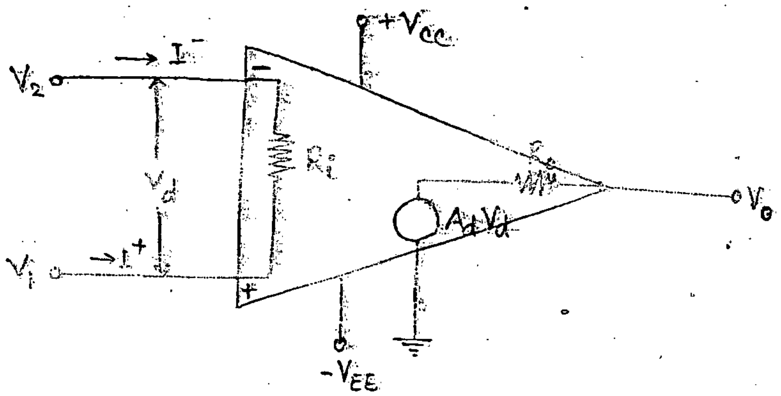
OP AMP



$V_d = V_1 - V_2$

$R_i = \infty$ but $(1 M\Omega)$

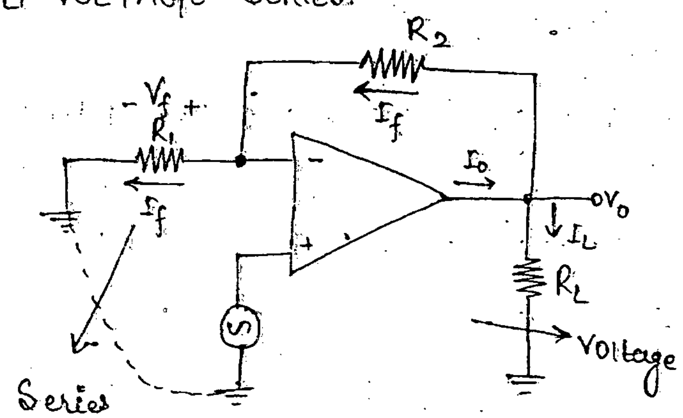
$R_o = 0$ but (25Ω)

$A_d = \text{gain} = \infty$ but (10^6)

Ideal Theory :- conditions.

1) $R_i = \infty$ 2) $R_o = 0$ 3) $I^+ = 0$; $I^- = 0$ 4) $I_o \neq 0$ 5) $A_d = \infty$

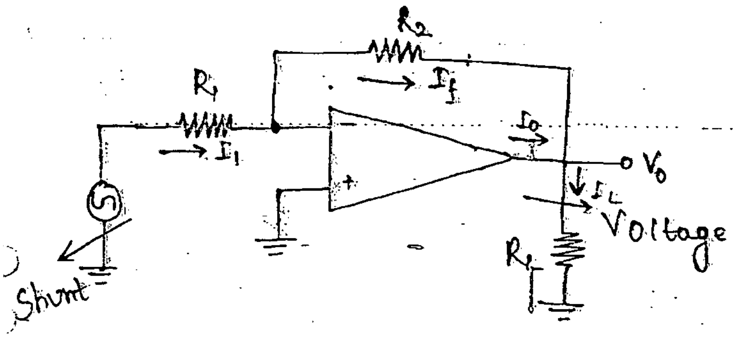
VOLTAGE SERIES.



(+)ve is always connected to voltage source.

Non-inverting.

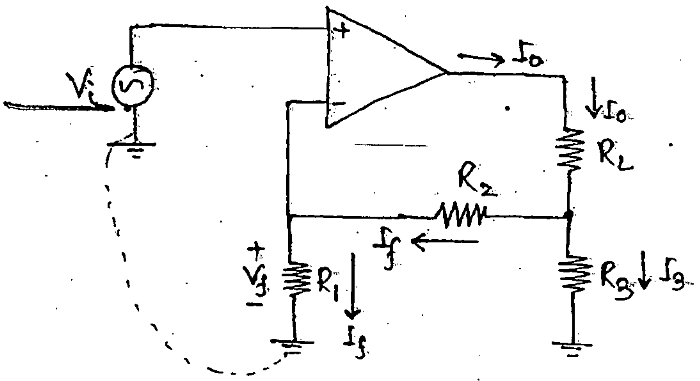
VOLTAGE SHUNT



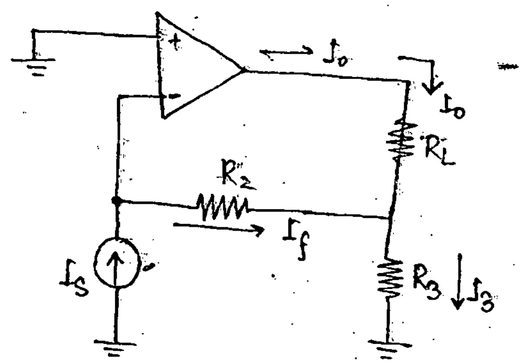
(-)ve is always connected to voltage source

inverting.

☐ CURRENT SERIES.



☐ CURRENT SHUNT.



☐ PROCEDURE FOR THE ANALYSIS OF NEGATIVE FEEDBACK AMPL^R

Case I :- To get the i/p ckt, modify the o/p.

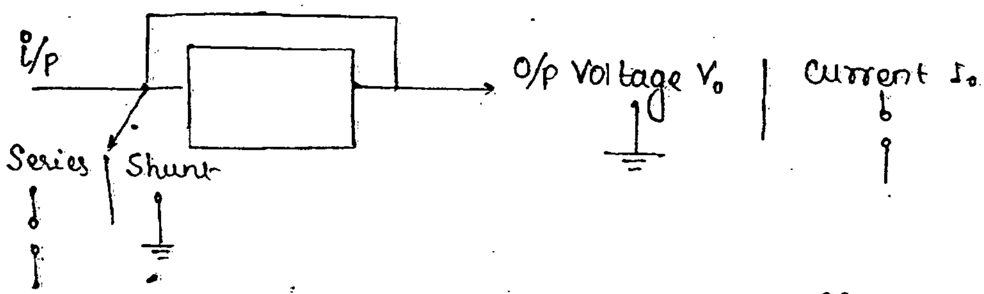
1. For Voltage Series (or) voltage Shunt make the o/p node ground.

2. For current Series (or) Voltage Series current Shunt make the o/p loop open.

Case II :- To get the o/p ckt ~~, modify~~ the i/p.

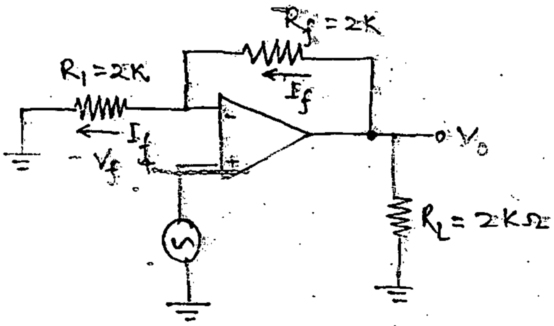
1. For Voltage Series (or) current Series make the i/p Loop open.

2. For Voltage Shunt (or) Current Shunt make the i/p node ground.



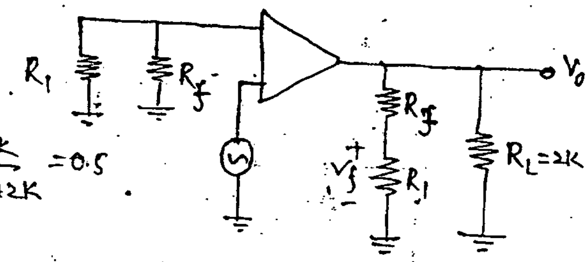
PROBLEM IN FEEDBACK AMPLIFIER.

Q1:-



Sol^n:- ∵ It is Voltage (S.C) Series (O.C)

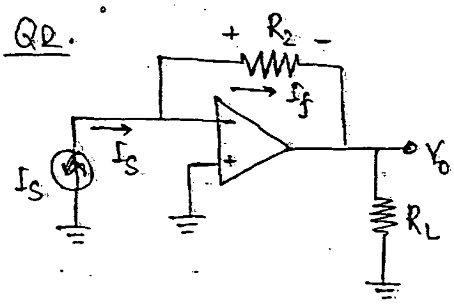
Final diagram



$$\therefore \beta = \frac{V_f}{V_o} = \frac{2k}{2k+2k} = 0.5$$

$$\Rightarrow A_f = 2.$$

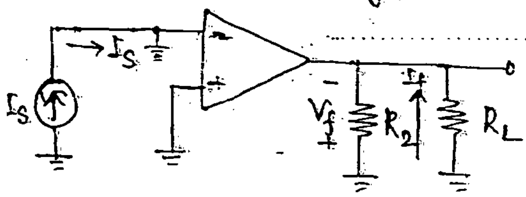
Q2.



Calculate $\beta = \dfrac{V_f}{V_o}$ $\Rightarrow \beta = \dfrac{I_f}{V_o}$

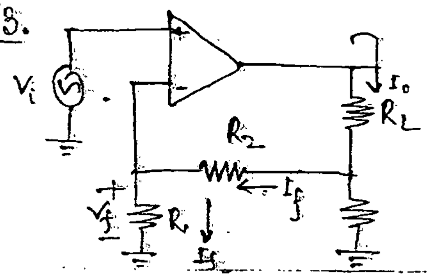
Sol^n:- To get o/p effect i/p is ~~shorted~~ grounded.

– It is a voltage shunt.

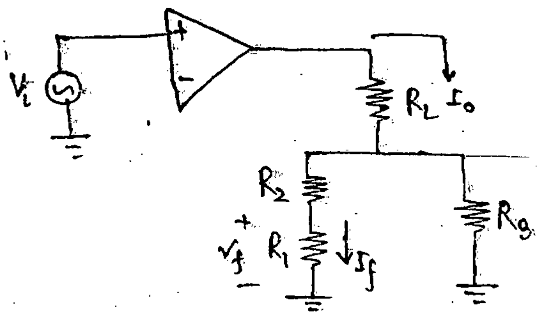


$$\beta = \frac{V_f}{V_o} = -1 \quad \Bigg| \quad \beta = \frac{I_f}{V_o} = -\frac{1}{R_2}$$

Q3.



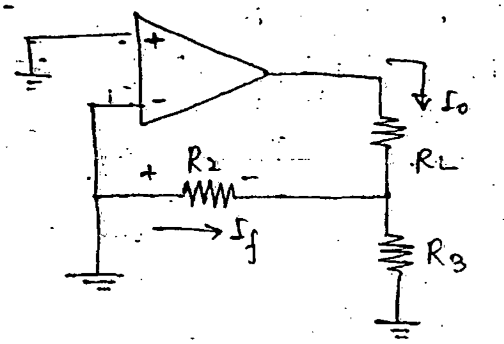
Sol^n:- ∵ It is current Series.



$$\beta = \frac{I_f}{I_o} = \frac{R_3}{R_1+R_2+R_3}$$

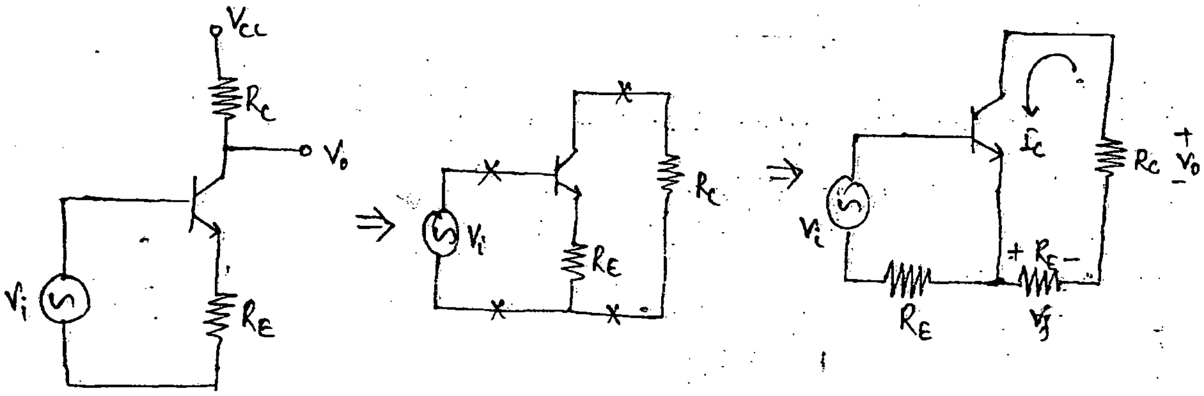
$$\beta' = \frac{V_f}{I_o} = \frac{R_1 \cdot R_3}{R_1+R_2+R_3}$$

Que:-



∵ It is current shunt.

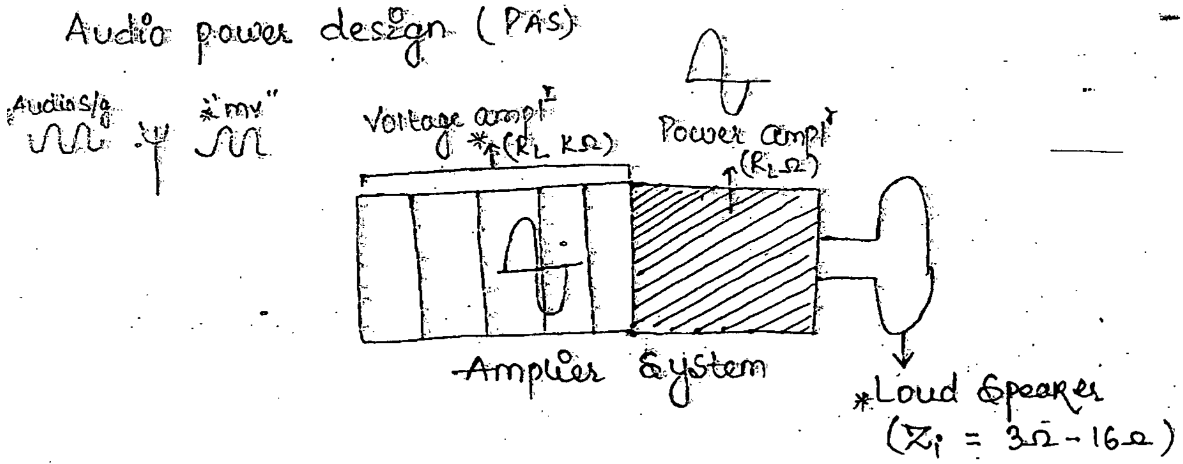
Que:- CE Unbypass Amplifier.



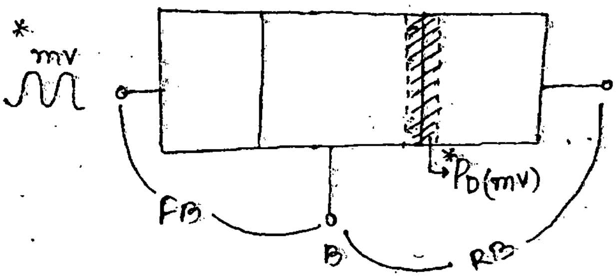
$$\beta = \frac{V_f}{V_o} = \frac{I_c R_E}{-I_c R_c} = -\frac{R_E}{R_c} \qquad A_f = \frac{1}{\beta} = -\frac{R_c}{R_E}$$

☐ POWER AMPLIFIERS

Audio power design (PAS)

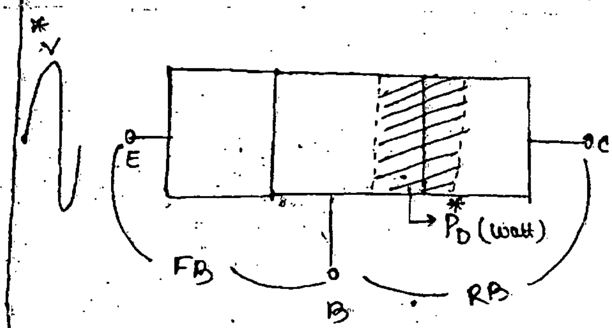


Voltage transistor | Power Transistor



*Base width is narrower

$*\beta\uparrow = \frac{I_C}{I_B\downarrow}$ (50 to 150)



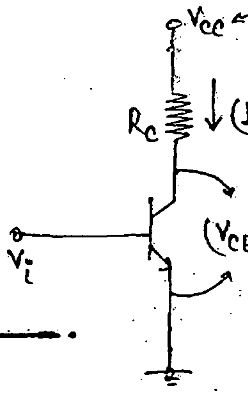
*Base width is wider

$*\beta\downarrow = \frac{I_C}{I_B\uparrow}$ (20 to 50)

Parameter	Vol. Ampl^r	Power Ampl^r
1. β	More	Less
2. R_C	KΩ	Ω
3. V_{in}	mV	V
4. P_0	mW	W
5. I_C	Less	More

Question: Why Voltage ampl^r design can't be used as power amplifier.

Voltage Amplifier



P_D external $= (I_c)_Q^2 R_c$ → heat

$(V_{CE})_Q = \frac{V_{cc}}{2}$

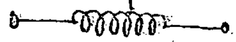
$P = \frac{V_{cc}}{2} \times (I_c)_Q$

$= P_{tr}$

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

Load

R_f

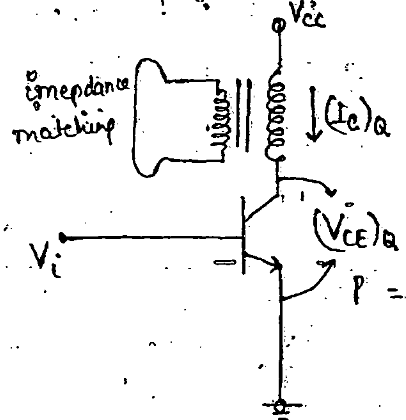


$R_f \propto f$

$f = 0$ (dc) $R_f = 0$ (S.C)

$f = \infty$ (ac) $R_f = \infty$ (O.C)

Power Amplifier



P_D external $= (I_c)_Q^2 R_f$

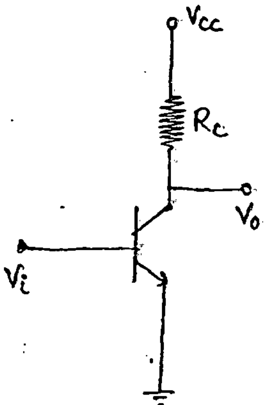
$= 0$

$(V_{CE})_Q = V_{cc}$

$P = V_{cc} \times (I_c)_Q$

$= P_{tr} = P_{DC}$

☐ POWER AMPLIFIER DESIGN



Power diagram

P_{dc}

- P_D External: $(I_c)_Q^2 \cdot R_c$
- $(P_{tr})_{DC}$
  - P_{ac}
  - $(P_c)_{DC}$ (internal power loss): $(V_{CE})_Q (I_c)_Q$

$$\boxed{P_{DC} = P_{ac} + P_D}$$

$$P_D \text{ internal} + P_D \text{ external}$$
$$\Downarrow \qquad\qquad \Downarrow$$
$$50\% \qquad\qquad 50\%$$

<u>Suppose</u> $P_D = 0$

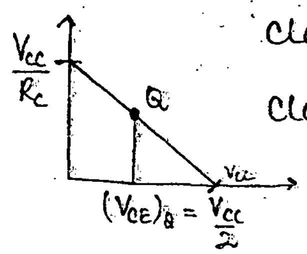
$$\% \eta = \frac{P_{ac}}{P_{dc}} = 100\%$$

<u>DEFINATION OF POWER AMPLIFIER</u> :- It is a device which convert dc power into ac power & whose action is controlled by ac input signal.

☐ POWER AMPLIFIER CLASSES.

→ AUDIO POWER DESIGN.

1. CLASS A

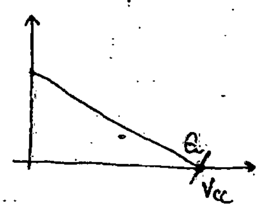


Class A

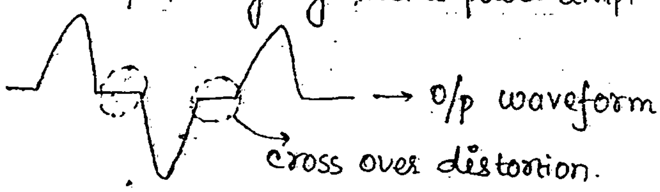
Class A Series fed power amplifier → $\eta = 25\%$

Class A Transformer coupled → $\eta = 50\%$.

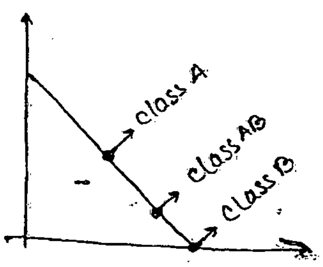
2. CLASS B



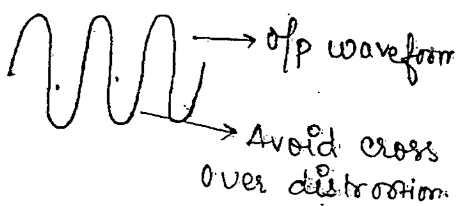
Class B push pull power amplifier
Class B complimentry symmetric power amplr
} $\eta = 78.5\%$



3. CLASS AB.

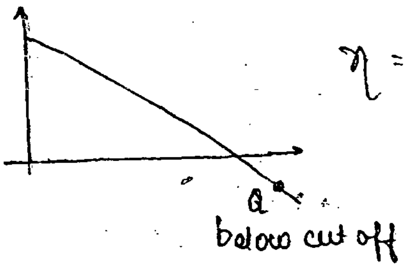


$\eta = 50\%$ to 78.5%



→ RADIO POWER DESIGN.

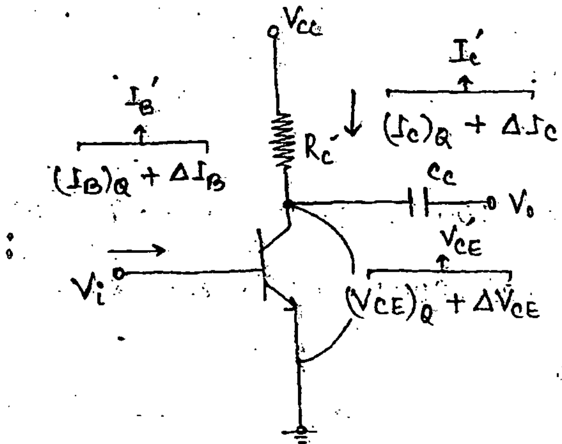
1. CLASS C



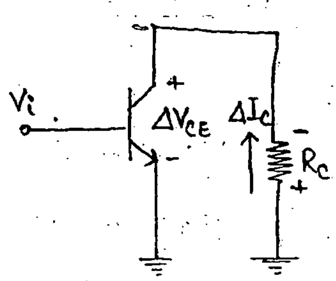
$\eta = 100\%$

~~AC LOADLIN~~

☐ AC LOAD LINE.



ac model



KVL at o/p.

$$\Delta I_c R_c + \Delta V_{CE} = 0$$

$$\Delta I_c = -\frac{\Delta V_{CE}}{R_c} \quad \text{—(1)}$$

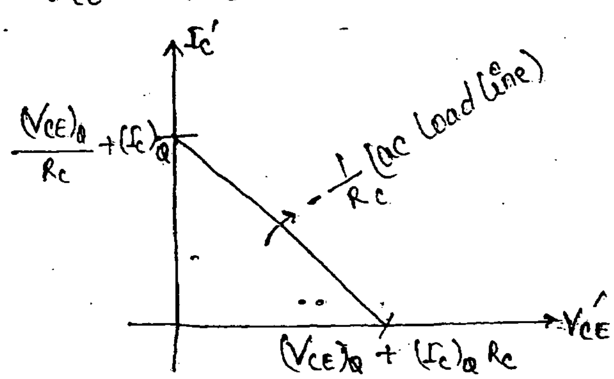
$$\left.\begin{aligned} I_c' &= (I_c)_Q + \Delta I_c \\ V_{CE}' &= (V_{CE})_Q + \Delta V_{CE} \end{aligned}\right\} \text{—(2)}$$

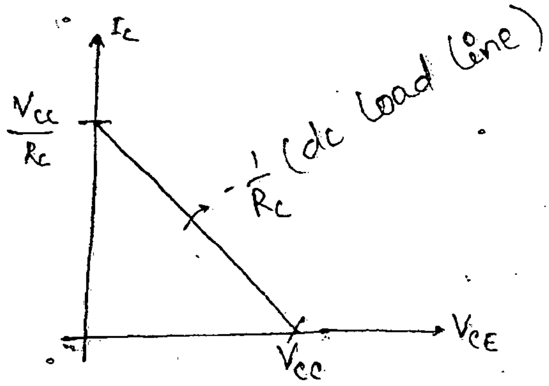
Putting eq^n (2) in (1) we get

$$I_c' - (I_c)_Q = -\frac{V_{CE}'}{R_c} + \frac{(V_{CE})_Q}{R_c}$$

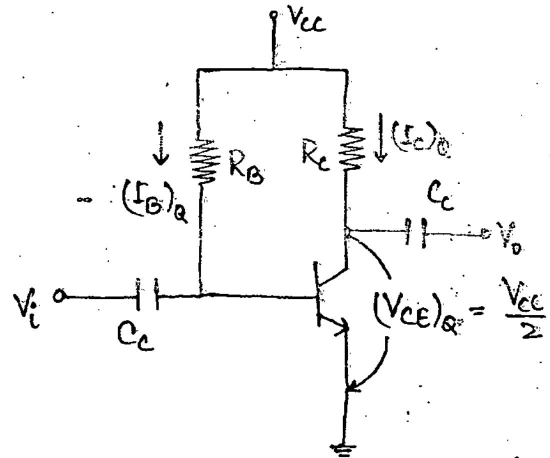
$$I_c' = -\frac{1}{R_c} \cdot V_{CE}' + \left\{ \frac{(V_{CE})_Q}{R_c} + (I_c)_Q \right\}$$

$$Y = m \quad x \quad + \quad C$$





1. CLASS A SERIES FED POWER AMPLIFIER (R_C)



DC power i/p

$$P_{DC} = V_{CC} \cdot (I_C)_Q$$

DC condition

$$(I_B)_Q = \frac{V_{CC} - V_{BE}}{R_B}$$

$$(I_C)_Q = \beta (I_B)_Q$$

$$(V_{CE})_Q = V_{CC} - (I_C)_Q R_C$$

AC power o/p

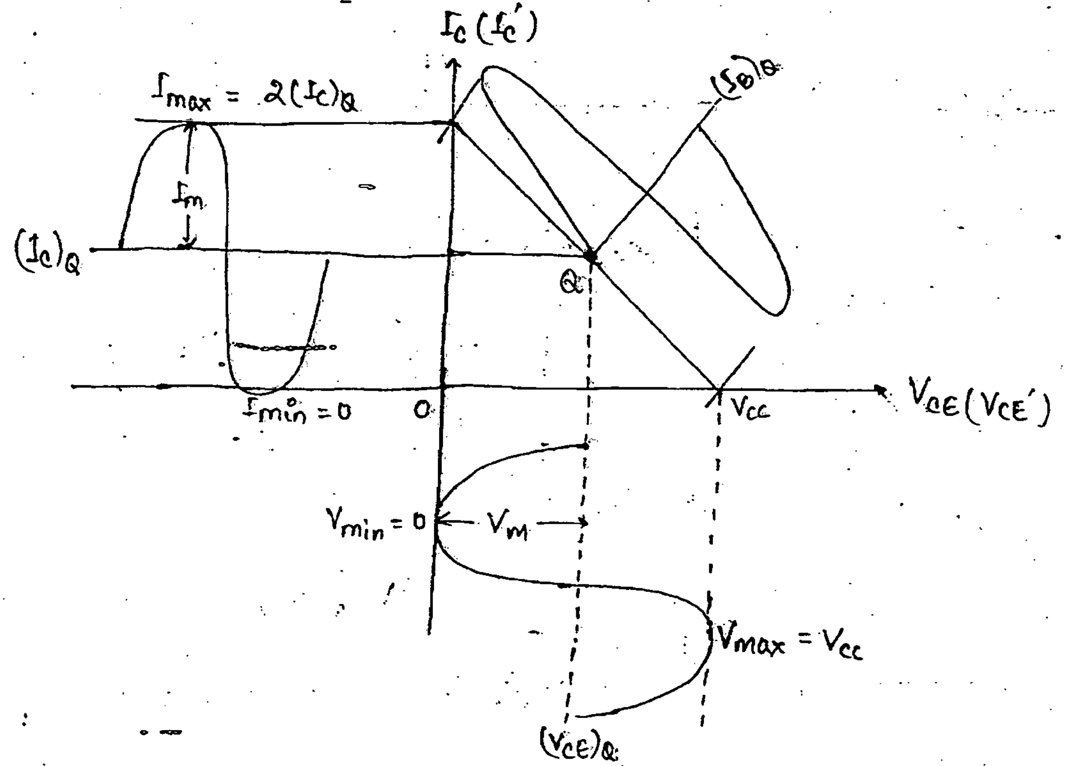
$$P_{ac} = V_{rms} \times I_{rms}$$

$$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$

$$P_{ac} = \frac{V_m \cdot I_m}{2}$$

$$V_m = \frac{V_{max} - V_{min}}{2}$$

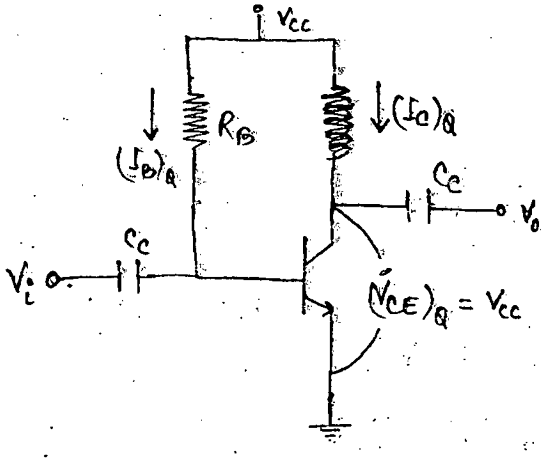
$$I_m = \frac{I_{max} - I_{min}}{2}$$



$$\% \eta = \frac{P_{ac}}{P_{DC}} = \frac{\frac{1}{8}(V_{max} - V_{min})(I_{max} - I_{min})}{V_{CC}\,(I_C)_Q}$$

$$= \frac{1}{8}\,\frac{(V_{CC} - 0)(2(I_C)_Q - 0)}{V_{CC}\,(I_C)_Q} = \frac{1}{4} = 25\%$$

CLASS A TRANSFORMER COUPLED POWER AMPLIFIER



DC power i/p

$$P_{DC} = V_{cc}\,(I_C)_Q$$

DC condition

$$(I_B)_Q = \frac{V_{cc} - V_{BE}}{R_B}$$

$$(I_C)_Q = \beta (I_B)_Q$$

$$\boxed{(V_{CE})_Q = V_{cc}}$$

ac power o/p

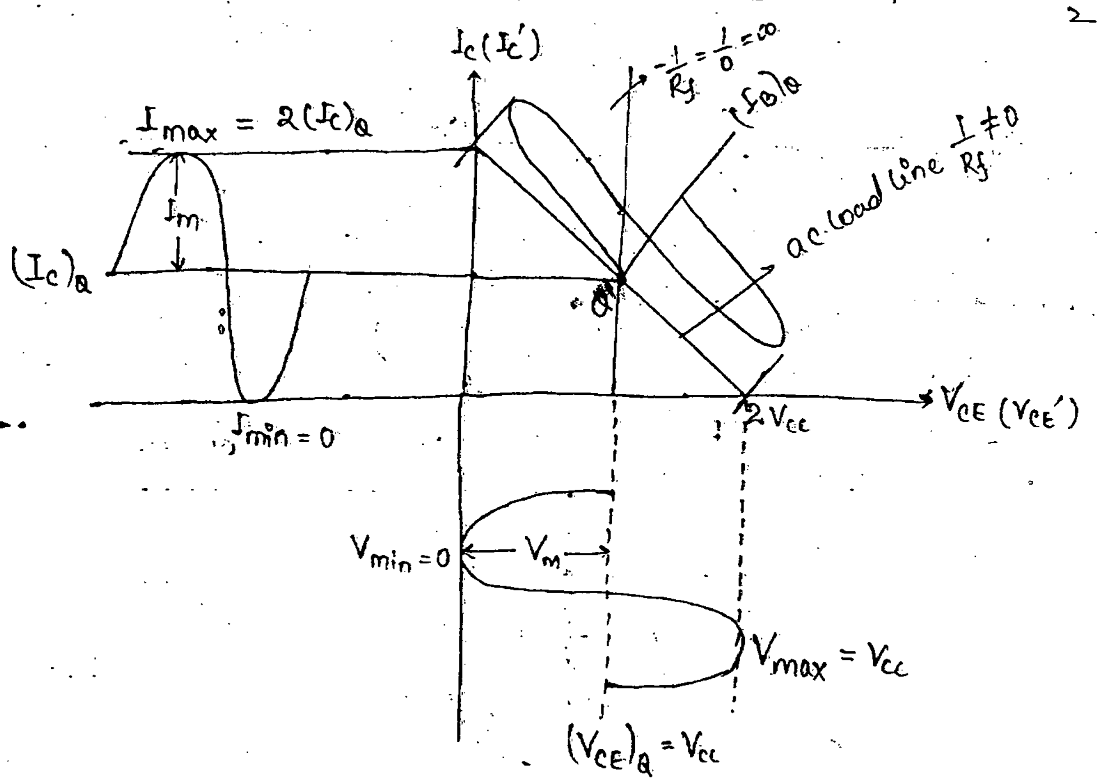
$$P_{ac} = V_{rms} \times I_{rms}$$

$$= \frac{V_m}{\sqrt{2}} \times \frac{V_m}{\sqrt{2}}$$

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

$$V_m = \frac{V_{max} - V_{min}}{2}$$

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



$$\%\eta = \frac{P_{ac}}{P_{dc}} = \frac{\frac{1}{8}(V_{max} - V_{min})(I_{max} - I_{min})}{V_{cc} \cdot (I_c)_Q}$$

$$= \frac{1}{8}\,\frac{(2V_{cc} - 0)\,(2(I_c)_Q - 0)}{V_{CE}\,(I_c)_Q} = \frac{1}{2} = 50\%$$

☐ POWER DISSIPATION IN CLASS A

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

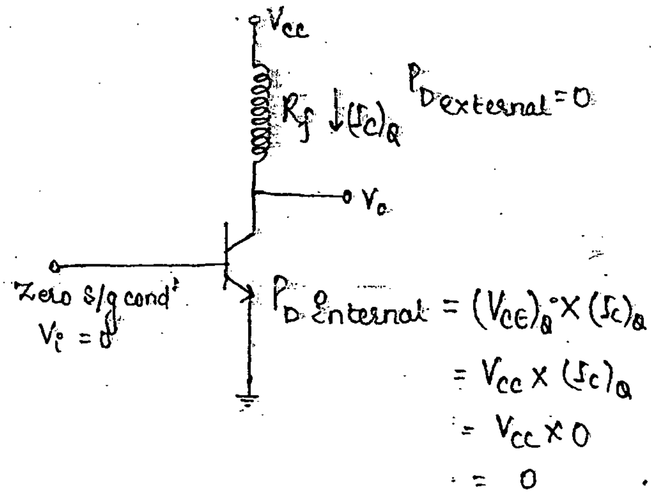
$P_D = V_{cc}(I_c)_Q - \frac{V_m \cdot I_m}{2}$

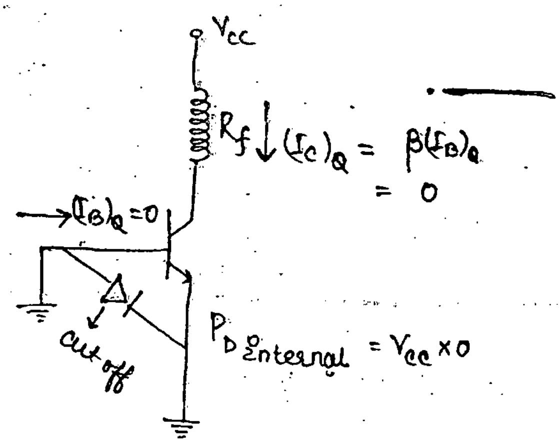
<u>at zero s/g condition</u> (DC)

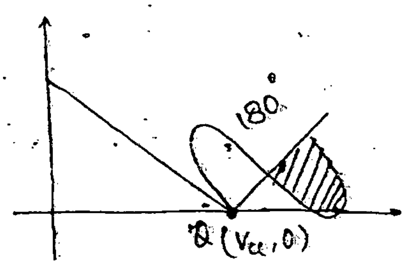
$V_M = 0$; $I_m = 0$

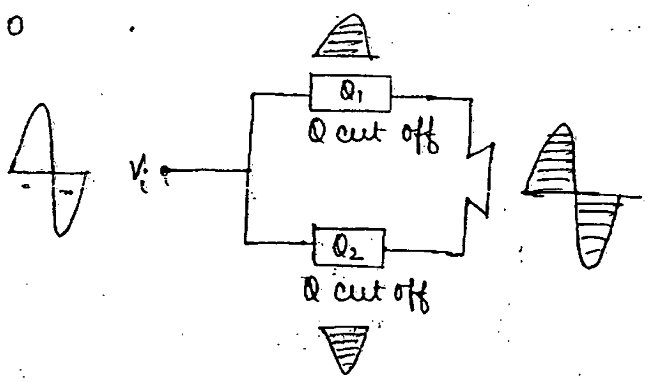
$P_{DC} = V_{cc}(I_c)_Q = P_{DC}$ (max^m power loss)

☐ CLASS B.

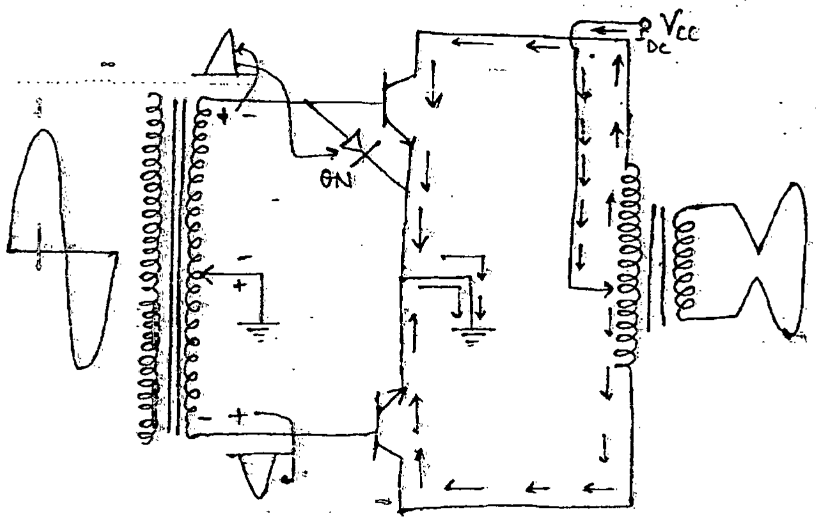




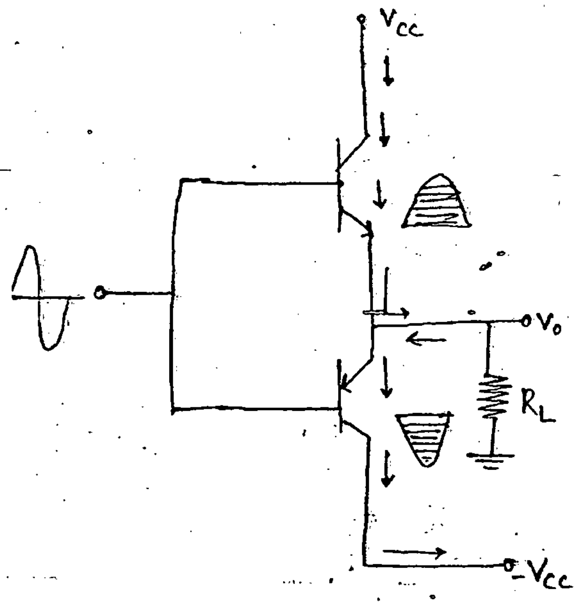




☐ CLASS B PUSH PULL AMPLIFIER



CLASS B COMPLEMENTARY SYMMETRY POWER AMPLIFIER.



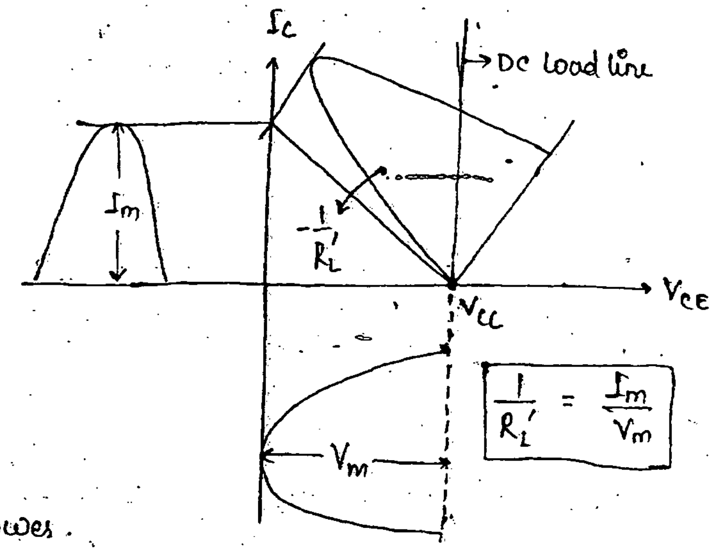
'cc' as impedance matching

POWER DISSIPATION.

$$P_{DC} = V_{cc} \times I_{DC}$$
$$= 2V_{cc} \times \frac{I_m}{\pi}.$$

$$P_{ac} = \frac{V_m I_m}{2}$$

$$\%\eta = \frac{P_{ac}}{P_{dc}} = \frac{\frac{V_m \cdot I_m}{2}}{2V_{cc} \cdot \frac{I_m}{\pi}}$$



$$\boxed{\frac{1}{R_L'} = \frac{I_m}{V_m}}$$

$\boxed{V_m = V_{cc}}$ → max^m ac power.

$$\%\eta = \frac{\frac{V_{cc} \cdot I_m}{\pi}}{2V_{cc} \cdot \frac{I_m}{\pi}} = \frac{\pi}{4} = 0.785 = 78.5\%$$

POWER DISSIPATION IN CLASS B.

$$P_D = P_{DC} - P_{ac}$$
$$= 2V_{cc} \cdot \frac{I_m}{\pi} - \frac{V_m \cdot I_m}{2}$$

At zero signal conditions (DC)

$V_m = 0$; $I_m = 0$

$P_D = 0.$

Max^{m} $\underline{AC}$ power dissipation.

$$P_D = 2V_{cc}\frac{I_m}{\pi} - \frac{V_m I_m}{2} \qquad P_D = 2V_{cc}\cdot\frac{V_M}{\pi R_L'} - \frac{V_M^2}{2R_L'}$$

$$\boxed{\frac{1}{R_L'} = \frac{I_m}{V_M}} \rightarrow \text{ac load line}$$

d. w.r.t V_M.

$$\frac{\partial P_D}{\partial V_M} = \frac{2V_{cc}\cdot 1}{\pi R_L'} - \frac{2V_M}{2R_L'} = 0$$

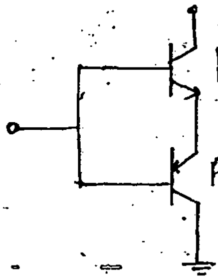
$$\Rightarrow \boxed{V_M = \frac{2V_{cc}}{\pi}} \rightarrow \text{max}^{m} \text{ power dissipation.}$$

$$\boxed{V_M = V_{cc}} \rightarrow \text{Max}^{m} \text{ ac power.}$$

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

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

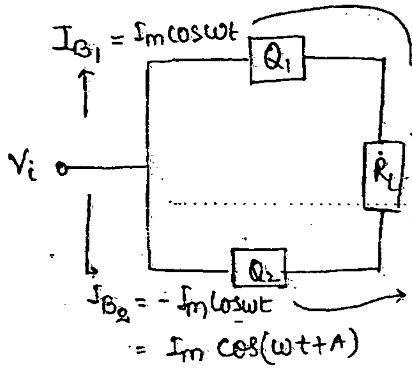
$$\boxed{P_{ac\,max} = \frac{V_{cc}^2}{2R_L'}}, \quad \boxed{P_{Dmax} = \frac{4}{\pi^2}P_{ac\,max}}$$



$$P_{Dmax} = \frac{2}{\pi^2}P_{ac\,max}$$

$$P_{Dmax} = \frac{2}{\pi^2}P_{ac\,max}$$

☐ HARMONICS DISTORTION IN CLASS B.



$$I_{C_1} = (I_C)_Q + K_1\cos\omega t + K_2\cos 2\omega t + K_3\cos 3\omega t + \ldots$$

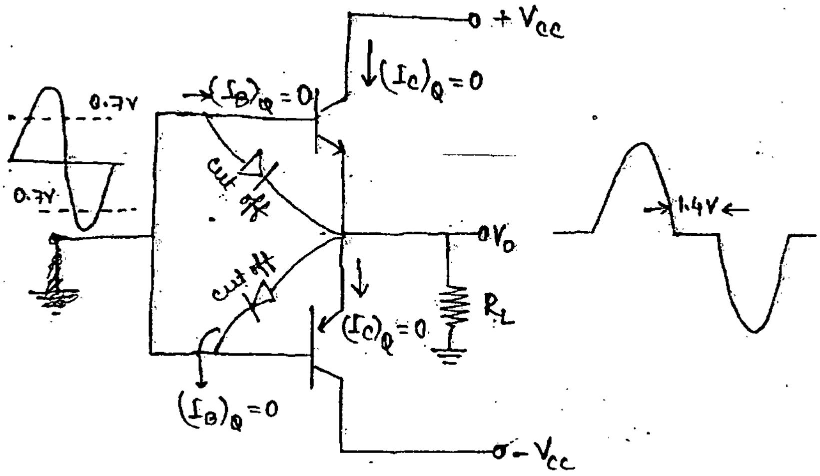
$$I_L = I_{C_1} - I_{C_2} = 2K_1\cos\omega t + \underbrace{2K_3\cos 3\omega t + \ldots}_{\text{Negligible harmonics}}$$

$$I_{C_2} = (I_C)_Q + K_1\cos(\omega t+\pi) + K_2\cos 2(\omega t+\pi) + K_3\cos 3(\omega t+\pi) + \ldots$$

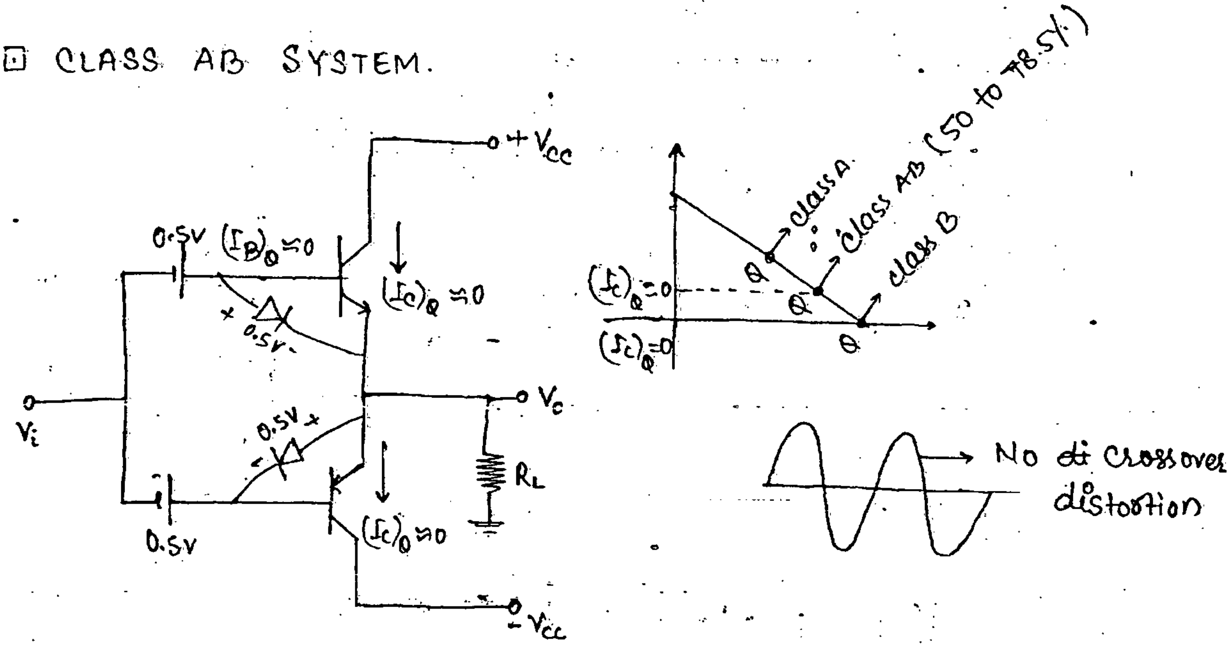
$$= (I_C)_Q - K_1\cos\omega t + K_2\cos 2\omega t - K_3\cos 3\omega t + \ldots$$

Even harmonic and dc are eliminated.

CROSS OVER DISTORTION IN CLASS B.

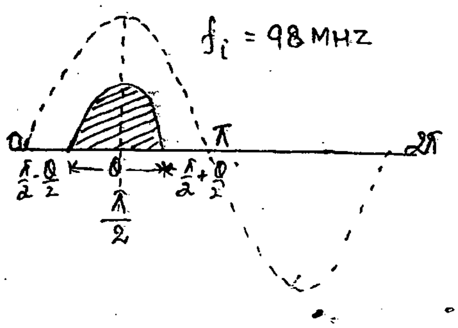


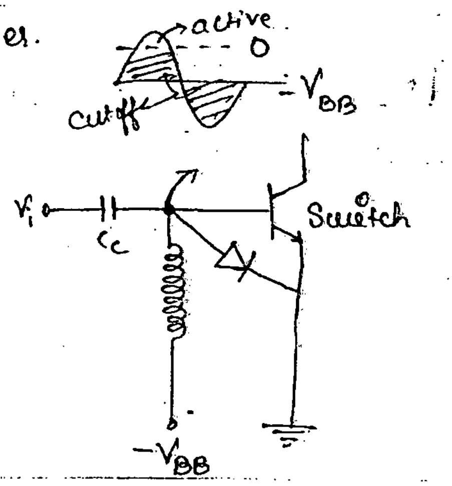
CLASS AB SYSTEM.



CLASS C POWER AMPLIFIER (RADIO)

- Tunned power Amplifier.





— ~~θ~~angle.

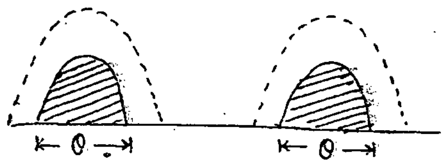
Transistor Q is in Saturation

$$P_D = (V_{CE})_Q \times (I_C)_Q$$
$$= 0 \times (I_C)_Q$$
$$= 0$$

$2\pi - \theta$

Transition Q is cut ~~off~~

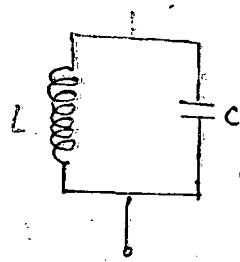
$$P_D = (V_{CE})_Q \times (I_C)_Q$$
$$= V_{CC} \times 0$$
$$= 0$$



Fourier Series expansions

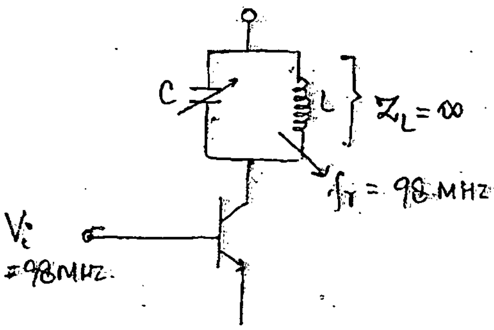
a_0 + $\underbrace{\text{Fundamental}}_{98\text{ MHz}}$ + 2^{nd} harmonic + 3^{rd}

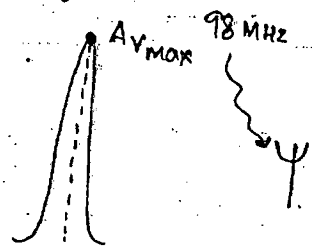
Band Pass



98 MHz

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





Parallel Resonance

$f_r = f_i$

$Z_L = \infty$

$$A_V = A_I \frac{Z_L}{Z_i} = A_I \frac{\infty}{Z_i} = \infty$$

$$A_V = \infty$$

Final circuit.