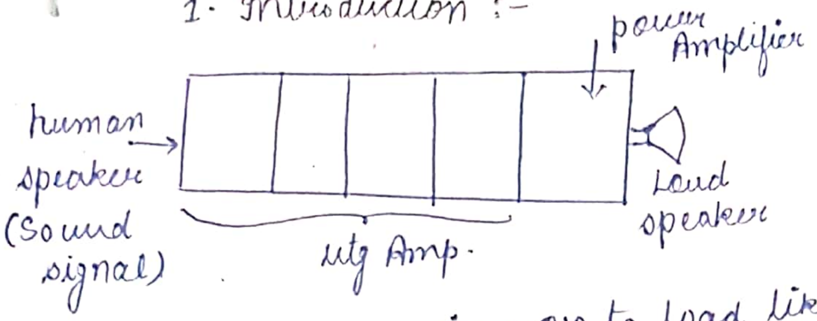
Keerti Dagliya

unit 5

2nd yr ECE

Power Amplifier

1. Introduction :-



- Input stage & all intermediate stages are small signal Amp^r and use to increase the gain of Amplifier. It is called vtg. Amplifier.
- Last stages gives O/P to load like loud speaker. It is large signal Amplifier or power Amplifier.
- Application : public address system, T.V. Rx, tape players.
- h parameter Analysis is applicable for small signals only. Hence Analysis of large signal are carried out graphically by drawing load line.
- The power Amp^r developing power at audio freq. range are called audio freq (A.F.) power Amplifiers.
- Power Amp consists of no. of stages that amplify a weak signal until sufficient power is available to operate a speaker.
- Last stages drives load and handles considerable amount of power.
- To obtain large power, it is essential that i/p vtg level of signal is large.
- Basically power Amplifiers converts DC power into AC power
- Power Tx has following features :
  - → size of power Tx is made quite large to ↑se the heat dissipation capacity.
  - → transformer coupling is used to match impedances.

performance criterion of power Amplifier :-

(1) collector efficiency (conversion efficiency) :-

P.A. convert DC power from supply to AC power. at O/P. efficiency is defined as ability to convert DC power into AC power. This is called conv. efficiency.

$$\%\eta = \frac{\text{AC power delivered to load}}{\text{DC power supply}} \times 100$$

$$= \frac{P_{ac}}{P_{dc}} \times 100$$

(2) Distortion :- characteristics of Tx are non linear. for large signal amplifier, major portion of characteristics is used which is almost non linear. Due to this non linearity, the waveshape of O/P becomes different from I/P signal.

Change of waveform of O/P signal of an Ampr is distortion.

(3) power dissipation capacity (collector dissipation) :-

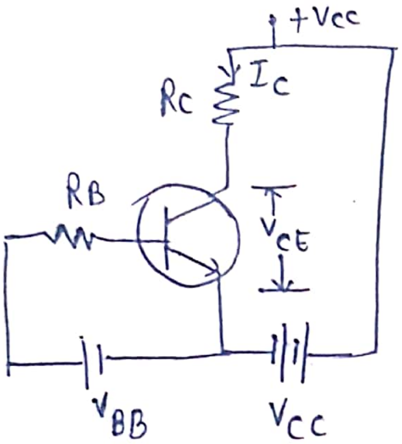
A power Tx handles large current, gets up heated during operation. Change in temp due to heat will change the Q point. To keep temp within limit the Tx must dissipate this heat to surroundings. To achieve this a heat sink is attached. which ↑ses effective area which causes the heat to escape easily and temp is maintained within limit.

The ability of Tx to dissipate heat developed in it is known as power dissipation capacity.

Classification of power Amplifier :-

For an Amp^r, a Q point is fixed by selecting the proper d.c. biasing to the Txs used.

i) Class A
ii) class B
iii) class C
iv) Class AB



Apply KVL : $V_{CC} - I_C R_C - V_{CE} = 0$

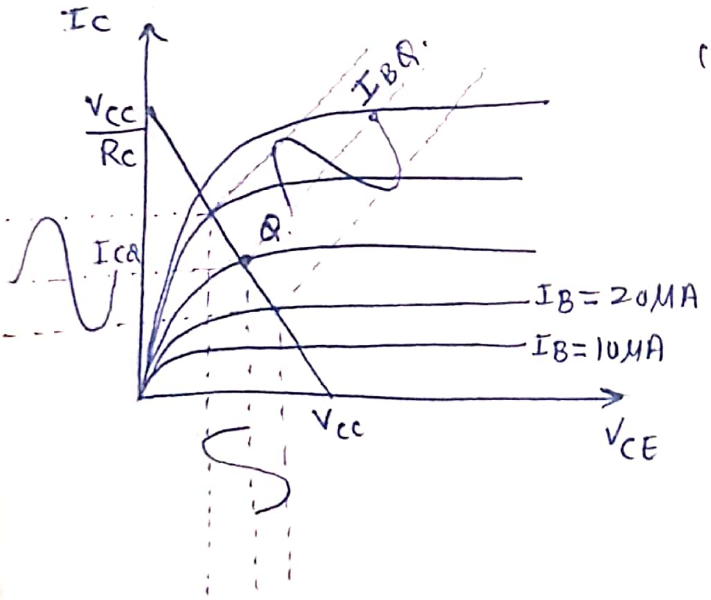
$$V_{CC} = I_C R_C + V_{CE}$$

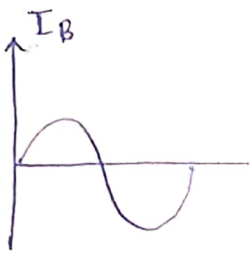
$$I_C = \left(-\frac{1}{R_C}\right) V_{CE} + \frac{V_{CC}}{R_C}$$

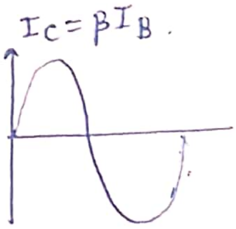
for straight line $y = mx + c$

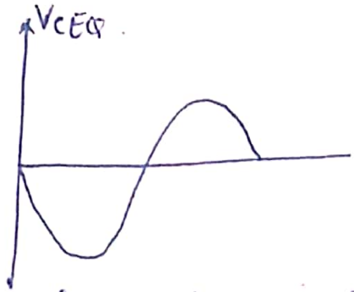
when (i) $V_{CE} = 0$, $I_C = \frac{V_{CC}}{R_C}$

(ii) $V_{CE} = V_{CC}$, $I_C = 0$



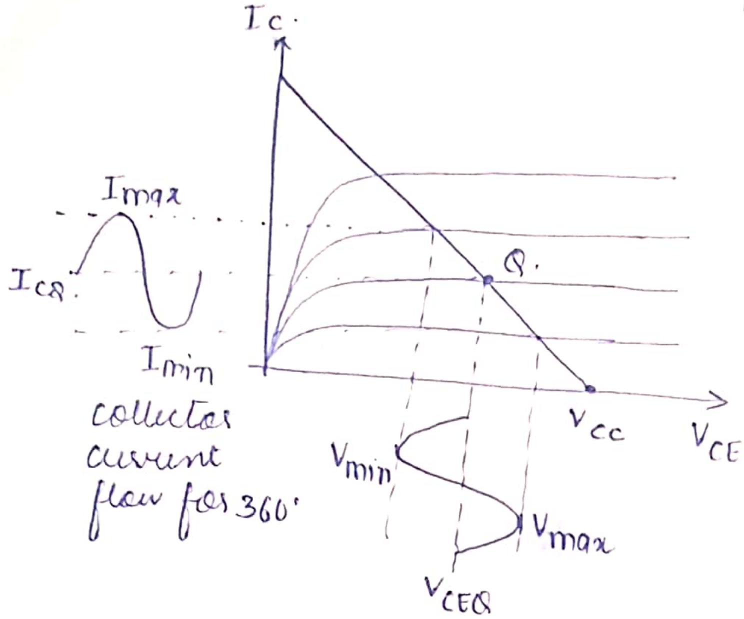






phase of V_{CE} is change because it is Reverse battery which is connected in output side.

i) class A Amplifier :-

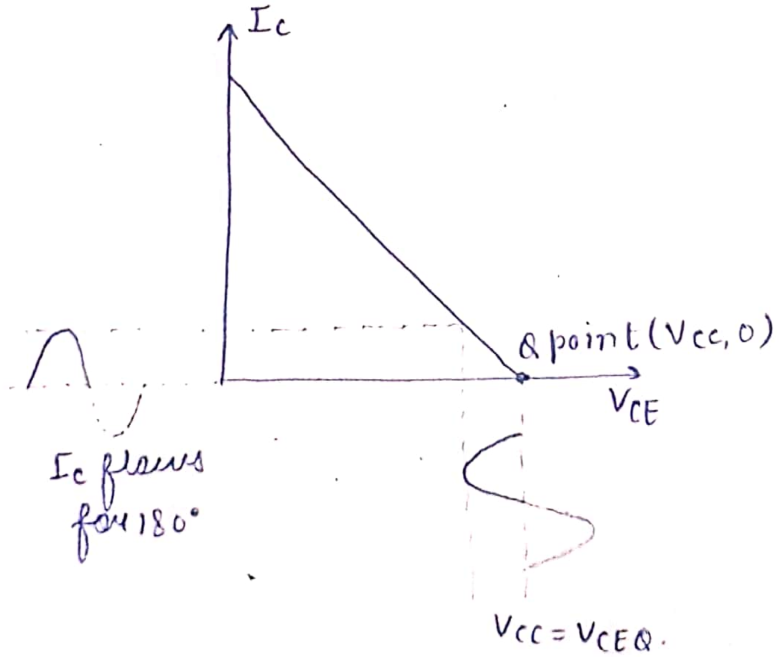


→ for all values of i/p signal, Tx remains in active region & never enters in cut off region.

→ distortion is low

→ efficiency is also small.

(ii) class B Amplifier :-

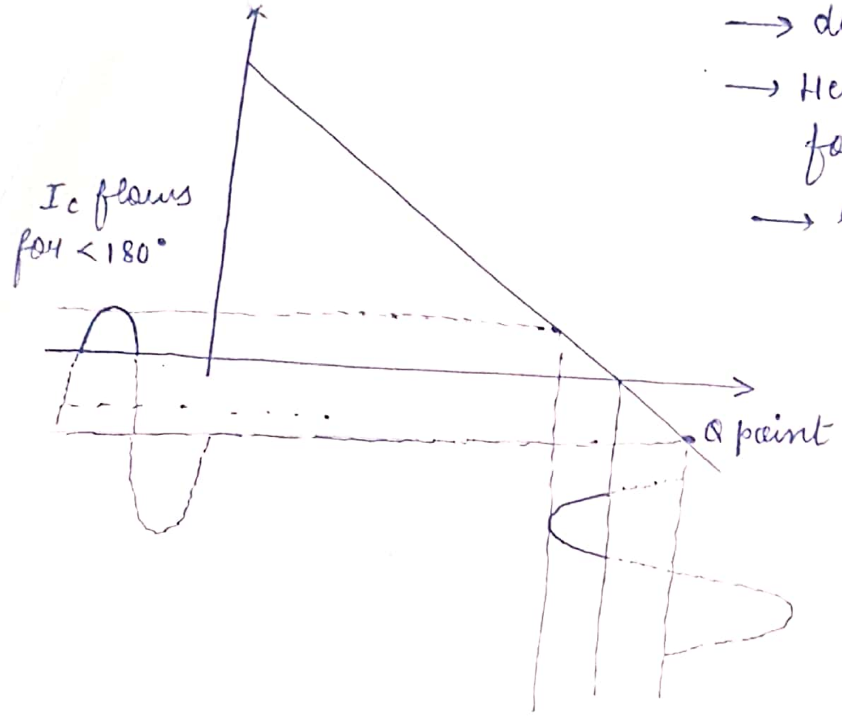


→ for +ve cycle, Tx is in active region & for -ve cycle Tx enters into cut off region.

→ efficiency is higher than A

→ distortion is high for class B because half cycle is obtained at output.

iii) class C Amplifier :-

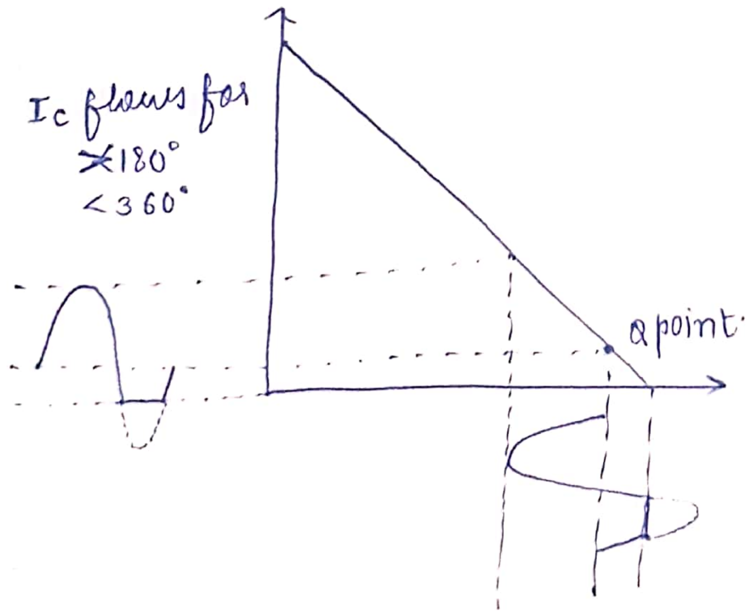


→ distortion is higher than A & B.

→ Hence class C Amp' is not used for A.F. Amplifier.

→ efficiency is higher than A & B ≅ 100%.

(iv) class AB Amplifier :-



→ eff. more than A But less than B. 50% to 78.5%.

→ class AB is important to eliminate cross over distortion.

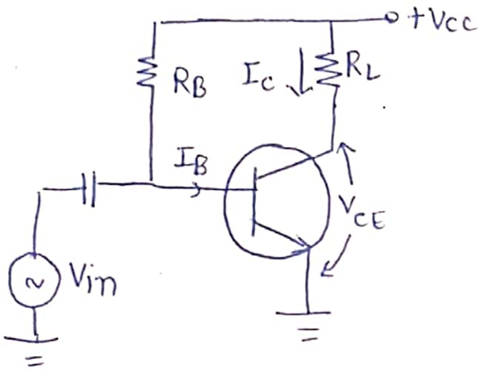
4. Analysis of class A Amplifier :-

It is classified into two parts :

(i) series fed directly coupled : load is directly connected in series with collector.

(ii) transformer coupled :- load is connected to Txf & Txf is connected with collector.

(i) Series fed directly coupled Class A Amplifier :



- Value of RB is selected such that Q point lies at centre of dc load line.
- Apply KVL at O/P side.

$$V_{CC} - I_C R_L - V_{CE} = 0$$

$$\boxed{V_{CEQ} = V_{CC} - I_C R_L}$$

- apply KVL at I/P side.

$$V_{CC} - I_B R_B - V_{BE} = 0$$

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B}.$$

$$\boxed{I_{BQ} = \frac{V_{CC} - 0.7}{R_B}}$$

$$\boxed{I_{CQ} = \beta I_{BQ}.}$$

Hence Q point is defined as (V_{CEQ}, I_{CQ})

(1) DC power input :-

$$P_{DC} = V_{CC} \cdot I_{CQ}.$$

V_{CC} → DC supply; I_{CQ} → O/P current.

(2) AC power output :-

V_{min} = min instantaneous value of O/P vtg.

V_{max} = Max ---- ..

V_{PP} = peak to peak value = $V_{max} - V_{min}$

V_m = peak Amplitude

$$V_m = \frac{V_{PP}}{2}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

similarly for current also.

(i) AC power using rms value

$$P_{ac} = V_{rms} I_{rms}$$

$$P_{ac} = I^2_{rms} R_L$$

$$P_{ac} = \frac{V^2_{rms}}{R_L}$$

(ii) using peak values:

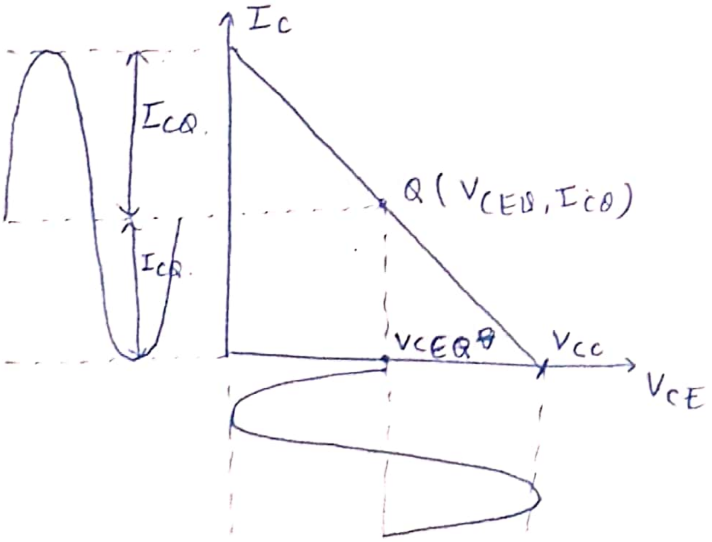
$$P_{ac} = V_{rms} I_{rms} = \frac{V_m I_m}{\sqrt{2}\sqrt{2}} = \frac{I_m^2 R_L}{2} = \frac{V_m^2}{2R_L}$$

(iii) using peak to peak values:

$$P_{ac} = \frac{V_m I_m}{2} = \frac{\frac{V_{PP}}{2} \cdot \frac{I_{PP}}{2}}{2} = \frac{V_{PP} I_{PP}}{8} = \frac{I_{PP}^2 R_L}{8} = \frac{V_{PP}^2}{8R_L}$$

$$P_{ac} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}$$

(3) efficiency :-



$$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100$$

$$= \frac{(V_{cc} - 0)(2I_{CQ} - 0)}{8 V_{cc} I_{CQ}} \times 100$$

$$= \frac{2 V_{cc} I_{CQ} \times 100}{4 V_{cc} I_{CQ}}$$

$$\boxed{\% \eta = 25\%} \text{ ideally.}$$

$\% \eta = 10$ to 15% practically.

(4) power dissipation :- It is a difference between i/p power (dc) & power delivered to load. (AC power)

$$P_d = P_{dc} - P_{ac}.$$

Max power is dissipate when power to load is zero means $P_{ac} = 0$

$$(P_d)_{max} = ~~P_{dc} = V_{cc} I_{CQ}~~,\ V_{cc} I_{CQ} - \frac{V_{cc} I_{CQ}}{4}$$

$$= \frac{3 V_{cc} I_{CQ}}{4} =$$

$$\boxed{(P_d)_{max} = 0.75\, P_{dc}}$$

(5) Advantage :-

(i) The circuit is simple to design

(ii) R_L is connected directly to collector. so Txf is not required.

(iii) Distortion is less.

(6) Disadvantage :-

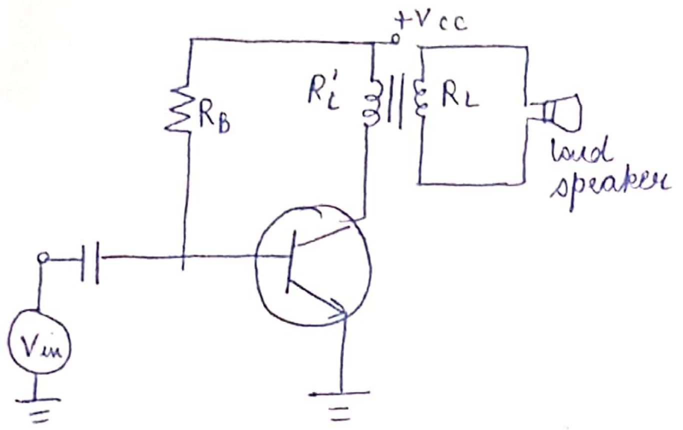
(i) R_L is directly connected in collector and carries the I_{CQ}. this causes considerable wastage of power.

(ii) power dissipation is more. Hence heat sink are essential.

(iii) O/P impedance is high, so ckt. is not used for low imp. device like Loudspeaker.

(iv) efficiency is very low due to high power Dissipation

ii) transformer coupled class A Amplifier :- for max. power transfer to the load, the impedance matching is required. for load like loudspeaker having low impedance values, impedance matching is difficult using directly coupled amplifier. So transformer coupled is used.



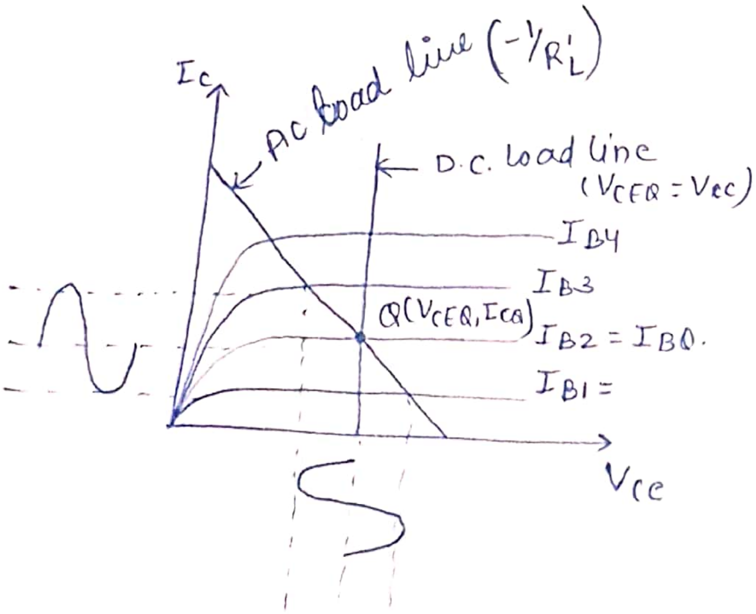
(1) DC ~~power~~ operation :-

Apply KVL to O/P circuit

$$V_{CC} - V_{CE} = 0$$

In this load Res is assumed 0 because we have to transfer maximum voltage at O/P.

$$\boxed{V_{CC} = V_{CEQ}}$$



(2) ~~O/P~~ dc power :- (Pdc)

$$P_{dc} = V_{CC} I_{CQ}$$

(3) AC o/p power :-

$$R_L = \frac{V_2}{I_2}, \quad R_L' = \frac{V_1}{I_1}$$

~~$V_1 = \frac{N_1 V_2}{N_2}$~~

$$\because \frac{V_2}{V_1} = \frac{N_2}{N_1} = n$$

$$\frac{I_2}{I_1} = \frac{N_1}{N_2} = \frac{1}{n}$$

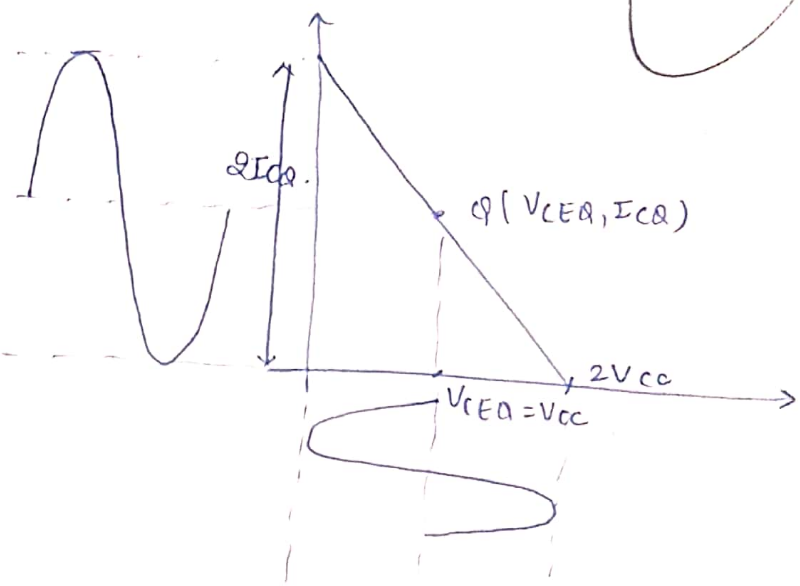
$$R_L' = \frac{\frac{N_1}{N_2} V_2}{\frac{N_2}{N_1} I_1} = \left(\frac{N_1}{N_2}\right)^2 \times \frac{V_2}{I_2}$$

$$\boxed{R_L' = \frac{R_L}{n^2} = \left(\frac{N_1}{N_2}\right)^2 R_L}$$

(3) $P_{ac} = \frac{(V_{max} - V_{min})(I_{max} - V_{min})}{8}$

$P_{ac} = \frac{(2V_{cc} - 0)(2I_{CQ} - 0)}{8}$

$P_{ac} = \frac{V_{cc} I_{CQ}}{2}$



(4) efficiency :-

$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100$

$= \frac{V_{cc} I_{CQ}}{2 V_{cc} I_{CQ}} \times 100$

$\boxed{\% \eta = 50\%}$ practically ideally

$\% \eta = 30 \text{ to } 35\%$ practically.

(5) V_{im} = peak value of primary vtg.

$V_{im} = \frac{V_{PP}}{2} = \frac{(V_{max} - V_{min})}{2} = \frac{(2V_{cc} - 0)}{2} = V_{cc}$

$R_L' = \frac{V_{im}}{I_{im}} = \frac{V_{cc}}{I_{CQ}}$

$(P_{ac})_{max} = \frac{V_{cc}^2}{2R_L'} = \frac{V_{cc}^2 I_{CQ}}{2V_{cc}}$

$\boxed{(P_{ac})_{max} = \frac{V_{cc} I_{CQ}}{2}}$

(6) power dissipation :-

$P_{d} = P_{DC} - P_{ac}$

$(P_d)_{max} = P_{DC} = V_{cc} I_{CQ}$.

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) Advantage :

(i) efficiency is higher than directly coupled.

(ii) d.c. bias current not flows directly from load in case of transformer coupled.

(iii) Impedance matching is required for Max power xfer.

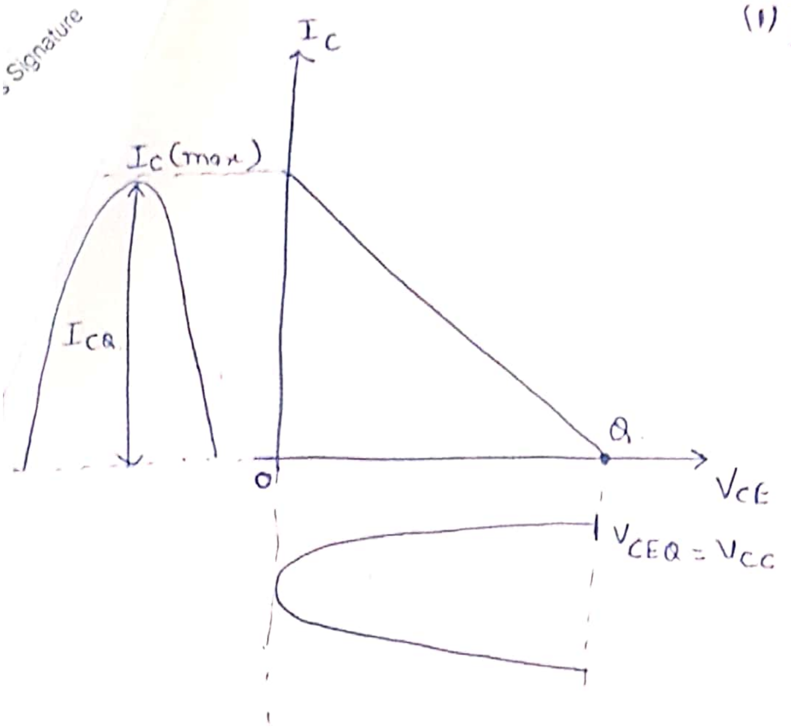
(8) Disadvantage :-

(i) Due to Txf, ckt. become bulkier, heavier & costlier.

(ii) ckt is complicated to design.

(iii) freq. response is poor.

5. Analysis of class B Amplifier :-



(i) DC operation :-

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} I_m \sin\theta \, d\theta$$

$$= \frac{I_m}{2\pi}\left(-\cos\theta\right)_0^{\pi}$$

$$= \frac{-I_m}{2\pi}\left(\cos\pi - \cos 0\right)$$

$$\boxed{I_{dc} = \frac{I_m}{\pi}}$$

$$P_{dc} = V_{cc} I_{dc}$$

$$= \frac{V_{cc} I_m}{\pi}$$

(ii) AC power :-

$$P_{ac} = \frac{V_{rms} I_{rms}}{2}$$ [for half cycle, power is also half]

$$= \frac{V_m I_m}{\sqrt{2}\sqrt{2}\cdot 2} = \frac{V_m I_m}{4}$$

(iii) $\% \eta = \frac{P_{ac}}{P_{ac}} \times 100$

$$= \frac{V_m I_m \cdot \pi}{4 V_{cc} I_m} \times 100\%$$

$\because V_{cc} = V_m$

$$= 25 \cdot \pi \%$$

$$\boxed{\% \eta = 78.5\%}$$

(iv) power dissipation :-

$$P_d = P_{DC} - P_{ac}$$

$$= \frac{V_{cc} I_m}{\pi} - \frac{V_m I_m}{4}$$

$$= \frac{V_{cc} V_m}{R_L \cdot \pi} - \frac{V_m^2}{4 R_L}$$

(v) Max power dissipation :-

$$\frac{dP_D}{dV_m} = \frac{V_{cc}}{\pi R_L} - \frac{2V_m}{4R_L} = 0$$

$$\frac{V_{cc}}{\pi R_L} = \frac{V_m}{2R_L}$$

$$V_m = \frac{2V_{cc}}{\pi}$$

So $$(P_d)_{max} = \frac{V_{cc}}{\pi R_L} \cdot \left(\frac{2V_{cc}}{\pi}\right) - \left(\frac{2V_{cc}}{\pi}\right)^2 \frac{1}{4R_L}$$

$$= \frac{2V_{cc}^2}{\pi^2 R_L} - \frac{4V_{cc}^2}{4\pi^2 R_L}$$

$$= \frac{2V_{cc}^2}{\pi^2 R_L} - \frac{V_{cc}^2}{\pi^2 R_L}$$

$$(P_d)_{max} = \frac{V_{cc}^2}{\pi^2 R_L}$$

$$(P_d)_{max} = \frac{P_{dc}}{\pi}$$

$$\boxed{(P_d)_{max} = 0.31\,P_{dc}}$$

$\because P_{dc} = \frac{V_{cc} I_m}{\pi}$

$= \frac{V_m V_m}{\pi R_L}$

$P_{dc} = \frac{V_m^2}{\pi R_L}$

$\because V_{cc} = V_m$

(vi) Advantage :-

(i) → Distortion is less than class C, class AB Ampr.
→ efficiency is higher than class A.
→ power dissipation is less than class A.

(vii) Disadvantage :-

→ Distortion is higher than class A Ampr. Only the half cycle is obtained at O/P.

(5) ~~classifi~~ Distortion in Amplifier :-

- frequency, Amplitude & phase ~~Amplifier~~ distortion are important in power Amplifier. phase distortion is not detectable by human ears which are insensitive to phase change so freq. distortion is important.

Dynamic characteristics is not perfectly linear O/P is different from I/P signal. Such a distortion is called non linear, Harmonic, or amplitude distortion.

(1) Harmonic Distortion :- H.D. means presence of freq. component in O/P wave form which are not present in input signal.

- fundamental freq :- freq. component same as I/P signal
- Harmonic freq :- The additional freq. component in O/P signal other than fund freq. which are integer multiple of fund. freq. are called harmonics.
- for eg: f Hz = fund freq.
  2f Hz = 2nd Harmonic
  3f Hz = 3rd Harmonic and so on
- 2nd Harmonic has largest amplitude. As harmonic ↑ses, amp. ↓ses
- As the 2nd harmonic ~~has is~~ has largest amplitude. it is more important in Analysis of P.A.
- B_1 = amp of fund. freq.
  B_n = Amp of n th freq. component.

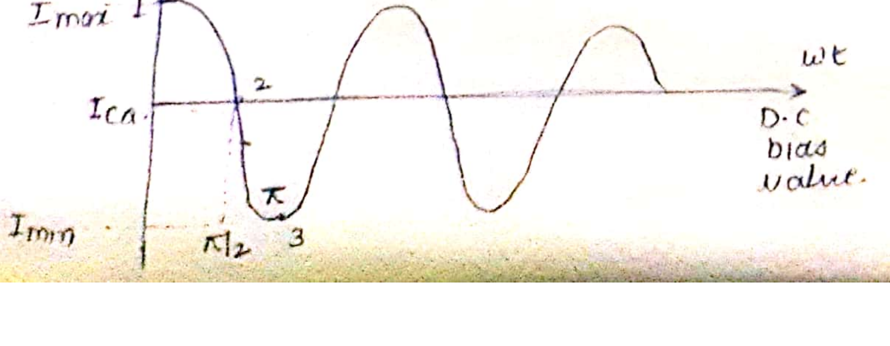
$$\% \, n^{th} \, H.D = \% \, D_n = \frac{|B_n|}{|B_1|} \times 100$$

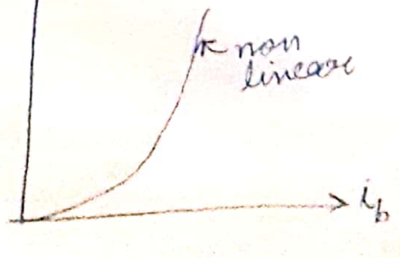
$$\% \, D_2 = \frac{B_2}{B_1} \times 100$$

- Total H.D. = D =

$$\% \, D = \frac{\sqrt{D_2^2 + D_3^2 + \cdots}}{D_1} \times 100$$

(2) Second H.D. :-





$i_b = I_{Bm} \cos \omega t$ (I/P signal which is assumed that cosine in nature).

$i_c = G_1 i_b + G_2 i_b^2$ (non linear nature between i_c & i_b)

$= G_1 I_{Bm} \cos\omega t + G_2 (\cos^2 \omega t) I_{Bm}^2$

$= G_1 I_{Bm} \cos\omega t + G_2 \left(\frac{1+\cos 2\omega t}{2}\right) I_{Bm}^2$

$i_c = G_1 I_{Bm} \cos\omega t + \frac{G_2}{2} I_{Bm}^2 + \frac{G_2}{2} I_{Bm}^2 \cos 2\omega t$

The eq^n shows that 2nd H.D. present

Total collector current: $I_c = I_{CQ} + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t$ — ⊛

where $(I_{CQ} + B_0)$ = d.c. component

B_1 = Amp. of fund freq.

B_2 = Amp of 2nd H.D.

It can be seen that due to presence of harmonics, the dc current rises. presence of harmonics can be detected by milliammeter in collector circuit. The readings can be obtained with ac and without ac signal. If two readings are almost same means no harmonic present. if mAmmeter shows an rises in current, harmonics present in o/p signal.

in ⊛ eq^n

At pt 1 ; $\omega t = 0$; $I_c = I_{CQ} + B_0 + B_1 + B_2$ — ①

At pt 2 ; $\omega t = \pi/2$; $I_c = I_{CQ} + B_0 - B_2$ — ②

At pt 3 ; $\omega t = \pi$; $I_c = I_{CQ} + B_0 - B_1 + B_2$ — ③

But at $\omega t = 0$ $I_c = I_{max}$

$\omega t = \pi/2$ $I_c = I_{CQ}$.

$\omega t = \pi$ $I_c = I_{min}$

put these values in eq^n ①, ②, ③

$B_0 = B_2$

$I_{max} - I_{min} = 2B_1$

$$B_1 = \frac{I_{max} - I_{min}}{2}$$

$I_{max} + I_{min} = 2I_{CQ} + 2B_0 + 2B_2$

$= 2I_{CQ} + 4B_2$

$$B_2 = \frac{I_{max} + I_{min} - I_{CQ}}{4}$$

$\% D_2 = \frac{B_2}{B_1} \times 100$

Higher Order Harmonic Distortion :-

$$i_c = G_1 i_b + G_2 i_b^2 + G_3 i_b^3 + G_4 i_b^4 \quad \text{(higher order H.D.)}$$

$$i_c = G_1 I_{Bm} \cos\omega t + G_2 I_{Bm} \cos^2\omega t + G_3 I_{Bm} \cos^3\omega t + G_4 I_{Bm} \cos^4\omega t$$

~~$i_c = B_1 I_{Bm} \cos\omega t + G_2 I_{Bm} \cos 2\omega t +$~~

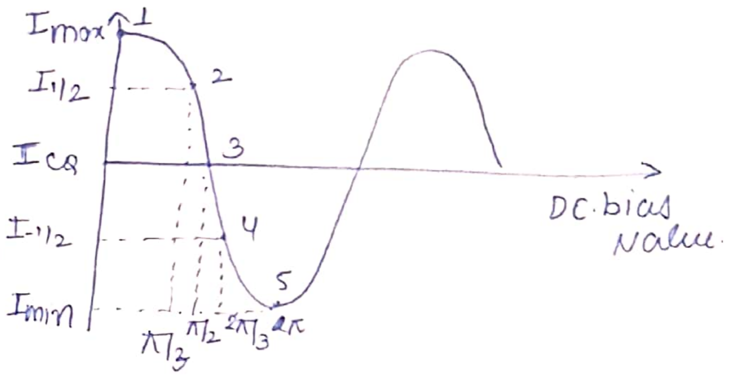
$$i_c = B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t + B_3 \cos 3\omega t + B_4 \cos 4\omega t$$

total collector current

$$I_C = i_c + I_{CQ}.$$

$$i_c = I_{CQ} + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t + B_3 \cos 3\omega t + B_4 \cos 4\omega t$$

($I_{CQ} + B_0$ → DC component; $B_1 \cos\omega t$ → fund. comp; $B_2 \cos 2\omega t$ → 2nd H.D.; $B_3 \cos 3\omega t$ → 3rd H.D; $B_4 \cos 4\omega t$ → 4th H.C.)



At pt 1, $\omega t = 0$; $i_c = I_{max}$

$$I_{max} = I_{CQ} + B_0 + B_1 + B_2 + B_3 + B_4 \quad -(1)$$

At pt 2; $\omega t = \pi/3$; $i_c = I_{1/2}$

$$I_{1/2} = I_{CQ} + B_0 + 0.5B_1 - 0.5B_2 - B_3 - 0.5B_4 \quad -(2)$$

At pt 3, $\omega t = \pi/2$; $i_c = I_{CQ}$

$$I_{CQ} = I_{CQ} + B_0 - B_2 + B_4 \quad -(3)$$

At pt 4; $\omega t = 2\pi/3$ $\quad i_c = I_{-1/2}$

$$I_{-1/2} = I_{CQ} + B_0 - 0.5B_1 - 0.5B_2 + B_3 - 0.5B_4 \quad -(4)$$

At pt 5; $\omega t = \pi$, $i_c = I_{min}$

$$I_{min} = I_{CQ} + B_0 - B_1 + B_2 - B_3 + B_4 \quad -(5)$$

solve eqn (1) to (5) we get:

$$B_0 = \frac{1}{6}[I_{max} + 2I_{1/2} + 2I_{-1/2} + I_{min}]$$

$$B_1 = \frac{1}{3}[I_{max} + I_{1/2} - I_{-1/2} - I_{min}]$$

$$B_2 = \frac{1}{4}[I_{max} - 2I_{CQ} + I_{min}]$$

$$B_3 = \frac{1}{6}[I_{max} - 2I_{1/2} + 2I_{-1/2} - I_{min}]$$

$$B_4 = \frac{1}{12}[I_{max} - 4I_{1/2} + 6I_{CQ} - 4I_{-1/2} + I_{min}]$$

Hence Harmonic coefficient $D_n = \frac{B_n}{B_1}$

...er O/P Due to distortion :-

$$P_{ac} = \frac{I_m^2 R_L}{2}$$

$$I_m = \frac{I_{PP}}{2} = \frac{I_{max} - I_{min}}{2} = B_1$$

$$\therefore P_{ac} = \frac{B_1^2 R_L}{2}$$

$$(P_{ac})_D = \frac{1}{2} B_1^2 R_L + \frac{1}{2} B_2^2 R_L + \cdots \frac{1}{2} B_n^2 R_L$$

$$= \frac{1}{2} B_1^2 R_L \left[1 + \frac{B_2^2}{B_1^2} + \cdots \frac{B_n^2}{B_1^2} \right]$$

~~$(P_{ac})_D = P_{ac}(1 + D_2^2)$~~

$$(P_{ac})_D = P_{ac}\left[1 + D_2^2 + \cdots D_n^2\right]$$

$$\therefore D^2 = D_2^2 + D_3^2 + \cdots D_n^2$$

$$\boxed{(P_{ac})_D = P_{ac}(1 + D^2)}$$

6. push pull Amplifier :-

→ for class B operⁿ, the Q pt. is located at x axis itself. Due to this collector current flows only for half cycle. Hence O/P signal is distorted.

To get a full cycle across load, a pair of Tx is used in class B operⁿ. Two Tx conduct in alternate half cycle of i/p signal & full cycle across load is obtained. The two Tx are identical in characteristics.

→ Depending upon the type of two Tx, The two ckt. configuration are possible:

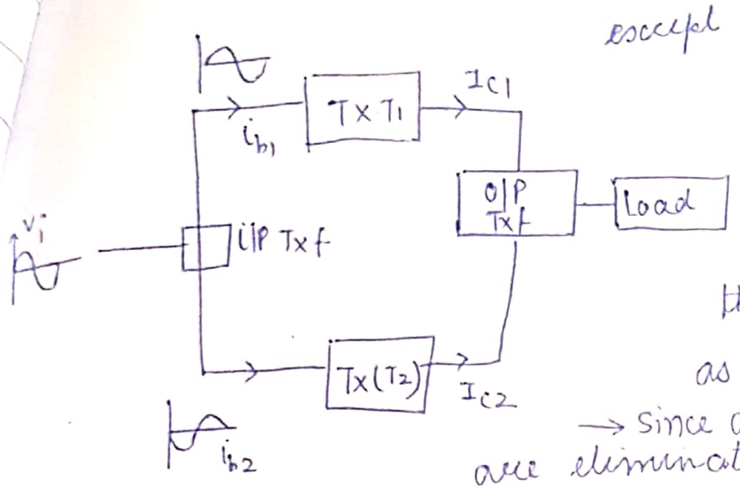
(i) When both Tx are of same type either npn or PNP. push pull Ampʳ

(ii) When two Tx from a complementry pair i.e. one npn, one pnp :- complementry symmetry Ampʳ.

Push pull Amplifier :-

→ O/P waveform of single ended amp (that uses only one Tx) is distorted due to non lin char. It is ↓↓ by operating two Tx in push pull conf.

→ It works on the principle that before amplification, the i/p signal is converted into two separate signals, which are identical except for 180° phase diff.



→ o/p has also 180° phase diff.

→ These o/p signals are combined at o/p & delivered to load.

→ since signal are 180° out of phase, their diff cancel out dc comp as well as even harmonics.

→ Since dc comp & half of the total harmonics are eliminated, the waveform improves a lot.

→ types of push pull conf :- (i) class A (ii) class B (iii) class AB

⇒ Mathematical expression :-

$$i_{b1} = I_m \cos \omega t$$

$$i_{b2} = I_m \cos(\omega t + \pi)$$

from previous derivations :-

$$I_{C1} = I_{CQ} + I_0 + I_1 \cos \omega t + I_2 \cos 2\omega t + \dots$$

$$I_{C2} = I_{CQ} + I_0 + I_1 \cos(\omega t + \pi) + I_2 \cos(2\omega t + \pi) + \dots$$

$$= I_{CQ} + I_0 - I_1 \cos \omega t + I_2 \cos 2\omega t - I_3 \cos 3\omega t$$

∵ In the o/p ckt, I_{C1} & I_{C2} flow in opposite direⁿ, therefore net current delivered to load through Txf is K times the diff b/w I_{C1} & I_{C2}

$$I_0 = K(I_{C1} - I_{C2})$$

$$I_0 = 2K(I_1 \cos \omega t + I_3 \cos 3\omega t + \dots)$$

from above expression it is clear that all even harmonics & dc comp is removed. Second H.D is higher from all above H.D.

⇒ Advantages :-

(i) Improved o/p waveform due to cancellation of even harmonics

(ii) Txf core remains unsaturated due to absence of dc comp

(iii) Since even Harmonics are absent in o/p, every Tx provide higher o/p for a given amount of distortion.

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(iv) Imp. Matching is possible due to presence of O/P Txf

Disadvantages :-

(i) use of two Txf, Tx make the ckt costlier & bulkier.

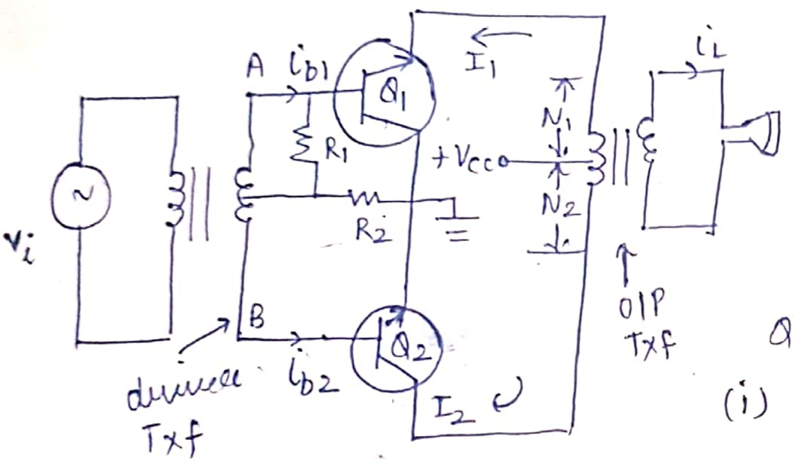
(ii) Two Tx cannot be completely identical, so dc comp & even harmonics are not completely eliminated.

(iii) freq Resp is affected due to inductance of Txf.

* class B push pull Amplifier :-

- If both Tx are of same type means either npn or pnp : it is push pull configuration
- If both Tx are of other type means one npn or other is pnp : it is complementary symmetry.

(1) class B push pull Amplifier with i/p & o/p transformer :-



- for +ve half cycle of i/p signal, pt A is +ve & B is -ve.
- vtg in two halves the secondary of driver Txf will be equal but with opposite polarity. but B of Tx Q_1 & Q_2 will be 180° out of phase.

(i) DC operation :-

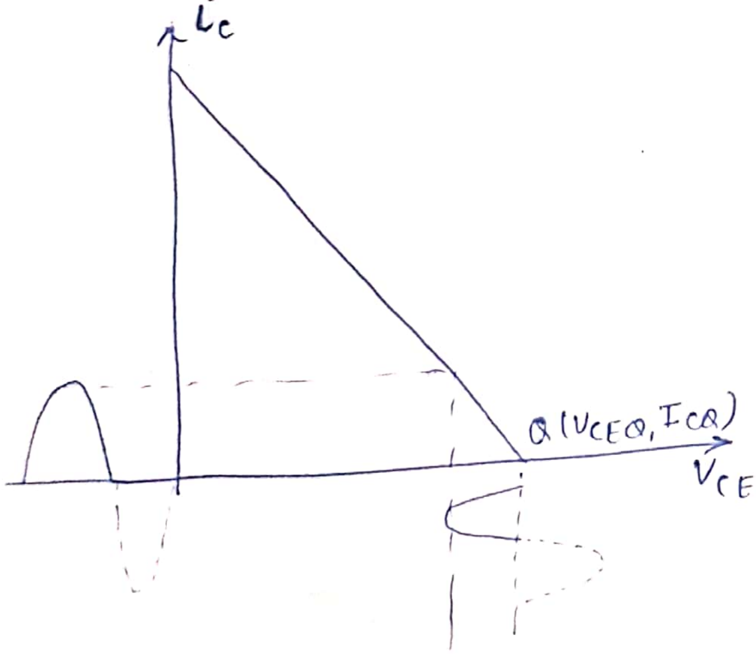
o/p waveform is Half wave so avg. value of current is

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} I_m \sin\theta \, d\theta$$

$$= \frac{I_m}{2\pi}(-\cos\theta)_0^{\pi}$$

$$= \frac{-I_m}{2\pi}(\cos\pi - \cos 0)$$

$$\boxed{I_{dc} = \frac{I_m}{\pi}}$$



$P_{dc} = V_{cc} \cdot I_{dc}$

$$\boxed{P_{dc} = \frac{V_{cc} I_m}{\pi}}$$

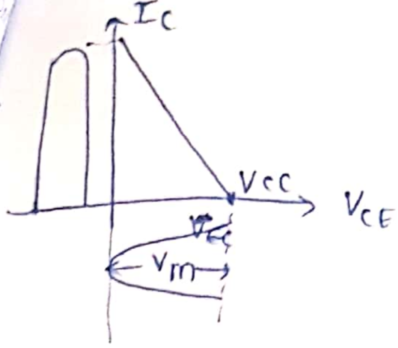
(ii) AC power

$P_{ac} = \frac{V_{rms} I_{rms}}{2}$ (for half wave; power is also half)

$$= \frac{V_m I_m}{\sqrt{2}\sqrt{2} \cdot 2} = \frac{V_m I_m}{4}$$

(3) $\% \eta = \frac{V_m I_m \pi}{4 V_{cc} I_m} \times 100 =$ ~~A 25 = 78.5%~~

$\because V_{cc} = V_m$



so $\%\eta = \frac{V_{cc} I_m \pi}{4 V_{cc} I_m} \times 100$

$= 25\pi$

$\boxed{\%\eta = 78.5\%}$

(4) power dissipation :-

$P_d = P_{DC} - P_{ac}$

$= \frac{2}{\pi}\frac{V_{cc} I_m}{\pi} - \frac{V_m I_m}{4}$

$= \frac{2}{\pi}\frac{V_{cc}}{\pi}\frac{V_m}{R_L'} - \frac{V_m^2}{4R_L'}$

(5) Max power dissipation :-

$\frac{dP_d}{dV_m} = \frac{V_{cc}}{\pi R_L'} - \frac{2V_m}{4R_L'} = 0$

$\Rightarrow \frac{V_{cc}}{\pi R_L'} = \frac{V_m}{2R_L'}$

$\Rightarrow \boxed{V_m = \frac{2V_{cc}}{\pi}}$

so $(P_d)_{Max} = \frac{V_{cc}}{\pi R_L'}\frac{2V_{cc}}{\pi} - \frac{4V_{cc}^2}{\pi^2 4R_L'}$

$= \frac{2V_{cc}^2}{\pi^2 R_L'} - \frac{V_{cc}^2}{\pi^2 R_L'}$

$(P_d)_{max} = \frac{V_{cc}^2}{\pi^2 R_L'}$

for Max eff $V_m = V_{cc}$

so $P_{ac} = \frac{V_m^2}{4R_L'} = \frac{V_{cc}^2}{4R_L'}$

$(P_d)_{max} = \frac{V_{cc}^2 4}{4\pi^2 R_L'} = \frac{4}{\pi^2}(P_{ac})_{Max}$

$\boxed{(P_d)_{max} = \frac{4}{\pi^2}(P_{ac})_{max}}$

→ In these ckt secon even harmonics are not present because o/p current is 180° out of phase. dc component is also eliminated.

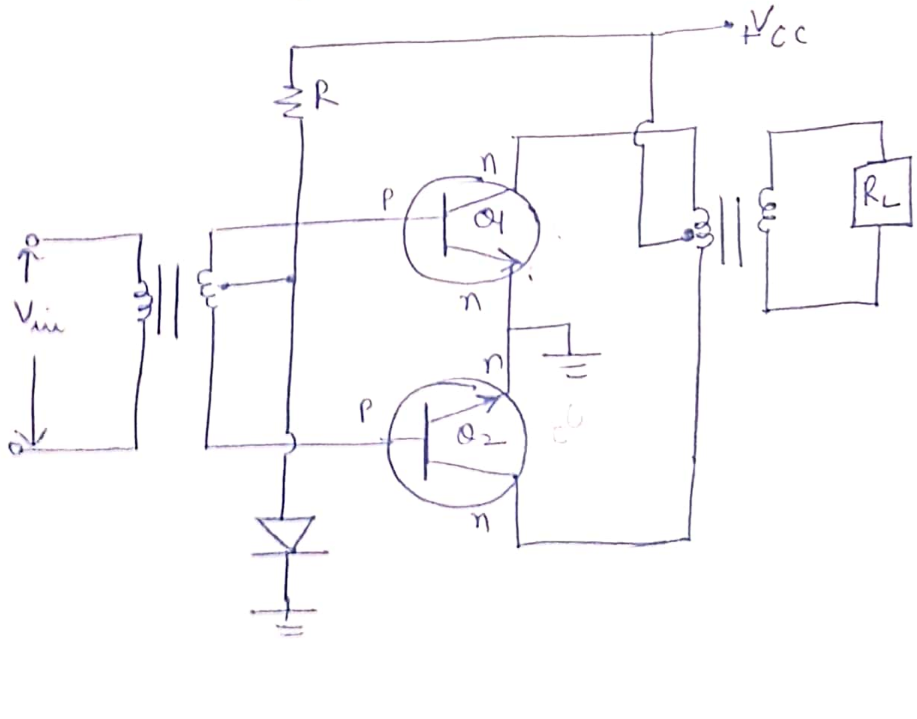
(5) Advantage :

- Efficiency is higher than class A Amplifier.
- even harmonic get cancelled so ↓ses H.D.
- Due to Txf, impedance Matching is possible.

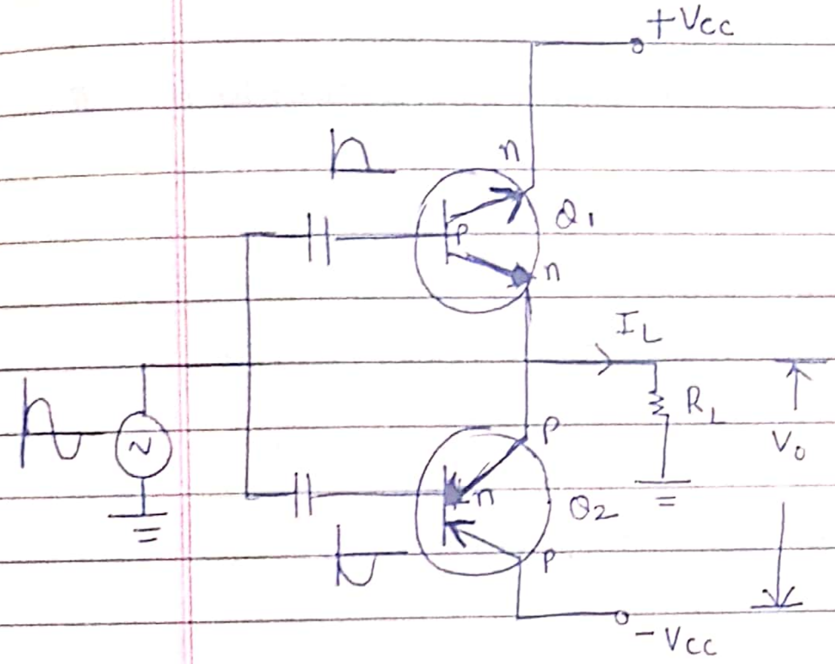
(6) Disadvantage :

- freq. Response is poor.
- Tx makes ckt costlier & bulkier.
- two centre tap Txf are necessary.

(7) elimination of cross over distortion :-



8. Complementary symmetry class B ~~push pull~~ Ampr
[push pull configuration without i/p & o/p Txf] :-



→ Use of Txformer in push pull conf. make the ckt. bulky & costly.

→ This ckt is Txformer less ckt, But with CE conf. it becomes difficult to match the o/p imp. for max. power transfer without an output transformer.

Hence matched pair of complementary Txs. are used in CC conf. [emitter follower]. This is because CC conf. has lowest o/p imp., hence imp. matching is possible.

→ The ckt is driven for dual supply of ± Vcc. Tx Q_1 is npn & Q_2 is PNP.

→ In +ve half cycle of i/p signal Q1 is active, Q2 is in saturation region. positive cycle across R_L is present.

→ for -ve cycle; Q1 = cut off ; Q2 = active
-ve cycle is present across R_L.

→ Thus for complete cycle of ~~o/p~~ i/p, complete cycle of o/p is developed.

→ All result derived for push pull Txf coupled class B ampr are applicable to complementary class B Ampr.

Advantage:-

→ Due to transformer less ckt., weight, size & cost are less.

→ Due to cc conf., Imp. Matching is possible.

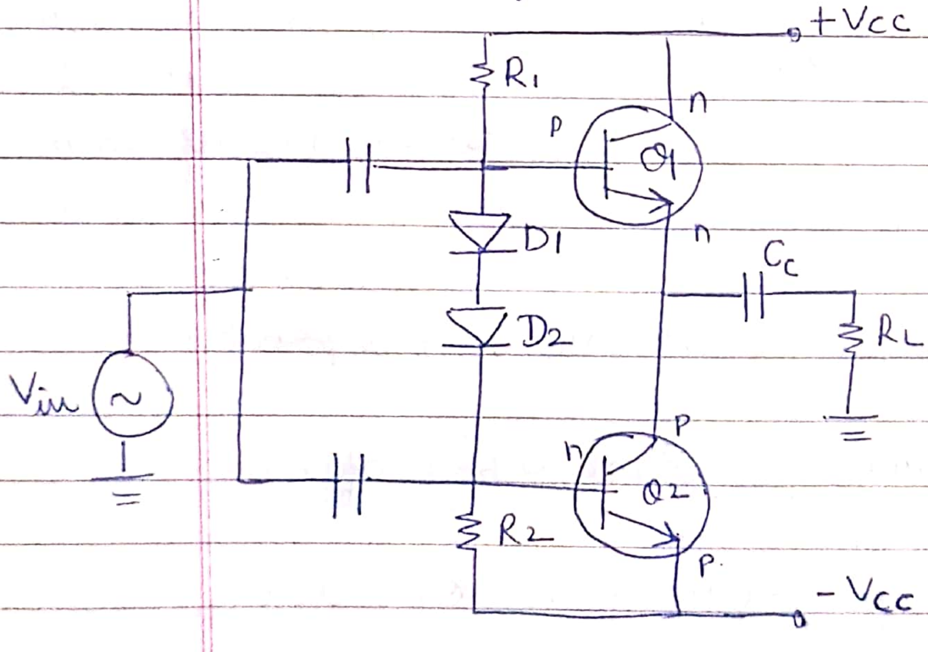
→ ~~freq~~ Distortion is reduced, full cycle is obtained at o/p.

Disadvantage:-

→ Two seperate supply required.

→ output is distorted. Cross over distortion is obtained.

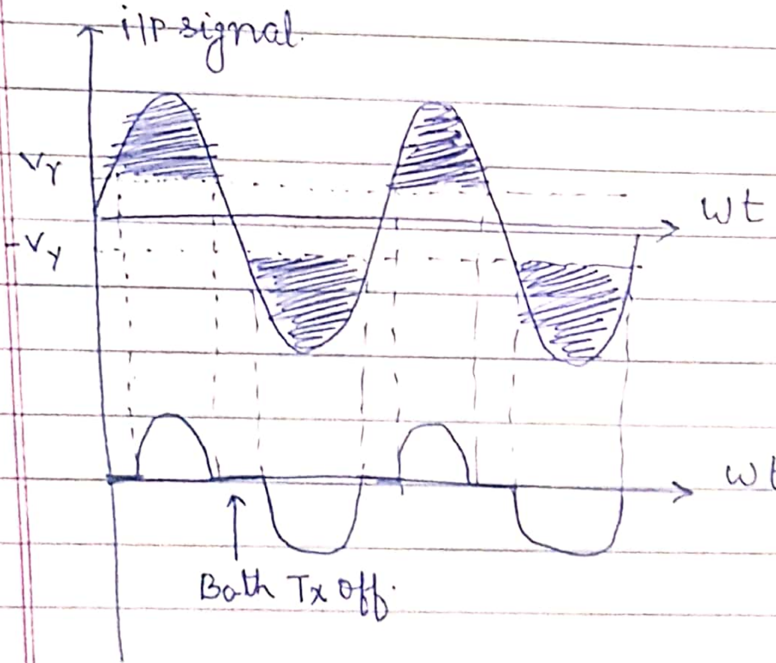
elimination of cross over distortion:-



9. Cross over distortion :-

→ for a Tx, to be in active region the base emitter junc must be forward bias. The junc cannot be made F.B. till the vtg applied becomes greater than cut in vtg. (V_γ) of the junc, which is 0.3 for Ge, 0.7 for Si.

Hence as long as magnitude of i/p signal is less than V_γ of BE junc, The I_c remains zero.



→ Hence there is a period b/w crossing of half cycle of i/p signal for which both Tx are cut off. Hence o/p signal get distorted.

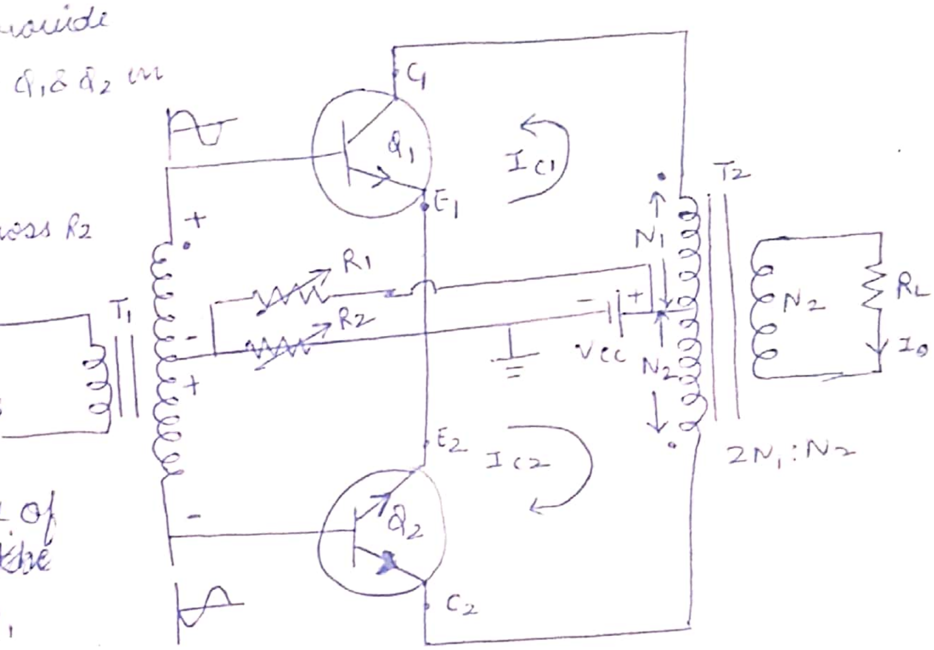
→ Such a distortion is called cross over distortion.

Due to these each Tx conducts for less than half cycle.

10.
(a) class A push pull configuration :- Dot marked on the winding of T_2 shows identical points (i.e points of polarity & mag)

→ R_1 & R_2 are used to provide proper dc bias to keep Q_1 & Q_2 in class A conf.

→ sum of vtg drop across R_2 & secondary vtg of T_1 is applied at i/p of Q_1 & Q_2. vtg drop across R_2 should be 0.5V higher than max. value of signal present at the the secondary value of Q_1



(since cut in vtg. of Si is 0.5V, for Ge it is must be higher than 0.1V) It keeps Q_1 & Q_2 always in A.E and a current flow for 360° and Tx operate in class A conf.

⇒ circuit operation :- Net vtg b/w B & E is sum of

- During +ve half cycle of ac signal, vtg drop across R_2 & ac vtg. across T_1.
- one Tx is more +ve than other (let Q_1 is more +ve than other), so Q_1 is pulled in & Q_2 is pulled out of conductions.
- for -ve half cycle Q_1 is pulled out & Q_2 is pulled in.
- ∴ When one Tx is pused in other is pulled out, so this is called push pull conf.
- $I_1 = I_{C1} \cdot \frac{N_1}{N_2} = K I_{C1}$

$I_2 = I_{C2} \cdot \frac{N_1}{N_2} = K I_{C2}$

$I_0 = I_1 - I_2 = K(I_{C1} - I_{C2})$

since I_{C1} & I_{C2} are in opposite dirn, dc comp & even harmonics are eliminated.

⇒ Advantage :- In push pull Amplifier, the H.D. present in ~~simple~~ directly coupled & Txf coupled are eliminated in push pull configuration of class A configuration.

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11. class AB push pull Amplifier :-

→ The basic circuit of class AB push pull Ampr is same as that of class A Ampr except that resistors R_1 & R_2 are so adjusted that vtg. drop across R_2 is slightly higher than cut in vtg. of Tx.

→ Now O/P current will flow for more than half cycle but less than full cycle.

→ Due to F.B. of Tx, cross over distortion is eliminated. But still current does not flow for complete cycle. therefore it is distorted wave.

Advantages :-

→ cross over distortion are not present.

→ efficiency is more than class A configuration.

→ O/P per Tx is more than class A operation.

→ Non linear distortion are less than class B operation.

Disadvantages :-

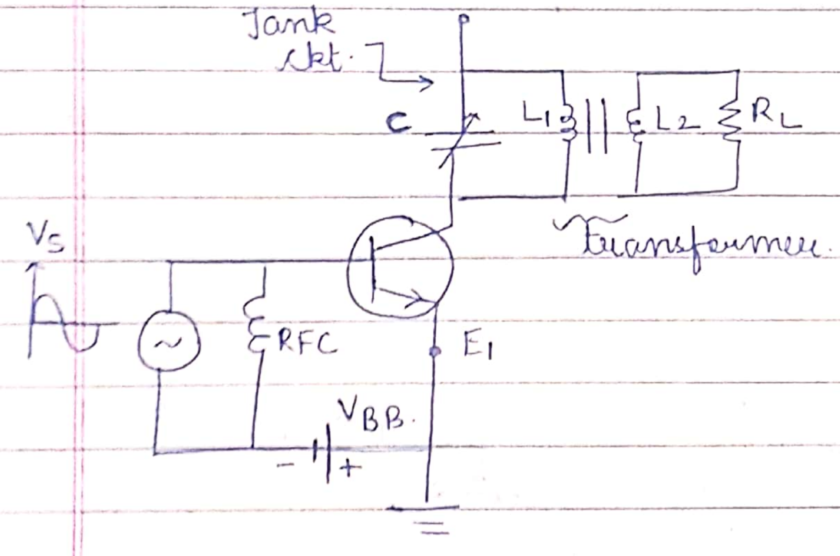
→ efficiency is less than class B operⁿ.

→ Lower O/P per Tx in comparison to class B conf.

→ Non linear distortion are more than class A conf.

12 Class C Amplifier :-

→ for operating ~~dc~~ power Ampr in class C, I/P is slightly R.B. so that O/P current flow for less than 180° of I/P I/P cycle.



→ Input is slightly R.B. with the help of dc battery.

→ Radio freq. coil (RFC) does not allow the ac signal to enter into dc battery VBB.

→ A tank ckt. comprising of L & C is included in the collector ckt of Tx, where L_1 is inductance offered by primary winding of transformer.

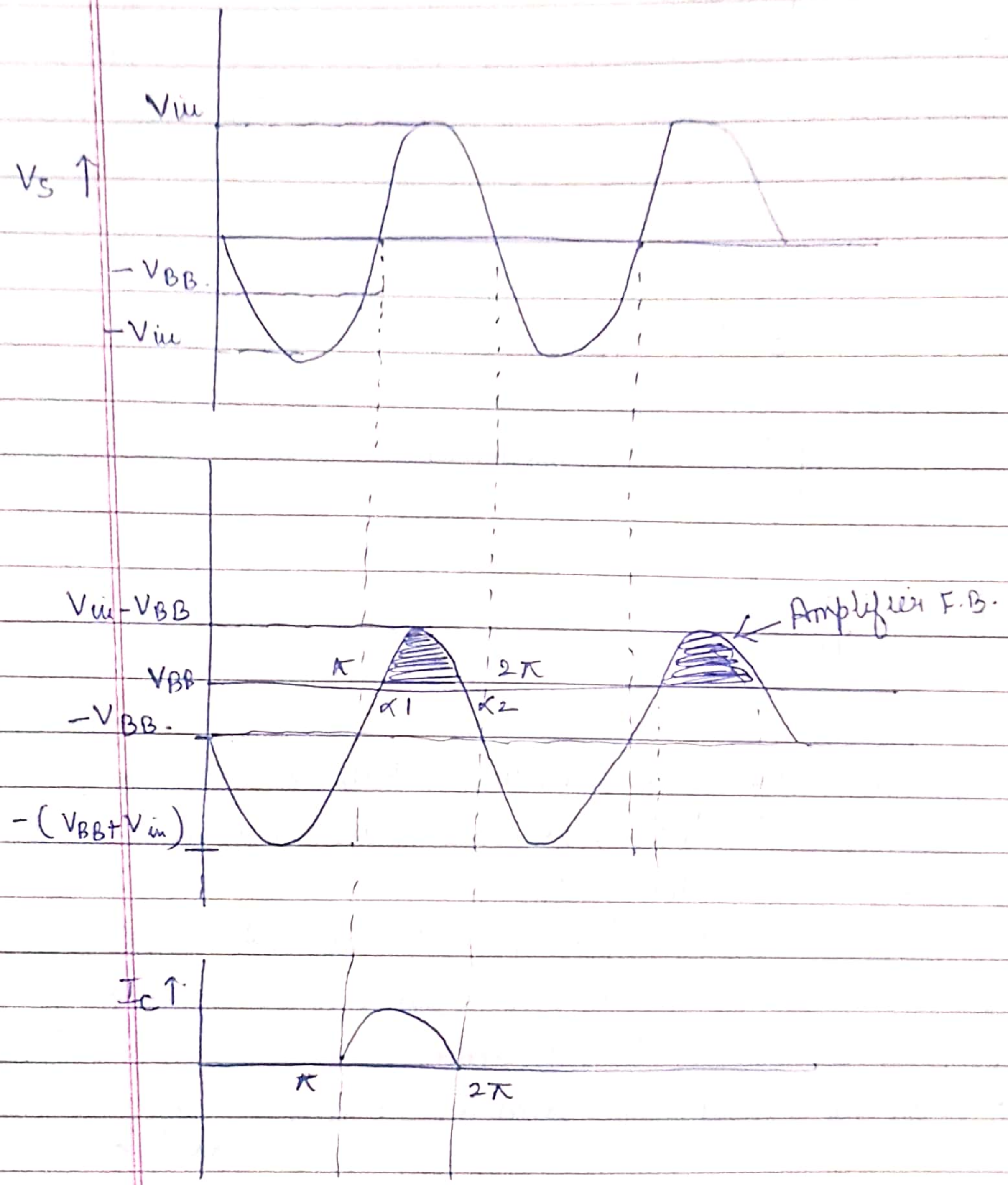
→ Tank ckt. is tuned to fundamental freq. $\left(f = \frac{1}{2\pi\sqrt{L_1 C}} \right)$.

Load R_L is connected in secondary winding of Txf. The ckt. can be tuned to any freq. by varying the capacitor C.

Circuit operation :-

→ for -ve half cycle of I/P signal (Vs), the I/P is R.B. by $-(V_S + V_{BB})$ & remains cut off & therefore O/P is Zero.

→ for +ve half cycle when I/P signal (Vs) is more than V_{BB} the Tx is F.B. & conducts. Since Tx is F.B. only for a period $(\alpha_2 - \alpha_1)$ which is less than 180°.



Advantages:-

(i) The efficiency is very high, which is more than class A, B, AB.

(ii) O/P delivered to load is free from harmonics, since ckt is tuned to fundamental & harmonics are rejected.

Disadvantages:-

(i) Distortion is higher than class A, B, AB.

(ii) Use of Txf. make ckt. heavy, expensive.

(iii) The ckt can be used for limited tuned freq. which is decided by capacitor.

13. Difference between voltage & power Amplifier :-

	voltage Amp^r.	power Amp^r
1) power O/P.	small & in range of mW	large in range of 100W
2) current gain β.	High (≈ 100)	small (≈ 20)
3) type of coupling.	RC coupling	transformer coupling.
4) Input vtg.	small (mV)	High (15V)
5) output Impedence	High (10KΩ)	Low (100 Ω)
6) Collector current	Low (1 mA)	High (100 mA)
7) type of signal	Small signal Amp^r	large signal Amp^r
8) Load Resistance	High	Small.
9) power dissipation capacity	Less	Large.
10) Operating Region	Linear	Non Linear
11) Non Linear distortion (cross over distortion)	Not present	Always present.