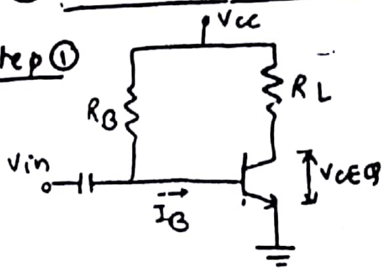
* Class A Amplifiers :-

① Direct coupled class A Ampl^r :-

- load is directly coupled to collector.

step①



② **DC Analysis** :-

Applying KVL in base loop

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

$\therefore I_B R_B = V_{CC} - V_{BE}$

$\therefore I_B = \dfrac{V_{CC} - V_{BE}}{R_B} \Rightarrow \boxed{I_B = \dfrac{V_{CC}}{R_B}}$ $\boxed{I_{CQ} = \beta I_B}$ — ①

Applying KVL in collector ckt,

$V_{CC} - I_{CQ} R_L - V_{CEQ} = 0$ $\quad \therefore \boxed{V_{CEQ} = V_{CC} - I_{CQ} R_L}$ — ②

Operating Point $Q = (V_{CEQ}, I_{CQ})$

step③ **DC load line** :-

from Eq^{n}②, $I_{CQ} R_L = V_{CC} - V_{CEQ}$

$I_{CQ} = \dfrac{V_{CC}}{R_L} - \dfrac{V_{CEQ}}{R_L}$

$\boxed{I_{CQ} = \left(-\dfrac{1}{R_L}\right) V_{CEQ} + \dfrac{V_{CC}}{R_L}}$ — ③

$y = mx + c \quad \therefore$ slope $= -1/R_L$ (of DC Load Line)

To find 2 pt's

ⓘ Transistor in saturat^n

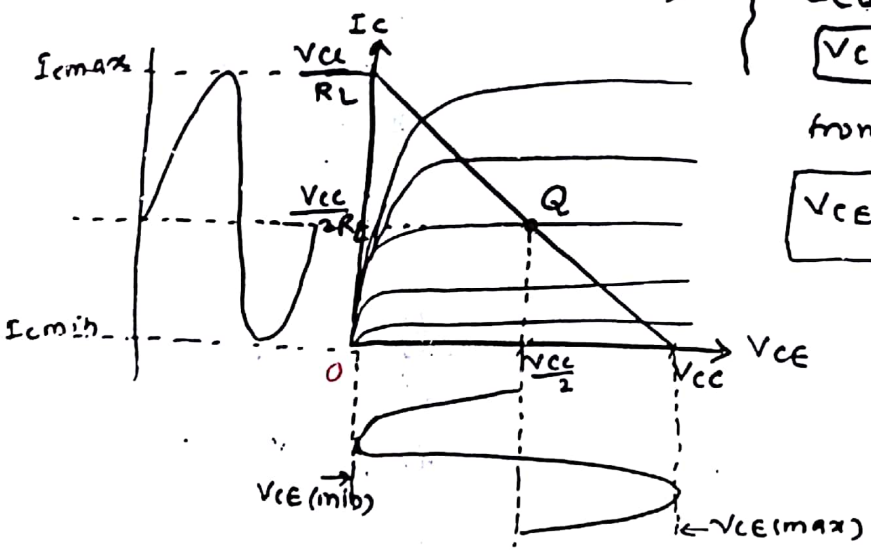
$V_{CE} \cong 0$ put in ③,

$\therefore \boxed{I_{CQ} = \dfrac{V_{CC}}{R_L}}$

ⓘⓘ Trans in cutoff

$I_{CQ} = 0$ put in ③

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



from graph,

$\boxed{V_{CEQ} = \dfrac{V_{CC}}{2} \; \& \; I_{CQ} = \dfrac{V_{CC}}{2R_L}}$ — ④

step④ **AC load line** : same ($\because$ ac & dc lod are same).

step⑤ **DC i/p Power** :- Assume $I_B = 0$

$P_{dc} = I_{CQ} . V_{CC}$ using ④, $P_{dc} = \dfrac{V_{CC}}{2R_L} . V_{CC} \Rightarrow \boxed{P_{dc} = \dfrac{V_{CC}^2}{2R_L}}$ — ⑤

step ⑥ AC power given to load :-

$$P_{ac} = V_{rms} \cdot I_{rms} = I_{rms}^2 R_L = \frac{V_{rms}^2}{R_L}$$

In terms of Peak values,

$$P_{ac} = \left(\frac{V_{o(p)}}{\sqrt{2}}\right) \cdot \left(\frac{I_{o(p)}}{\sqrt{2}}\right) = \frac{V_{o(p)} \cdot I_{o(p)}}{2} \quad \text{— ⓐ}$$

In terms of Peak to Peak values,

$$P_{ac} = \left(\frac{V_{o(pp)}}{2\sqrt{2}}\right) \cdot \left(\frac{I_{o(pp)}}{2\sqrt{2}}\right) = \frac{V_{o(pp)} \cdot I_{o(pp)}}{8} \quad \text{— ⓑ}$$

In terms of Max & Min values,

$$P_{ac} = \left[\frac{(V_{CEmax} - V_{CEmin})}{2\sqrt{2}}\right] \cdot \left[\frac{(I_{Cmax} - I_{Cmin})}{2\sqrt{2}}\right]$$

$$P_{ac} = \frac{(V_{CEmax} - V_{CEmin})(I_{Cmax} - I_{Cmin})}{8} \quad \text{— ⓒ}$$

By Referring graph,

$$P_{ac} = \frac{(V_{cc} - 0)(V_{cc}/R_L - 0)}{8} \qquad \therefore \boxed{P_{ac(max)} = \frac{V_{cc}^2}{8R_L}} \quad \text{— ⑥}$$

step ⑦ Efficiency of ampl^{r} (Theoretically)

$$\%\eta = \frac{P_{ac}}{P_{dc}} \times 100 \qquad \therefore \text{from eq}^n \text{ ⑤ \& ⑥},$$

$$\eta_{max} = \frac{\cancel{V_{cc}^2}}{\cancel{8}_4 \cancel{R_L}} \times \frac{\cancel{2}^1 \cancel{R_L}}{\cancel{V_{cc}^2}} \times 100 = \frac{100}{4} = 25\% \qquad \boxed{\eta = 25\%}$$

step ⑧ Power Dissipation in transistor :

$$P_D = V_{CEQ} \times I_{CQ} \qquad \text{using eq}^n \text{ ⑥},$$

$$P_{Omax} = \frac{V_{cc}}{2} \cdot \frac{V_{cc}}{2R_L} = \frac{V_{cc}^2}{4R_L}$$

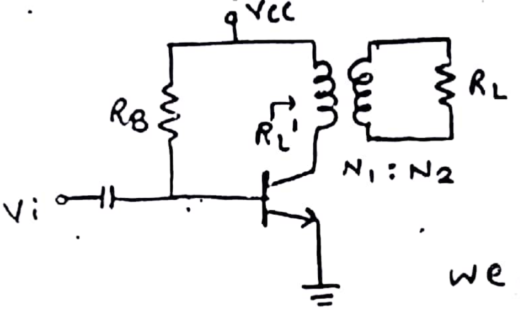
step ⑨ Figure of Merit :-

$$FM = \frac{P_{Omax}}{P_{acmax}} = \frac{\cancel{V_{cc}^2}}{4\cancel{R_L}} \times \frac{8\cancel{R_L}}{\cancel{V_{cc}^2}} = 2 \qquad \boxed{FM = 2}$$

> * Angle of conduction = 360°
> η = very poor (25%)
> FM = 2
> Transistor Power Dissipation = very large
> Drawback = less η, higher P_D, Generates Hum

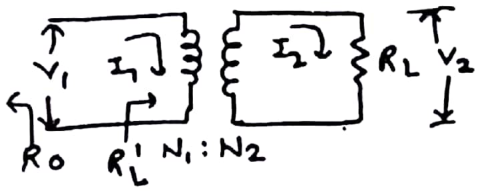
* Transformer coupled class A Ampl^r :-

① ckt diagram :-



- AF transformer is used with turns ratio as $N_1 : N_2$
- By adjusting no. of turns, o/p resist. of X'mer can be matched with load resist R_L for Max. Power Transfer.

we know, $\dfrac{N_1}{N_2} = \dfrac{V_1}{V_2} = \dfrac{I_2}{I_1} = K$



or $K = \dfrac{V_2/R_L}{V_1/R_L'} = \dfrac{I_2}{I_1}$

R_L' = load Resi. seen from primary

$\therefore K = \dfrac{V_2}{V_1} \cdot \dfrac{R_L'}{R_L} = \dfrac{1}{K} \dfrac{R_L'}{R_L}$ $\quad \therefore \dfrac{R_L'}{R_L} = K^2$ OR $\dfrac{R_L'}{R_L} = \left(\dfrac{N_1}{N_2}\right)^2$

OR $\boxed{\dfrac{N_1}{N_2} = \sqrt{\dfrac{R_L'}{R_L}}}$ $\Rightarrow$ By adjusting N_1, N_2, we can (adjust) make o/p resist of ampl^r = Reflected load Resistance R_L'.

② DC Analysis or DC load line :-

Apply KVL in Base loop, $I_{BQ} = \dfrac{V_{CC} - V_{BE}}{R_B}$; $\boxed{I_{BQ} \cong \dfrac{V_{CC}}{R_B}}$

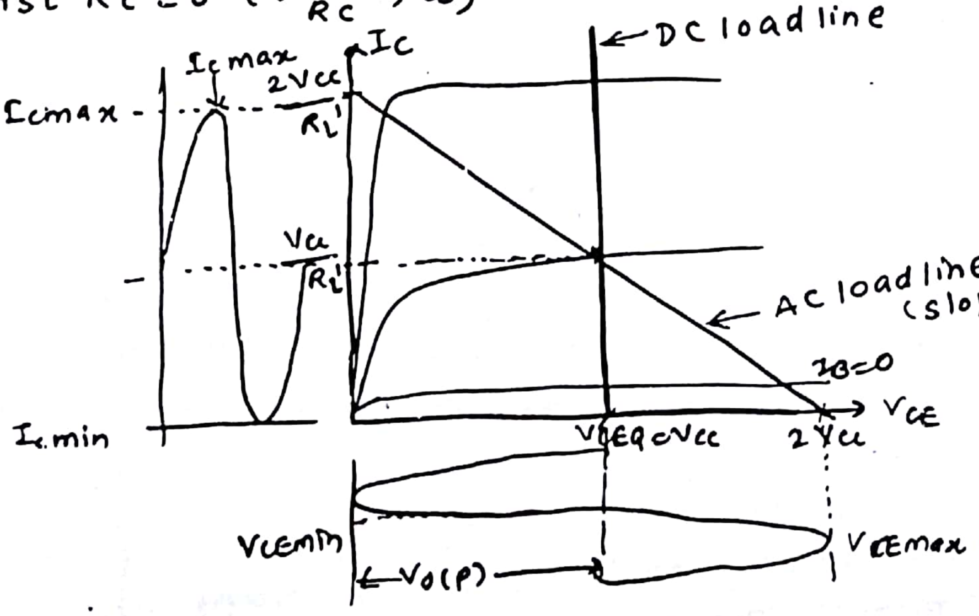
$\therefore \boxed{I_{CQ} = \beta I_{BQ}}$

Apply KVL in collector loop, for DC, f = 0, X_L of Primary = 0

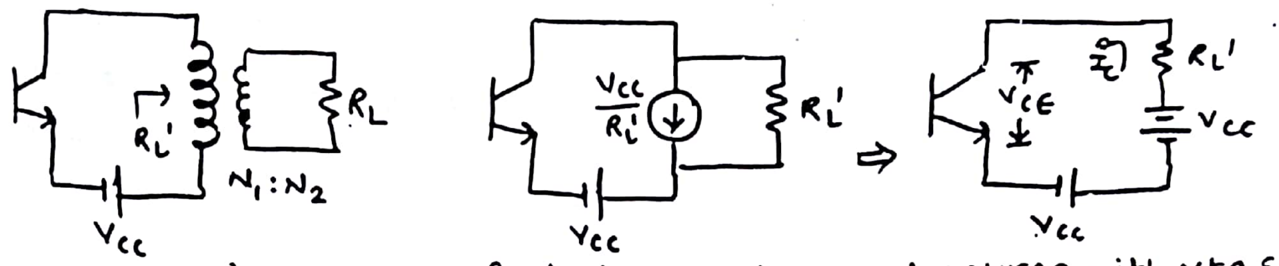
$\therefore \boxed{V_{CEQ} = V_{CC}}$ $\quad \therefore$ Q point is (V_{CEQ}, I_{CQ})

To draw DC load line, $V_{CEQ} = V_{CC}$ $\therefore$ slop = ∞ $\because$ collector DC resist $R_C = 0$ $\left(\because \dfrac{1}{R_C} \to \infty\right)$

(For AC load line turn page)



To draw AC load line, primary winding inductance is always selected in such a manner that for ac i/p signal, it works as open.
ie value of L_p is very large & current flowing through it will always remains constant.
∴ Primary of X'mer can be replaced by const current source



Replacing const current source with vtg source

Now considering worst condn of transistors,

(i) In cut off, $I_c = 0$ $(I_c R_L' = 0)$ ∴ $V_{CE} = 2V_{cc}$

(ii) In saturation, $V_{CE} = 0$ ∴ $I_c = \frac{2V_{cc}}{R_L'}$, ∴ pts ⇒ $(2V_{cc}, 0)$ & $(0, \frac{2V_{cc}}{R_L'})$

from the graph, $V_{CEQ} = \frac{V_{CEmax}}{2} = V_{cc}$

$$I_{CQ} = \frac{I_{cmax}}{2} = \frac{2V_{cc}}{R_L'} \cdot \frac{1}{2} = \frac{V_{cc}}{R_L'}$$

③ DC i/p Power (P_{dc}) :-

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

$$P_{dcmax} = \frac{V_{cc}}{R_L'} \cdot V_{cc} = \boxed{\frac{V_{cc}^2}{R_L'}}$$

④ Ac power given to load (P_{ac})

(any formula from a, b, c in previous case)

$$P_{ac(max)} = \frac{(V_{CEmax} - V_{CEmin})(I_{cmax} - I_{cmin})}{8}$$

$$= \frac{(2V_{cc} - 0)(2V_{cc}/R_L' - 0)}{8} = \frac{4V_{cc}^2}{8R_L'}$$

$$∴ \boxed{P_{cmax} = \frac{V_{cc}^2}{2R_L'}}$$

⑤ Max η of Ampl^r :-

$$\eta_{max} = \frac{P_{acmax}}{P_{dcmax}} \times 100$$

$$= \frac{V_{cc}^2}{2R_L'} \times \frac{R_L'}{V_{cc}^2} \times 100$$

$\boxed{\eta_{max} = 50\%}$ — Better than Direct coupled

⑥ Power dissipatn in Trans. (max)

$$P_{Dmax} = I_{CQmax} \times V_{CEmax}$$

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

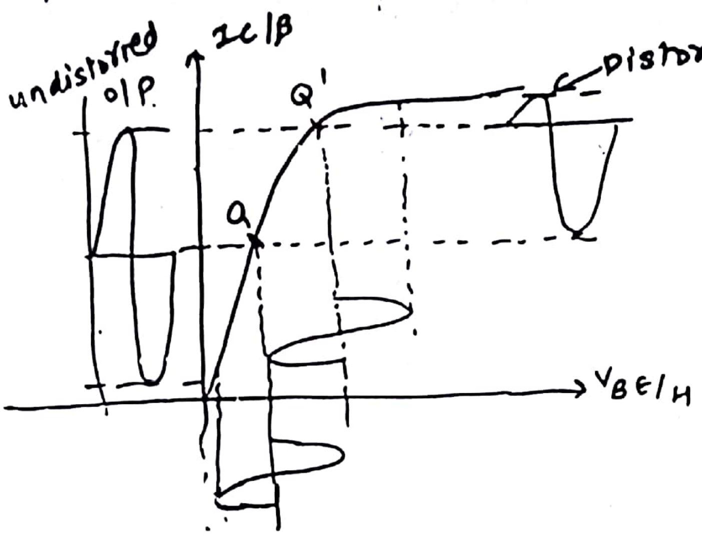
⑦ Figure of Merit (FM) :-

$$FM = \frac{P_{Dmax}}{P_{acmax}} = \frac{\cancel{V_{cc}^2}}{\cancel{R_L'}} \times \frac{2\cancel{R_L'}}{\cancel{V_{cc}^2}} = 2$$

∴ $\boxed{FM = 2}$ ⇒ ∴ $\boxed{P_{Dmax} = 2P_{acmax}}$

* Drawbacks of Single ended Transformer coupled A (Class A).

① ∵ Q pt is in center of transfer characteristics, $I_C = I_{CQ}$
Even when i/p is not applied, Hence continuous power dissipation of power occurs. ⇒ reduces η of Ampr.

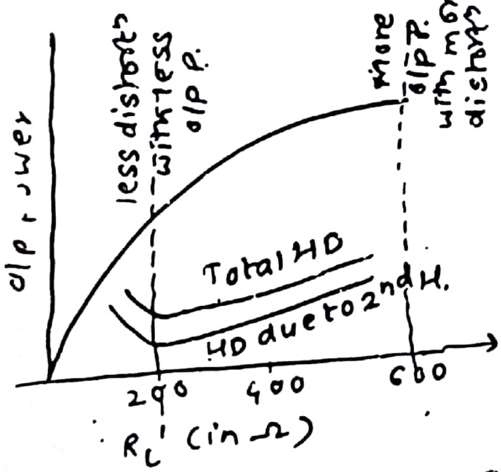


Q = Q pt before core saturation

Q' = Q pt (shifted) after saturat^n of core

② ∵ large dc current flows through X'mer primary windings, even $V_i = 0$, core becomes saturated.
Due to core saturation, variation in o/p collector current will not be according to i/p variation. This generates distortion in o/p.

③ Distortion in o/p increases with increase in load resistance



④ Distortion due to 2nd Harmonic is Max

⑤ operating pt at which distortion is less, o/p is also less.
Hence max Power & min distortion points are different.
For designing this ampl^r, it will be a compromise bet^n Max Power & min distort^n.

* Distortion in Power Amplifiers :-

- In VA, Q pt is selected at the center of load line.
  $\because$ amplitude of i/p vtg is small, operatⁿ of transistor remains in linear region.
- In PA, i/p vtg swing is large. $\therefore$ operation of transistor also enters in nonlinear region.
- If a signal $v_i = V_i \cos\omega t$ is applied to an active device (eg transistor) with nonlinear charct., the o/p current is given by Taylor's series.

$$V_i\cos\omega t \longrightarrow \boxed{\text{Device with Nonlinear char.}} \longrightarrow i_o = i_c$$

(collector current)

$$i_c = I_c + a_1 V_i\cos\omega t + a_2 (V_i\cos\omega t)^2 + a_3 (V_i\cos\omega t)^3 + \dots$$

$$= I_c + a_1 V_i \cos\omega t + a_2 V_i \tfrac{1}{2}(\cos 2\omega t + 1) + \dots$$

$$\left[\because \cos^2\theta = \frac{1+\cos 2\theta}{2}\right]$$

$$= I_c + \frac{a_2 V_i}{2} + a_1 V_i \cos\omega t + \frac{a_2 V_i}{2}\cos 2\omega t + \dots$$

$$= I_c + \frac{a_2 V_i}{2} + a_1 V_i \cos(2\pi f t) + \frac{a_2 V_i}{2}\cos(2\pi f t) + \dots \quad \text{--- (1)}$$

where $\frac{a_2 V_i}{2}$ is new dc vtg at o/p.

f = fundamental freq of i/p signal

$2f_1, 3f_1, 4f_1$ = $2^{nd}, 3^{rd}$ & 4^{th} harmonics of i/p signal.

$\therefore$ Eqⁿ (1) can be written as,

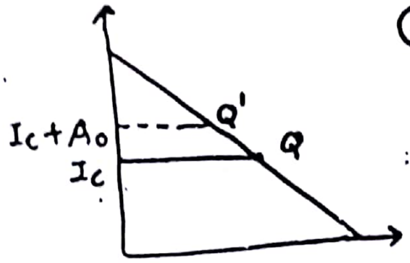
$$\boxed{i_c = I_c + A_0 + A_1\cos\omega t + A_2 \cos 2\omega t + A_3 \cos 3\omega t + \dots} \quad \text{--- (2)}$$

from eqⁿ (2),

(i) If signal with f_1 freq is applied at i/p of nonlinear device, we get fundamental freq with harmonics of i/p freq. This type of distortion is known as <u>Harmonic Distortion</u> (HD)

$\because$ Amplitude of 2^{nd} harmonic is max.

(ii) At o/p we also get a new dc current. A_0 added to designed dc current I_c. Hence Q point will get shifted towards saturatⁿ. This changes shape of o/p signal in +ve peak. This type of distortion is called as <u>Amplitude distortion</u>. (AD)



③ ∵ charct of transistor is not linear the o/p current i_c is not directly proportional v_i. Hence we get distortion in o/p. This type of distortion is known as <u>Non linear Distortion</u>

Total Distortion / THD in PA :-

from eqⁿ②, % HD produced by 2nd harmonic is given by,

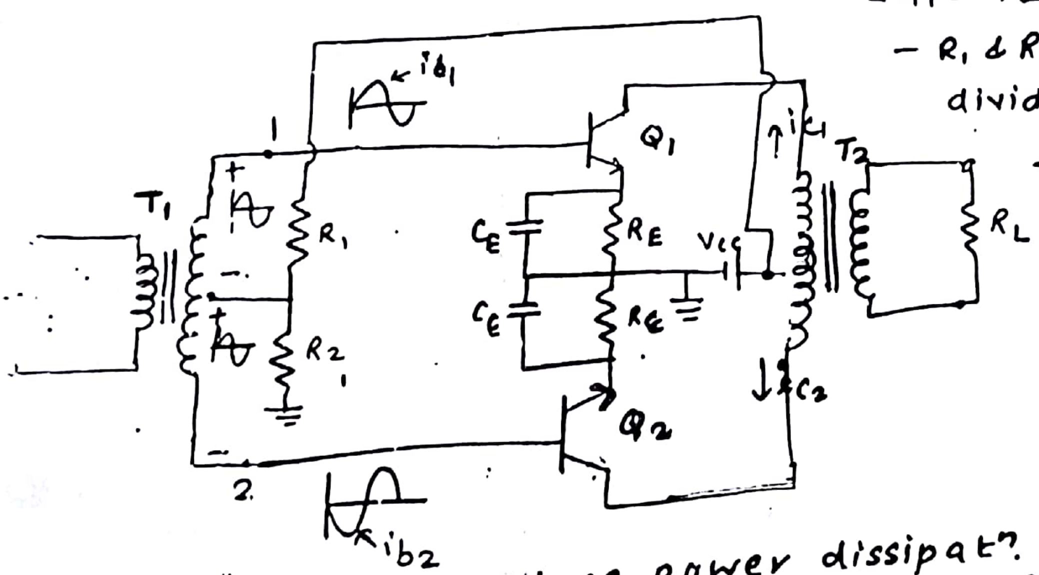
$$D_2 = \frac{A_2}{A_1} \times 100$$

while due to 3rd harmonics

$$D_3 = \frac{A_3}{A_1} \times 100$$

$$\therefore \boxed{THD = \sqrt{D_2^2 + D_3^2 + D_4^2 + \ldots}}$$

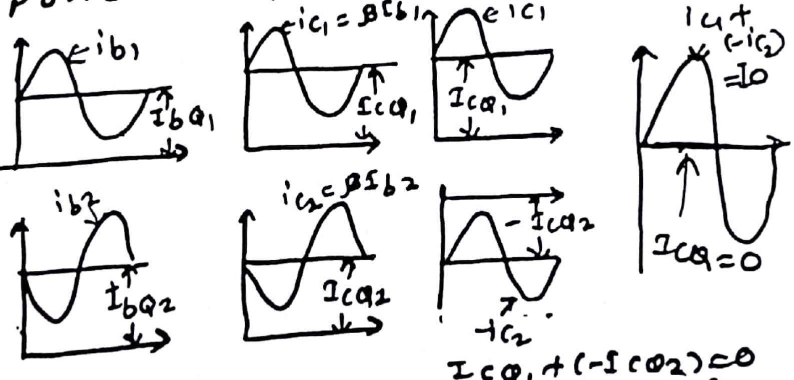
* Class A pushpull amplifier :-



- Q_1 & Q_2 are matched
- R_1 & R_2 is potential divider for biasing.
- R_1, R_2 selected such that Q pt of Q_1, Q_2 remains in the center of load line. (class A operatⁿ)

- R_E used to reduce power dissipatⁿ. R_E very small to provide stability of Q pt.
- T_1 : centertapped i/p X'mer
- T_2 : combines o/p of Q_1 & Q_2 provides power amplified i/p signal.

i_{c1} → pulled down
i_{c2} → pushed up } so push pull Ampr.



$I_{cQ_1} + (-I_{cQ_2}) = 0$
$I_{c1} + (-I_{c2}) = I_0$

* Advantages of Pushpull amplifiers :-

① How distortion is reduced in pushpull ampl^r?

→ If we assume Q_1, Q_2 both matched transistors

$v_i = V_i \cos\omega t$ then i_{b1} & i_{b2} are 180° out of phase

$e_{b1} = V_i \cos\omega t$

$e_{b2} = V_i \cos(\omega t + \pi)$

Then $i_{c1} = I_c + A_0 + A_1\cos\omega t + A_2\cos 2\omega t + A_3\cos 3\omega t + \ldots$ — ⓐ

$i_{c2} = I_c + A_0 + A_1\cos(\omega t+\pi) + A_2\cos 2(\omega t+\pi) + A_3\cos 3(\omega t + \pi) + \ldots$

But $\cos(\theta + n\pi) = \cos\theta$ — n is even

$\cos(\theta + n\pi) = -\cos\theta$ — if n is odd

$\therefore i_{c2} = I_c + A_0 - A_1\cos\omega t + A_2\cos(2\omega t) - A_3\cos(3\omega t) + \ldots$ — ⓑ

$\because$ o/p current is $I = i_{c1} - i_{c2}$

$\therefore \boxed{I = 2A_1\cos\omega t + 2A_3\cos 3\omega t}$ — ⓒ

- Here component with $2\omega t$ is cancelled which is cancelled.
  $\because$ main source of HD is 2nd harmonic which is cancelled.
  so (HD) Harmonic distortion reduces.
- from eq^n ⓒ, all dc components are cancelled, problem of core saturat^n is eliminated.
  $\therefore$ Amplitude Distort^n due to core saturat^n is eliminated.
- from eq^n ⓒ, amplitude of fundamental components get doubled.
- other than push pull ampl^r, even if power supply is rectified, filtered, we get some ripple at o/p in the form of 'humming' Noise
  In this pushpull ampl^r, ripples get cancelled.
  In this pushpull ampl^r (rippled current flow in opposite direct^n in 2 halves of o/p transformer. Hence ripple vtg doesn't affect o/p).
- It is less costly. Power supply can be used.