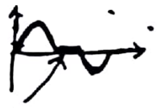
* Class B Amplifiers :-

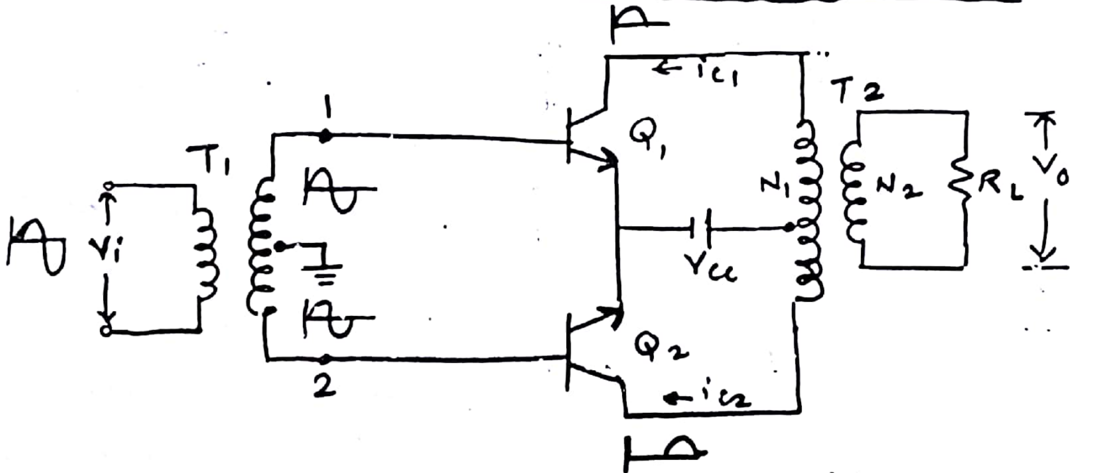
- amplify half of i/p cycle.
- creates large amount of distortion
- Improved efficiency 78.5% ($\pi/4$)
- Amplifying element is switched off altogether half of the time so cann't dissipate power.

* Class B push pull Amplifiers :-

- practical ckt using class B is complementary pair or "push-pull" arrangement.
- complementary or Quasi-complementary devices are used to each amplify opposite halves of i/p & then recombined at o/p.
- This provides excellent efficiency.



But there is a small mismatch at "joins" betn two halves of signal, called Crossover distortion.



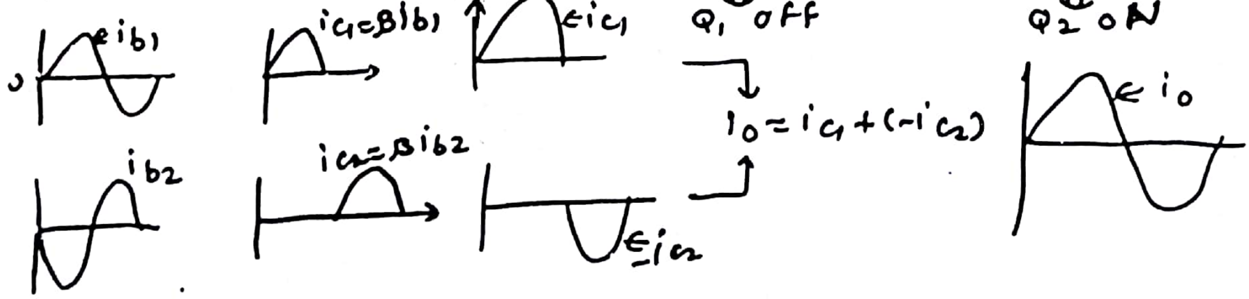
(1:1:1)

T_1 : i/p transformer

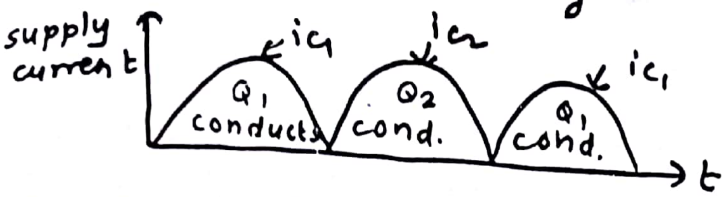
T_2 : o/p X'mer

- Q_1, Q_2 are biased in cut off (No biasing vtg at base)

- since Q pt is shifted to cutoff, one transistor will conduct for one half cycle of i/p v_i
- For +ve half cycle, V_i at pt ① = +ve & at pt ② −ve
  $\Downarrow$ Q_1 conducts $\Downarrow$ Q_2 off
- For −ve half cycle V_i at pt ① ⇒ −ve & at pt ② +ve
  $\Downarrow$ Q_1 off $\Downarrow$ Q_2 ON



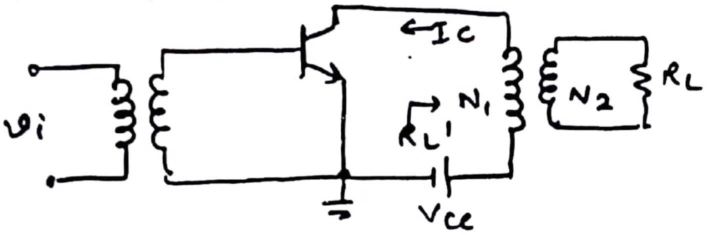
current taken from Vcc is in same direction wheather Q_1 or Q_2 is conducting.



① **DC Analysis:-**

- For both Q_1 & Q_2, V_{cc}, collector & base currents are same hence both transistors have same ckt.

$\therefore$ we can do all analysis on only 1 transistor.



$\because$ Base biasing is zero,

$I_{BQ} = 0 \quad \therefore I_{CQ} = \beta I_{BQ} = 0$

& DC resistance of transformer primary $\cong 0$

$\therefore V_{CEQ} = V_{cc} \quad \therefore$ Q pt $(V_{cc}, 0)$

Hence DC load line = with slop $-1/R_c = 1/R_p = \infty$

② **AC loadline -**

- consider R_L' (R_L seen from primary) Apply KVL in collector L

$V_{cc} - I_c R_L' - V_{CE} = 0$

$\therefore I_c = \left(-\frac{1}{R_L'}\right) V_{CE} + \frac{V_{cc}}{R_L'}$

$y = mx + c$

To find 2 pts

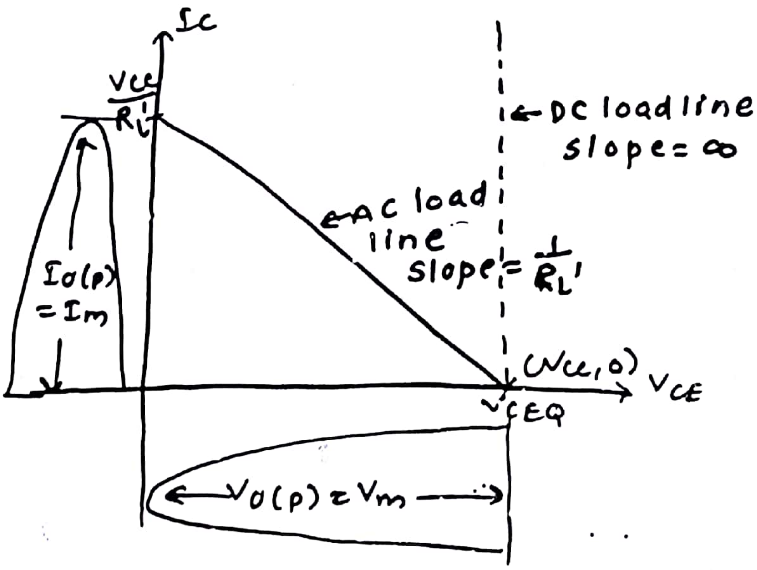
i) In sat., $V_{CE} = 0$, $\therefore I_c = \frac{V_{cc}}{R_L'}$

ii) in cutoff, $I_c = 0$

$\therefore V_{CE} = V_{cc}$

$\therefore$ 2 pts for AC load line

$\left(0, \frac{V_{cc}}{R_L'}\right)$ & $(V_{cc}, 0)$



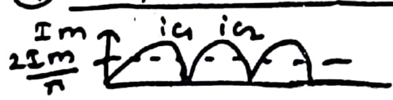
③ **Pac given to load -**

$$P_{ac} = \frac{V_{rms}^2}{R_L'} = \frac{(V_m/\sqrt{2})^2}{R_L'} = \frac{V_m^2}{2R_L'}$$

$$\boxed{P_{ac\,max} = \frac{V_{cc}^2}{2R_L'}}$$

$\because$ (V_m is max) for max power $V_{cc} = V_m$

④ **DC power i/p to ampl^r (P_{dc})**



$\therefore I_{av} = \frac{2I_m}{\pi}$

$I_m = \frac{V_{cc}}{R_L'} \quad \therefore I_{av} = \frac{2V_{cc}}{\pi R_L'}$

$\therefore P_{d\,max} = V_{cc} \times I_{av}$

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

$$\therefore \boxed{P_{d\,max} = \frac{2V_{cc}^2}{\pi R_L'} = \frac{2V_{cc} \cdot V_m}{\pi R_L'}}$$

⑤ Max efficiency :-

$$\% \eta_{max} = \frac{P_{acmax}}{P_{dcmax}} \times 100 = \frac{V_{cc}^2}{2R_L'} \times \frac{R_L' \cdot \pi}{2V_{cc}^2} \times 100 = \frac{\pi}{4} = 78.5\%$$

ⓒ Power dissipation in transistor :-

P_{dc} ⇒ was for both transistors (∵ At a time only one transistor conducts).
P_{ac} ⇒ —"— —"—

$$2P_D = P_{dc} - P_{ac}$$

$$2P_D = \frac{2V_{cc} \cdot V_m}{\pi R_L'} - \frac{V_m^2}{2R_L'} \quad \therefore \boxed{P_D = \frac{V_{cc} \cdot V_m}{\pi R_L'} - \frac{V_m^2}{4R_L'}} \text{ — (A)}$$

To find P_{Dmax} differentiate P_D w.r.t V_m & equat to zero

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

$$\therefore \frac{V_{cc}}{\pi \cancel{R_L'}} = \frac{2V_m}{4\cancel{R_L'}} \quad \therefore \boxed{V_m = \frac{2V_{cc}}{\pi}} \text{ put in (A)}$$

$$P_{Dmax} = \frac{V_{cc}}{\pi R_L'} \cdot \frac{2V_{cc}}{\pi} - \frac{4V_{cc}^2}{\pi^2} \cdot \frac{1}{4R_L'} = \frac{2V_{cc}^2}{\pi^2 R_L'} - \frac{V_{cc}^2}{\pi^2 R_L'}$$

$$\boxed{P_{Dmax} = \frac{V_{cc}^2}{\pi^2 R_L'}}$$

⑦ Figure of Merit (FM)

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

$\boxed{FM = 0.2}$ ∴ $P_{Dmax} = 0.2\, P_{acmax}$

Points :-

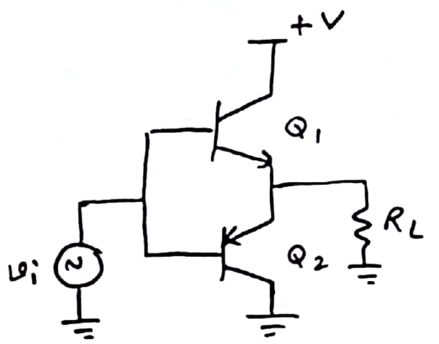
Biasing	→ in cutoff region
No of Transistors	→ 2 one for each half cycle
η_{max}	→ 78.5% better than class A
FM	→ 0.2

Disadvantage :-

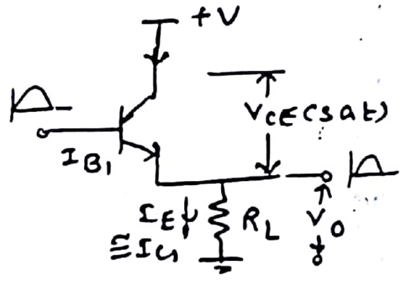
- High non linear distortion
- cross over distortion
- 2 transistors & 2 transformers are required hence size increases.

* Class B complementary symmetry Power Amplifiers:- Or Transformerless PA :- (18)

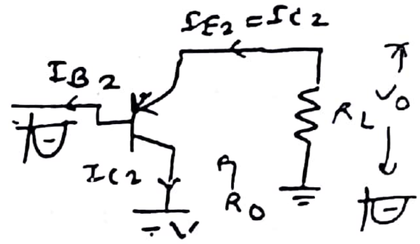
- In single ended or push pull (double ended) ampl^r, phase shifting x'mers, impedance matching x'mers & bypass capacitors are used. These components makes ampl^r bulky, costly & not suitable for IC
To overcome this problems complementary symmetry PA are used. →
- In this we use nearly matched pair of NPN & PNP transistor instead of phase shifting x'mer
- Operation of transistor is in CC configurat^n ∴ its low o/p impedance nearly matches with that of low i/p impedance of load (speakers).



ckt diagram



v_i = +ve Halfcycle
Q_1 ON, Q_2 OFF



v_i = -ve half
Q_1 OFF Q_2 ON

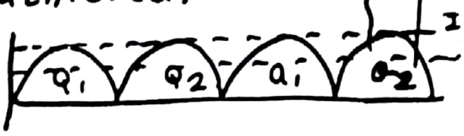
For +ve Halfcycle :-

- Q_1 is ON, Q_2 OFF
- ckt works as CC ampl^r with v_o inphase with v_i with high current gain (No vtg gain)
- gives Higher Power η
∵ R_o is small $\cong R_L$ (coil resist of speaker) so Max Power transfered
- Higher η is achieved.

For -ve Half cycle :-

- Q_1 is OFF, Q_2 ON
- works as CC ampl^r
- o/p is -ve halfcycle with high current gain & impedance matching is obtained for max power transfer.

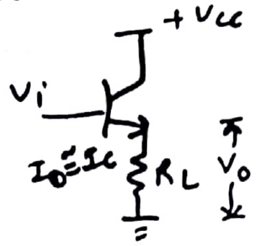
current drawn :-

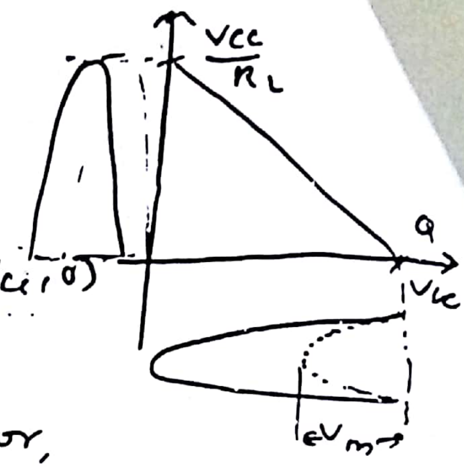


$$I_{DC} = I_{av} = \frac{2 I_m}{\pi} = \frac{2}{\pi} \cdot \frac{V_m}{R_L}$$

DC load line :-

$\because$ DC & AC load lines are same with slope $(-1/R_L)$





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

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

$$Y = mx + c$$

$\therefore$ Points for load line will be $\left(0, \frac{V_{CC}}{R_L}\right)$ & $(V_{CC}, 0)$

Power calculations :-

- Assuming operation of only one transistor,

$V_{CE(sat)} = 0 \quad I_{Cmin} = 0$

a) $P_{dc} = V_{CC} \cdot I_{DC} = \dfrac{V_{CC} \cdot 2 I_m}{\pi R_L}$ $\quad \boxed{P_{DCmax} = \dfrac{2 V_{CC}^2}{\pi R_L}}$

b) $P_{ac} = \dfrac{(V_m/\sqrt{2})^2}{R_L} = \dfrac{V_m^2}{2R_L}$ $\quad \boxed{P_{acmax} = \dfrac{V_{CC}^2}{2R_L}}$

c) $\% \eta_{max} = \dfrac{P_{acmax}}{P_{dcmax}} \times 100 = \dfrac{V_{CC}^2}{2R_L} \times \dfrac{\pi R_L}{V_{CC}^2} \times 100 = 78.5\%$

d) Power dissipated by both transistors $= P_{DC} - P_{ac}$

$$= \frac{2 V_m V_{CC}}{\pi R_L} - \frac{V_m^2}{2R_L} = P_D'$$

$\therefore$ P_D / transistor $= \dfrac{P_D'}{2} = \dfrac{V_m V_{CC}}{\pi R_L} - \dfrac{V_m^2}{4R_L}$

To find P_{Dmax} differentiating P_D w.r.t. V_m & $= 0$

$\therefore \quad V_m = \dfrac{2 V_{CC}}{\pi}$ $\quad \therefore P_{Dmax} = \dfrac{V_{CC}}{\pi R_L} \times \dfrac{2 V_{CC}}{\pi} - \dfrac{1}{4R_L} \times \dfrac{4 V_{CC}^2}{\pi^2}$

$$\boxed{P_{Dmax} = \frac{V_{CC}^2}{\pi^2 R_L}}$$

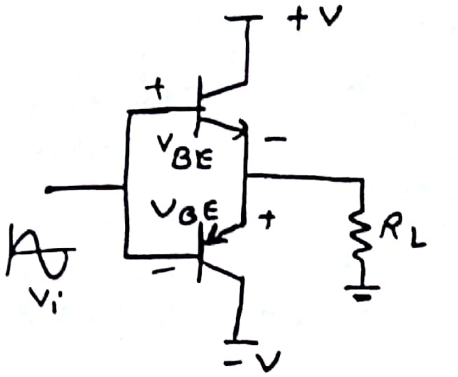
e) Figure of Merit :-

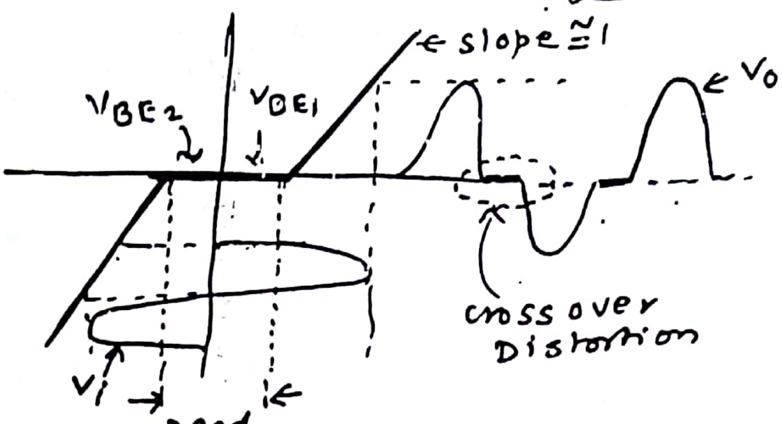
$$FM = \frac{P_{Dmax}}{P_{acmax}} = \frac{V_{CC}^2}{\pi^2 R_L} \times \frac{2R_L}{V_{CC}^2} = 0.2$$

$$\therefore \boxed{P_{Dmax} = 0.2\, P_{acmax}}$$

* Cross over Distortion in complementary Symmetry PA :-

(2.0)





- Assuming $V_{BE_1} = V_{BE_2} = V_{BE}$,
- $V_0 = V_i - V_{BE}$ for $-0.7V \geq V_i \geq 0.7V$
- But for interval $-0.7V \geq V_i \geq 0.7V$, both Q_1 & Q_2 are in cutoff & $V_0 = 0$

  This causes Deadzone & cross over Distortion.

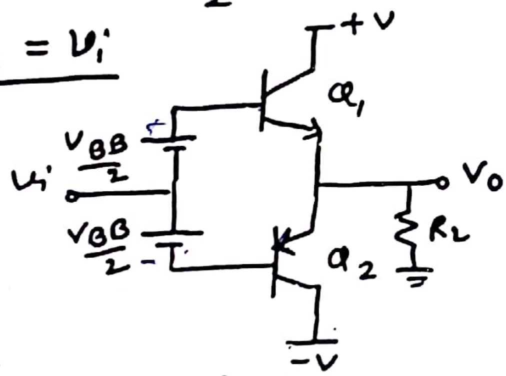
Methods to overcome :-

① Make $V_{BE} = \frac{V_{BB}}{2}$

- when Q_1 is conducting

$V_0 = V_i + \frac{V_{BB}}{2} - V_{BE}$

$V_0 = V_i$

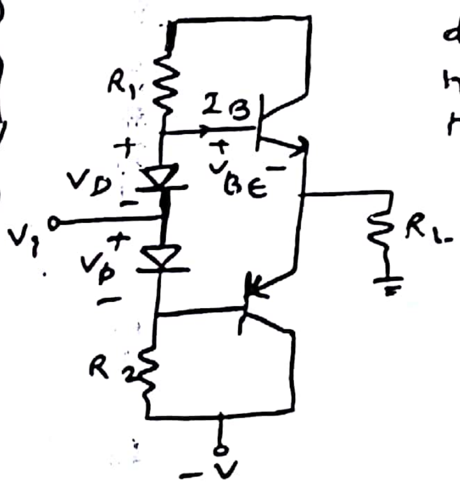


But as temp ↑, V_{BE} ↓, I_B ↑, I_C ↑, P_D (heat) ↑↑

I_C ↑, → device may get damaged.

(Becoze of thermal runaway)

② Dioade Biasing

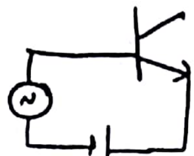


diodes are having same temp coeff for V_D as that of V_{BE}

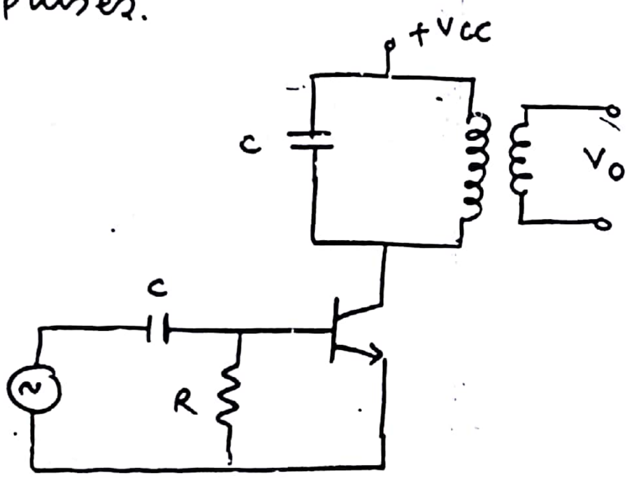
as temp ↑, V_{BE} ↓ I_B tries to increase but sametime V_D also ↓ by same amount ∴ I_D ↑ keeping I_B constant & avoids thermal runaway.

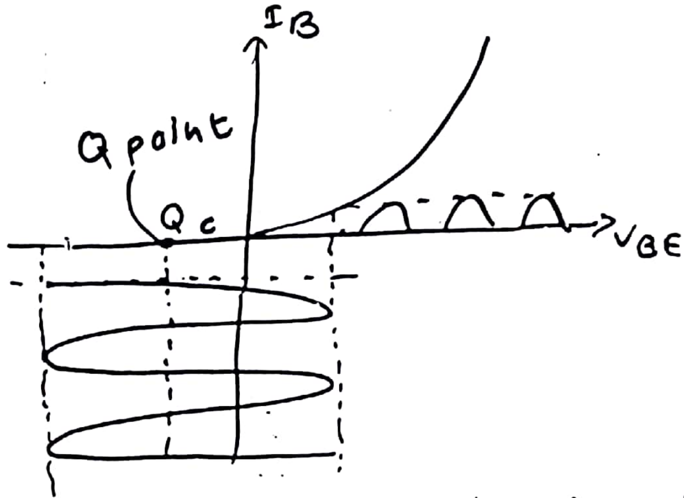
* Class C Amplifier :—

- Q pt is located below cutoff & o/p current flows for less than half of the i/p cycle.
- current flow in the form of pulses.
- Efficiency is very high
- Angle of conduction of transistor < 180°

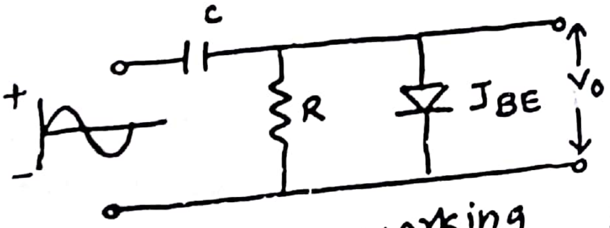


- ∵ o/p is in the form of pulses it will contain lot of harmonics if resistive load is used. Hence tuned Resonant ckt (Tank) is used as load.
- Tank ckt is tuned to fundamental freq of o/p current pulses.

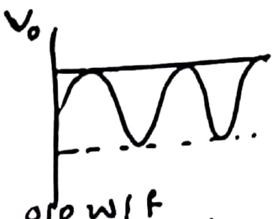




- A tuned class C amplifier works as narrow band ampr & can amplify only a small band of freq around resonant freq of tuned ckt.
- It can be used only at RF. Because at AF, size of L & C (used in tank) becomes very large.



RC & JBE working as clamper



o/p w/f sinewave clamped to -vely to zero.

- Here RC & JBE works as clamper & clamps i/p w/f -vely w.r.t 0V.

- During each cycle VBE increases beyond zero to make JBE FB during each +ve peak of i/p signal.
- whenever JBE becomes FB, the operating pt moves from cutoff towards sat ∴ we get narrow collector current pulses.

- The amplitude of these pulses depends upon amplitude of i/p signal.
- The smaller angle of conductⁿ, the less will be average power dissipatⁿ in transistor.

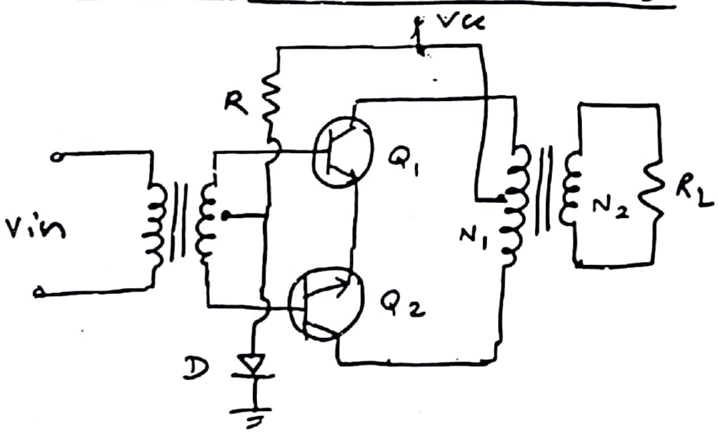
- These pulses when given to tank ckt, we get sine wave across than the freq of which is same as that of i/p signal & amplitude of which depend upon amplitude of pulses.

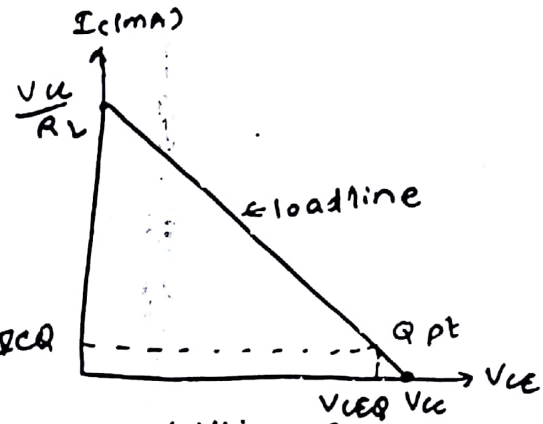
Applications:-

1. used in frequency multiplier
- In this application tank ckt is tuned to 2^{nd} & 3^{rd} harmonic of o/p current pulses.

2. If f/b is used to strengthend the i/p signal (+ve f/b) then we can get class C oscillator.

* Class AB Pushpull Amplifier:-

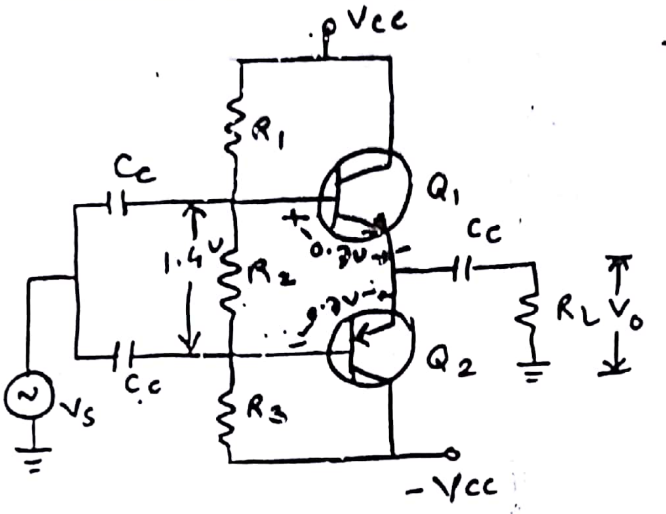




shifting of Q pt

- class B pushpull amplʳ is converted into class AB push pull amplʳ by connecting Resistor R & diode D in the ckt.
- dc vtg across diode is connected to base of both transistors through secondary winding of i/p x'mer.
- This vtg acts as dc bias for transistors because it is equal to cut in vtg & they will conduct for complete half cycle of i/p to eliminate cross over distortion.
- Due to this kind of biasing, Q pt is shifted slightly above x-axis. operation same as class B.

* complementary symmetry class AB ampl^r :-



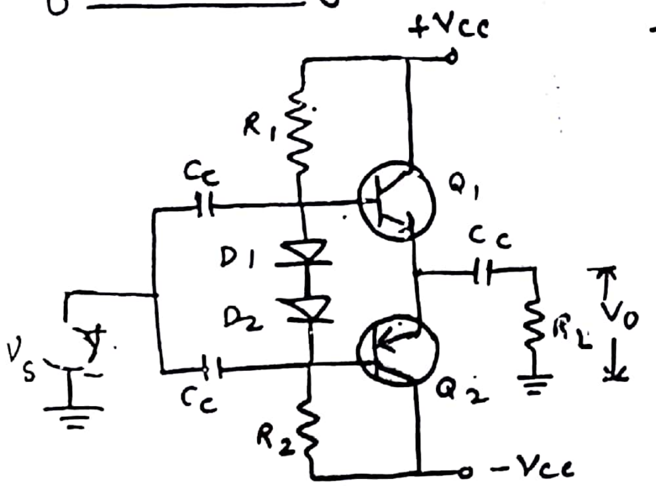
→ Here vtg drop across one diode (like push pull) is not sufficient to F.B. the BE juncⁿ of both the transistors.

→ 1.4V must appear betⁿ their bases to ensure both BE juncⁿ are FBed.

- R1, R2 & R3 are adjusted to give 1.4V const vtg across R2.

Drawback:- A fixed bias of 1.4V is applied betⁿ bases of two transistors. But the juncⁿ cut in vtg of transistors will change with temp. Thus there is a still possibility of cross over distortion, taking place.

* Complementary symmetry class AB Ampl^r using Diodes for Biasing:-



- replace R2 by two series connected diodes to overcome drawback of complementary symmetry class AB

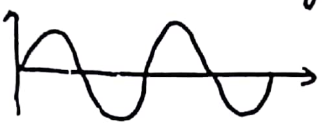
- vtg drop across these diodes will forward bias the BE junction of two transistors.

Advantage:-

diode characteristics are closely matched with char. of BE junction. ∴ changes in temp causes change in vtg drop across diode in same way change in vtg across BE juncⁿ. This will eliminate possibility of cross over distortion.

class A

- Q point is selected at the center of active region
- o/p current flows for full cycle of i/p signal
  conduction angle = 360°



- Maximum efficiency
  $\% \eta_{max} = \frac{P_{acmax}}{P_{dc}} \times 100 = 50\%$
- Power dissipat^n under no signal cond^n is max. (disadv)
- Min. one transistor is required
- No crossover distortion
- $P_{Dmax} = 2 P_{acmax}$

class B

Q pt is set at cutoff region

o/p current flows for half cycle of i/p signal

conduction angle = 180°

Maximum efficiency

$\% \eta_{max} = 78.54\%$

Power dissipat^n under no load cond^n is zero. Hence it is used as o/p stage of Radio and TV receivers

Two transistors are required

cross over distortion

$P_{Dmax} = 0.2\ P_{acmax}$

class B

- Q pt at cutoff
  o/p current only for half cycle
- one transistor conducts for half cycle so 2 transistors are required to obtain class B operation
- $\% \eta_{max} = 78.54\%$
- Distortion is less, used as linear ampl^r.
- problem of crossover distortion

class C

Q pt below cut off

o/p current for slightly less than half cycle.

one transistor is required.

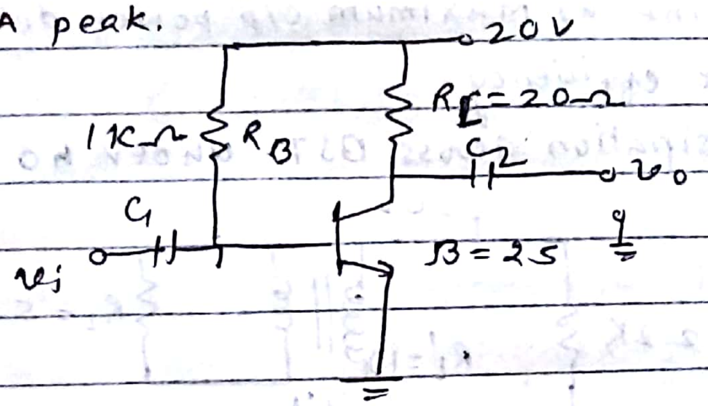
$\% \eta_{max} = 85 \text{ to } 90\%$

Distortion is more, used as Nonlinear ampl^r, oscillat^r

No cross over distortion only nonlinear distort^n.

Ex 1) Calculate the i/p power, o/p power & efficiency of the amplifier ckt for an i/p vtg that results in a base current of 10mA peak.

Sol^n :-



① DC Analysis :-

$$I_B = \frac{V_{cc} - V_{BE}}{R_B} = \frac{20 - 0.7}{1k\Omega} = 19.3mA$$

$$I_{CQ} = \beta I_B = 25 \times 19.3mA = 482.5mA$$

$$V_{CEQ} = V_{cc} - I_C R_C = 10.4V$$

$$P_i(dc) = V_{cc} \times I_{CQ}$$
$$= 20 \times 482.5mA$$

$$\boxed{P_i(dc) = 9.65W}$$

② o/p ac Power $P_o(ac)$

$I_b = 10mA$ (peak) — given

$$I_c = \beta I_b = 25 \times 10mA = 250mA$$

$$P_o(ac) = \frac{I_o^2(p)}{2} \times R_L \quad \text{as } I_o = I_c$$

$$= \frac{(250)^2 mA}{2} \times 20 \quad \text{or} \quad \frac{I_c^2(p)}{2} \times R_C$$

$$\boxed{P_o(ac) = 0.625W}$$

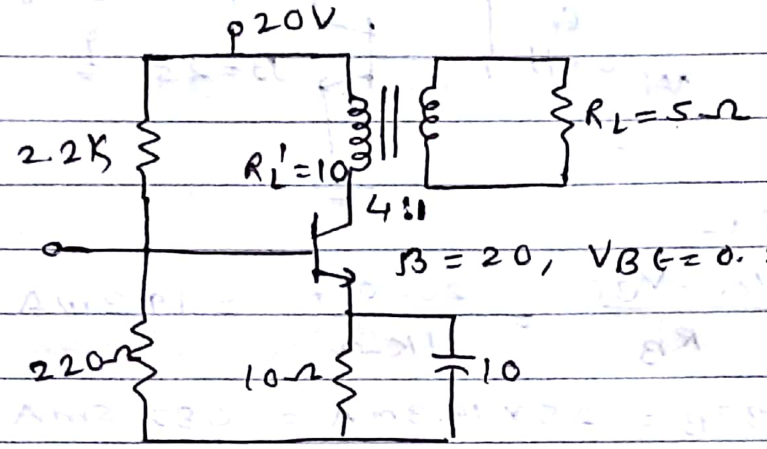
③ $$\%\eta = \frac{P_o(ac)}{P_i(dc)} \times 100$$

$$= \frac{0.625}{9.65} \times 100$$

$$\boxed{\%\eta = 6.48\%} \simeq \boxed{6.5\%}$$

Ex 2) For class A transformer coupled PA, transformer efficiency is 90% primary winding dc resistance is 10Ω.
Determine a) Maximum o/p power delivered to load
b) ckt efficiency
c) Dissipation across BJT under no i/p signal condn.

(University Quest)



soln:- ① DC Analysis

$$I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta)R_E} \quad \text{—①}$$

$$V_B = \frac{R_2}{R_1+R_2} \times V_{cc} = \frac{220}{(2.2K + 220)} \times 20 =$$

$$\underline{V_B = 1.82\ V}$$

$$R_B = R_1 \parallel R_2$$
$$= 2.2K \parallel 220\Omega$$

$$\underline{R_B = 0.182K\ \Omega} \quad \text{put in ①}$$

$$I_B = \frac{1.82 - 0.5}{0.182 + [(1+20)10]} = 3.367\text{mA}$$

$$I_{CQ} = \beta I_B = 20 \times 3.367 = \underline{\underline{67.35\text{mA}}}$$

$$P_{i(dc)} = V_{cc} \times I_{CQ}$$
$$= 20V \times$$

$$\boxed{P_{i(dc)} = 1.28\ W}$$

Scanned by CamScanner

primary side.

$R_L' = n^2 R_L$
$= \left(\frac{4}{1}\right)^2 \times 5$
$\underline{\underline{R_L' = 80\,\Omega}}$

$P_o(\text{primary}) = \frac{I_o^2(p)}{2} \times R_L'$
$= \frac{I_{CQ}^2}{2} \times R_L'$
$= \frac{(67.35 \times 10^{-3})^2}{2} \times 80$
$\underline{\underline{= 0.1814\,W}}$

$P_o'(ac) = \frac{(V_{CEQ})^2}{2R_L'} = \frac{(18.72)^2}{2 \times 80\,\Omega} =$

$\boxed{P_o'(ac) = }$

$\eta\,(\text{xmer}) = \frac{P_o(\text{sec})}{P_o(\text{prim})} = \cancel{\frac{P_o'(ac)}{P_o(ac)} \times 100} =$
$\Downarrow$
90

$\underline{\underline{P_o(ac) =}}$

$90 = \frac{P_o(\text{sec})}{0.1814\,W} \times 100 \therefore P_o(\text{sec}) = 0.9 \times 0.1814$
$\underline{P_o(\text{sec}) = 0.163\,W}$

② ckt efficiency $\%\eta = \frac{P_o(ac)}{P_i(dc)} \times 100$

$= 0.163/1.28 \times 100$

$\boxed{\%\eta = 12.73\%}$

③ Dissipation across BJT under no i/p signal condn

$P_d = P_i(dc) - P_o(ac)$

$\boxed{P_d = 1.28\,W - 0.163\,W} =$