is generally around 90°, which means the transistor remains idle for more than half of the input signal.
- so output current will be delivered for less time compared to the application of input signal.
- The following figure shows the operating point and output of a class C amplifier



- The kind of biasing gives a much improved efficiency of around 80% to the amplifier, but introduces heavy distortion in the output signal.
- using the class C amplifier, the pulses produced at its output can be converted to complete sine wave of a particular frequency by using LC circuit in its collector circuit.