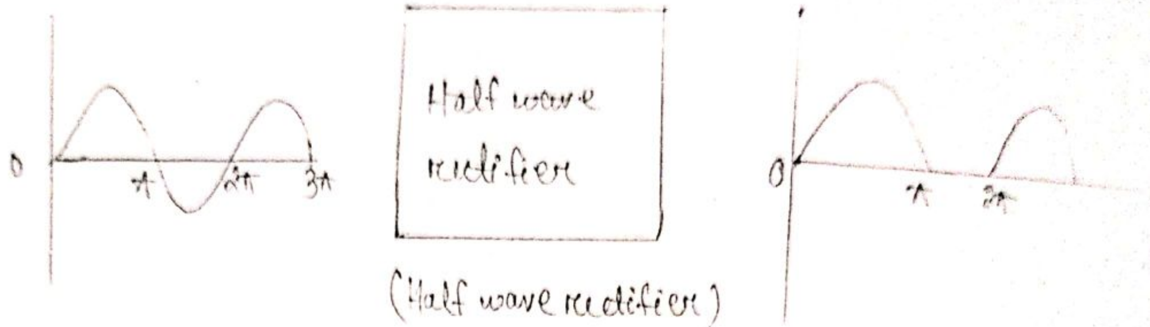
CHAPTER3 RECTIFIER D-13.8.19

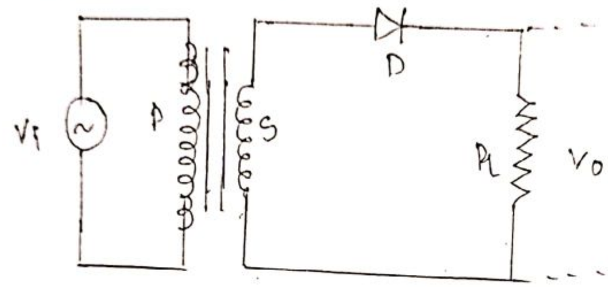
Rectifier:-

A rectifier is defined as an electronic device used in converting A.C voltage or current in unidirectional voltage or current (D.C).



(Half wave rectifier)

Halfwave Rectifier:-



Analysis:-

→ Let a sinusoidal voltage v_i be applied to the input of the rectifier

then $v_i = V_m \sin\omega t$.

→ where, V_m = max^m value of supply voltage

→ Let the diode be the idealized with resistance R_f in forward direction i.e in on-state

$R_r = \infty$ in the reverse direction in the off-state.

→ Now current I in the diode in the load resistor (R_L)

$$I = I_m \sin\omega t$$

where $I_m = \dfrac{V_m}{R_f + R_L}$

18.10

DC output current & voltages.

(i) The average current I_{dc} is given by

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i\, d(\omega t)$$

We know, $i = I_m \sin\omega t$

$$= \frac{1}{2\pi}\int_0^{2\pi} I_m \sin\omega t\, d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{\pi} I_m \sin\omega t + \frac{1}{2\pi}\int_{\pi}^{2\pi} I_m \sin\omega t\, d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{\pi} I_m \sin\omega t + 0 \quad \left(\because I_m \sin\omega t\, d(\omega t) = 0 \text{ when } \pi \text{ to } 2\pi\right)$$

$$= \frac{1}{2\pi}\int_0^{\pi} I_m \sin\omega t\, d(\omega t)$$

$$= \frac{I_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi}$$

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

$$= \frac{I_m}{2\pi}\{-(-1-1)\}$$

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

$$= \frac{I_m}{2\pi}\times 2 = \frac{I_m}{\pi}$$

$$= 0.318\, I_m$$

$$\boxed{I_{dc} = \frac{I_m}{\pi} = 0.318\, I_m} \quad \left(\because \frac{1}{\pi} = 0.318\right)$$

Substituting the value of I_m: $\boxed{I_{dc} = 0.318\,\frac{V_m}{r_f + R}}$

If R

(ii) DC

(iii) Root RMS

Th

$$I_{dc} = \frac{V_m}{\pi(R_f + R_L)}$$

If $R_f << R_L$ then

$$I_{dc} = \frac{V_m}{\pi(0 + R_L)}$$

$$\Rightarrow I_{dc} = \frac{V_m}{0 + \pi R_L}$$

$$\Rightarrow I_{dc} = \frac{V_m}{\pi R_L}$$

(ii) DC output voltage $V_{DC} = I_{DC} \times R_L$

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

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

$$\boxed{V_{DC} = \frac{V_m}{\pi} = 0.318\ V_m}$$

Root mean square

(iii) RMS current & voltage:-

The value of RMS current is given by

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} i^2\, d(\omega t)\right]^{1/2}$$

$$= \left[\frac{1}{2\pi}\int_0^{2\pi} i^2\, d(\omega t)\right]^{1/2}$$

$$= \left[\frac{1}{2\pi}\int_0^{\pi} (I_m \sin(\omega t))^2 d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)\right]^{1/2}$$

$$= \left[\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2(\omega t)\, d(\omega t)\right]^{1/2}$$

$$= \left[\frac{I_m^2}{2\pi} \cdot \left(\frac{1 - \cos 2\omega t}{2}\right) d(\omega t)\right]^{1/2} \quad \left(\because \sin^2\theta = \frac{1 - \cos 2\theta}{2}\right)$$

$$= \left[\frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1}{2} - \frac{\cos 2\omega t}{2}\right) d(\omega t)\right]^{1/2}$$

$$= \left[\frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1}{2}-\frac{\cos 2\omega t}{2}\right)d(\omega t)\right]^{1/2}$$

$$= \left[\frac{I_m^2}{2\pi}\cdot\left[\frac{1}{2}\omega t-\frac{1}{2}\times\frac{\sin 2\omega t}{2}\right]_0^{\pi}\right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi}\left[\omega t-\frac{\sin 2\omega t}{2}\right]_0^{\pi}\right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi}\left(\pi-0-\left(\frac{\sin 2\pi}{2}-\sin 0\right)\right)\right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi}\times\pi\right]^{1/2}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{4}} = \frac{I_m}{2}$$

Substituting the value of I_m

$$I_{rms} = \frac{V_m}{R_f+R_L}$$

$$\Rightarrow I_{RMS} = \frac{V_m}{2(R_f+R_L)}$$

If $R_f <<< R_L$

$$I_{rms} = \frac{V_m}{2(0+R_L)}$$

$$\Rightarrow I_{rm} = \frac{V_m}{2R_L}$$

Rms voltage $V_{rms} = I_{rms}\times R_L$

$$= \frac{V_m}{2(R_f+R_L)}\times R_L$$

$$R_f << R_L = \frac{V_m}{2R_L}\times R_L$$

$$\Rightarrow \boxed{V_{rms} = \frac{V_m}{2}}$$

RECTIFIER EFFICIENCY:- D-16.8.19

The rectifier effeency is defind as ratio of DC out put power to DC input power.

$$\eta = \frac{\text{dc power delivered to load}}{\text{a.c input power}} = \frac{P_{dc}}{P_{ac}}$$

$$P_{dc} = (I_{dc})^2 \cdot R_L$$

$$= \left(\frac{I_m}{\pi}\right)^2 \cdot R_L$$

$$= \frac{I_m^2}{\pi^2} \times R_L$$

further $P_{ac} = P_a + P_R$

where, P_a = power dissipated at the junction diode

$$P_a = (I_{rms})^2 \cdot R_f$$

$$= \left(\frac{I_m}{2}\right)^2 \cdot R_f$$

$$= \frac{I^2 m}{4} R_f$$

P_R = power dissipated by the load resistance.

$$P_R = (I_{rms})^2 \cdot R_L$$

$$= \left(\frac{I_m}{2}\right)^2 \times R_L$$

$$= \frac{I_m^2}{4} \cdot R_L$$

$$P_{ac} = P_a + P_R$$

$$= \frac{I_m^2}{4} \cdot R_f + \frac{I_m^2}{4} \cdot R_L$$

$$= \frac{I_m^2}{4} (R_f + R_L)$$

$$\eta = \frac{\frac{I_m^2}{\pi^2} \cdot R_L}{\frac{I_m^2}{4}(R_f + R_L)} = \frac{\frac{I_m^2 \cdot R_L}{\pi^2}}{\frac{I_m^2 (R_f + R_L)}{4}}$$

$$= \frac{4 I_m^2 \cdot R_L}{\pi^2 I_m^2 (R_f + R_L)}$$

$$\eta = 0.406 \times \frac{R_L}{(R_f + R_L)}$$

when, $R_f <<< R_L$

$$\boxed{\eta = 40.6\%}$$

RIPPLE FACTOR:-

→ The output of a rectifier consists of dc component as well as

, The a.c component in the output called rectifier this is undesired.

→ Smaller is the ripple more effective will be the rectifier.

→ The ripple factor(γ) give an idea about the waviness of the rectifier voltage and it is defind as ratio of effective value of a.c component of voltage.

$$\text{Ripple factor}(\gamma) = \frac{\text{Ripple voltage}}{\text{D.C voltage}}$$

$$= \frac{\text{Rms value of a.c component}}{\text{D.C value of wave}} = \frac{(V_{r})_{Rms}}{V_{dc}}$$

$(V_r)_{rms}$ = Rms value of a.c component of o/p voltage

V_{dc} = D.c value of o/p component

$$(V_r)_{rms}^2 = (V_m)_{rms}^2 - V_{dc}^2$$

$$\Rightarrow (V_r)_{rms} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

$$\text{Ripple factor} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$$

$$= \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{V_{dc}^2}} = \sqrt{\frac{\left(\frac{V_m}{2}\right)^2}{\frac{(V_m)^2}{\pi^2}} - 1}$$

$$= \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} = 1.21$$

The ripple factor also defind as

$$\text{Ripple factor} = \frac{(I_r)_{rms}}{I_{dc}}$$

REGULATION:-

It is defind as the variation of dc o/p voltage with change in d.c ~~out~~ load current.

$$\% \text{ of Regulation} = \frac{V_{noload} - V_{full\ load}}{V_{full\ load}} \times 100$$

TRANSFORMER UTILISATION FACTOR:-

The dc power to be delivered to the load in a rectifier circuit decides the rating of the transformer used in the circuit. So transformer utilisation factor is defind as.

$$TUF = \frac{\text{dc power to be deliver to the load}}{\text{Ac rating to the transfer secondary}}$$

$$= \frac{P_{dc}}{(P_{ac})\text{rating}}$$

D - 18.8.18

According to theory of transformer the rated of secondary will be $\frac{V_m}{\sqrt{2}}$ and the actual RMS current flowing through it will be $\frac{I_m}{2}$

$$TUF = \frac{P_{dc}}{P_{ac\ rated}}$$

$$= \frac{(I_{dc})^2 R_L}{V_{a.c} \times I_{rms}}$$

$$= \frac{\left(\frac{I_m}{\pi}\right)^2 \times R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{2}}$$

$$= \frac{\frac{I_m^2 \times R_L}{\pi^2}}{\frac{V_m \cdot I_m}{2\sqrt{2}}}$$

$$= \frac{I_m^2 \times R_L \times 2\sqrt{2}}{\pi^2 \times V_m \times I_m}$$

we know $V_m = I_m(R_f + R_L)$

$$\frac{I_m^2 \times R_L \times 2\sqrt{2}}{\pi^2 I_m^2 (R_f + R_L)}$$

$$TUF = \frac{2\sqrt{2}}{\pi^2} \frac{R_L}{R_f + R_L}$$

when $R_f << R_L$ $\quad \frac{2\sqrt{2}}{\pi^2}\left(\frac{R_L}{0 + R_L}\right)$

$$= \frac{2\sqrt{2}}{\pi^2}\left(\frac{R_L}{R_L}\right)$$

$$= \frac{2\sqrt{2}}{\pi^2} = 0.287$$

This means that if the transfer rating is 1KVA/1000 V.A then half wave rectifier can deliver $1000 \times 0.287 = 287$ watt to the resistance load.

Peak inverse voltage (PIV) :-

The peak inverse voltage (PIV) is defind as the max^m voltage across the diode in the reverse direction

$PIV = V_m$

Form Factor (F) :-

It is defind as the ratio of rms value of current to the ~~ratio of~~ average value of the current

$$F = \frac{I_{rms}}{I_{Avg}}$$

$$= \frac{I_m/2}{I_m/\pi}$$

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

$$= \pi/2 = 1.57$$

Peak Factor :-

It is defind as the ratio of peak value to the rms value of voltage.

$$\text{Peak Factor} = \frac{V_{peak}}{V_{rms}}$$

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

$$= 2$$

Q:- In the power supply dc output voltage drop from 44v with no load to 42v at a full load what is the % of regulation.

$$\% \text{ of regulation} = \frac{V_{no\,load} - V_{full\,load}}{V_{full\,load}} \times 100$$

$$= \frac{44-42}{42} \times 100 = 0.0476 \times 100 = 4.76\%.$$

Q:- What is ripple 2v on avg of 50v what is.

ripple = 2

Avg = 50v

$$\text{ripple} = \frac{2}{50} = 0.04$$

Q:- An a.c supply of 230v is applied to a half wave rectifier circuit through transfer of turn ratio 5:1 assume the diode is an ideal one. The load resistance is 300 Ω.

find (i) DC output voltage

(ii) PIV

(iii) Max^m value power deliver to the load

(iv) The avg. value of power deliver to the load.

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

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

$$\Rightarrow \frac{230}{5} = 46$$

$$V_m = 46 \times \sqrt{2} = 65$$

$$V_{dc} = \frac{V_m}{\pi} = \frac{65}{\pi} = 20.7$$

$$PIV = V_m = 65\,V$$

$$V_m = I_m(R_f + R_L) \quad (R_f \to 0)$$

$$\frac{V_m}{R_L} = I_m.$$

$$I_m = \frac{65}{300} = 0.217\,\text{Amp}$$

$$P_m = I_m^2 \times R_L$$

$$= (0.217)^2 \times 300 = 14.12$$

$$I_{dc} = \frac{0.217}{3.142} = 0.069$$

$$P_{dc} = (I_{dc})^2 \times R_L$$

$$= (0.069)^2 \times 300 = 1.428$$

D - 20.8.18

18

A sinosoidal voltage of amplitude 25V & freq 50 Hz is applied to a halfwave rectifier the load resistor is 1000Ω the forward resistance Rf of ideal diode is 10Ω. Calculate peak average, and rms value of current, dc power output, rectifier η, ripple factor.

$V_m = 25V$

$I_m = \frac{V_m}{R_f + R_L} = \frac{25}{10+1000} = 0.02475 \text{ Amp} = 24.75 \text{ mA}$

$I_{dc} = \frac{I_m}{\pi} = 7.87 \text{ mA}$

$I_{rms} = \frac{I_m}{2} = \frac{24.75}{2} = 12.37 \text{ mA}$

$P_{dc} = I_{dc}^2 \times R_L$

$= (7.87)^2 \times 1000$

$= 61.9 \text{ mW}$

$P_{ac} = I_{rms}^2 (R_f + R_L)$

$= \left(\frac{12.37}{1000}\right)^2 \times (10+1000)$

$= 154.53 \text{ mW}$

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

$= \frac{61.9}{154.53} \times 100$

$= 40\%$

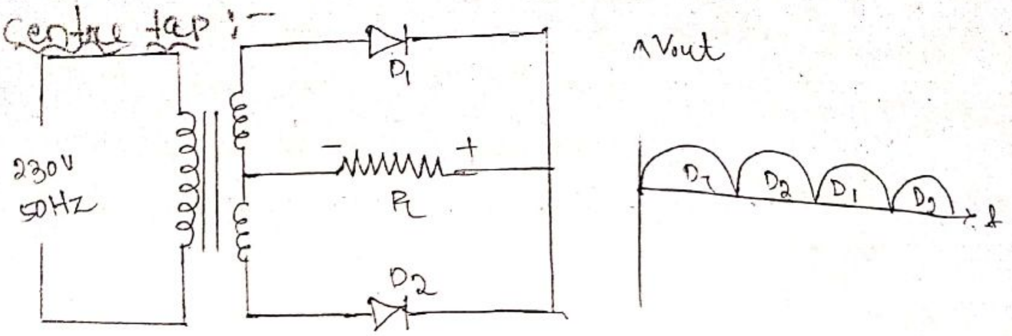
Ripple factor $= \frac{(I_{ac})_{rms}}{I_{dc}}$

$\sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} \quad \sqrt{\left(\frac{12.37}{7.87}\right)^2 - 1}$

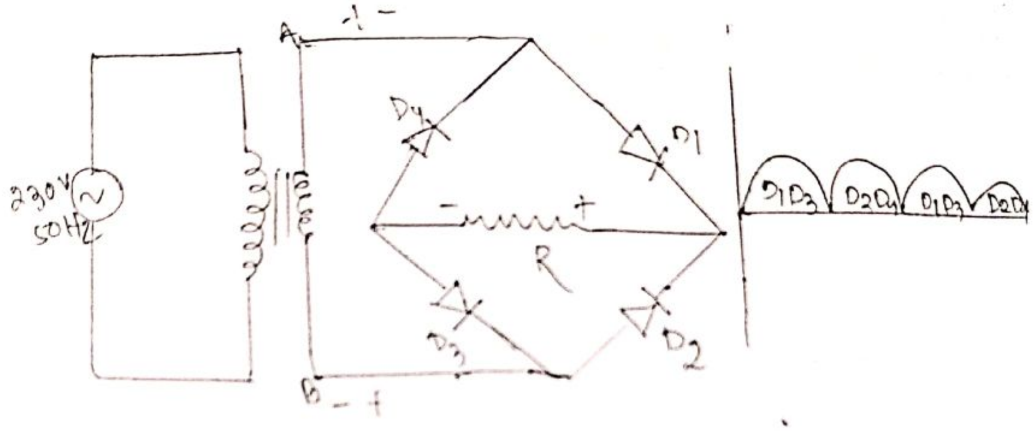
$= 1.21$

Full-wave Rectifier:-

Centre tap:-



Bridge Rectifier:-



D- 21.8.18

for +ve

D1 & D3 . forward bias

D2 & D4 R.B

for -ve

D1 & D3 Reverse bias

D2 & D4 forward bias.

Analysis :-

→ Let the input voltage V_i is given by $V_i = V_m \sin\omega t$

→ The Current i_1 through diode D_1 & load resistor is given by $i_1 = I_m \sin\omega t$, for $0 \leq \omega t \leq \pi$

$i_1 = 0$, for $\pi \leq \omega t \leq 2\pi$

$$I_m = \frac{V_m}{R_f + R_L}$$

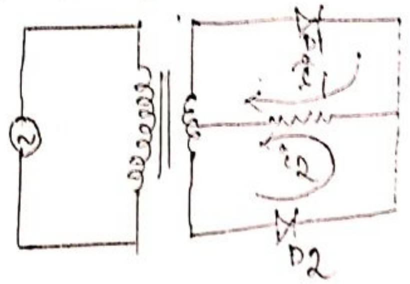
where, R_f = Diode resistance in ON condition

Similarly,
The current i_2 flowing to diode D_2 at load resistor R_L is given by,

$i_2 = 0$ for $0 \le \omega t \le \pi$

$i_2 = I_m \sin\omega t$ for $\pi \le \omega t \le 2\pi$

The total current flowing through the R_L is the sum of the current i_1 & i_2 i.e $\boxed{i = i_1 + i_2}$



DC or Avarage current:-

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} (i)\, d(\omega t)$$

$$\Rightarrow I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i_1 + i_2 \, d(\omega t)$$

$$\Rightarrow I_{dc} = \frac{1}{2\pi}\left[\int_0^{2\pi} i_1\, d(\omega t)\right] + \frac{1}{2\pi}\left[\int_0^{2\pi} i_2\, d(\omega t)\right]$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t\, d(\omega t)\right] + \frac{1}{2\pi}\left[\int_{\pi}^{2\pi} I_m \sin\omega t\, d(\omega t)\right]$$

$$= \frac{1}{2\pi}\left[I_m\left[-\cos\omega t\right]_0^{\pi}\right] + \frac{1}{2\pi}\left[I_m\left[-\cos\omega t\right]_{\pi}^{2\pi}\right]$$

$$= \frac{1}{2\pi}\left[I_m(-1(-1-1))\right] + \frac{1}{2\pi}\left[I_m\left[-(1-(-1))\right]\right]$$

$$= \frac{1}{2\pi}\left[2I_m\right] + \frac{1}{2\pi}\left[2I_m\right]$$

$$= \frac{I_m}{\pi} + \frac{I_m}{\pi}.$$

$$\boxed{I_{dc} = \frac{2I_m}{\pi} = 0.636 I_m}$$

$V_{dc} = I_{dc} \times R_L$

$= \frac{2I_m}{\pi} \times R_L$

$\boxed{V_{dc} = 0.636\, I_m R_L}$

D - 28.8.18

RMS current:-

The rms value of current is given by,

$I_{rms} = \left[\frac{1}{\pi}\int_0^{\pi} i^2\, d(\omega t)\right]^{1/2}$

$= \left[\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2(\omega t)\, d(\omega t)\right]^{1/2}$ (since the current is of the same form in the two halves)

$= \left[\frac{I_m^2}{\pi}\int_0^{\pi} \sin^2(\omega t)\, d(\omega t)\right]^{1/2}$

$= \left[\frac{I_m^2}{\pi}\int_0^{\pi} \left(\frac{1-\cos 2\omega t}{2}\right) d(\omega t)\right]^{1/2}$

$= \left[\frac{I_m^2}{2\pi}\left(\int_0^{\pi} d(\omega t) - \int_0^{\pi} \cos 2\omega t\, d(\omega t)\right)\right]^{1/2}$

$= \left[\frac{I_m^2}{2\pi}\left[(\omega t) - \frac{\sin 2\omega t}{2}\right]_0^{\pi}\right]^{1/2}$

$= \left[\frac{I_m^2}{2\pi}(\pi - 0 - 0 - 0)\right]^{1/2}$

$= \left[\frac{I_m^2}{2\pi} \times \pi\right]^{1/2}$

$= \left[\frac{I_m^2}{2}\right]^{1/2}$

$\boxed{I_{rms} = \sqrt{\frac{I_m^2}{2}} = \frac{I_m}{\sqrt{2}}}$

RMS voltage:-

$V_{rms} = I_{rms} \cdot R_L$

$= \frac{V_m}{\sqrt{2}(R_f + R_L)} \times R_L \quad \left(\because I_m = \frac{V_m}{R_f + R_L},\ I_{rms} = \frac{I_m}{\sqrt{2}}\right)$

If $R_f \ll R_L$

$\boxed{V_{rms} = \frac{V_m R_L}{\sqrt{2}(0 + R_L)} = \frac{V_m \times R_L}{\sqrt{2} R_L} = \frac{V_m}{\sqrt{2}}}$

Rectifier efficiency for full wave:-

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

$$P_{dc} = I_{dc}^2 R_L$$
$$= \frac{V_{dc}^2}{R_L}$$
$$= \frac{4V_m^2}{\pi^2 R_L} \quad \left(\because V_{dc} = \frac{2V_m}{\pi}\right)$$

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

$$\eta = \frac{\frac{4V_m^2}{\pi^2 R_L}}{\frac{V_m^2}{2R_L}}$$
$$= \frac{4V_m^2}{\pi^2 \times R_L} \times \frac{2R_L}{V_m^2} = \frac{8}{\pi^2} = 0.812 = 81.2\%$$

Ripple Factor:-

$$\gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$
$$= \sqrt{\left(\frac{\frac{I_m}{\sqrt{2}}}{\frac{2I_m}{\pi}}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1}$$
$$= \sqrt{\frac{\pi^2}{8} - 1} = 0.48$$

Regulation:-

The dc output voltage is given by, $V_{dc} = \frac{2I_m \cdot R_L}{\pi}$

$$V_{dc} = \frac{2I_m \cdot R_L}{\pi}$$
$$= \frac{2V_m R_L}{\pi (R_f + R_L)} \quad \left(\because I_m = \frac{V_m}{R_f + R_L}\right)$$
$$= \frac{2V_m}{\pi}\left(1 - \frac{R_f}{R_f + R_L}\right) = \frac{2V_m}{\pi} - \frac{2V_m}{\pi} \cdot \frac{R_f}{R_f + R_L}$$
$$= \frac{2V_m}{\pi} - I_{dc} \cdot R_f$$

Peak Inverse voltage :-

→ The peak inverse voltage is the max^n possible voltage across a diode when it is reverse biased.

→ In centre tap Fullwave rectifier the peak inverse voltage =

$V_m + V_m = 2V_m$

→ In bridge full wave rectifier the peak inverse voltage is V_m

D-26.8.18

Transformer utilisation factor (TUF) :- (Fullwave centre tap)

→ The average TUF in full wave rectifying circuit is determined by considering the primary and secondary winding separately

→ There are two secondary is here; each secondary is associated with one diode this is just similar to secondary of half wave rectifier.

→ Each secondary has TUF of 0.287

TUF of Primary :-

$$\text{TUF of primary} = \frac{P_{dc}}{\text{V-I rating of primary}}$$

$$= \frac{(I_{dc})^2 \times R_L}{V_{rms} \times I_{rms}}$$

$$= \frac{\left(\frac{2I_m}{\pi}\right)^2 R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}}$$

$$= \frac{4I_m^2 R_L \times \sqrt{2} \times \sqrt{2}}{\pi^2 \times V_m \times I_m} = \frac{8I_m^2 R_L}{I_m^2 (R_f + R_L)\pi^2}$$

$$= \frac{8R_L}{\pi^2 (R_f + R_L)}$$

when $R_f \lll R_L$

$$= \frac{8R_L}{\pi^2 R_L} = \frac{8}{\pi^2} = 0.810$$

$$(TUF)_{avg} = \frac{(TUF)_p + 0.287 + 0.287}{2}$$

$$= 0.692$$

Form factor :-

$$F = \frac{I_{rms}}{I_{dc}} = \frac{I_m/\sqrt{2}}{2I_m/\pi}$$

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

$$= \pi/2\sqrt{2} = 1.110$$

Peak factor :-

$$PF = \frac{V_{peak}}{I_{rms}}$$

Comparision bet^n half wave rectifier with full wave rectifier.

Terms	halfwave	fullwave
Avg or dc value of current (I_{dc})	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$
Avg. or dc value of voltage (V_{dc})	$\frac{V_m}{\pi}$	$\frac{2V_m}{\pi}$
RMS current (I_{rms})	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$
RMS voltage (V_{rms})	$\frac{V_m}{2}$	$\frac{V_m}{\sqrt{2}}$
efficiency (η)	40.6 %	81.2 %
ripple factor	1.21	0.48
PIV	V_m	$2V_m$ (Centre tap) V_m (bridge rectifier)
TUF	0.287	0.692 (Centre tap) 0.812 (bridge rectifier)
Form factor	1.57	1.110
Peak factor	2	$\sqrt{2}$

TUF (bridge) :- The transformer utilisation factor TUF the primary & secondary will be same as the [illegible] is always current through primary & secondary.

$$\frac{(TUF)_p + (TUF)_s}{2} = \frac{0.810 + 0.810}{2} = 0.81$$

D-27.8.18

Q. A full wave rectifier supply a load 1kΩ. The ac voltage applied to the diode is 220 - 0 - 220V rms. If diode resistance is neglected calculate :- (1) Avg dc voltage
(2) Avg dc current
(3) Ripple current

(1) $V_{dc} = \frac{2V_m}{\pi} = 0.636\ V_m$

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

$\Rightarrow V_m = V_{rms} \times \sqrt{2}$

$= 0.636 \times 220 \times \sqrt{2}$.

$= 198\ V$

(2) $I_{dc} = \frac{V_{dc}}{R_L}$

$= \frac{198}{1000} = 0.198 = 198\ mA$

(3) $\gamma = \frac{(V_{ac})_{rms}}{V_{dc}}$

$= \gamma \cdot V_{dc} = (V_{ac})_{rms}$

$= 0.48 \times 198 = ~~45.04~~\ V$

$= 09.04\ V$

Q:- The full wave PN diode rectifier uses a load resistor of 1500Ω no filter is used. Diode to have idealised characteristics with $R_f = 10Ω$ and $R_r = \infty$. Since the wave voltage applied to the each diode has amplitude of 30V calculate peak, dc, rms, load current and DC power o/p, I/P and efficiency.

Given data,

$R_f = 10Ω$
$V_m = 30V$

$I_m = \frac{V_m}{R_f + R_L}$

$= \frac{30}{10 + 1500}$.

$= 0.01986\ Amp$

$I_{dc} = \frac{2I_m}{\pi}$

$= \frac{2 \times 0.01986}{\pi}$

$= \frac{2 \times 0.01986}{3.14}$

$= 0.01264\ Amp$

$I_{rms} = \frac{I_m}{\sqrt{2}}$

$= \frac{0.01986}{} = 0.01404\ Amp$

dc power o/p :- $P_{dc} = (I_{dc})^2 \times R_L$

$= (0.01264)^2 \times 1500$

$= 0.23965\ watt$

Dc power i/p :-

$P_{ac} = (I_{rms})^2 \times (R_f + R_L)$

$= (0.01404)^2 \times (10 + 1500)$

$= 0.29765\ watt$

efficiency :- $\frac{P_{dc}}{P_{ac}} \times 100$

$= \frac{0.23965}{0.29765} \times 100$

$= 80.51\%$

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Q:- A full wave rectifier delivers 50 watt to the load 200Ω. If ripple factor 2%. calculate the AC ripple voltage across the load.

$P_{dc} = \frac{V_{dc}^2}{R}$

$\Rightarrow P_{dc} \times R = V_{dc}^2$

$\Rightarrow V_{dc} = \sqrt{P_{dc} \times R}$

$= \sqrt{50 \times 200} = 100V$

$r = \frac{(V_{r})_{rms}}{V_{dc}} = \frac{2}{100} \times 100 = 2V$

Q:- A bridge rectifier is used supply dc load of 20 Amp and 20 volt. from 117 volt source. What are the rating from the power transformer :

$V_{dc} = 20V$

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

$\Rightarrow 20 = \frac{2V_m}{\pi}$

$\Rightarrow V_m = \frac{20\pi}{2} = 10\pi = 31.4 volt$

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

$= \frac{31.4}{\sqrt{2}}$

$= 22.2 volt$

$I_{dc} = \frac{2I_m}{\pi}$

$\Rightarrow 20 = \frac{2I_m}{\pi}$

$\Rightarrow I_m = 31.4 Amp$

$I_{rms} = 22.2 A$

$\frac{V_2}{V_1} = \frac{I_1}{I_2}$

$\Rightarrow \frac{22.2}{117} = \frac{I_1}{22.2}$

$\Rightarrow I_1 = \frac{22.2 \times 22.2}{117} = 4.21$

$V_{rms} \times I_{rms} = 22.2 \times 22.2$
$= 492.84$

$V_1 \times I_1 = 117 \times 4.21$
$= 492.57$

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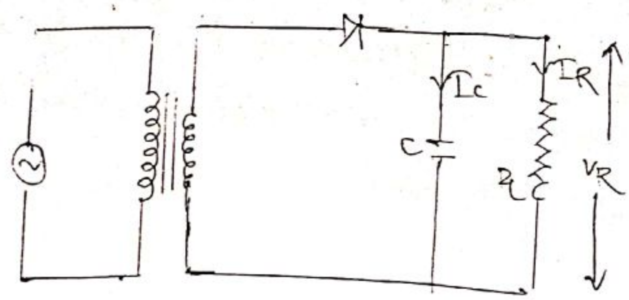
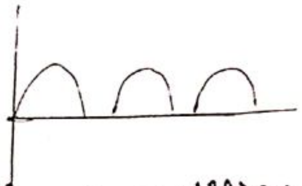
Shunt capacitor filter:-



(Halfwave rectifier with capacitor filter)



(Halfwave rectifier without filter)

(Halfwave rectifier with filter)

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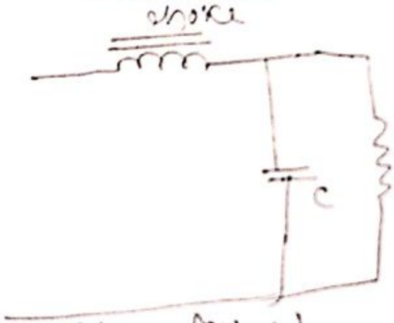
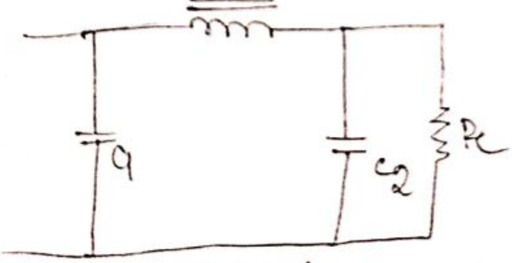
Choke



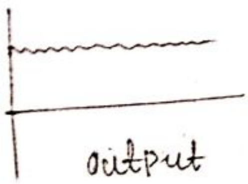
(Choke filter)

(output)

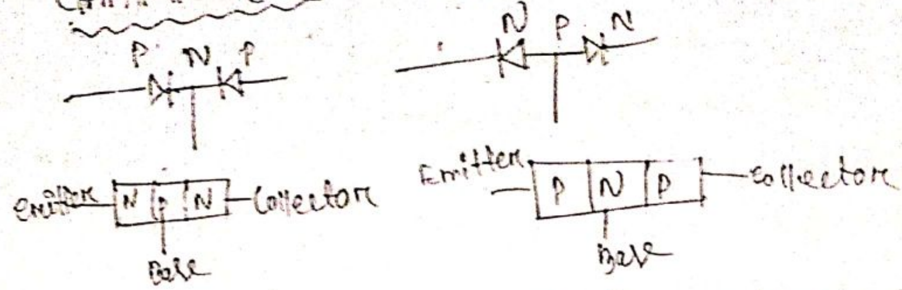
π Filter:-



(π Filter)



CHAPTER:- 4 TRANSISTOR



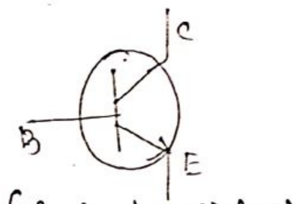
Emitter:- The emitter section is more heavely doped in comparison to other two region.

→ Emitter is always forward bias with respect to base.

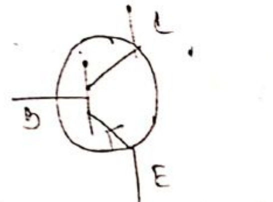
Collector:- The collector is moderately doped.

→ The size of collector is more as compere to base as well as emitter.

Base:- Base is lightly doped. Base is very thin as compare to either emitter or collector.



(NPN transistor)



(PNP transistor)

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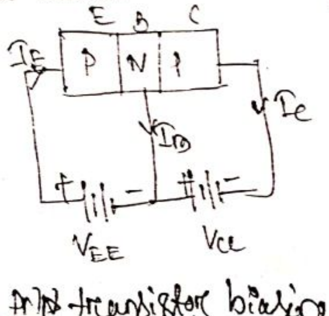
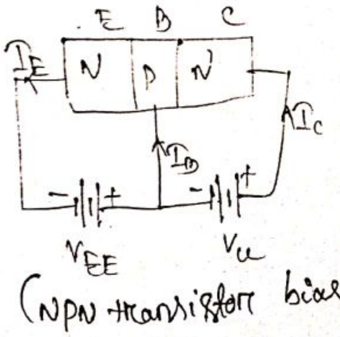
Transistor Biasing:-

The emitter base junction is always forward bias. while the collector base juction is always reverse bias.



(PNP transistor biasing)



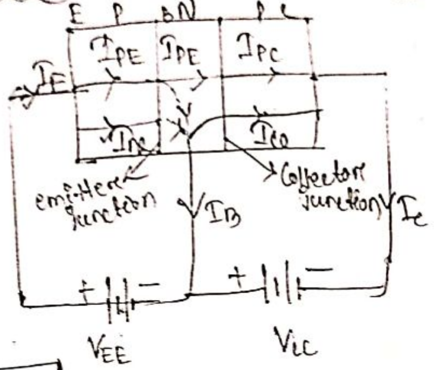
(NPN transistor biasing)

Different modes of operation of a transistor:-

There are 4 possible ways of biasing of a transistor these are called mode of opration of a transistor.

Cases	Base-emitter junction	Base-collector junction	mode of operation
1.	Forward bias	Reverse bias	Active
2.	Forward bias	Forward bias	Saturation
3.	Reverse bias	Reverse bias	cutoff
4.	Reverse bias	Forward bias	Inverted

Current component in a transistor :-



$I_E = I_{PE} + I_{nE}$
$I_C = I_{PC} + I_{CO}$
$I_E = I_C + I_B$

I_{PE} : Hole current I_{PE} constituted by holes (holes crossing from emitter to base)

I_{nE} : Electron current I_{nE} constitute by electron.

Total emitter current $I_E = I_{PE} + I_{nE}$

→ In commercial transistor the doping of emitter region is made much more heavier than base. & hence electron current component I_{nE} is negligible small in comparision with hole current I_{PE}.

→ The emitter current consists almost entirely of holes.

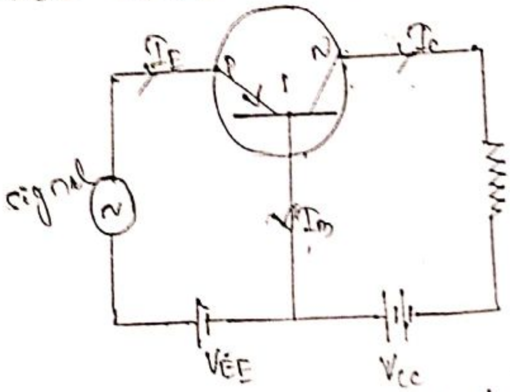
→ If the emitter were open circuited $I_E = 0$ i.e. $I_{pE} = 0$. under this condition the base and collector together act as a reverse diode. and the collector current (I_C) = the reverse saturation current(I_{CO}) which consists of following two parts:- (i) I_{nCO} (ii) I_{pCO}

(i) I_{nCO}:- I_{nCO} caused by electron moving across J_C from P-region to N-region.

(ii) I_{pCO}:- I_{pCO} caused by hole moving across J_C from N-region to p-region.

$$I_{CO} = I_{pCO} + I_{nCO}$$

Transistor, act as an amplifier:



→ The weak signal to be amplified is applied bet. emitter & base circuit & the output is taken across the load resistor R_L connected in the collector circuit.

→ A dc voltage V_{EE} is also connected in the input circuit.

→ A small change in signal voltage produce an applicable in appreciable change in emitter current because the input ckt has low resistance.

→ Due to transistor action the change in emitter current causes almost the change in collector current.

→ when the collector current flow through the load resistor (R_L) a large voltage is developed across it.

→ In this way the weak signal is applied in the input circuit appears in the amplified form across the output circuit. Thus the transistor act as an amplifier.

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↳ ~~Thus the transistor act as an amplifier.~~

Transistor circuit configuration:-

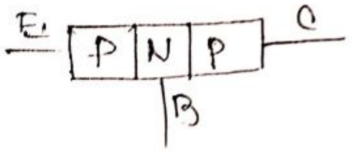
Transistor ~~ckt~~ is of three types:-

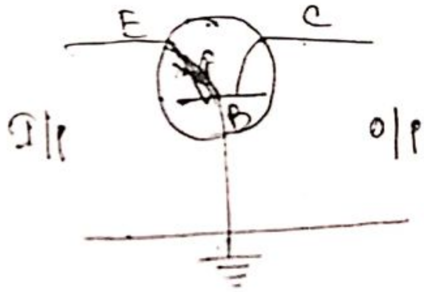
(i) Common base connection

(ii) Common emitter connection

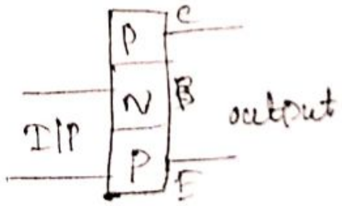
(iii) Common collector connection

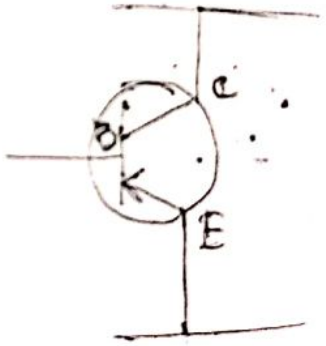
Common base:-



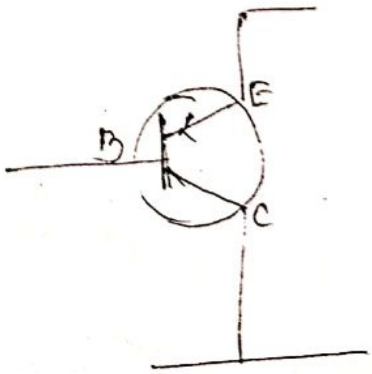


Common emitter:-





Common collector:-



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Transistor biasing:-

Among the basics function of a transistor is its amplification. For faith full amplification being following three condition must be satisfied.

(i) The emitter base junction should be forward bias.

(ii) Collector base junction should be reverse bias.

(iii) There should be proper zero signal collector current. or proper operating point of a transistor

Stabilisation:-

→ The maintance of operating point stable it is known as 'Stabilisation'.

→ There are two factors which are responsible for shifting the operating point

→ Many of the transistor parameter are markedly temp. sensitive and secondly when a transistor is replaced by another of the same time.

→ So stabilisation of operating point is necessary due to following reason.

(i) Temperature dependence of I_c.

(ii) Individual variation

(iii) Thermal runaway

Temperature dependence of I_c:-

- The collector leakage current I_{co} is greatly influence by temp. change.

- Increase in β with increase in temp.

- The instability of I_c is caused by above two reason.

Individual variation:-

- When a transistor is replaced by another transistor of same time the value of β & V_{BE} are not exactly same.

- Hence the operating point is change.

Theremal runaway :-

→ If the temp. increases behond particulare range then transistor burned out.

→ The range of temp. lies bet^n 60° to 100°c for germanium transistor and 150°-225°c for silicon.

→ The increase in collector junction temp is due to thermal runaway.

→ When a collector current flow in a transistor it is heated. its temp. increases.

→ If no stabilisation is done the collector leakage current also increases.

→ This further increases transistor temperature.

→ The action become cumutative & the the transistore may ultimetaly burnout.

→ This self destruction of an unstabilised transistore is known as "thermal runout".

Stability Factor :-

→ The stability factor (S) is defined as the rate of change of collector current I_c w.r.t reverse saturation current I_{co} keeping β & V_{BE} constant.

$$S = \frac{\partial I_c}{\partial I_{co}} = \frac{\Delta I_c}{\Delta I_{co}}$$

Expression for stability factor (S) :-

→ When a transistore is biased in active reason of its characterstics the collector current I_c is related to base current (I_B) by following expression.

$$I_c = \beta I_B + (1+\beta) I_{co}$$

→ Differentiating eq^n w.r.t I_c. considering β to be const. we get we get, $\frac{dI_B}{dI_C} = \frac{d\beta I_B}{dI_C} + \frac{d(1+\beta)I_{CO}}{dI_C}$

$\Rightarrow 1 = \beta \frac{dI_B}{dI_C} + (1+\beta)\frac{dI_{CO}}{dI_C}$

$\Rightarrow 1 = \frac{\beta dI_B}{dI_C} + (1+\beta)\frac{1}{S}$

$\Rightarrow 1 - \frac{\beta dI_B}{dI_C} = (1+\beta)\frac{1}{S}$

$\Rightarrow \frac{1}{S}(1+\beta) = 1 - \beta\frac{dI_B}{dI_C}$

$\Rightarrow \frac{1+\beta}{1-\beta\frac{dI_B}{dI_C}} = S$

$$\Rightarrow S = \frac{1+\beta}{1-\beta\frac{dI_B}{dI_C}}$$

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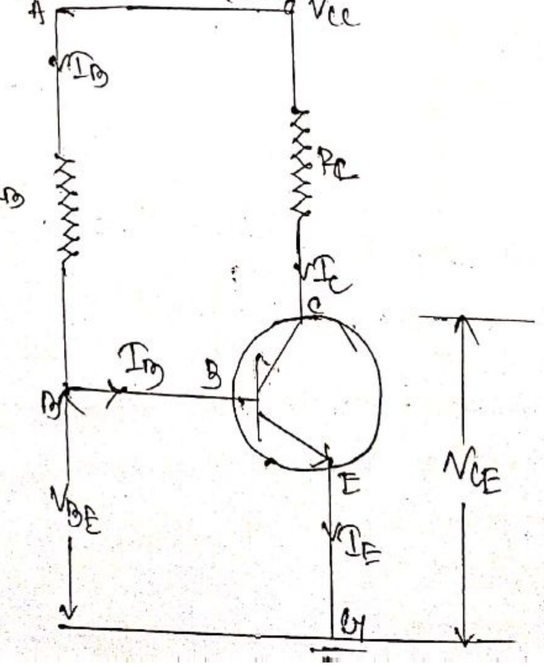
Different method of transistor biasing:-

Some of the method used for providing bias for transistor are as follows:-

(i) Base resistor method
(ii) Collector to base bias
x(iii) Base bias with collector & emitter feedback.
(iv) Voltage divider bias

Base resistor method:-



(CE NPN transistor with base resistor method)

→ In this method a high resistance R_B is connected bet^n +ve terminal of supply V_{CC} and base of the transistor.

→ The required zero signal base current flow through R_B. and is provided by V_{CC}.

→ The base emitter junction is forward bias because the base is positive w.r.t emitter.

Analysis:—

Considering the closed circuit ABEDA and apply KVL:

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

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

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

$$\Rightarrow \boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B}}$$

Further $\beta = \frac{I_C}{I_B}$

$$\Rightarrow I_C = \beta I_B$$

$$\Rightarrow I_B = \frac{I_C}{\beta}$$

Putting the value of $I_B = \frac{I_C}{\beta}$

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

$$\Rightarrow \frac{I_C}{\beta} = \frac{V_{CC} - V_{BE}}{R_B}$$

$$\Rightarrow \boxed{I_C = \frac{(V_{CC} - V_{BE})\beta}{R_B}}$$

The value of V_B can be see form transistor manual.

The value of R_B can be calculated as V_{BE} generally very small as compared to V_{CC} hence

$$\boxed{I_C = \frac{V_{CC}\beta}{R_B}}$$

$$\boxed{R_B = \frac{V_{CC}\beta}{I_C}}$$

The value of I_B can found directly. Hence this method is some time called as fix bias method.

Stability factor (S):—

$$S = \frac{1+\beta}{1-\beta\left(\frac{dI_B}{dI_C}\right)}$$

$$S = \frac{1+\beta}{1-\beta(0)} \quad (\because I_B \text{ is independent } I_B = 0)$$

$$S = 1+\beta$$

- If $\beta = 100$ then $S = 101$, this shows I_C change 101 times as much as any change in I_{CO} 180.
- I_C is very dependent upon I_{CO}. Hence upon temperature.
- The value of S is the heights that can obtained.

Hence the circuit has very poor stability.

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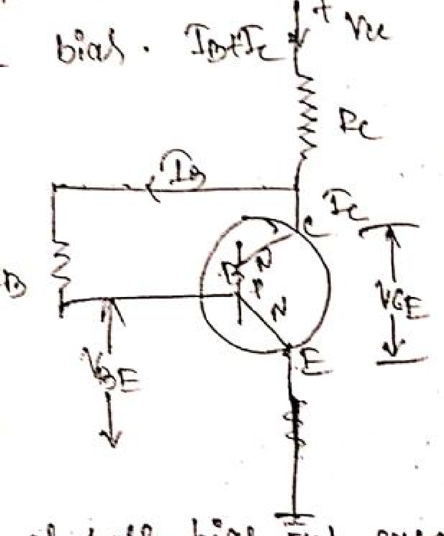
Collector to base bias:—

The ckt of an NPN transistor connected in C configuration with collector to base bias.



- The ckt is same as base bias ckt except that the base resistor R_B is returned to collector greater than to Vcc supply.
- Using this ckt there is considerable improvement in the stability.
- If the collector current I_C tends to increase consequently V_{CE} decreases as a result base current I_{BE} also decrease.
- This will tends to compenset for the original increases.

Analysis:—

voltage drop across $R_e = (I_B + I_C) R_e$, apply KVL to input loop

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

$$\Rightarrow V_{CC} = I_C R_e + I_B R_B + V_{BE}$$

$$\Rightarrow I_B R_B = V_{CC} - I_C R_C - V_{BE}$$

$$\Rightarrow \boxed{R_B = \frac{V_{CC} - I_C R_e - V_{BE}}{I_B}}$$

we know $\beta = \frac{I_C}{I_B}$

$$\Rightarrow I_B = \frac{I_C}{\beta}$$

Put in eq^n

$$R_B = \frac{(V_{CC} - I_C R_e - V_{BE})\beta}{I_C}$$

Stability Factor (S):—

$$V_{CC} - (I_B + I_C) R_e - I_B R_B - V_{BE} = 0$$

$$\Rightarrow V_{CC} - I_B R_e - I_C R_e - I_B R_B - V_{BE} = 0$$

$$\Rightarrow V_{CC} - I_B (R_e - R_B) - I_C R_e - V_{BE} = 0$$

$$\Rightarrow I_B (R_e - R_B) = V_{CC} - I_C R_e - V_{BE}$$

$$\Rightarrow \boxed{I_B = \frac{V_{CC} - I_C R_e - V_{BE}}{R_e - R_B}}$$

Since V_{BE} is almost independent of collector current (I_C)

(V_{BE} = 0.7 silicon, & 0.3 for ge)

$$I_B = \frac{V_{CC}}{R_C + R_B} - \frac{I_C R_e}{R_B + R_e} - \frac{V_{BE}}{R_B + R_e}$$

$$\Rightarrow \frac{dI_B}{dI_C} = \frac{-R_e}{R_B + R_e} \cdot \frac{dI_C}{dI_C} \quad \left(\because \frac{V_{CC}}{R_B + R_e}, \frac{V_{BE}}{R_B + R_e} \text{ is const} = 0\right)$$

$$\Rightarrow \frac{dI_B}{dI_C} = \frac{-R_e}{R_B + R_e} \cdot 1$$

$$\Rightarrow \frac{dI_B}{dI_C} = \frac{-R_e}{R_B + R_e}$$

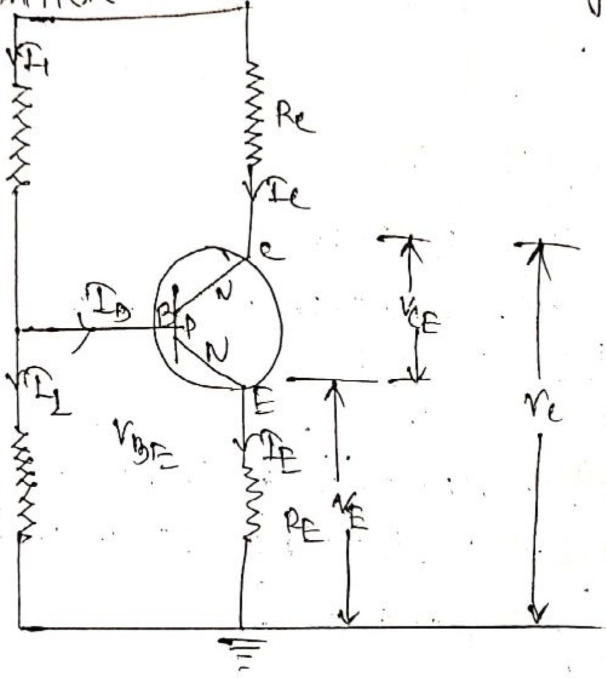
$$S = \frac{1+\beta}{1-\beta\left(\frac{dI_B}{dI_C}\right)} = \frac{1+\beta}{1-\beta\left(\frac{-R_C}{R_C+R_B}\right)}$$

$$= \frac{1+\beta}{1+\beta\left(\frac{R_C}{R_C+R_B}\right)}$$

↳ This value is smaller than $1+\beta$ which is obtained for base resistor method. Thus their is an impravment in stability.

Self bias or emitter bias (voltage divider bias):-

↳ A very small commonly used biasing arrangement it self bias or emitter bias. The circuit arrangement is shown.



↳ This is known as universal bias stabilisation ckt. In this method two resistance R_1 & R_2 connected across supply voltage V_{CC} provide biasing.

↳ The emitter resistance R_E provide stabilisation the name volte divider is derived due to fact their resistor R_1 & R_2 form a potential devider across V_{CC}.

↳ The resistance R_E causes a voltage drop in a direction so as to reverse bias reduce the increase in I_C. and improves the operating point stability.

ANALYSIS:-

Let current I_1 flows through R_1 as base current is very small the current flowing through R_2 can also be taken as I_1, the calculation of collector current.

The current I_1 flowing through R_1 & R_2 is given by

$$I_1 = \frac{V_{cc}}{R_1 + R_2}$$

The voltage V_2 developed across R_2 is given by

$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right) \times V_{cc}.$$

Applying KVL to the base circuit

$$V_2 = V_{BE} + V_E$$

$$\Rightarrow V_2 = V_{BE} + I_E R_E$$

$$\Rightarrow V_2 = V_{BE} + I_C R_E \quad (\because I_C = I_E)$$

$$I_C = \frac{V_2 - V_{BE}}{R_E}$$

Here I_C almost independent of transistor parameter. Hence good stabilisating is ensured.

Applying KVL to output side

$$V_{CC} - I_C R_C - I_E R_E - V_{CE} = 0$$

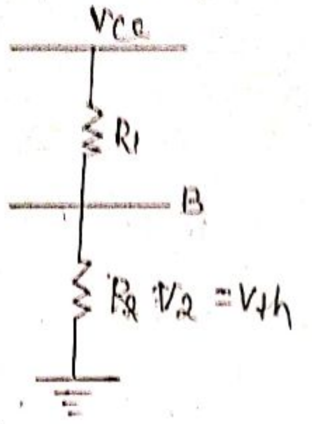
$$\Rightarrow V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

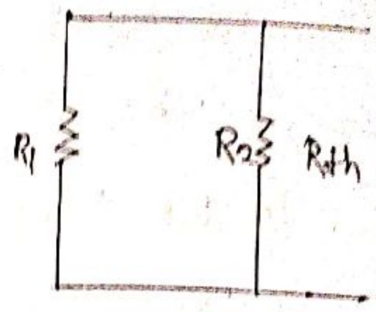
$$\Rightarrow V_{CE} = V_{CC} - I_C R_C - I_E R_E \quad (\because I_C \simeq I_E)$$

$$\Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E)$$

$$\Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E)$$

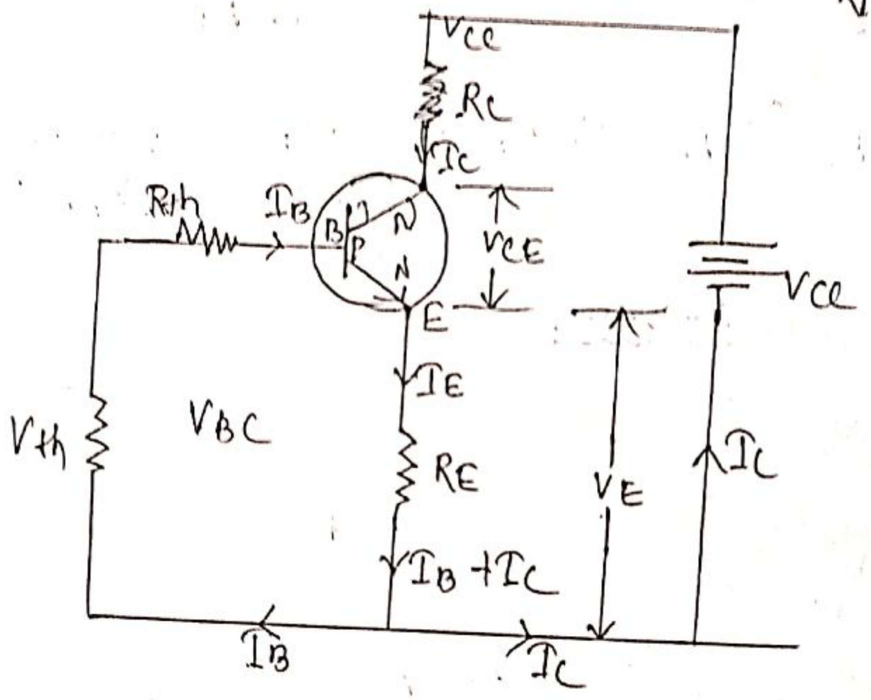
circuit analysis using thevinins theorem :-





$$V_2 = V_{th} = \frac{R_2}{R_1 + R_2} \times V_{CC}$$

$$R_{th} = R_1 \parallel R_2 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$



(Simplified equivalent circuit)

Applying KVL to base emitter circuit

$$V_{th} - I_B R_{th} - V_{BE} - (I_B + R_C) R_E = 0.$$

$$\boxed{V_{th} = I_B R_{th} + V_{BE} + (I_B + I_C) R_E}$$

Applying KVL to emitter collector circuit.

$$V_{CE} - V_{CC} + I_C (R_E - R_E) = 0 \quad (\because I_C \gg I_B).$$

$\Rightarrow I_C (R_C + R_E) = V_{CC} - V_{CE}$

$$\Rightarrow \boxed{I_C = \frac{V_{CC} - V_{CE}}{R_C + R_E}}$$

Substituting the value of I_C in V_{th} eqn.

$$V_{th} = I_B R_{th} + V_{BE} + (I_B + I_C) R_E$$

$$\Rightarrow V_{th} = I_B R_{th} + V_{BE} + \left(I_B + \frac{V_{CC} - V_{CE}}{R_C + R_E}\right) \cdot R_E$$

$$\Rightarrow V_{th} = I_B R_{th} + V_{BE} + I_B R_E + \frac{V_{CC} - V_{CE}}{R_C + R_E} \times R_E$$

$$\Rightarrow \boxed{V_{th} = I_B R_{th} + V_{BE} + I_B R_E + \frac{V_{CC} \times R_E}{R_C + R_E} - \frac{V_{CE} \times R_E}{R_C + R_E}}$$

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Stability Factor :-

~~$V_{th} = I_B R_{th} + V_{BE} + I_B R$~~

Considering $R_{th} = R_B$

$$V_{th} = I_B R_{th} + V_{BE} + (I_B + I_C) R_E$$

differentiate eqn with respect to I_C

$$\Rightarrow 0 = \frac{dI_B}{dI_C} R_B + 0 + \left(\frac{dI_B}{dI_C} + 1\right) R_E$$

$$\Rightarrow \frac{dI_B}{dI_C} R_B + \frac{dI_B}{dI_C} R_E + R_E = 0$$

$$\Rightarrow \left(\frac{dI_B}{dI_C}\right) \{R_B + R_E\} + R_E = 0$$

$$\Rightarrow \frac{dI_B}{dI_C} \cdot (R_B + R_E) = -R_E$$

$$\Rightarrow \boxed{\frac{dI_B}{dI_C} = \frac{-R_E}{R_B + R_E}}$$

we know that, the stability factor is given by

$$S = \frac{1+\beta}{1-\beta\left(\frac{dI_B}{dI_C}\right)}$$

$$S = \frac{1+\beta}{1-\beta\left(\frac{-R_E}{R_B+R_E}\right)}$$

$$\boxed{S = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_B+R_E}\right)}}$$

we can also written as

$$S = \frac{1+\beta}{1+\beta\left(\frac{1}{\frac{R_B}{R_E}+1}\right)}$$

$$\Rightarrow S = \frac{1+\beta}{1+\frac{\beta R_E}{R_B+R_E}}$$

$$\Rightarrow S = \frac{(1+\beta)(R_B+R_E)}{R_B+R_E+\beta R_E}$$

$$\Rightarrow S = \frac{(1+\beta)\left(\frac{R_B}{R_E}+1\right)}{\frac{R_B}{R_E}+1+\beta} \quad (\because \text{divided } R_E)$$

$$\Rightarrow S\left(\frac{R_B}{R_E}\right)+S+S\beta = (1+\beta)\left(\frac{R_B}{R_E}+1\right)$$

$$\Rightarrow S\left(\frac{R_B}{R_E}\right)+S+S\beta = 1+\beta+\frac{R_B}{R_E}+\beta\frac{R_B}{R_E}$$

$$\Rightarrow -1-\beta+S+S\beta = \frac{R_B}{R_E}+\beta\frac{R_B}{R_E}-S\frac{R_B}{R_E}$$

$$\Rightarrow \beta(S-1)+(S-1) = \frac{R_B}{R_E}(1+\beta-S)$$

$$\Rightarrow (S-1)(1+\beta) = \frac{R_B}{R_E}(1+\beta-S)$$

$$\Rightarrow \boxed{\frac{R_B}{R_E} = \frac{(S-1)(1+\beta)}{1+\beta-S}}$$

Voltage divider

Q:- A silicon transistor uses potential divider method of biasing, $V_{cc} = 12$ volt, $R_1 = 10k\Omega$, $R_2 = 5k\Omega$, $R_L = 1k\Omega$, $R_E = 3k\Omega$ determine operating point using thevinin's theorem.

$$V_{th} = \frac{R_2}{R_1+R_2} \times V_{cc}$$

$$= \frac{5}{10+5} \times 12$$

$$= 4V$$

$$R_{th} = R_1 \| R_2$$

$$= \frac{R_1 \times R_2}{R_1+R_2} = \frac{10 \times 5}{10+5} = 3.33k\Omega$$

$$V_{th} = I_B R_{th} + V_{BE} + (I_B + I_C) R_E$$

$$\Rightarrow V_{th} = I_B R_{th} + V_{BE} + I_C R_E \quad (\because I_C >> I_B)$$

$$\Rightarrow V_{th} = I_B R_{th} + V_{BE} + \beta I_B R_E$$

$$\Rightarrow V_{th} - V_{BE} = I_B (R_{th} + \beta R_E)$$

$$\Rightarrow I_B = \frac{V_{th} - V_{BE}}{R_{th} + \beta R_E}$$

$$\Rightarrow \frac{I_C}{\beta} = \frac{V_{th} - V_{BE}}{R_{th} + \beta R_E} \quad \left(\because I_C = \beta I_B \Rightarrow I_B = \frac{I_C}{\beta}\right)$$

$$\Rightarrow \frac{I_C}{\beta} = \frac{V_{th} - V_{BE}}{\beta\left(\frac{R_{th}}{\beta} + R_E\right)}$$

$$\Rightarrow I_C = \frac{V_{th} - V_{BE}}{\frac{R_{th}}{\beta} + R_E}$$

$$\Rightarrow I_C = \frac{V_{th} - V_{BE}}{\frac{R_{th}}{\beta} + R_E} \quad \left(\because \frac{R_{th}}{\beta} <<< R_E\right)$$

$$\Rightarrow I_C = \frac{V_{th} - V_{BE}}{R_E}$$

$$= \frac{4 - 0.7}{3} = \frac{3.3}{3} = 1.1 \text{ mA}$$

$V_{CE} = V_{cc} - I_c (R_c + R_E)$

$\Rightarrow V_{CE} = 12 - 1.1(1+3)$

$\Rightarrow V_{CE} = 12 - 1.1(4)$

$= 7.6$ volt.

Operating point (7.6V, 1.1mA)

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Q:- A germanium transistor is to be operated at zero signal $I_c = 1mA$. If the collector supply $V_{cc} = 10V$, What is the value of R_B in base resistor method (i) take $\beta = 100$. (ii) If another transistor of same bach with $\beta = 50$ what will be the value of I_c zero signal I_c for same R_B

$I_c = 1mA$

$V_{cc} = 10V$

(i) $R_B = \frac{(V_{cc} - V_{BE})\beta}{I_c}$

$= \frac{10 - 0.3V \times 100}{1mA}$

$= 970000$

$= 970 k\Omega$

(ii) $\beta = 50$

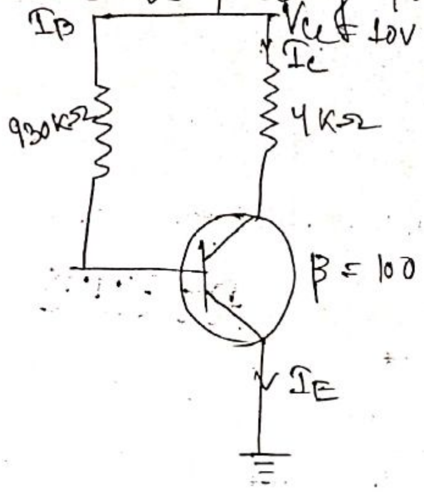
$I_c = \frac{(V_{cc} - V_{BE})\beta}{R_B}$

$= \frac{(10 - 0.3)50}{970 \times 10^3}$

$= \frac{9.7 \times 50}{970 \times 10^3} = 5 \times 10^{-4} A$

$= 0.5mA$

Q:- A silicon transistor with $\beta = 100$ and biased by base resistor method determine operating point.



Ans:- $I_C = \frac{(V_{CC} - V_{BE})\beta}{R_B}$

$= \frac{(10 - 0.7)100}{930 \times 10^3}$

$= 1 \times 10^{-3}$

$= 1mA$

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

$= 10 - 1 \times 10^{-3} \times 4 \times 10^3$

$= 10 - 4$

$= 6V$

~~operating point~~ $V_{CE} = 6V$, $I_C = 1mA$

operating point (6V, 1mA)

Collector to base bias:-

Q:- It is required to set operating point by biasing with feedback resistor at $I_C = 1mA$, $V_{CE} = 6V$ if $\beta = 100$, $V_{CC} = 10V$, $V_{BE} = 0.3V$ (i) How will you do it.

(ii) What will be the new operating point, if $\beta = 50$ and all other circuit value will remain same.

Ai:- $R_C = \frac{V_{CC} - V_{CE}}{I_C}$

$= \frac{10 - 6V}{1mA} = \frac{4V}{1mA} = 4K\Omega$

$R_B = \frac{(V_{CC} - V_{BE}) - I_C R_C)\beta}{I_C}$

$= \frac{(10 - 0.3 - 1 \times 10^{-3} \times 4 \times 10^3)100}{1 \times 10^{-3}}$

~~= 5740KΩ~~

$= 570K\Omega$

$$I_C = \frac{V_{CC} - V_{CE}}{R_C}$$

$$= \frac{10 - 6}{4 \times 10^3}$$

(ii) $\beta = 50$

$$R_B = \frac{(V_{CC} - V_{BE} - I_C R_E)\beta}{I_C}$$

$$\Rightarrow 570 \times 10^3 = \frac{(10 - 0.3 - I_C \times 4 \times 10^3)50}{I_C}$$

$$\Rightarrow 570 \times 10^3 \times I_C = 9.7 \times 50 - I_C \times 4 \times 10^3 \times 50$$

$$\Rightarrow I_C (570 \times 10^3 + 200 \times 10^3) = 9.7 \times 50$$

$$\Rightarrow I_C = \frac{9.7 \times 50}{570 \times 10^3 + 200 \times 10^3}$$

$$= \frac{9.7 \times 50}{570 \times 10^3} = \frac{9.7 \times 50}{770 \times 10^3}$$

$$= 0.63 \text{ mA}$$

$$V_{CE} \leq V_{CC} - V_{CE} - I_C R_C = 0$$

$$\Rightarrow V_{CE} = V_{CC} - I_C R_C$$

$$= 10 - 0.63 \times 10^{-3} \times 4 \times 10^3$$

$$= 10 - 0.63 \times 4$$

$$= 7.48 V$$

New operating point $(V_{CE}, I_C) = (7.48 V, 0.63 mA)$

D-11.9.19 TRANSISTOR AMPLIFIER Chapter

↳ One of the most important function of electronic ckt is amplification.

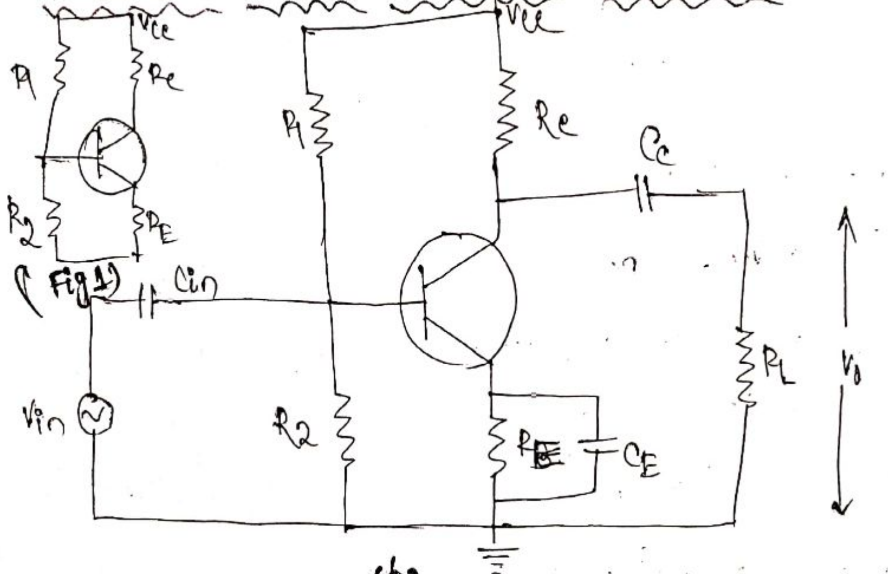
↳ In absence of this property many other specific circuit function could not be possible.

↳ For example oscillator to produce sine wave, square wave or any other desired wave shape could not be possible.

Almost all electronic system use amplifier.

✱ So an amplifier is defind as a devices that increases the voltage, current or power of an input signal with aid of transistor.

Pratical ckt of transistor amplifier :-



(b)

↳ A pratical ckt of transistor amplifier in common emitter configuration is shown in above figure.

↳ Fig (a) represent the voltage divider biasing circuit. The various ckt elements and their function are :-

circuit:-

... R_1, R_2 & R_E from the biasing and stabilisation cx.

Load R_L:-

The resistance R_L is connected are the output is known as load: when a number of stages is used then, R_L represent the input resistance of next stage.

Coupling capacitance C_C:-

→ The capacitor passes ac signal from one side to another. It's value is approximetly 10μF

→ This is also known as "blocking capacitance" because it does not allow the dc voltage to pass through it.

→ Due to presence of C_C the output across the resistor R_L is free from the collector dc voltage.

(IV) Input capacitor C_{in} :-

→ This capacitor couples the signal to the base of transistor

→ This is an electrolyte capacitor of value of approximetly 10μF.

→ In absence of this capacitor the source resistance will come in parallel with R_2, and thus change the bias.

(V) Emitter bypass capacitor C_E:-

→ This capacitor C_E acts as a bypass capacitor. Its value approximetly 100μF.

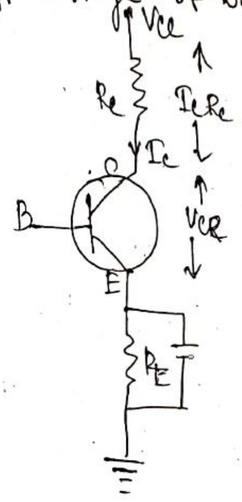
→ This provide a low ~~reactanc~~ reactance path to amplifiee ac signals.

→ In presence of C_E amplified ac signal will pass through this.

DC load line:–

The DC load line is a line on the output characteristics of a transistor which gives the value of I_C and V_{CE} corresponding to zero signal condition.

~~Consider the o/p voltage of basic amplifier ckt:–~~



Consider the o/p. voltage of the basic amplifier ckt shown in fig.

Applying KVL we have,

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

$$\Rightarrow V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

$$\Rightarrow \boxed{V_{CE} = V_{CC} - I_C (R_C + R_E)} \quad (\because I_E \simeq I_C)$$

Here V_{CC} & $R_C + R_E$ is constant, therefore it represent a straight line known as "load line".

The load line can be plotted in following way:–

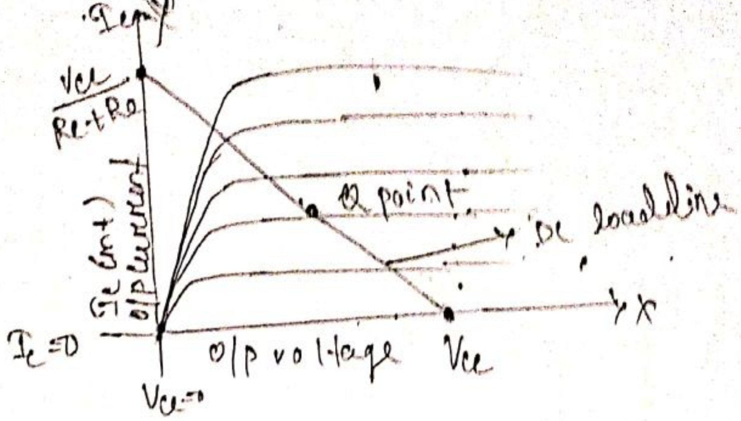
(i) when we put $I_C = 0$ the V_{CE} would be max^m

$$V_{CE(max)} = V_{CC}$$

(ii) when we put $V_{CE} = 0$ then;

$$0 = V_{CC} - I_C (R_C + R_E)$$

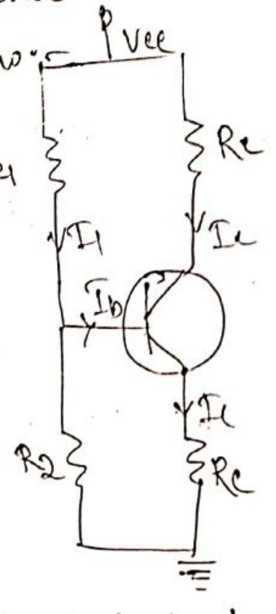
$$\Rightarrow \boxed{I_C = \frac{V_{CC}}{R_C + R_E}}$$



DC equivalent ckt :-

In case of DC equivalent ckt no signal is applied and all the capacitor look like open ckt. Thus to draw the equivalent ckt we open all the capacitor and reduce all ac sig source to zero.

The DC equivalent ckt of a transistor amplifier is shown below:-



(DC equivalent ckt)

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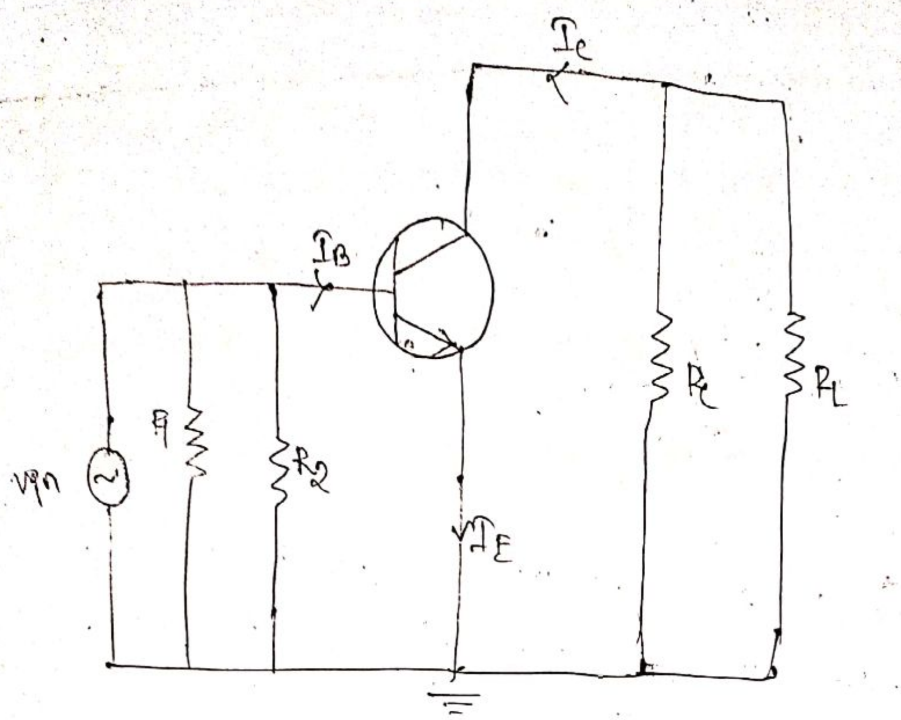
AC equivalent circuit:-

⇒ For AC equivalent ckt only a.c condition are to be consider

⇒ In this case the variations are so fast that the capacitor may be treated as short ckt.

⇒ We need not consider DC supply.

⇒ In order to draw AC equivalent ckt we reduce all DC sources to zero & a short ckt all the capacitor.



(Ac equivalent circuit)

Ac load line:-

↳ The variation in the collector current & voltage are seen with the help of ac load line. Corresponding to this ac load. Hence ac load line is different from dc load line.

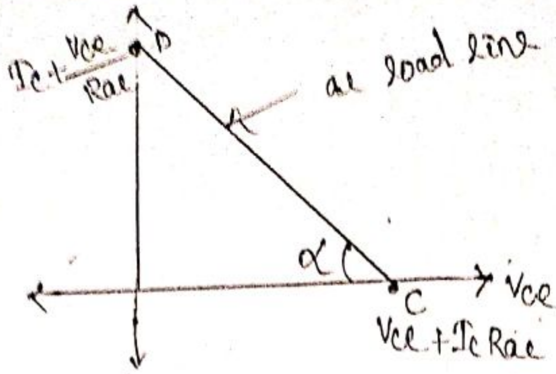
↳ As regards ac signals the transistor amplifier ac load R_{ac}.

$$R_{ac} = R_C \parallel R_L$$

$$\boxed{R_{ac} = \frac{R_C \cdot R_L}{R_C + R_L}}$$

↳ Max^m collector, emitter voltage $= V_{CE} + I_C R_{ac}$.
This locate a point on collector emitter voltage axis.

↳ Max^m collector current $= I_C + \frac{V_{CE}}{R_{ac}}$. This locate a point on collector current axis.



Slope of ac load line:-

The slope of load line is given by; $\tan\alpha =$

$$\tan\alpha = \frac{OD}{OC}$$

$$= \frac{I_c + \frac{V_{ce}}{R_{ac}}}{V_{ce} + I_c R_{ac}}$$

$$= \frac{I_c + \frac{V_{ce}}{R_{ac}}}{R_{ac}\left(I_c + \frac{V_{ce}}{R_{ac}}\right)}$$

$$\frac{I_c + \frac{V_{ce}}{R_{ac}}}{V_{ce} + I_c R_{ac}} = \frac{\frac{I_c R_{ac} + V_{ce}}{R_{ac}}}{V_{ce} + I_c R_{ac}} = \frac{1}{R_{ac}}$$

$$\boxed{\text{Slope} = \frac{1}{R_{ac}}}$$

Calculation of Gain:-

$$\text{Current gain} = \frac{I_c(max) - I_c(min)}{I_b(max) - I_b(min)}$$

$$\text{Voltage gain} = \frac{V_{ce}(max) - V_{ce}(min)}{V_{in}(max) - V_{in}(min)}$$

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Calculation of gain using ckt analysis:-

$$R_{ac} = R_c \parallel R_L$$

$$= \frac{R_c \cdot R_L}{R_c + R_L}$$

$$R_{in} = R_1 \parallel R_2$$

$$\text{Voltage gain} = \frac{V_{out}}{V_{in}}$$

$$\text{output voltage} = I_c \times R_{ac}$$

Input voltage = $I_b \times R_{in}$

voltage gain = $A_v = \frac{V_{out}}{V_{in}}$

$= \frac{I_c \times R_{ac}}{I_b \times R_{in}}$

$= \frac{I_c}{I_b} \times \frac{R_{ac}}{R_{in}}$

$= \beta \times \frac{R_{ac}}{R_{in}}$ $\left(\because \frac{I_c}{I_b} = \beta\right)$

Power gain = A_p = $\frac{\text{output power}}{\text{input power}}$

$= \frac{I_c^2 \times R_{ac}}{I_b^2 \times R_{in}}$

$= \frac{I_c^2}{I_b^2} \times \frac{R_{ac}}{R_{in}}$

$\boxed{A_p = \beta^2 \times \frac{R_{ac}}{R_{in}}}$ $\left(\because \frac{I_c^2}{I_b^2} = \beta^2\right)$

Q:- $R_c = 5k\Omega$, $R_L = 10k\Omega$, $\beta = 100$, $R_{in} = 2k\Omega$, find the ac load R_{ac} voltage gain & power gain.

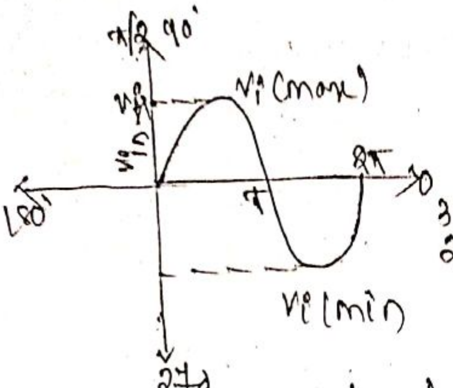
$R_{ac} = \frac{5 \times 10}{5+10} = 3.33$

$A_v = 100 \times \frac{3.33}{2} = 166.5$

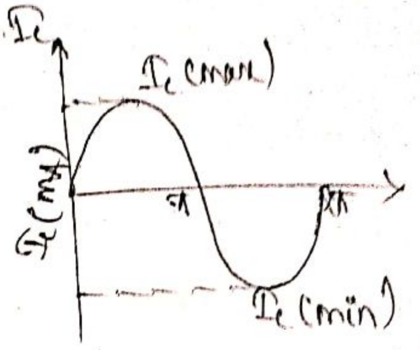
$A_p = (100)^2 \times \frac{3.33}{2} = 16650$

Phase Reversals—

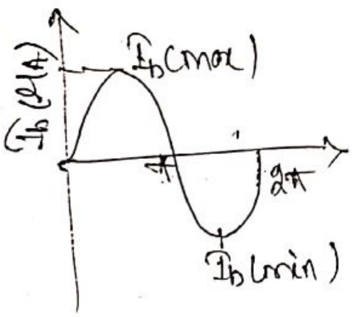
The phase difference of 180° bet^n i/p voltage & o/p voltage in common emitter amplifier is known as "Phase reversal".



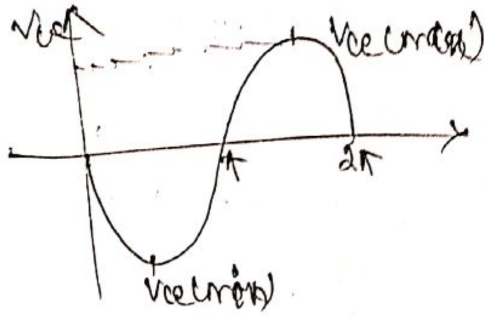
(input voltage)



(output current)



(Input current)



(Collector emitter voltage)

When the base current is max^m in –ve direction Collector emitter voltage (V_{CE}) in max^m in +ve direction. In this way the i/p and the o/p voltage are in opposite phase. Thus the transistor produce 180° Phase reversal bet^n i/p & o/p voltage.

D-27.9.18

CHAPTER D-5.11.18 HYBRID MODEL

Hybrid Model (H-parameter):-

$(v_1, i_2) = f(i_1, v_2)$

Here, v_1, i_2 are two dependent parameter.

i_1, v_2 are two Independent parameter.

we have to represent V_1 in terms of parameter i_1 & V_2.

Similarly,

we represent I_2 in terms of parameter i_1 & v_2.

$V_1 = h_{11} i_1 + h_{12} V_2$

$i_2 = h_{21} i_1 + h_{22} V_2$

Assuming short circuit condition in o/p port

$V_2 = 0$

$V_1 = h_{11} i_1$ $\{h_{11} = \frac{V_1}{i_1}$ (input impedance)

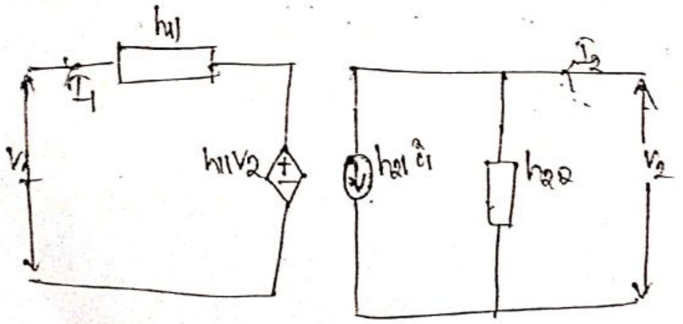
$i_2 = h_{21} i_1$ $\{h_{21} = \frac{i_2}{i_1}$ (Forward current gain)

Assuming open circuit condition in i/p port.

$i_1 = 0$

$V_1 = h_{12} V_2$ $\{h_{12} = \frac{V_1}{V_2}$ revers voltage gain)

$i_2 = h_{22} V_2$ ($h_{22} = \frac{I_2}{V_2}$ output admitance)



~~Simpl~~

Simplified CE hybrid parameters–

We use hybrid parameter i.e. $h_{11}, h_{12}, h_{21}, h_{22}$ in different transistor configuration such as :- Common base, Common collector, Common emitter.

* For common emitter,
  h_{11} = input impedance.

  we use this parameter as :- h_{ie}

  Similarly for common base h_{ib}

  for common collector :- h_{ic}

* h_{12} :- revers voltage gain
  for : common emitter :- h_{re}
  common base :- h_{rb}
  common collector :- h_{rc}

* h_{21} :- Forward current gain
  Common emitter :- h_{fe}
  Common base :- h_{fb}
  Common collector :- h_{fc}

* h_{22} :- o/p adimetance
  Common emitter :- h_{oe}
  Common base :- h_{ob}
  Common collector :- h_{oc}

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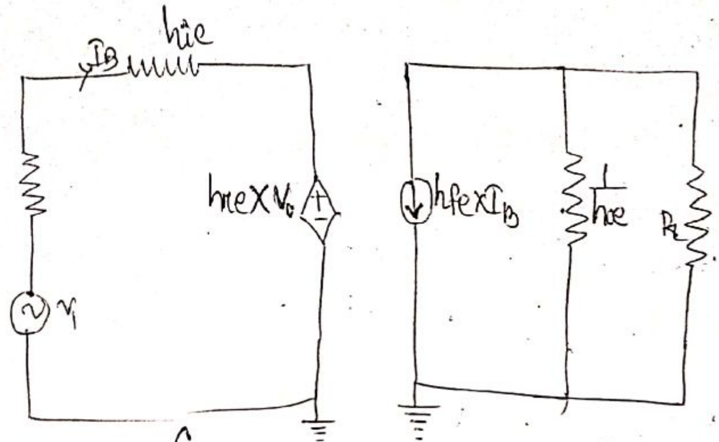
⇒ We have claculate current gain, voltage gain, input impedance and output impedance in different configuration of a transistor using H-parameter.

⇒ In most of the practical circuit we may use simplified Hybrid-model such an approximately model is justify because H-parameter.

⇒ Since CE configuration is most widely used it is taken for consideration.



(Exact CE Hybrid Model)

⇒ We proceed to find simplified approximate and accurate version of this model.

⇒ From the figure the resistance $\left(\frac{1}{h_{oe}}\right)$ appears in parallel with load resistance R_L.

⇒ The collector current is given by; forward current gain × input current $(h_{fe} \times I_B)$

$V_0 = I_c R_L$

$$\boxed{V_0 = h_{fe} \times I_B \times R_L}$$

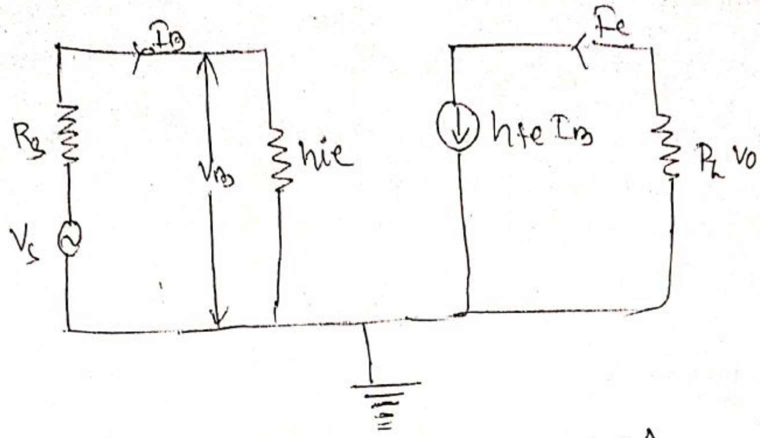
⇒ According to magnitude of voltage generation in emitter circuit also gets modified. It is given by; $h_{re} \times V_0$

$= h_{re} \times h_{fe} \times I_B \times R_L$

Since $h_{re} \times h_{fe} \simeq 0.01$

⇒ This voltage may be neglected in comparison with the voltage drop across hie $= hie \times I_B$. provided that R_L is not too large.

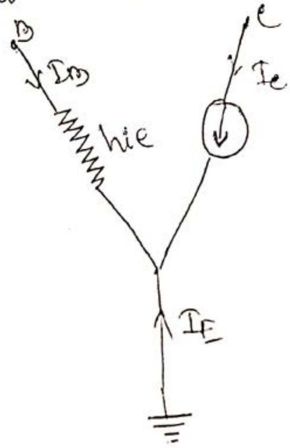
⇒ Thus it becomes possible to neglate parameter hoe & hre in approximate CE hybrid model and used only remainly to other H-parameter (hfe, hie)



(Approximate CE hybrid model)

Generalised approximate model:-

⇛ The approximate CE h-model is re-drawn.

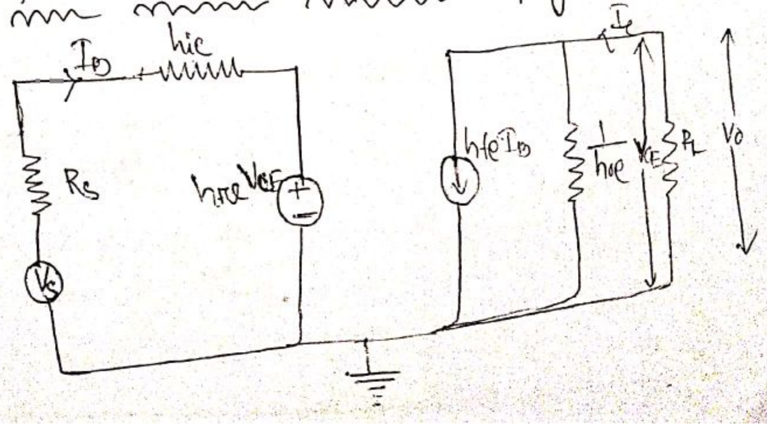


(Generalised CE hybrid model)

⇛ This model can be used for any configuration by shifting grounding the approcreat terminal ;

⇛ It is observed that the error in calculating Z_i, A_i, A_v, Z_o by the use of approximate model is less than 10%.

Analysis of a transistor Amplifier using H-parameters:-



The hybrid eq^n for this configuration is given by;

$$V_{BE} = I_b \times h_{ie} + V_{CE}\, h_{re} \quad \text{—— (1)}$$

Similarly, $$I_c = h_{fe} I_b + V_{CE} \times h_{oe} \quad \text{—— (2)}$$

$$V_{CE} = -I_c R_L \quad \text{—— (3)}$$

(i) Current gain :- (A_{ie}) :-

The current gain is defined as the ratio of o/p current to the i/p current.

$$A_{ie} = \frac{I_L}{I_b} = \frac{-I_c}{I_b}$$

Substituting V_{CE} from eq^n (3) in eq^n (2) we get,

$$I_c = h_{fe} I_b - I_c R_L \times h_{oe}$$

$$\Rightarrow I_c + I_c R_L h_{oe} = h_{fe} I_b$$

$$\Rightarrow I_c (1 + R_L h_{oe}) = h_{fe} I_b$$

$$\Rightarrow \frac{I_c}{I_b} = \frac{h_{fe}}{1 + R_L \times h_{oe}}$$

$$A_{ie} = -\frac{I_c}{I_b}$$

$$\Rightarrow \boxed{A_{ie} = -\left(\frac{h_{fe}}{1 + R_L h_{oe}}\right)}$$

(ii) Input resistance (R_i/Z_i) :-

This is defined as the ratio of i/p voltage across the i/p terminal of an amplifier to the i/p current.

$$Z_i \text{ or } R_i = \frac{V_{be}}{I_b}$$

Substituting the value of I_c from eq^n (3) in eq^n (2). we get,

$$I_c = h_{fe} I_b + V_{ce} h_{oe}$$

$$V_{ce} = -I_c R_L$$

$\Rightarrow I_c = -\frac{V_{ce}}{R_L}$

$I_c = h_{fe} I_b + V_{ce} h_{oe}$

$\Rightarrow -\frac{V_{ce}}{R_L} = h_{fe} I_b + V_{ce} h_{oe}$

$\Rightarrow -\frac{V_{ce}}{R_L} - V_{ce} h_{oe} = h_{fe} I_b$

$\Rightarrow -V_{ce}\left(\frac{1}{R_L} + h_{oe}\right) = h_{fe} I_b$

$\Rightarrow -\frac{V_{ce}}{I_b} = \frac{h_{fe}}{\frac{1}{R_L} + h_{oe}}$

$$\boxed{\Rightarrow \frac{V_{ce}}{I_b} = -\left(\frac{h_{fe}}{\frac{1}{R_L} + h_{oe}}\right)}$$

from eqn (1) $V_{be} = I_b h_{ie} + V_{ce} \cdot h_{re}$

$\Rightarrow \frac{V_{be}}{I_b} = \frac{I_b \cdot h_{ie}}{I_b} + \frac{V_{ce} \cdot h_{re}}{I_b}$

$\Rightarrow \frac{V_{be}}{I_b} = h_{ie} + h_{re}\left(\frac{V_{ce}}{I_b}\right)$

$\Rightarrow \frac{V_{be}}{I_b} = h_{ie} + h_{re}\left(\frac{-h_{fe}}{\frac{1}{R_L} + h_{oe}}\right)$

$\Rightarrow \frac{V_{be}}{I_b} = h_{ie} - \frac{h_{re} h_{fe}}{\frac{1}{R_L} + h_{oe}}$

$$\boxed{Z_i \text{ or } R_i = h_{ie} - \frac{h_{re} h_{fe}}{\frac{1}{R_L} + h_{oe}}}$$

(iii) Voltage gain (A_V) :-

Voltage gain is defind as the ratio of o/p voltage to the i/p voltage.

$A_{ve} = \frac{V_{ce}}{V_{be}}$

R_{ie} or $Z_{ie} = \frac{V_{be}}{I_b}$

$\Rightarrow V_{be} = I_b \times R_{ie}$

$$A_{ve} = \frac{V_{ce}}{I_b \times R_{ie}}$$

$$\Rightarrow A_{ve} = \left(\frac{V_{ce}}{I_b}\right) \times \frac{1}{R_{ie}}$$

$$\boxed{\Rightarrow A_{ve} = \frac{-h_{fe}}{\frac{1}{R_L} + h_{oe}} \times \frac{1}{R_{ie}}}$$

(iv) output resistance or impedance :-

The o/p resistance R_{oe} is obtained by setting V_{be} to zero. R_L to ∞ and by driving o/p terminal from a generator from voltage V_{CE}.

The o/p resistance $R_{oe} = \frac{\text{output voltage}}{\text{output current}}$

$$\Rightarrow R_{oe} = \frac{V_{ce}}{I_c}$$

from eqn (2) $I_c = h_{fe} I_b + V_{ce} h_{oe}$

$$\Rightarrow \frac{I_c}{V_{ce}} = \frac{h_{fe} I_b}{V_{ce}} + \frac{h_{oe} \cdot V_{ce}}{V_{ce}}$$

$$\Rightarrow \frac{I_c}{V_{ce}} = \frac{h_{fe} \cdot I_b}{V_{ce}} + h_{oe}$$

$\left\{ \begin{array}{l} V_{be} = 0 \\ R_L = \infty \end{array} \right\}$ from eqn (1)

$$V_{be} = V_{ce} h_{re} + I_b h_{ie}$$

$$\Rightarrow 0 = V_{ce} h_{re} + I_b h_{ie}$$

$$\Rightarrow -V_{ce} h_{re} = I_b \cdot h_{ie}$$

$$\Rightarrow \frac{-V_{ce}}{I_b} = \frac{h_{ie}}{h_{re}}$$

$$\Rightarrow \boxed{\frac{V_{ce}}{I_b} = -\frac{h_{ie}}{h_{re}}}$$

$$\Rightarrow \frac{I_b}{V_{ce}} = -\frac{h_{re}}{h_{ie}}$$

$$\frac{I_c}{V_{ce}} = \frac{h_{fe} I_b}{V_{ce}} + h_{oe}$$

$$\Rightarrow \frac{I_c}{V_{ce}} = \frac{-h_{fe} \cdot h_{re}}{h_{ie}} + h_{oe}$$

$$\Rightarrow \frac{I_c}{V_{ce}} = \frac{-h_{fe} \cdot h_{re} + h_{oe} \cdot h_{ie}}{h_{ie}}$$

$$\Rightarrow \frac{V_{ce}}{I_c} = \frac{h_{ie}}{h_{oe} \cdot h_{ie} - h_{fe} \cdot h_{re}}$$

$$\Rightarrow R_{oe} = \frac{V_{ce}}{I_c} = \frac{h_{ie}}{h_{oe} h_{ie} - h_{fe} \cdot h_{re}}$$

$\Delta h = h_{ib} \cdot h_{ob} - h_{fb} \cdot h_{rb}$

characteristics	common emitter	common base	common collector
Input impedance	$R_{ie} = h_{ie} - \frac{h_{fe}\, h_{re}}{\frac{1}{R_L} + h_{oe}}$	$R_{ib} = h_{ib} - \frac{h_{fb} h_{rb} R_L}{1 + h_{oe} \times R_L}$	$R_{ic} = h_{ic} - \frac{h_{fc} \cdot h_{rc} R_L}{1 + h_{oc} \cdot R_L}$
voltage gain	$A_{ve} = \frac{-h_{fe}}{\frac{1}{R_L} + h_{oe}} \cdot \frac{1}{R_{ie}}$	$A_{vb} = \frac{-h_{fb} R_L}{h_{ib} + \Delta h R_L}$	$A_{vc} = \frac{-h_{fc} \cdot R_L}{h_{ic} + \Delta h \cdot R_L}$
Current gain	$A_{ie} = \frac{-h_{fe}}{1 + h_{oe} \cdot R_L}$	$A_{ie} = \frac{-h_{fb}}{1 + h_{ob} \cdot R_L}$	$A_{ic} = -\frac{h_{fc}}{1 + h_{oc} \cdot R_L}$
out put impedance	$R_{oe} = \frac{h_{ie}}{h_{ie} \cdot h_{oe} - h_{fe} \cdot h_{re}}$	$R_{ob} = \frac{R_s + h_{ib}}{R_s h_{ob} + h_{ib} \cdot h_{ob} - h_{fb} \times h_{rb}}$	$R_{oc} = \frac{R_s + h_{ic}}{R_s \cdot h_{oc} + \Delta h}$

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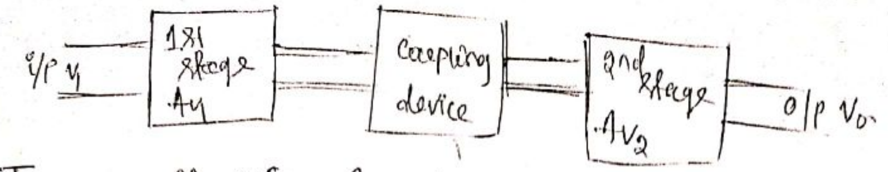
Multi stage transistor Amplifier:-

- When the voltage amplification or power gain of a single stage amplifier is in sufficient to meet the requirement then multistage transistor amplifier is used.
- In multi stage amplifier in o/p of the 1st stage is combined to the next stage through the coupling device. This process is called cascading.

⇒ A two stage amplifier connected in cascade



⇒ The over all gain of multi stage amplifier is equal to product of individual amplifier.

⇒ If A_v be the overall gain then $A_v = A_{v1} \times A_{v2}$

⇒ The following are the purpose of coupling device :-

→ To transfer the A.C output of one stage to the i/p of next stage.

→ To block the dc to pass from one stage to next stage.

⇒ The four basic method of couplings are :-

(I) Resistance and capacitance coupling

(II) Impedance coupling

(III) transformer coupling

(IV) Direct coupling

(i) Resistance and capacitance coupling :-

⇒ The amplifier using Rc coupling is known as "Rc coupled amplifier"

⇒ In this coupling a resistance or capacitor are used as coupling device.

⇒ The capacitor conects the o/p of 1st stage to i/p of next stage. to pass Ac signal & to block DC bias voltage.

(ii) Impedance coupling :-

⇒ Amplifier using this coupling is known as "impedance coupled amplifier"

→ This coupling network consists of inductance and capacitance. 41

(iii) Transformer Coupling:-

⇨ Amplifier using this coupling is known as "transformer coupled amplifier."

⇨ In this coupling transformer used as coupling device.

⇨ In this case there is capacitor is used as coupling device. because the secondary of coupling transformer convey the a.c component directly.

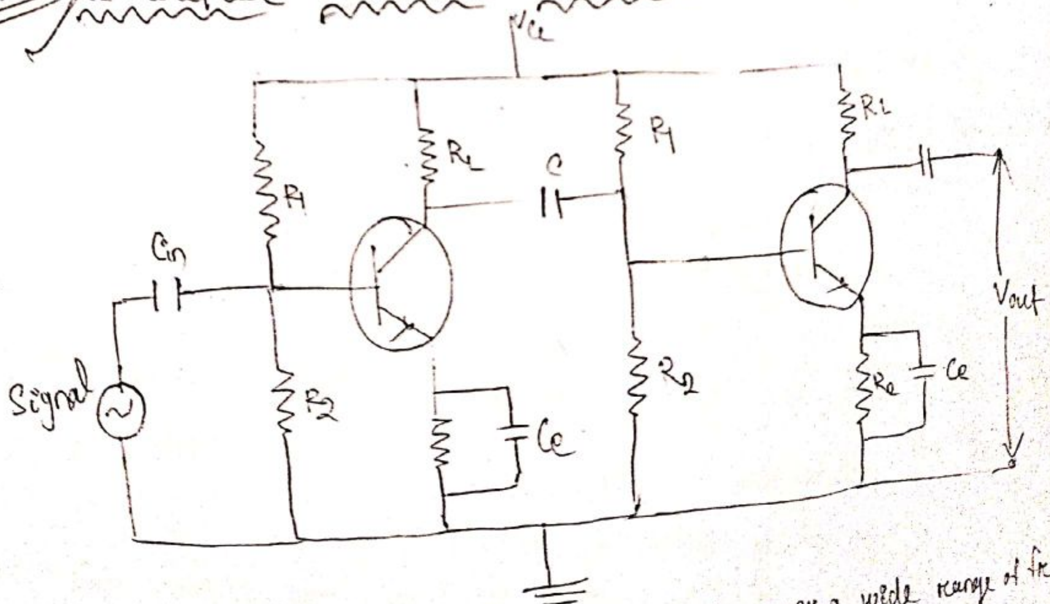
(iv) Direct coupling:-

⇨ Amplifier using this coupling is known as "Direct coupled device."

⇨ In this case the individual amplifier stage bias condition are so design that two stages may be directly connected without necessary DC isolation.

Imp ⇨ Thus the majority of transistor amplifier are of common emitter type. The resistance, capacitance network is most commonly used as coupling bet' two stages.

Imp RC-coupled transistor amplifier:



Application:- (i) They have excellent audio fedelity over a wide range of freq. (ii) widely used as voltage amplifier (iii) Due to poor impedance matching RC coupling is rarely used in final stage.

⇒ Fig. shows a two stage RC coupled amplifier using common emitter configuration.

⇒ The two transistors are identical & a common power supply Vcc is used.

⇒ The resistors R_1 & R_2 & R_E form the biasing and stabilization network.

⇒ The emitter by pass capacitor C_E offers low reactance path to signal.

⇒ The resistor R_L is used as load impedance.

⇒ The i/p capacitor C_{in} couples ac signal voltage to the base of transistor!

⇒ In absense of C_{in} the signal source will be in parallel with R_2.

⇒ The bias voltage of base will be changed.

⇒ Thus the fun of C_{in} is to allow only a.c current from signal flow to source to flow into the i/p ckt

⇒ The o/p of the 1st stage is coupled to the i/p of 2nd stage through a coupling capacitor 'C'.

⇒ This allow a-c signal to pass through it and blocks dc components.

⇒ When ac signal is applied to the base of 1st transistor it appears across collected load R_L. in the amplified form.

⇒ Through coupling capacitor C_E the amplified signal is transfer to the next stage of amplifier this is further amplied next stage.

⇒ So cascaded stage amplify the signal and overall gain is increased.

Analysis:-

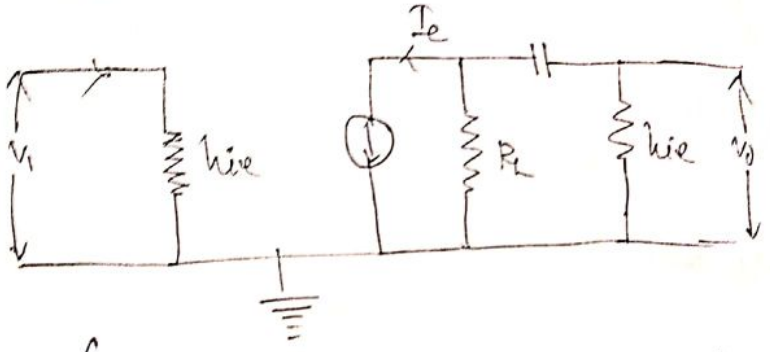
⇒ In the analysis RC coupled amplifier the following assumption is made.

(i) hre is so small that voltage source hre V_0 can be neglected.

(ii) $\frac{1}{hoe}$ is so large so it is open circuit.

(iii) The reactance of Ce for any given i/p freq. is so small that the parallel combination Re & Ce can be effectively consider as short ckt.

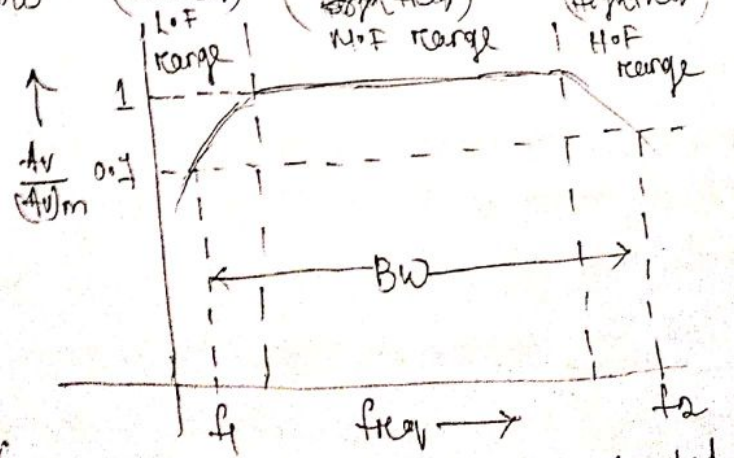
(iv) The bias resistor R_1 and R_2 are usually large as compare to hie



(Simplified equivalent ckt of RC coupled amplifier)

IMP Freq. response curve and bandwidth:-

The freq. response curve of RC coupled amplifier is shown below



(frequency response curve of RC coupled amplifier)

⇒ It is obvious from analysis of RC coupled amplifier that the gain of the amplifier is independent of freq. bet mid freq (MF) range but decreases at both high and low freq.

⇒ At low frequency the reactance of coupling capacitor $\left(\frac{1}{2\pi f c}\right)$ is quite high. Hence a very small part of a signal passes from one stage to the next stage.

⇒ At low freq the reactance of Ce is comparable to the resistance Re.

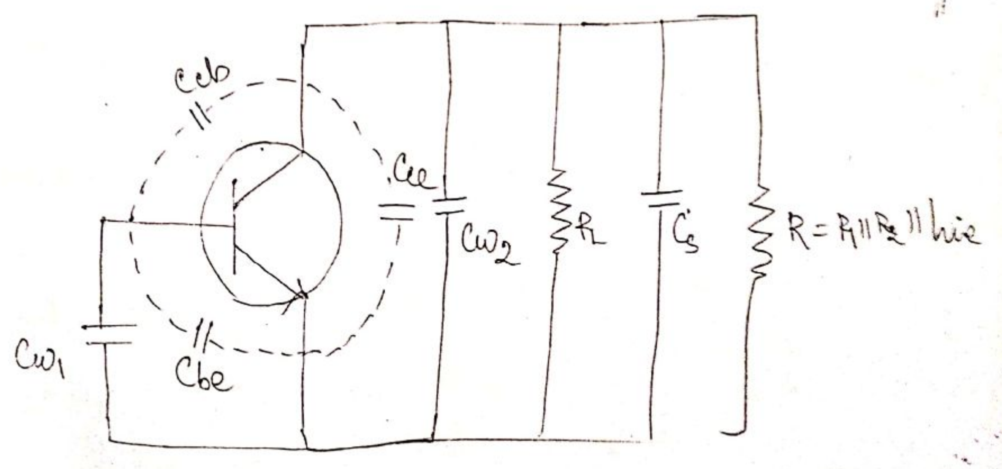
⇒ So the bypass action of this capacitor is no longer as could as at mid & high freq range. Hence it reduces the voltage.

⇒ At high freq. the capacitan Cbc betn base & collector connect the o/p with i/p.

⇒ As a result -ve feedback takes place. Hence gain decreases

⇒ Beside inter electrode capacitance there are wiring capacitance C_{w1}, C_{w2} and o/p capacitance C_{in}.

⇒ The effect of o/p circuit can be expressed by a single capacitance. C_s. $C_s = C_{ce} + C_{w1} + C_{in}$



(output section of high freq.)

Band width:—

⇒ The difference of upper cut-off freq. and lower cut-of freq. is called as band width.

$$BW = f_2 - f_1$$

⇒ when the BW is multiplied with the gain at mid freq this is called as gain band width (gBW)

⇒ we know the power ∝ square of voltage. Thus the power o/p at the cut-off freq become 1/2 of the power at the mid freq because

$$\frac{(AV)_L}{(AV)_m} = \frac{1}{\sqrt{2}}$$

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Transformer coupled circuit Amplifier:—

⇒ Here a coupling transformer T_1 is used to fed the o/p of 1st stage to the i/p of the next stage.

⇒ The collector load is replaced by primary winding of the transformer.

⇒ The secondary is connected betn base of 2nd stage and voltage divider i.e the secondary of transformer gives i/p to the next stage.

⇒ The transfer T_2 is the o/p transformer. The other components are same as in Rc coupled amplifier.

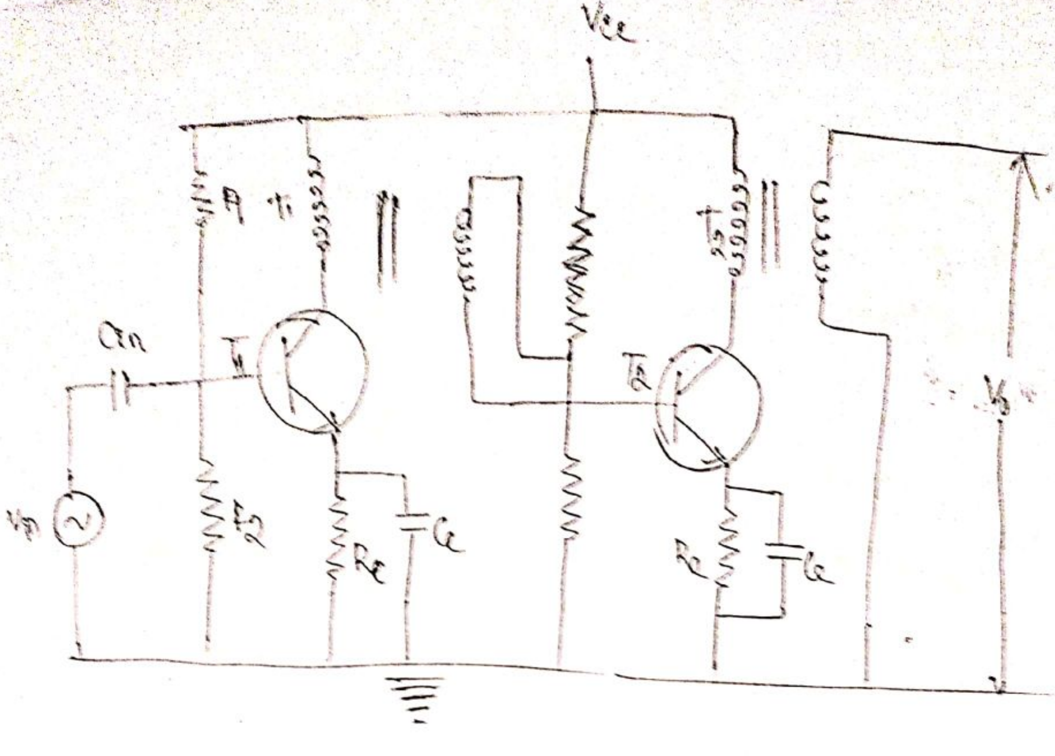
⇒ It should be noted that there is no coupling capacitor.

⇒ When i/p is applied to the base of transistor T_1 it is amplified and appears across the primary transformer T_1.

⇒ By magnetic induction it is passed to the secondary. Now the o/p is applied to the base of transistor T_2.

⇒ The amplified o/p appers across the primary of transformer T

⇒ The circuit diagram of two stage transformer coupled amplifier is shown below.



Advantage:-

⇒ The absence of resistor R2 in the collector circuit eliminates the unnecessary power loss in the resistor.

⇒ The operation of transformer coupled system is more efficient because of low dc resistance of primary ~~winding~~ connected in collector ckt.

⇒ Due to excellent impedance matching the transformer coupling provides higher gain

Dis advantage:-

⇒ It has poor freq. response.

⇒ The ckt transformer is bulky & costly.

Negative feedback in Amplifier:-

⇒ When a part of fraction of o/p is combined to the i/p feedback is said to exist.

⇒ Thus a process of a combining a fraction of o/p energy back to the i/p is known as "feed back".

⇒ If the net effect of feed back is to reduce the magnitude of i/p signal is called as -ve or inverse or de-generative.

⇒ The -ve feed back reduces the gain of amplifier

Imp Advantage of -ve feedback :-

⇒ Stabilization of gain reduction in distortion.

⇒ Reducing in noise.

⇒ Increase in i/p impedance.

⇒ Decrease in o/p impedance.

⇒ Increase in range of uniform amplification.

Positive feed back :-

⇒ If the net effect of feedback is to increase the magnitude of i/p signal it is called as "+ve direct or regenerative."

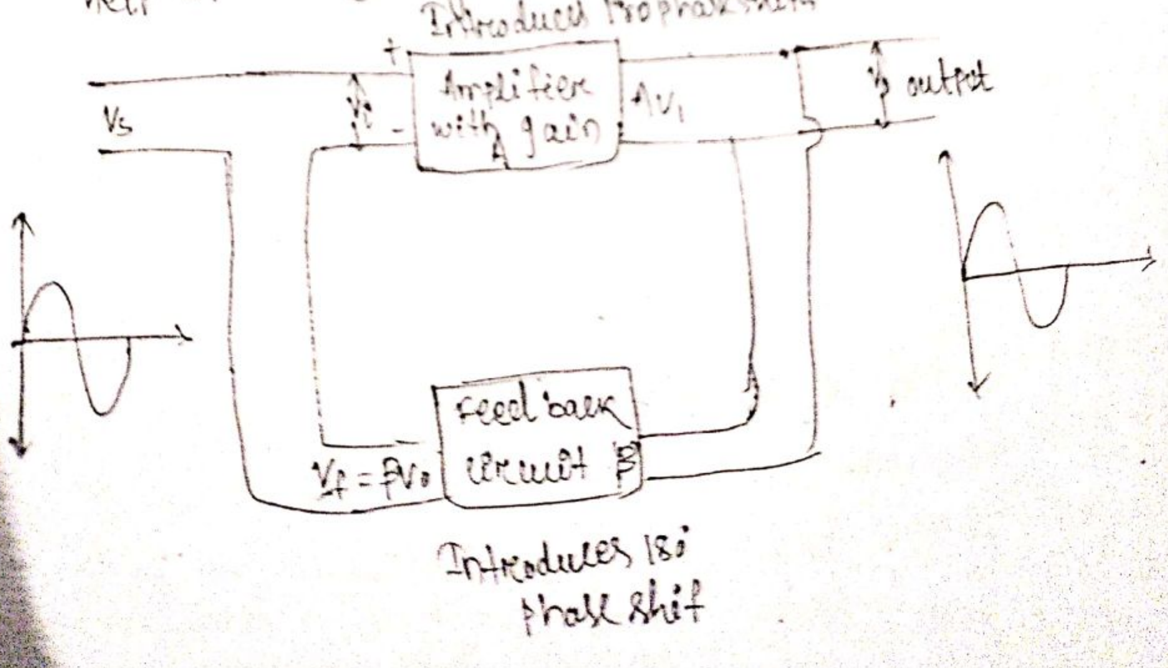
⇒ The +ve feedback has the dis-advantage of increased distortion and instability.

⇒ So +ve feed back is seldom used in amplifier.

General theory of feedback :-

The feedback amplifier are classified into two general classes :-
(i) voltage feedback
(ii) current feedback

The general theory of feedback can be understood with the help of block diagram.



⇒ The feedback amplifier have two parts :-

(i) Amplifier

(ii) feedback circuit

⇒ The feedback circuit usually consists of resistors.

⇒ This return a fraction of o/p voltage back to the i/p.

⇒ Let 'A' be the gain of amplifier. This is the gain of amplifier

⇒ The feed back network extract a voltage $V_f = \beta V_0$ from the o/p V_0 of the amplifier.

⇒ The voltage is added or subtracted from the signal voltage 'V_s'.

$V_i = V_s + V_f$ (for +ve feed back)

$V_i = V_s + \beta V_0$

Similarly, $V_1 = V_s - V_f$ (for +ve feed back)

$V_1 = V_s - \beta V_0$

⇒ Consider, in the case of -ve feed back the o/p V_0 must be equal to i/p voltage ($V_s - \beta V_0$ multiplied by gain 'A' of amplifier).

$(V_s - \beta V_0) A = V_0$

$\Rightarrow AV_s - A\beta V_0 = V_0$

$\Rightarrow AV_s = V_0 + A\beta V_0$

$\Rightarrow AV_s = V_0 (1 + A\beta)$

$$\Rightarrow \boxed{\frac{V_0}{V_s} = \frac{A}{1 + A\beta}}$$

⇒ Let A_f be the overall gain of the amplifier this is defind as the ratio of o/p voltage V_0 to the applied voltage V_s.

$$A_f = \frac{\text{output voltage}}{\text{I/p signal voltage}} = \frac{V_0}{V_s}$$

we have $\boxed{A_f = \frac{A}{1+A\beta}}$ (for -ve feed back).

Similarly, $\boxed{A_f = \frac{A}{1-A\beta}}$ (for +ve feed back)

we consider thus three cases:-

(i) for -ve feed back, $A_f < A$

(ii) for +ve feed back, $A_f > A$

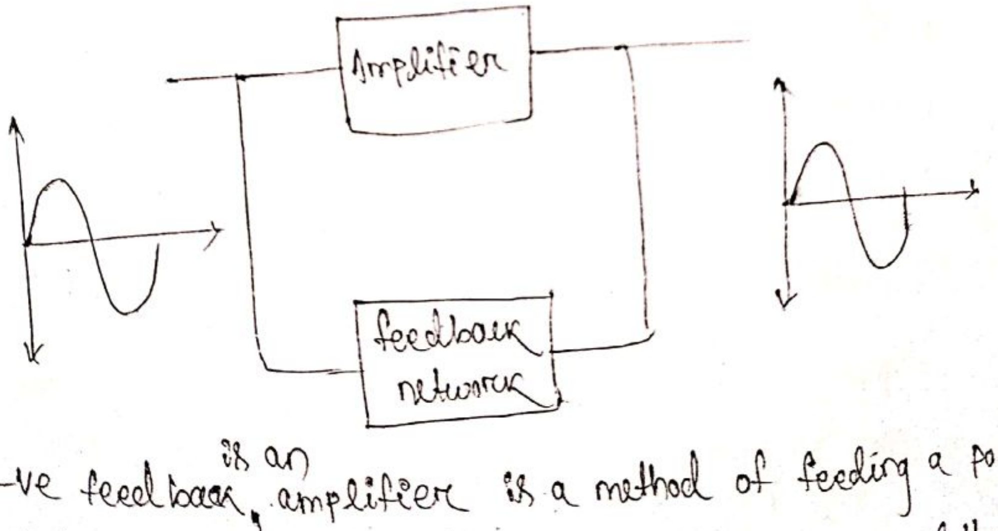
(iii) If $A\beta = 1$, then $A_f = \infty$

This is only possible when i/p is zero.

Negative feed back ckt:-

⇒ when the feed back signal is out of phase with the i/p signal and thus opposes it then the feed back is known as "-ve feed back".

⇒ The -ve feed back amplifier interduce phase shift of 180° in the i/p
⇒ While the feed back amplifier interduces no phase shift.
⇒ i.e the feed back network is desind such a way that it does not interduces any phase shift.



⇒ -ve feed back is an amplifier is a method of feeding a portion of the amplifier o/p energy back to the i/p of the amplifier.

There are two type of -ve feed back ckt

voltage feed back

voltage feed back :-

→ In this method the voltage feed back to the i/p of the amplifier is a portion of the o/p voltage.

→ This is further classified into two types :-

(i) voltage series feedback

(ii) voltage shunt feedback

negative current feedback :-

In this method the voltage feed back to the i/p of the amplifier is poportional to the o/p current.

It is further classified into two parts :-

(i) current series feedback

(ii) current shunt feedback

POWER AMPLIFIER :-

→ The power amplifier are large signal amplifier which raise the power level of the signal.

→ The power amplifier may also be defind as a device which converts DC power to AC power. whose action is controlled by the i/p signal.

→ Power amplifier takes power from dc power supply connected to o/p circuit & converts it into useful AC signal power.

→ The DC power is distributed acco. to the relation

DC power i/p = AC power o/p + losses

→ Power amplifiers divided in to two parts :-

(i) Audio power amplifier

(ii) Radio power Amplifier

Audio power amplifiers—

⇒ The audio power amplifier raise the power level of signal that have audio freq. range (20 Hz – 20 KHz).

⇒ They are also known as small signal power amplifier.

Radio Amplifiers—

⇒ Radio Amplifier or tuned power amplifier raise the power the power level of the signal that have radio freq. range (3 KHz – 300 GHz).

⇒ They are also known as "large signal power amplifier"

on the basis of mode of operation the portion of i/p cycle during which collector current flow the power amplifier may be classified as:-

(i) class-A power Amplifier
(ii) Class-B power Amplifier
(iii) class-C power Amplifier

(i) Class-A power Amplifier:—

When the collector current flow at all time during the full cycle of signal the power amplifier is known as "class A power Amplifier".

(ii) class-B power Amplifier:—

when the collector current flow only during the half cycle of the i/p signal the power amplifier is known as "class B power amplifier".

(iii) class-C power Amplifier:—

When the collector current flow for less than half cycle of the i/p signal the power amplifier is known as "class C power amplifier."

Difference betn voltage amplifier and power amplifier :-

voltage amplifier :-

⇒ The fun of voltage amplifier is to raise the voltage level of the signal.

⇒ The voltage amplifier is given by; $A_v = \beta\left(\frac{R_C}{R_{in}}\right)$

The voltage amplifier having following characteristics:-

- The transistor with high β should be used.
- The i/p resistance Rin should be low.
- Collector load should be high
- They are used for small signal voltage.

Power amplifier :-

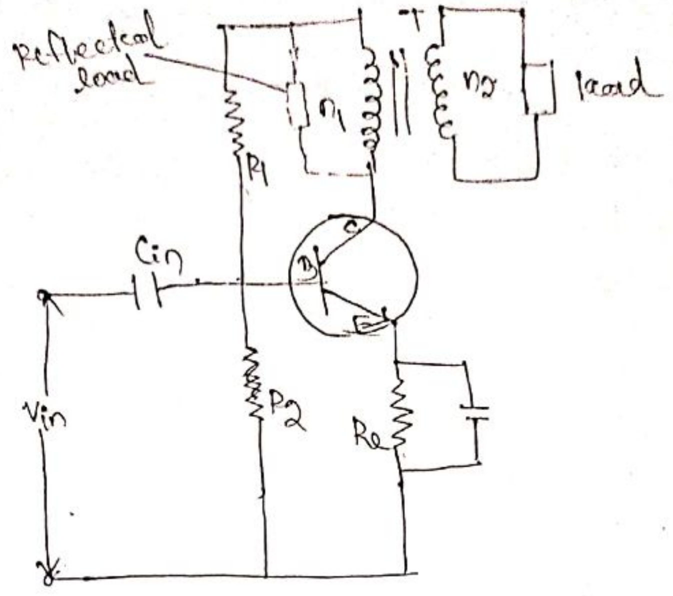
⇒ The fun of power amplifier is to raise the power level of the signal.

⇒ The power amplifier have following characteristics:-

- The transistor with comparatively low β is used.
- In order dissipate heat produced in transistor during operation
- Collector resistance made low.
- Transformer coupling is used.

Characteristics	voltage amplifier	power amplifier
β	high	low
Rc	high	low
o/p voltage	low	high
o/p impedance	high	low
Coupling	RC coupled amplifier	transformer coupling

Class A power amplifier (transformer coupled):-



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⇒ R_1 and R_2 provide a potential divider arrangement for forward biasing emitter base junction. of the power transistor.

⇒ The RE is emitter resistor for bias stabilisation C_E is bypass capacitor, RE. to prevent AC voltage.

⇒ The capacitor Cin blocks any dc from the previous stage. Input signal from pre-amplifier is applied to the i/p terminal.

⇒ T is the stepdown transformer. the high impedance primary of the transformer is connected to high impedance of the collector circuit.

⇒ The low impedance secondary is connected to load.

Transformer impedance matching:-

⇒ Let R_L is the load connected in secondary of a transformer

⇒ The reflected load in the primary of the transformer R_L'

⇒ n_1 and n_2 are the number of turns in primary and secondary respectively.

⇒ Let V_1 & V_2 be the primary and secondary voltage and i_1 and i_2 primary & secondary current respectively.

⇒ We know $\frac{V_1}{V_2} = \frac{n_1}{n_2}$ and $\frac{I_2}{I_1} = \frac{n_1}{n_2}$

$V_1 = \frac{n_1}{n_2} \times V_2$ and $I_2 = \frac{n_1}{n_2} \times I_1$

$\Rightarrow I_1 = \frac{n_2}{n_1} \times I_2$

$$\frac{V_1}{I_1} = \frac{\frac{n_1}{n_2} \times V_2}{\frac{n_2}{n_1} \times I_2}$$

$$\Rightarrow \frac{V_1}{I_1} = \frac{n_1^2}{n_2^2} \times \frac{V_2}{I_2}$$

$$\boxed{\Rightarrow R_L' = \left(\frac{n_1}{n_2}\right)^2 \times R_L}$$

Circuit operation:-

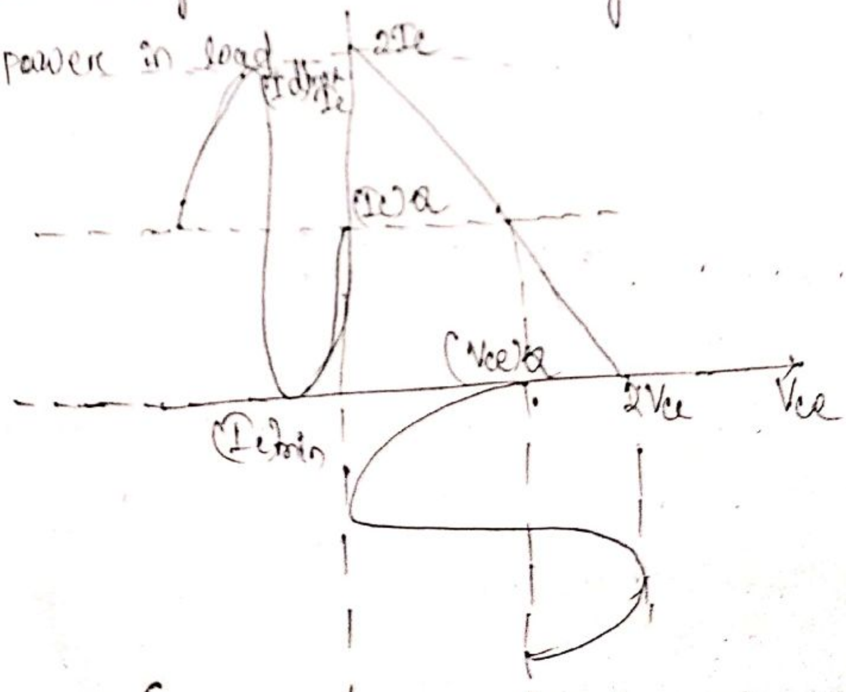
⇒ When ac signal is applied the collector current fluctuates

⇒ The operating point Q moves up and down the load line.

⇒ The collector voltage varies in opposite phase to the collector current.

⇒ The variation of collector voltage appears across the primary transformer.

⇒ The a.c voltage induced in secondary which in turns Ac power in load.



(output voltage & current wave form)

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→ The power loss in primary transformer is negligible small because its resistance is very small.

→ Under this condition $(P_{in})_{dc} = (P_{in})_{dc} = (I_c)_Q V_{CC}$

→ under max^n capacity of a class-A amplifier voltage swing bet^n V_{CC} max $(V_{CE})_{max}$ to zero and the current from $(I_c)_{max}$ to zero.

→ $V_{rms} = \frac{1}{\sqrt{2}}\left\{\frac{(V_{CE})_{max} - (V_{CE})_{min}}{2}\right\}$

$= \frac{1}{\sqrt{2}}\left\{\frac{2V_{CC}}{2}\right\}$

$= \frac{V_{CC}}{\sqrt{2}}$

$I_{rms} = \frac{1}{\sqrt{2}}\left\{\frac{(I_c)_{max} - (I_c)_{min}}{2}\right\}$

$= \frac{1}{\sqrt{2}}\left\{\frac{2I_{CQ}}{2}\right\}$

$= \frac{I_{CQ}}{\sqrt{2}}$

Power o/p = $V_{rms} \times I_{rms}$

$= \frac{V_{CC}}{\sqrt{2}} \times \frac{I_{CQ}}{\sqrt{2}}$

$= \frac{V_{CC} \cdot I_{CQ}}{2}$

Collector efficiency $= \frac{(P_o)_{out}}{(P_{in})_{dc}} \times 100$

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

$= \frac{1}{2} \times 100$

$= 50\%$

In pratical case the efficiency of power amplifier is less than 50%.

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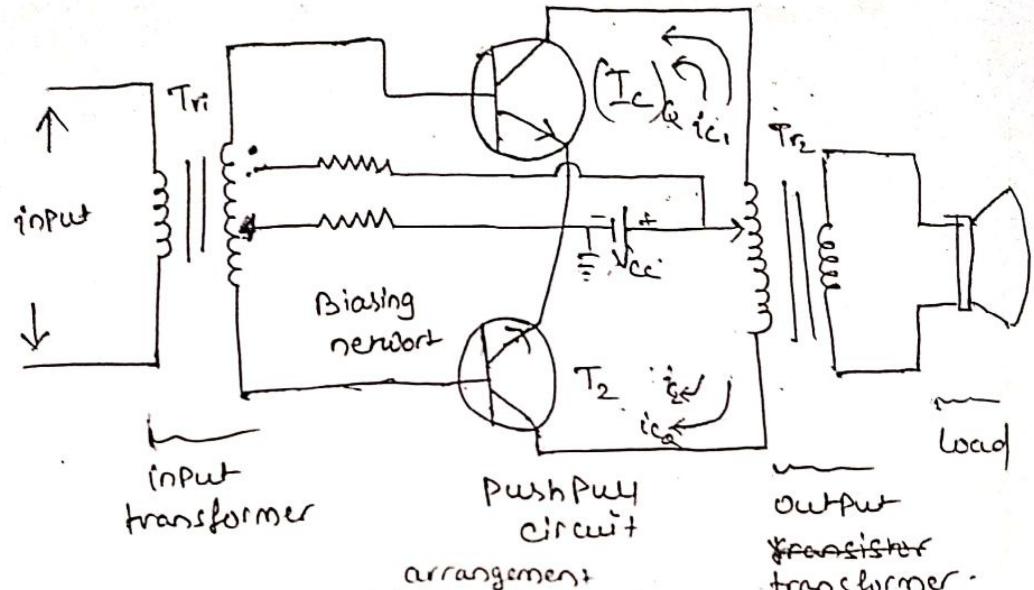
Class-A push pull power Amplifiers-

The distortion introduced by non-linearity of a dynamic transfer characteristics



⇒ In Pull Push amplifier two identical transistor T_1 & T_2 are used. The emitter terminals of two transistors are connected together the input signal is applied to the inputs of the two transistor through center tap transformer (Tr_1)

⇒ This transformer provides opposite polarity signal of the two transistor input

⇒ The collector of the both transistor are connected to the Primary of the output transformer (Tr_2) This transformer is also centre tap

⇒ The collector of both transistor are connected to supply V_{cc} through primary of output transformer

⇒ The Resistor R_1 & R_2 provides the biasing arrangement

⇒ The load (a loudspeaker) is connected across the secondary of output transformer

⇒ The turn ratio of the output transformer is chosen in such a way that the load is well matched with the O/P impedance of transi-

⇒ So maximum power is delivered to load by the amplifier

Advantage

⇒ Even harmonics are absent in the output
⇒ High AC O/P power
⇒ The effect of Ripple voltage contain in power supply due to inadequet.

Disadvantage

⇒ Two identical transistor are required
⇒ Centre tap transformer is required.

CLASS B : PUSH PULL POWER AMPLIFIER

We have seen that class A push pull power amplifier reduces the harmonic distortion but the conversation efficiency is only 50 %. To increase the efficiency class 'B' push pull amplifier is used

⑧ Overall efficiency of class B push pull amplifier:-

$$\text{Power input}(P_{in})_{dc} = V_{cc} \times I_{dc}$$

$$\text{we know } I_{dc} = \frac{(I_c)_{max}}{\pi}$$

$$(P_{in})_{dc} = \frac{V_{cc} \times (I_c)_{max}}{\pi}$$

$$\text{Rms value of collector current} = \frac{(I_c)_{max}}{\sqrt{2}}$$

$$\text{Rms value of voltage} = \frac{V_{cc}}{\sqrt{2}}$$

$$P_{out} = (P_o)_{ac} = \frac{1}{2} \times \frac{V_{cc}}{\sqrt{2}} \times \frac{(I_c)_{max}}{\sqrt{2}}$$

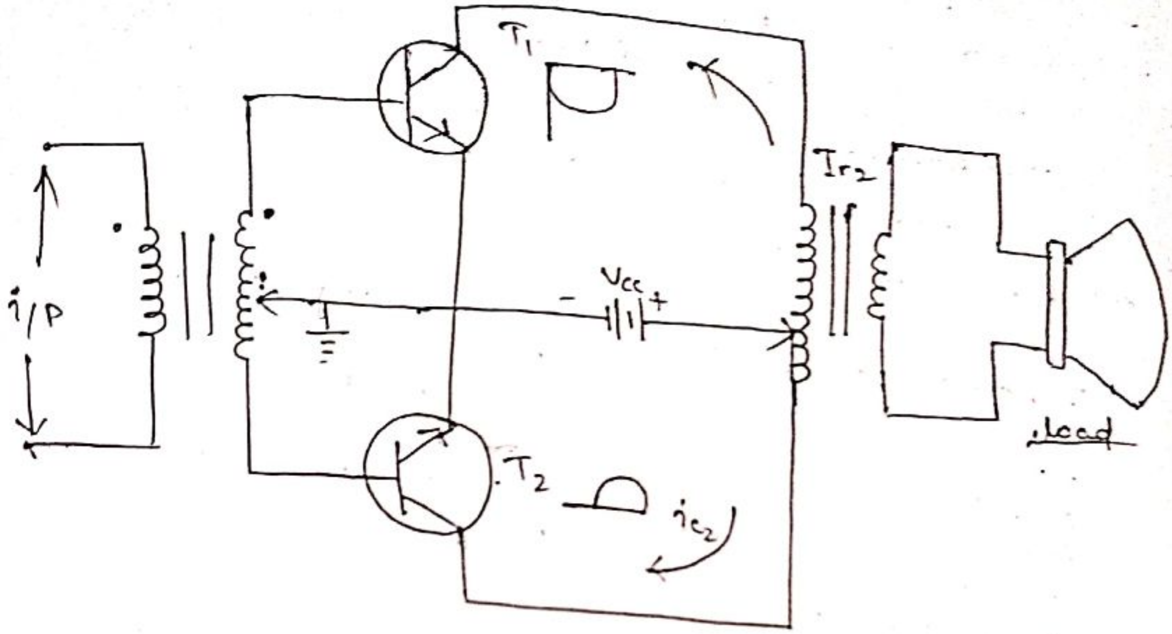
$$= \frac{V_{cc} \times (I_c)_{max}}{2 \times 2}$$

$$= \frac{V_{cc} \times (I_c)_{max}}{4}$$

$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\frac{V_{cc}\,(I_c)_{max}}{4}}{\frac{V_{cc} \times (I_c)_{max}}{\pi}}$$

$$= \pi/4 = 0.785 \times 100 = 78.5\,\%$$

Note	
Class A Push Pull	= 50%
Class B Push Pull	= 78.5%



Class B Push-Pull amplifier

- The circuit arrangement of class B Push Pull amplifier is same as that of class A Push Pull amplifier except that transistor are biased at cut off. This is done by Providing zero bias on the base of each transistor
- By connecting the base and emitter together
- As shown in fig. the bases of two CE connected identical transistor have been connected to the opposite end of secondary of the input transformer (Tr_1) & collectors ends to the primary of the output transformer (Tr_2). In order to get balanced circuit the emitter of the transistor are connected to the centre tap of the secondary of transformer (Tr_1) & V_{CC} is connected to the centre tap on the primary transformer (Tr_1) The two bases have been earthed

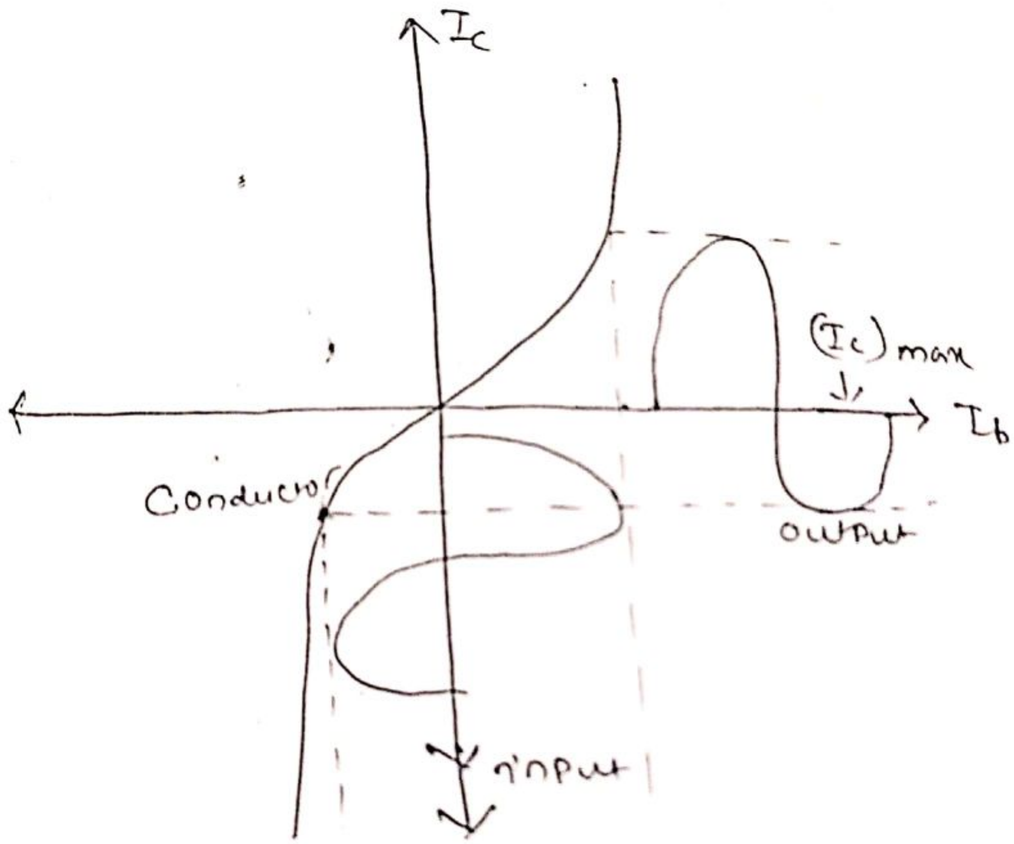
Advantage

⇒ It efficiency is greater than class A push pull Ampl

⇒ High AC output power

Disadvantage

The disadvantage of Class B is same as Class A.



Output wave form of class B push pull amplr