High - Frequency Analysis:

Topics to be covered:-

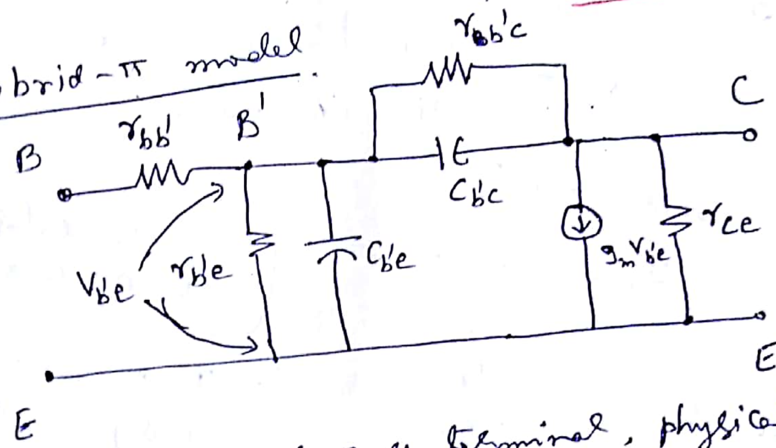
1) Hybrid - π model and typical parameter values.
2) Hybrid-π Conductances in terms of h-parameters.
3) short ckt current gain at HFs.
4) Definitions of f_β, f_α and f_T
5) Gain Bandwidth Product (Figure of Merit)
6) Current gain with load resistance (R_L)

1 Hybrid-π model and typical parameters values:

- h-parameter model is not valid at high frequency. At Low frequencies it is assumed that the rate of diffusion is larger than the rate of change of input voltage or current but at high frequencies this assumption is not valid. So, a new model, Hybrid-π model, is derived for BJT ~~at~~ ~~to~~ for the use at High frequencies.

GIACOLETTO model

Hybrid-π model.



- B' is the virtual Base terminal, physically can not be accessible.
- $r_{bb'}$ → Base Spreading Resistance.
- $r_{b'e}$ → the ~~dynamic~~ resistance across FB Emitter Junction.
- $C_{b'e}$ → Diffussion capacitance accross Emitter Junction
- $r_{b'c}$ → Reverse biased collector Junction resistance.
- g_m → Trans or Mutual Conductance
- r_{ce} → Resistance between Collector and Emitter.

(P.T.O.)

Note: Hybrid-π Conductances are sensitive to quiescent conditions. If I_c changes all conductances changes.

Typical values of Hybrid-π mode

for $I_C = 1.3\ mA$ at room temperature

$g_m = 50\ mA/V$; $r_{bb'} = 100\ \Omega$

$r_{b'e} = 1K\Omega$; $r_{b'c} = 4M\Omega$

$r_{ce} = 80\ K\Omega$; $C_c = 3\ pF$ &

$C_e = 100\ pF$.

② Hybrid-π Conductances in terms of h-parameters:

ⓐ Trans Conductance (g_m)

It is defined as

$$g_m = \left.\frac{\partial I_C}{\partial V_{B'E}}\right|_{V_{CE}=0}$$

We know that

$$I_C = I_{CO} - \alpha I_E$$

[From Transistor Current Components in CB Configuration]

$$\therefore g_m = -\alpha \frac{\partial I_E}{\partial V_{B'E}}$$

($\because I_{CO}$ is Constant and α is independent of $V_{B'E}$.)

$$g_m = +\alpha \frac{\partial I_E}{\partial V_E}$$ ~~for~~

[$\because$ for p-n-p transistor $V_E = -V_{B'E}$ and for n-p-n Transistor $V_E = +V_{B'E}$.]

$$\therefore g_m = \alpha \times \frac{1}{r_e}$$

[$\because r_e = \frac{\partial V_E}{\partial I_E}$ is the dynamic resistance of the Emitter Junction.]

P.T.O. ④

but we know that $r = \frac{\eta V_T}{I}$ for a given diode

$\therefore r_e = \frac{V_T}{I_E}$ for emitter Junction with $\eta = 1$.

$$\therefore g_m = \frac{\alpha I_E}{V_T}$$

$$g_m = \frac{I_{CO} - I_C}{V_T}$$

$$g_m = \frac{-I_C}{V_T} \quad \because |I_{CO}| << |I_C|$$

but for p-n-p ~~cha~~ transistor I_C is negative leaves the collector terminal.

$$\therefore g_m = \frac{I_C}{V_T} \quad \text{for p-n-p}$$

for n-p-n transistor I_C is positive but

$$V_E = +V_{B'E}$$

$$\therefore g_m = \frac{I_C}{V_T} \quad \text{for n-p-n}$$

in general for any transistor

$$\boxed{g_m = \frac{|I_C|}{V_T}}$$

(P.T.O.)

(b) Input Conductance ($g_{b'e}$) ($= \frac{1}{r_{b'e}}$)

The Hybrid-π model at low frequencies can be obtained as [∵ at low frequencies all capacitors are open]

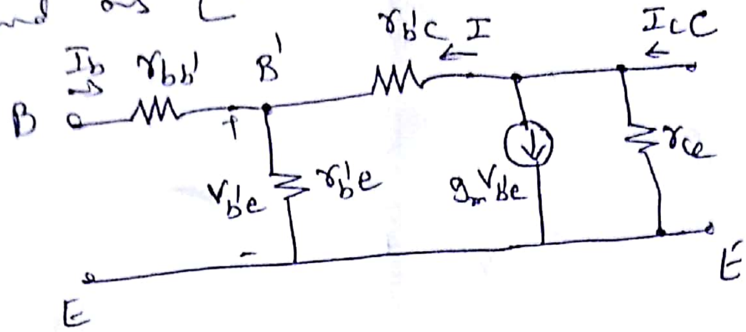


Fig : 1

and the h-parameter model valid for low frequencies is given below.

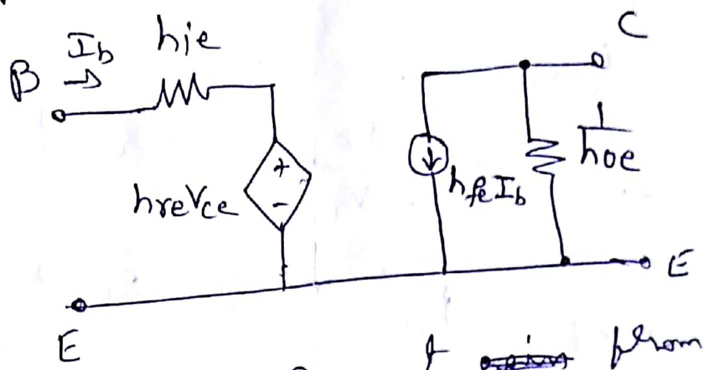


Fig : 2

The short circuit current ~~gain~~ from Fig : 1 is given by $-g_m V_{b'e}$ and the same from Fig : 2 is $-h_{fe} I_b$

$$\therefore h_{fe} I_b = g_m V_{b'e}$$

but $V_{b'e} \simeq I_b r_{b'e}$

$$\therefore h_{fe} \cancel{I_b} = g_m \cancel{I_b} r_{b'e}$$

$$\boxed{\therefore r_{b'e} = \frac{h_{fe}}{g_m}} \quad \text{or} \quad \boxed{g_{b'e} = \frac{g_m}{h_{fe}}}$$

<u>Note</u>: Since $g_m = \frac{|I_c|}{V_T}$ & $V_T = \frac{T}{11,600}$

$r_{b'e} \propto T$ and

$\propto \frac{1}{|I_c|}$

(P.T.O.)

(c) Feed back Conductance ($g_{b'c}$) $\left(= \frac{1}{r_{b'c}}\right)$

In Fig: 2, h_{re} is defined as

$$h_{re} = \frac{\text{o/p voltage}}{\text{o/p voltage}} = \left.\frac{V_{b'e}}{V_{ce}}\right|_{I_b = 0}$$

From Fig: 1

$$V_{ce} = (r_{b'e} + r_{b'c}) I$$

$$V_{b'e} = r_{b'e} I$$

$$\therefore h_{re} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}}$$

$$\therefore h_{re} r_{b'c} = (1 - h_{re}) r_{b'e} \simeq r_{b'e}$$

$\left[\because h_{re} << 1 \quad h_{re} = 10^{-4}\right]$

$$\boxed{\therefore r_{b'c} = \frac{r_{b'e}}{h_{re}}}$$

or

$$\boxed{g_{b'c} = h_{re}\, g_{b'e}}.$$

(d) Base - Spreading resistance ($r_{bb'}$)

From Fig: 2 the i/p resistance with o/p short ckt is h_{ie}.

From Fig: 1 when o/p short ckted then i/p impedance is given by $r_{bb'} + (r_{b'e} \| r_{b'c})$

$$\therefore h_{ie} = r_{bb'} + (r_{b'e} \| r_{b'c}) \qquad (\because r_{b'c} >> r_{b'e})$$

$$h_{ie} = r_{bb'} + r_{b'e}$$

$$\boxed{\therefore r_{bb'} = h_{ie} - r_{b'e}}$$

(P.T.O.)

(e)

~~For~~ The Output Conductance $g_{ce} \left(= \frac{1}{r_{ce}}\right)$

In Fig: 2 o/p Conductance, ~~is~~ when i/p is open-circuited (i.e. $I_b = 0$) is defined as hoe

From Fig: 1 when $I_b = 0$

$$I_c = \frac{V_{ce}}{r_{ce}} + \frac{V_{ce}}{r_{b'c} + r_{b'e}} + g_m V_{b'e}$$

$$\text{but } V_{b'e} = \frac{V_{ce}\, r_{b'e}}{r_{b'c} + r_{b'e}}$$

$$\text{and } r_{b'c} >> r_{b'e}$$

$$\therefore I_c = \frac{V_{ce}}{r_{ce}} + \frac{V_{ce}}{r_{b'c}} + \frac{g_m V_{ce}\, r_{b'e}}{r_{b'c}}$$

$$\therefore \frac{I_c}{V_{ce}} = \frac{1}{r_{ce}} + \frac{1}{r_{b'c}}(1 + h_{fe})$$

$$\therefore h_{oe} = g_{ce} + g_{b'c}(1 + h_{fe})$$

$$\boxed{\therefore g_{ce} = h_{oe} - g_{b'c}(1 + h_{fe})}$$

SUMMARY.

① $g_m = \frac{|I_c|}{V_T}$

② $g_{b'e} = \frac{g_m}{h_{fe}}$

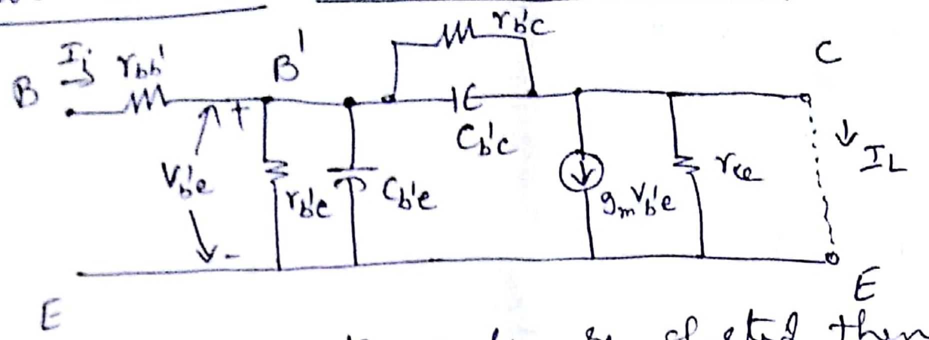
③ $r_{bb'} = h_{ie} - r_{b'e}$

④ $g_{b'c} = h_{re}\, g_{b'e}$

⑤ $g_{ce} = h_{oe} - (1 + h_{fe})\, g_{b'c}$

(P.T.O.)

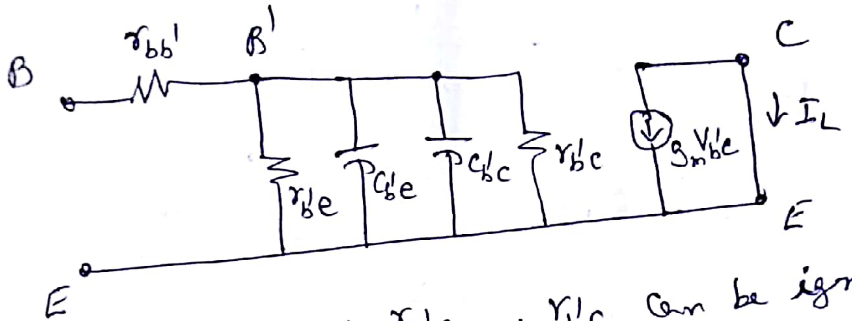
(3) Short circuit Current Gain at High Frequencies:



when o/p terminals are shorted then

$$I_L = -g_m V_{b'e}$$

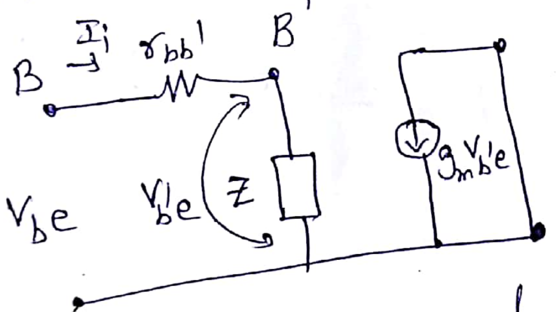
and the ckt can be represented as follows:



Since $r_{b'c} >> r_{b'e}$, $r_{b'c}$ can be ignored.

and $C_T = C_{b'e} + C_{b'c} = C_e + C_c$

Now the ckt can be represented as



$$\therefore V_{b'e} = I_i Z \quad \text{where}$$

$$Z = r_{b'e} \parallel jX_{C_T}$$

$$= \frac{r_{b'e} \frac{1}{j\omega C_T}}{r_{b'e} + \frac{1}{j\omega C_T}} = \frac{r_{b'e}}{1 + j\omega r_{b'e} C_T}$$

$$Z = \frac{r_{b'e}}{1 + j\frac{f}{f_H}}$$

where

$$f_H = \frac{1}{2\pi r_{b'e} C_T}$$

(P.T.O.)

$\therefore I_L = -g_m V_{b'e}$

$= -g_m I_i Z$

$\therefore A_{Isc} = -g_m Z$

$= \dfrac{-g_m r_{b'e}}{1 + j\dfrac{f}{f_H}}$

$|A_{Isc}| = \dfrac{h_{fe}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$ $\quad \underline{|180 - \tan^{-1}\left(\frac{f}{f_H}\right)}$

$$\boxed{\therefore A_{Isc} = \dfrac{-h_{fe}}{1 + j\dfrac{f}{f_H}}}$$

where $f_H = \dfrac{1}{2\pi r_{b'e}(C_e + C_c)}$

at $f < f_H \Rightarrow A_{Isc} = -h_{fe}$ and $\phi = 180^0$ MidBand Region

at $f = f_H \Rightarrow A_{Isc} = \dfrac{-h_{fe}}{\sqrt{2}}$ $\phi = 135^0$ [i.e. 3dB frequency

this f_H is represented with f_β, called as β-cut off frequency (in CE configuration)]

for $f >> f_H \Rightarrow A_{Isc} \simeq 0$ & $\phi = 90^0$.

(or) $f \to \infty$

Band Width: The frequency range upto f_β is reffered to as the band width of the ckt.

(P.T.O.)

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4 & 5 Figure of Merit (f_T) or Threshold Frequency:

f_T is defined as the frequency at which the short-circuit Common Emitter Current gain attains unity magnitude.

$$\therefore \frac{h_{fe}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}} = 1$$

$$\therefore h_{fe}^2 = 1+\left(\frac{f}{f_H}\right)^2$$

$$\therefore \left(\frac{f}{f_H}\right)^2 = h_{fe}^2 - 1 \qquad (\because h_{fe}^2 >> 1)$$

$$= h_{fe}^2$$

$$\boxed{\therefore f_T = f_H h_{fe}} \quad \text{GBP.}$$

This f is called as f_T

for CE Configuration $f_H = f_\beta \therefore f_T = f_\beta h_{fe}$

for CB Configuration $f_H = f_\alpha \therefore f_T = f_\alpha h_{fb}$

for CC Configuration $f_H = f_\gamma \therefore f_T = f_\gamma h_{fc}$

Note: f_T is a constant for a given transistor, hence from this we can say

$f_\alpha h_{fb} = f_\beta h_{fe} = f_\gamma h_{fc}$, $\boxed{f_\beta \simeq f_\gamma}$ $\because h_{fc} = 1 + h_{fe} \simeq h_{fe}$.

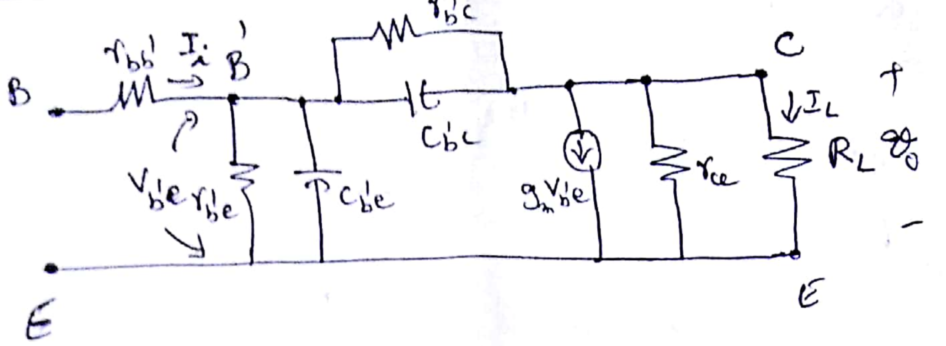
$\boxed{f_\alpha >> f_\beta}$ and

Large f_α makes CB as a video Amplifier.

Carry Forward

(P.T.O.)

⑥ Current Gain at HFs with load resistance (R_L):



Brought ~~Carry~~ Forward

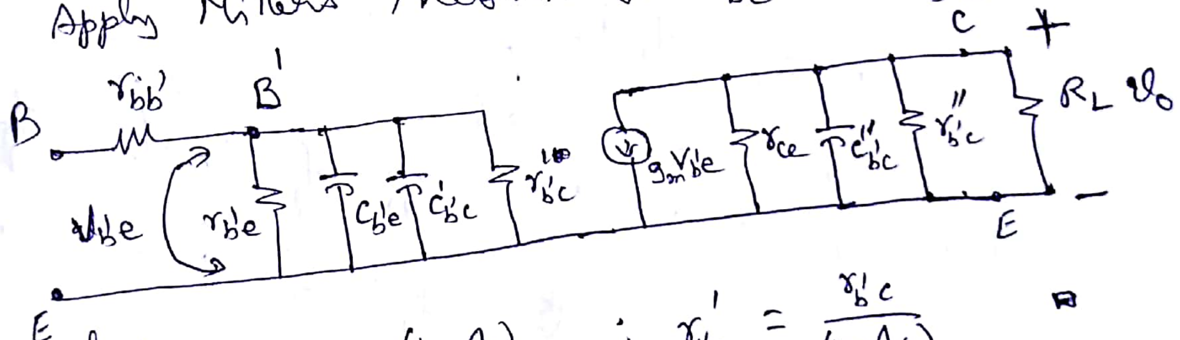
We know that $f_\beta = \dfrac{1}{2\pi r_{b'e}(C_e+C_c)}$

$\therefore f_T = \dfrac{h_{fe}}{2\pi r_{b'e}(C_e+C_c)}$ $\quad \because g_m = \dfrac{h_{fe}}{r_{b'e}}$

$$\boxed{\therefore f_T = \frac{g_m}{2\pi C_e}}$$

$C_e >> C_c$

step :1 Apply Miller's theorem on $r_{b'c}$ and $C_{b'c}$



where $C'_{b'c} = C_{b'c}(1-A_V)$; $r'_{b'c} = \dfrac{r_{b'c}}{(1-A_V)}$

$C''_{b'c} = C_{b'c}\left(1-\dfrac{1}{A_V}\right)$; $r''_{b'c} = \dfrac{r_{b'c}}{\left(1-\dfrac{1}{A_V}\right)}$

~~but~~ ~~we~~ ~~know~~ where $A_V = \dfrac{v_o}{v_{b'e}}$

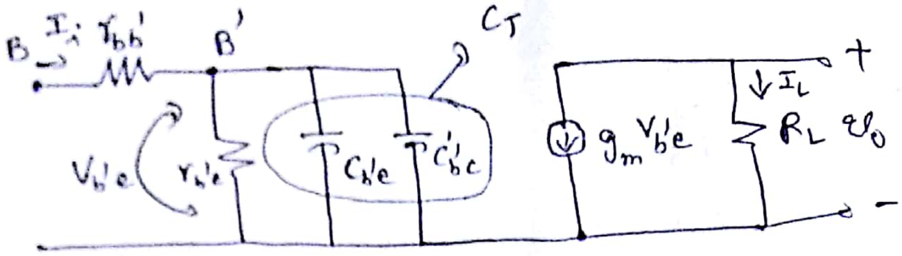
we know that $r'_{b'c} >> r_{b'e}$

$R_L << r_{ce}$ and $C''_{b'c} \simeq C_{b'c}$ $\quad \because A_V >> 1$

$R_L << r''_{b'c}$ ~~and hence neglected~~.

hence neglect r_{ce}, $r''_{b'c}$, $C''_{b'c}$ and $r'_{b'c}$, then the ckt be come

(P.T.O.)



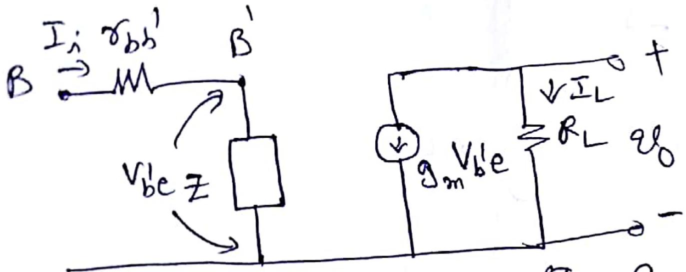
$$\therefore \quad v_o = -g_m V_{b'e} R_L$$

$$\therefore \quad A_v = \frac{v_o}{V_{b'e}} = -g_m R_L$$

hence $C'_{b'c} = C_{b'c}(1 + g_m R_L)$ this is called Miller's capacitance.

$\therefore$ total input capacitance $C_T = C_{b'e} + C_{b'c}(1 + g_m R_L)$

$$= C_e + C_c(1 + g_m R_L)$$



The current gain with R_L can be obtained as

$$A_{IHF} = \frac{I_L}{I_i} = \frac{-g_m V_{b'e}}{\frac{V_{b'e}}{Z}} = -g_m Z$$

where $Z = (r_{b'e}) \parallel (X_{C_T})$

$$= \frac{r_{b'e} \times \frac{1}{j\omega C_T}}{r_{b'e} + \frac{1}{j\omega C_T}}$$

$$= \frac{r_{b'e}}{1 + j\omega r_{b'e} C_T}$$

$$Z = \frac{r_{b'e}}{1 + j\left(\frac{f}{f_H}\right)}$$

where $\boxed{f_H = \frac{1}{2\pi r_{b'e} C_T}}$

(P.T.O.)

$$\therefore A_{IHF} = -g_m Z$$

$$= \frac{-g_m r_{b'e}}{1+j\left(\frac{f}{f_H}\right)}$$

$$A_{IHF} = \frac{-h_{fe}}{1+j\left(\frac{f}{f_H}\right)}$$ where $\boxed{f_H = \frac{1}{2\pi r_{b'e} C_T}}$

It can be observed that $f_H < f_\beta$

$$\boxed{f_\beta = \frac{1}{2\pi r_{b'e}(C_e + C_c)}}$$

Gain Band Width Product:

(a) Current GBT

$$|GBP| = |A_{mid}| \times BW$$

$$A_{mid} = -h_{fe}$$

$$BW = f_H = \frac{1}{2\pi r_{b'e} C_T}$$

$$\therefore |GBP| = \frac{h_{fe}}{2\pi r_{b'e} C_T} = \frac{g_m}{2\pi C_T}$$

including R_s $$|GBP| = \frac{g_m R_s}{2\pi C_T (R_s + r_{bb'})}$$

(b) Voltage GBP.

$$|GBP| = |A_{Vmid}| \times BW$$ (including R_s)

$$A_{Vmid} = -h_{fe} \times \frac{R_L}{R_s + r_{bb'}}$$

$$\therefore |GBP| = \frac{h_{fe}}{2\pi r_{b'e} C_T} \times \frac{R_L}{(R_s + r_{bb'})}$$

$$\boxed{|GBP| = \frac{g_m}{2\pi C_T} \times \frac{R_L}{R_s + r_{bb'}}}$$

(P.T.O.) → 9

Problems From Unit-II.

(1) For an amplifier mid band gain is 100 and lower cut off frequency is 1KHz. (a) Find the gain of the amplifier at 20Hz (b) Find the frequency at which the gain is 10% smaller than ~~her~~ mid band gain.

Sol: given data $A_{mid} = 100$; $f_L = 1KHz$

$A_v = ?$ at $f = 20Hz$

a) calculate gain at $f = 20Hz$ i.e. $A_v = ?$ at $f = 20Hz$

we know

$$|A_v| = \frac{A_{mid}}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}} \angle 180 + \tan^{-1}\left(\frac{f_L}{f}\right)$$

$$\therefore A_v = \frac{100}{\sqrt{1+\left(\frac{1000}{20}\right)^2}} \angle 180 + \tan^{-1}(50)$$

$$= 2 \angle 180 + 88.85^\circ$$

$$\boxed{\therefore A_v = 2 \angle 268.85^\circ}$$

(b) Calculate $f = ?$ at which $A_v = \left[A_{mid} - \cancel{A_{mid}} \frac{\times 10}{\cancel{100}} \times \cancel{100}\right]$

$A_v = 90$

we know

$$A_v = \frac{A_{mid}}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}}$$

$$\therefore 1+\left(\frac{f_L}{f}\right)^2 = \left(\frac{A_{mid}}{A_v}\right)^2 = \frac{100}{90} = \left(\frac{10}{9}\right)^2$$

$$\therefore \left(\frac{f_L}{f}\right)^2 = \frac{100-81}{81} = \frac{19}{81}$$

$$\therefore \frac{f_L}{f} = \frac{4.36}{9}$$

$$\therefore f = \frac{9}{4.36} \times f_L = 2.065KHz$$

(P.T.O)

(2) The 3dB gain of an amplifier is given as 200 and the higher cut off frequency is 20KHz. Find the gain of the amplifier at $f = 100 KHz$.

Sol: given data $A_{VHF}\Big|_{3dB} = 200$

$f_H = 20 KHz$.

determine $A_{VHF} = ?$ at $f = 100 KHz$

We know

$$A_{VHF} = \frac{A_{mid}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$

at $f = f_H \Rightarrow A_{VHF} = 200$ $\quad (\because f = f_H)$

$$\therefore A_{mid} = A_{VHF}\Big|_{3dB} \times \sqrt{2}$$

$$= 200 \times 1.414$$

$$A_{mid} = 282.4$$

$$\therefore A_{VHF} = \frac{282.4}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$

$\therefore$ at $f = 100 KHz$

$$A_{VHF} = \frac{282.4}{\sqrt{1+\left(\frac{100K}{20K}\right)^2}} = \frac{282.4}{\sqrt{26}}$$

$$\boxed{\therefore A_{VHF}\Big|_{100K} = 55.46}$$

(P.T.O)

3) At $I_c = 1\,mA$ and $V_{CE} = 10V$ a certain transistor data shows $C_{b'c} = 3\,pF$, $h_{fe} = 200$ and $\omega_T = 50\,M\,rad/sec$. Calculate g_m, $r_{b'e}$, $C_{b'e}$ and $\omega_\beta (f_\beta)$.

Sol: given data $I_c = 1\,mA$, $\boxed{V_{CE} = 10V \text{ (not useful)}}$

$C_{b'c} = 3\,pF$, $h_{fe} = 200$ and $\omega_T = 50\,M\,rad/sec$

$\therefore f_T = \frac{50}{2\pi}\,MHz.$

We know that

$V_T = \frac{T}{11{,}600}$ at room Temp.

$\therefore g_m = \frac{|I_c|}{V_T}$ where $V_T = 26\,mV$.

$\therefore g_m = \frac{1\,mA}{26\,mV}$

$= \frac{1}{26}\,\mho$

$\boxed{g_m = 38.46\,m\mho}$

We know that

$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{200}{38.46}\,K\Omega$

$\boxed{r_{b'e} = 5.2\,K\Omega}$

We know that

$f_T = \frac{h_{fe}}{2\pi\, r_{b'e}(C_{b'e} + C_{b'c})}$

$\therefore (C_{b'e} + C_{b'c}) = \frac{h_{fe}}{2\pi\, r_{b'e}\, f_T}$

$= \frac{h_{fe}}{\cancel{2\pi} \times 5.2 \times 10^3 \times \frac{50}{\cancel{2\pi}} \times 10^6}$

$= \frac{200}{260 \times 10^9}$ $= \cancel{3.846}\,pF \times 200$

$= 77.92\,pF$

$\therefore C_{b'e} = 77.92 - 3$

$C_{b'e} = 74.92\,pF.$

$f_\beta = \frac{f_T}{h_{fe}}$

$\therefore \omega_\beta = \frac{\omega_T}{h_{fe}}$

$= \frac{50}{200}\,M\,rad/sec$

$= 0.25\,M\,rad/sec$

~~$\omega_\beta = 250\,K\,rad/sec$~~

$f_\beta = \frac{1}{2\pi\, r_{b'e}(C_{b'e} + C_{b'c})}$

$= 2.5\,M\,rad/sec$

(P.T.O.)

(A) Short circuit CE current gain of transistor is 25 at a frequency of 2 MHz. If $f_\beta = 200$ KHz, Calculate
i) f_T, ii) h_{fe}, iii) A_I at $f = 10$ MHz and 100 MHz.

Sol : We know that CE short ckt current gain at HF is given by

$$|A_{vsc}| = \frac{+h_{fe}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$ here $f_H = f_\beta$.

given data ; $A_{vsc} = 25$, at $f = 2$ MHz & $f_\beta = 200$ KHz

(i) $\therefore h_{fe} = |A_{vsc}| \sqrt{1+\left(\frac{f}{f_H}\right)^2}$

$= 25 \times 10$

$h_{fe} = 250$

(ii) $\therefore f_T \simeq f_\beta h_{fe} = 250 \times 200$ KHz

$= 500$ MHz.

(iii) A_I at $f = 10$ MHz is

$$A_I\Big|_{10\,MHz} = \frac{250}{\sqrt{1+\left(\frac{10 \times 10^6}{200 \times 10^3}\right)^2}} \simeq \frac{250}{\sqrt{(50)^2}}$$

$A_I = 5$

A_I at $f = 100$ MHz

$$A_I\Big|_{100\,MHz} = \frac{250}{\sqrt{1+\left(\frac{100 \times 10^6}{200 \times 10^3}\right)^2}} = \frac{250}{500}$$

$A_I\Big|_{100\,MHz} = 0.5$

(P.T.O.)

(5)

A BJT has the following parameters measured at $I_c = 1mA$, $h_{ie} = 3K\Omega$, $h_{fe} = 100$, $f_T = 4MHz$, $C_c = 2pF$ & $C_e = 18pF$. Find $r_{b'e}$, $r_{bb'}$, g_m, f_H for $R_L = 1K\Omega$.

Sol: We know that

i) $$g_m = \frac{|I_c|}{V_T}$$ where $V_T = 26mV$ at Room Temp.

$$\therefore g_m = \frac{1 \times 10^{-3}}{26 \times 10^{-3}}$$

$$= 0.0385 \mho$$

$$\boxed{\therefore g_m = 38.5 m\mho}$$

ii) We know

$$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{100}{38.5 \times 10^{-3}} = 2600\Omega$$

$$\boxed{r_{b'e} = 2.6K\Omega}$$

iii) We know that

$$r_{bb'} = h_{ie} - r_{b'e}$$

$$= 3000 - 2600$$

$$\boxed{\therefore r_{bb'} = 400\Omega}$$

iv) We know that

$$f_H = \frac{1}{2\pi r_{b'e} C_T}$$

where C_T is the ~~Miller's~~ i/p capacitance given by

$$C_T = C_{b'e} + C_{b'c}(1 + g_m R_L)$$

$$= 18pF + 2pF(1 + 38.5)$$

$$39.5$$

$$= 18 + \cancel{78.0}\ 79$$

$$\therefore C_T = 97pF$$

(P.T.O.)

$$\therefore f_H = \frac{1}{2\pi \times 2.6\times10^{3} \times 97\times10^{-12}} \text{ Hz}$$

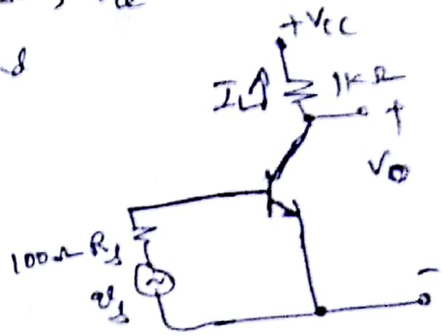
$$= \frac{10^9}{2\pi \times 2.6 \times 97}$$

$$\boxed{\therefore f_H = 631 \text{ KHz}}$$

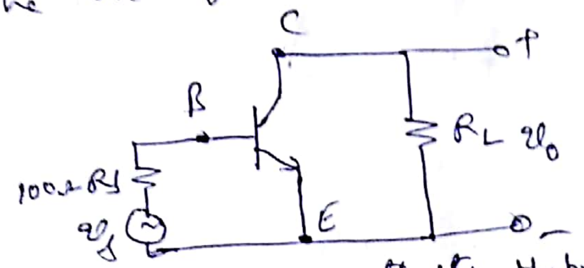
(6) The Hybrid-π parameters of the transistor used in the circuit shown are, $g_m = 50\text{mA/V}$, $r_{b'e} = 1K\Omega$, $r_{b'c} = 4M\Omega$, $r_{ce} = 80K\Omega$, $C_c = 3pF$, $C_e = 100pF$ and $r_{bb'} = 100\Omega$, find

i) Upper 3dB frequency of A_I

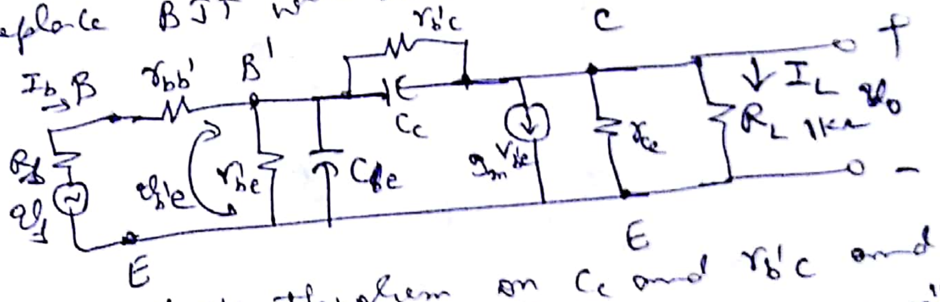
ii) The voltage gain A_{Vs} at midband



Sol: The ac equivalent ckt is obtained as



Replace BJT with its Hybrid-π model



Apply Miller's theorem on C_c and $r_{b'c}$ and then neglect r_{ce}, $r''_{b'c}$ because $r_{ce} >> R_L$ and $r''_{b'c} >> R_L$ on o/p side. On i/p side neglect $r'_{b'c}$ as $r'_{b'c} >> r_{b'e}$ and

$$C_i = C_e + C_c(1+g_m R_L)$$

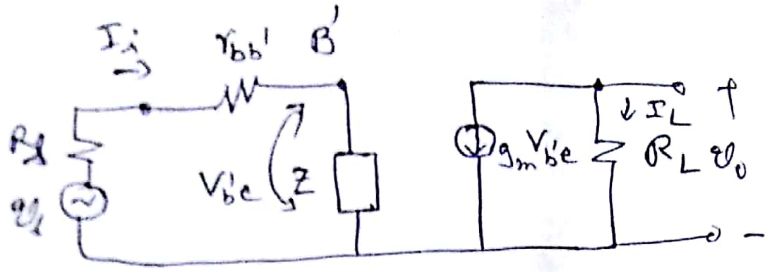
$$= 100 + 3(1+51)$$

$$= 100 + 156$$

$$C_i = 256 \, pF$$

(P.T.O.)

The simplified equivalent ckt becomes



where C_c'' is neglected and

$$Z = r_{b'e} \parallel X_{C_i}$$

$$= \frac{r_{b'e} \times \frac{1}{j\omega C_i}}{r_{b'e} + \frac{1}{j\omega C_i}}$$

$$= \frac{r_{b'e}}{1 + j\omega r_{b'e} C_i}$$

$$\therefore Z = \frac{r_{b'e}}{1 + j\frac{f}{f_H}} \quad \text{where } f_H = \frac{1}{2\pi r_{b'e} C_i}$$

$$\therefore A_I = \frac{I_L}{I_i} = \frac{-g_m V_{b'e}}{I_i} = \frac{-g_m \cancel{I_i} Z}{\cancel{I_i}} = -g_m Z$$

$$\therefore A_I = \frac{-g_m r_{b'e}}{1 + j\left(\frac{f}{f_H}\right)} = \frac{-h_{fe}}{1 + j\frac{f}{f_H}}$$

$$\text{where } f_H = \frac{1}{2\pi r_{b'e} C_i}$$

$$\therefore f_H = \frac{1}{2\pi \times 1 \times 10^{3} \times 256 \times 10^{-12}}$$

$$= \frac{10^{+9}}{2 \times \pi \times 256} \text{ Hz}$$

$$\boxed{\therefore f_H = 621.7 \text{ KHz}}$$

(P.T.O.)

ii) The voltage gain $A_{vs}|_{Mid}$ is given by

$$A_{vs} = \frac{v_o}{v_s}$$

$$= \frac{-g_m V_{b'e} R_L}{v_s}$$

write KVL to i/p loop

$$v_s - I_i\left(100 + Z + r_{bb'}\right) = 0$$

$$\therefore v_s = I_i\left(200 + Z\right) = 1.2\, I_i \times 10^3$$

$$A_{vs} = \frac{-g_m I_i r_{b'e} R_L}{I_i (1.2)\times 10^3}$$

$$= \frac{-50\times 10^{-3} \times 1\times 10^3}{1.2\times 10^3}$$

$$A_{vs} = -41.667$$

$$\therefore A_{vs} = \frac{-g_m I_i Z R_L}{I_i (200+Z)}$$

$$= \frac{-g_m R_L}{1 + \frac{200}{Z}} = \frac{-g_m R_L}{1 + \frac{200\left(1 + j\frac{f}{f_H}\right)}{r_{b'e}}}$$

$$|A_{vs}|_{3dB} = \frac{-g_m R_L}{\sqrt{1 + \left(\frac{200}{|Z|}\right)^2}}$$

$$|Z|_{3dB} = \frac{r_{b'e}}{\sqrt{2}} = 1K$$

$$\therefore |A_{vs}| = \frac{-g_m R_L}{\sqrt{1 + \left(\frac{200\times\sqrt{2}}{1\times 10^3}\right)^2}}$$

$$= \frac{-50}{\sqrt{1 + 0.16}} = -50$$

$.2 \times 2$

$(0.4)^2$

0.16

$$A_{vs} = \frac{-g_m R_L}{1 + 0.2 + j\, 0.2 \frac{f}{f_H}}$$

$$A_{vs} = \frac{-50}{1.2 + j\, 0.2\frac{f}{f_H}}$$

$$\therefore A_{vs\,mid} = \frac{+50}{1.2} = 41.67.$$

$$A_{vs\,3dB} = 41.10$$

Cascading of Amplifiers:

1) over all gain expression (Linear and in dB)
2) Effect of cascading, n-stages, on f_L
3) Effect of cascading, n-stages, on f_H
4) Effect of cascading on BW.

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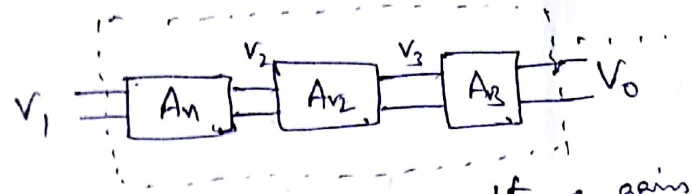
① gain of n-stage cascaded amplifier:

Assumptions made:

① All individual stages are identical
② All stages are non-interacting stages



the overall voltage gain A_V is given by

$$A_V = \frac{V_0}{V_1} = \frac{V_0}{V_3} \times \frac{V_3}{V_2} \times \frac{V_2}{V_1} \cdots$$

$$\boxed{\therefore A_V = A_{V_1} \times A_{V_2} \times A_{V_3}}$$

If it is converted into dB scale

$$20\log_{10} A_V = 20\log_{10} A_{V_1} + 20\log_{10} A_{V_2} + 20\log_{10} A_{V_3} \cdots$$

the overall gain is the sum of individual gains in dB.

(P.T.O.)

② Effect of cascading on f_L.

We know the gain of n-stage cascade amp is given by

$$A_V = A_{V_1} \times A_{V_2} \times A_{V_3} \ldots n \text{ stages}$$

assume that all stages identical

$$\therefore A_V = A_{V_1}^n$$

but we know at low frequencies

$$|A_V| = \left| \frac{A_{mid}}{1 - j\frac{f_L}{f}} \right| = \frac{A_{mid}}{\sqrt{1 + \left(\frac{f_L}{f}\right)^2}}$$

$$\therefore A_V = \left[\frac{A_{mid}}{\sqrt{1 + \left(\frac{f_L}{f}\right)^2}} \right]^n$$

The lower 3dB frequency f_L^* is defined as the frequency at which the ~~mid~~ gain reduces the frequency at which the gain i.e. A_{mid}^n by $\sqrt{2}$ times of its maximum gain

$$\therefore \left[\frac{A_{mid}}{\sqrt{1 + \left(\frac{f_L}{f_L^*}\right)^2}} \right]^n = \frac{[A_{mid}]^n}{\sqrt{2}} ~~= \frac{A_{mid}^n}{2}~~$$

$$\therefore \left[1 + \left(\frac{f_L}{f_L^*}\right)^2 \right]^{\frac{n}{2}} = 2^{1/2}$$

$$\therefore 1 + \left(\frac{f_L}{f_L^*}\right)^2 = 2^{1/n}$$

$$\therefore \frac{f_L}{f_L^*} = \sqrt{2^{1/n} - 1}$$

$$\therefore f_L^* = \frac{f_L}{\sqrt{2^{1/n} - 1}}$$

for $n = 1$, $f_L^* = f_L$.

for any higher value of n, $\boxed{f_L^* > f_L}$

(P.T.O.)

3 Effect of cascading on f_H :

The overall voltage gain of n-stage amplifier is

$$A_v = A_{v_1}^n$$

at high frequencies we know that

$$|A_{v_1}| = \left|\frac{A_{mid}}{1 + j\frac{f}{f_H}}\right| = \frac{A_{mid}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$

$\therefore$ for n-stages

$$A_v = \left[\frac{A_{mid}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}\right]^n$$

The upper 3dB frequency f_H^* of the n-stage amplifier is defined as the frequency at which the gain reduces by $\sqrt{2}$ times of its midband gain.

$$\therefore \left[\frac{A_{mid}}{\sqrt{1+\left(\frac{f_H^*}{f_H}\right)^2}}\right]^n = \frac{A_{mid}^n}{\sqrt{2}}$$

$$\therefore 1+\left(\frac{f_H^*}{f_H}\right)^2 = 2^{1/n}$$

$$\therefore \frac{f_H^*}{f_H} = \sqrt{2^{1/n}-1}$$

$$\boxed{\therefore f_H^* = f_H\left(\sqrt{2^{1/n}-1}\right)}$$

for $n=1 \Rightarrow f_H^* = f_H$: for $n>1$ $\boxed{f_H^* << f_H}$

(P.T.O.)

④ <u>Effect of cascading on B.W:</u>

We know that f_L^* and f_H^* are given by

$$f_L^* = \frac{f_L}{\sqrt{2^{1/n}-1}} \quad \text{and} \quad f_H^* = f_H\sqrt{2^{1/n}-1}$$

for $n > 1$,

$$f_L^* > f \quad \text{and} \quad f_H^* < f_H$$

Therefore

$$B.W_{n\,stage} = f_H^* - f_L^*$$

$$= f_H\sqrt{2^{1/n}-1} - \frac{f_L}{\sqrt{2^{1/n}-1}}$$

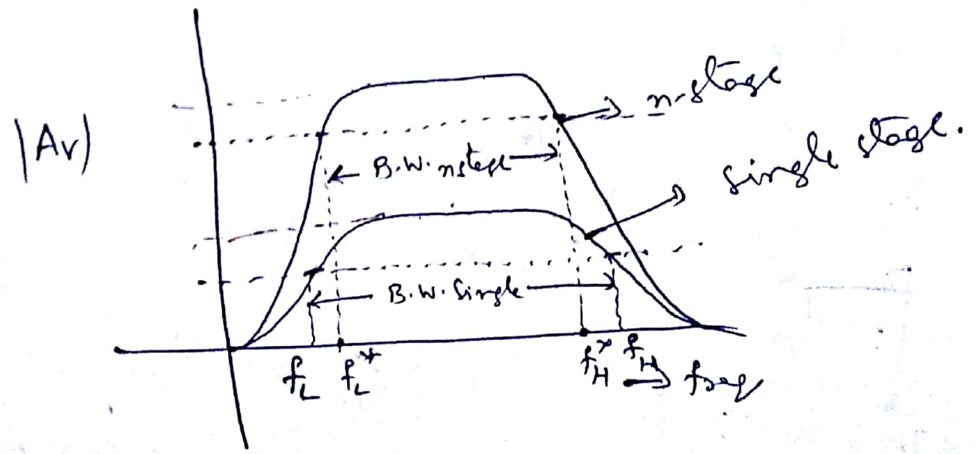
$$\simeq f_H\sqrt{2^{1/n}-1}$$

$$\therefore B.W_{n\,stage} = B.W._{single\ stage} \times \sqrt{2^{1/n}-1}$$

for $n > 1$; $\sqrt{2^{1/n}-1} < 1$

$$\boxed{\therefore B.W_{n\text{-}stage} < B.W_{single\ stage}.}$$

$$\therefore B.W_{n\,stage} = f_H\sqrt{2^{1/n}-1}$$



(P.T.O.)

Problems:

① For an amplifier mid band gain is 100 and lower cut off frequency is 1KHz. Find

a) gain at $f = 20Hz$

b) Mid band gain and f_L^* of three such stages are cascaded.

Sol: given that

$$A_{mid} = 100 \text{ and } f_L = 1KHz$$

ⓐ we know that

$$|A_{VLF}| = \frac{A_{mid}}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}}$$

$$\therefore A_V \text{ at } f=20Hz = \frac{A_{mid}}{\sqrt{1+\left(\frac{1\times10^3}{20}\right)^2}} = \frac{100}{\sqrt{2501}}$$

$$\boxed{\therefore A_{VLF}|_{20Hz} \simeq 2}$$

ⓑ when 3 stages are cascaded the overall gain is given by

$$A_V|_{n=3} = \left[\frac{A_{mid}}{\cancel{\sqrt{1+\left(\frac{f_L^*}{f}\right)^2}}}\right]^3 = A_{mid}^3$$

$$= 100\times100\times100$$

$$\boxed{\therefore A_V|_{n=3} = 10^6}$$

we know that

$$f_L^* = \frac{f_L}{\sqrt{2^{1/n}-1}} = \frac{1000}{\sqrt{2^{1/3}-1}} \text{ Hz}$$

$$\underline{f_L^* = 1.962 \text{ KHz}}$$

(P.T.O.)

② For an amplifier, the upper dB frequency is given as 20KHz and the gain at this frequency is 200. Find

a) The gain at $f = 100\ KHz$

ⓑ If 2 such stages are cascaded determine the maximum gain and upper 3dB frequency.

Sol : a) It is given. $f_H = 20\ KHz$ and $A_V|_{f_H} = 200$

We know that

$$A_{VHF} = \frac{A_{mid}}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$

at 3dB frequency

$$A_V = \frac{A_{mid}}{\sqrt{2}} = 200$$

$$\therefore A_{mid} = \sqrt{2} \times 200$$

$$\underline{A_{mid} = 282.8}$$

$$\therefore A_{VHF} = \frac{282.8}{\sqrt{1+\left(\frac{f}{20\times K}\right)^2}}$$

$$\therefore A_{VHF}\Big|_{f=100k} = \frac{282.8}{\sqrt{1+\left(\frac{\cancel{100}^{5}K}{\cancel{20}K}\right)^2}}$$

$$= \frac{282.8}{\sqrt{26}}$$

$$\boxed{\therefore A_V\Big|_{f=100k} = 55.46}$$

(P.T.O.)

(b) when 2-stages are cascaded

$$A_V\big|_{n=2} = A_{mid}^2$$

$$= (282.8)^2$$

$$\boxed{A_V\big|_{n=2} = 79975.84}$$

$$\boxed{A_V\big|_{n=2\ in\ dB} = 98.06\,dB}$$

we know

$$f_H^* = f_H\left(\sqrt{2^{1/n}-1}\right)$$

$$= 20\times10^3\left(\sqrt{2^{1/2}-1}\right)\ Hz$$

$$\boxed{\therefore f_H^* = 12.87\ KHz}$$

---

(3) If 4 identical amplifiers are cascaded each having $f_L = 100\ Hz$, determine the overall lower 3dB frequency f_L^*

Sol: given $f_L = 100\ Hz$, $n = 4$, we know

$$f_L^* = \frac{f_L}{\sqrt{2^{1/n}-1}} = \frac{100}{\sqrt{2^{1/4}-1}} = 229.9\ Hz.$$

---

(4) If 4 identical amplifiers are cascaded each having $f_H = 100\ KHz$, determine the overall upper 3dB frequency f_H^*.

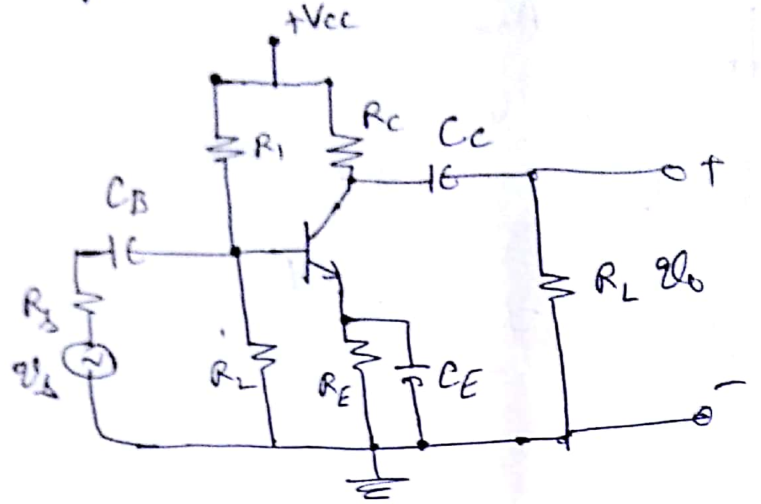
Sol: given $f_H = 100\ KHz$, $n = 4$ we know

$$f_H^* = f_H\left(\sqrt{2^{1/n}-1}\right) = 100\times\left(\sqrt{2^{1/4}-1}\right)\ KHz$$

$$f_H^* = 43.5\ KHz$$

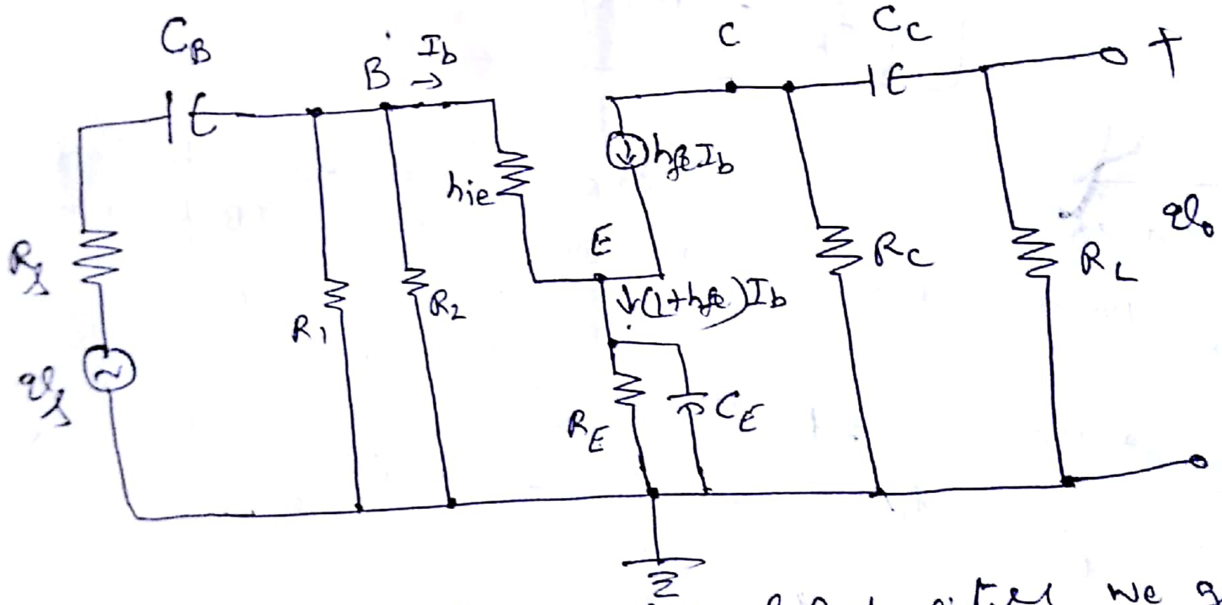
SINGLE STAGE CE AMPLIFIER RESPONSE:

CE amplifier ckt is as shown below



a) Low Frequency Analysis :

The ac equivalent ckt using approximate ~~A~~ h-parameters model, by considering all external capacitances is given below



Since there are 3 external capacitors we get 3 time constant and hence 3 cut off frequencies in Low Frequency region. Each cut off frequency can be exactly obtained as follows:

① ~~cut off frequency due to CB~~

(P.T.O.)

Note: while considering one ~~C_B~~, other two capacitances are to be short circuited.

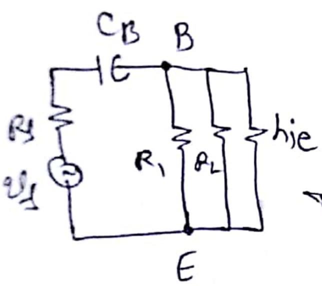
① Considering C_B alone:

The Time Constant τ for an RC circuit is given by the product of RC and the cut off frequency is given by

$$f = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC}$$

where $C \rightarrow$ The capacitor under consideration

$R \rightarrow$ the equivalent Resistance associated with that capacitor C. (The resistance seen by the capacitor)



Note: R_1 can be obtained by setting $v_s = 0$.

Therefore

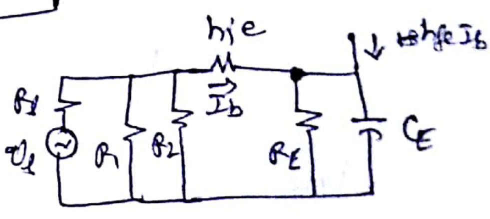
$$f_{CB} = \frac{1}{2\pi R_1 C_B}$$

where $R_1 = R_s + (R_1 \| R_2 \| R_{ie})$ then

if $R_1 \gg hie$ and $R_2 \gg hie$

$$R_1 = R_s + hie$$

$$\boxed{\therefore f_{c_1} = \frac{1}{2\pi(R_s + hie)C_B}} \quad \text{—— ①}$$



② Considering C_E alone:

$$f_{CE} = \frac{1}{2\pi R_2 C_E}$$

where

$$R_2 = R_E \,\Big\|\, \left[\frac{hie + (R_1 \| R_2 \| R_s)}{(1+h_{fe})}\right]$$

(P.T.O.)

If $R_1 > R_S$, $R_2 > R_S$ then

$$R_1 \parallel R_2 \parallel R_S = R_S$$

$$\therefore R_2 = R_E \parallel \left(\frac{R_S + h_{ie}}{1 + h_{fe}}\right)$$

If $R_E >> \left(\frac{R_S + h_{ie}}{1 + h_{fe}}\right)$ $\quad \because h_{fe}$ very large.

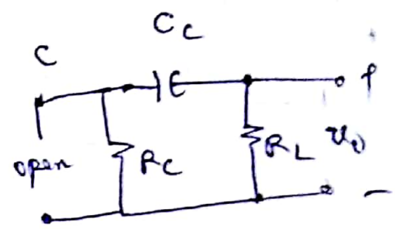
then

$$R_2 \simeq \frac{R_S + h_{ie}}{(1 + h_{fe})}$$

$$\therefore f_{CE} = \frac{1}{2\pi \frac{(R_S + h_{ie})}{(1 + h_{fe})} . C_E}$$

$$\boxed{\therefore f_{CE} = \frac{1 + h_{fe}}{2\pi (R_S + h_{ie}) C_E}} \quad \text{—— (2)}$$

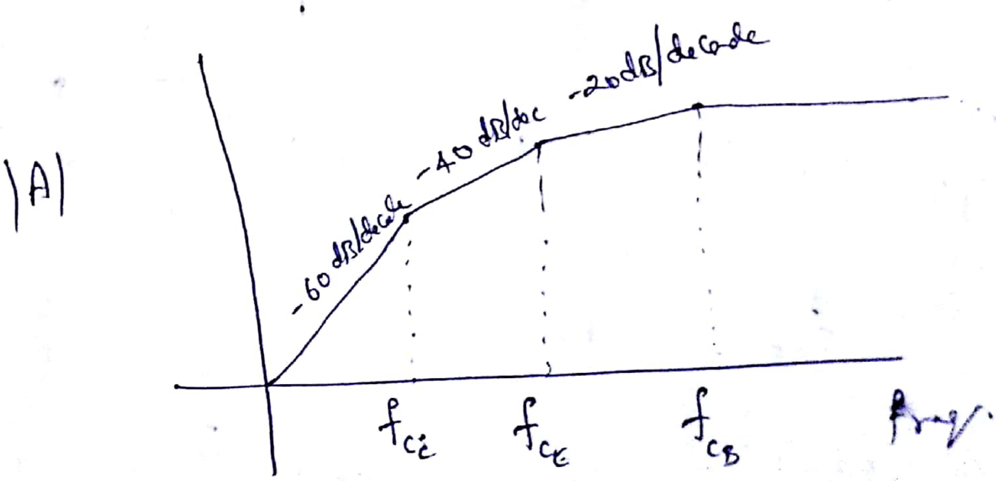
(3) Considering C_C alone :



$$f_{CC} = \frac{1}{2\pi R_3 C_C}$$

where $R_3 = R_C + R_L$

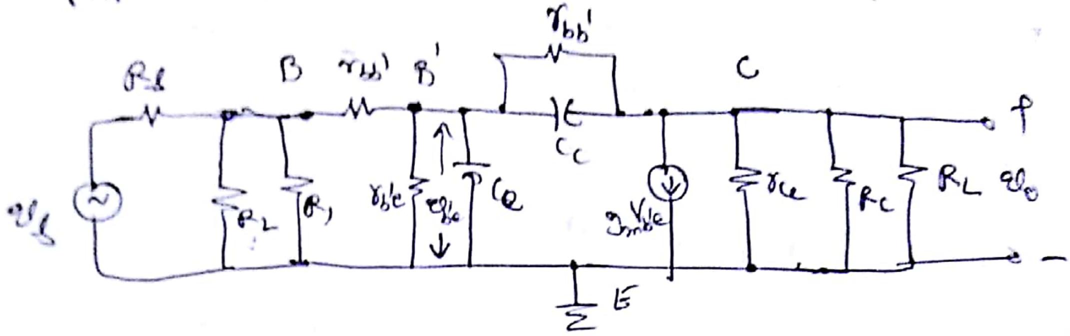
$$\boxed{\therefore f_{CC} = \frac{1}{2\pi (R_C + R_L) C_C}} \quad \text{—— (3)}$$



(P.T.O.)

(b) High Frequency Analysis:

The AC equivalent ckt using Hybrid-π model & by short ckting all external capacitances.

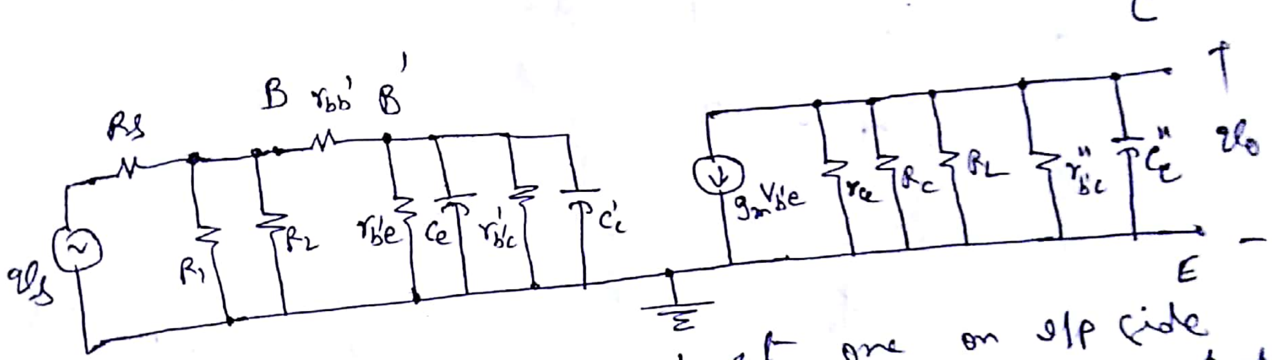


Applying Miller's Theorem on $r_{bb'}$ & C_c results in

$$r'_{bb'} = \frac{r_{bb'}}{1-A_v} \quad \& \quad r''_{bb'} = \frac{r_{bb'}}{1-\frac{1}{A_v}}$$

$$C'_c = C_c(1-A_v) \quad \& \quad C''_c = C_c\left(1-\frac{1}{A_v}\right)$$

The equivalent ckt now becomes



This ckt has 2 RC part one on i/p side and other on o/p side. So we get 2 cut off frequencies ~~ø~~ in High frequency region.

(a) Considering the i/p RC network:

$$f_{HC_i} = \frac{1}{2\pi R_{in} C_i} \quad ; \quad \tau_i = R_{in} C_i$$

where $C_i = C_e + C_c(1-A_v)$

$C_i = C_e + C_c(1+g_m R'_L)$

where $R'_L = r_{ce} \| R_c \| R_L \| r''_{b'c}$.

(P.T.O.)

and

$$R_{in} = r_{b'e} \,||\, r'_{b'c} \,||\, [r_{bb'} + (R_s || R_1 || R_2)]$$

$$\simeq r_{b'e}$$

$$\boxed{\therefore f_{c_i} \simeq \frac{1}{2\pi r_{b'e} C_i}} \quad — \text{(A)}$$

(b) Considering o/p network.

$$f_{co} = \frac{1}{2\pi R_o C_o} \quad ; \quad \tau_o = R_o C_o$$

where $C_o = C''_c = C_c\left(\frac{1 + g_m R'_L}{g_m}\right)$

$$R_o = r_{ce} \,||\, R_c \,||\, R_L \,||\, r''_{b'c}$$

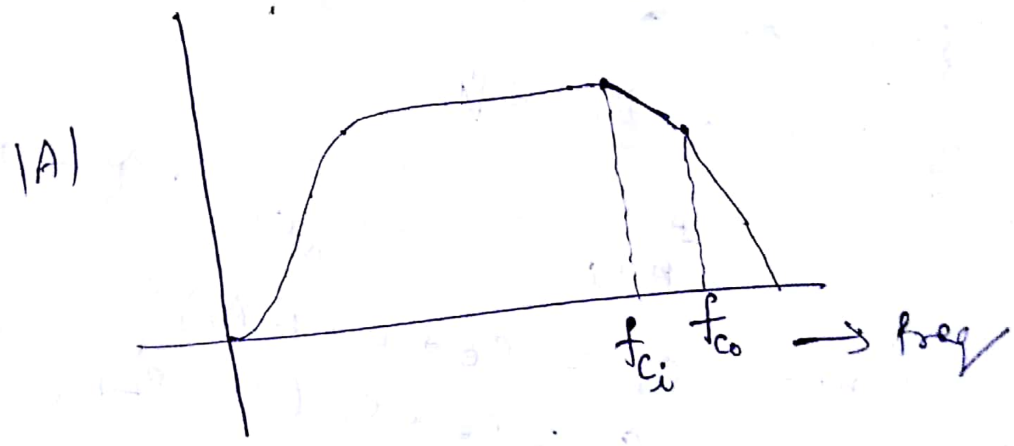
By considering the typical values

$$\tau'_i >> \tau_o$$

Therefore

$$f_{ci} << f_{co}$$

Hence the High frequency response is mainly decided by f_{ci} alone.



(P.T.O.)

Logarithmic scale for Expressing gain:

1) In most of the ckts, used in practice, the gain is a very large number. So, it is difficult to represent or reproduce. Hence logarithmic scale is used to express gains in Engineering applications.

2) Very large numbers can be represented as small numbers in log scale.

3) Example:

Linear Ratio / no.	log(No.)		log. value
1	$\log_{10} 1$	=	0
10	$\log_{10} 10$	=	1
100	$\log_{10} 100$	=	2
1000	$\log_{10} 1000$	=	3
⋮	⋮		⋮
1000000	$\log_{10} 10^6$	=	6

check for every 10 times linear value only one increment is there in log scale with base 10.

- So, logarithmic scales are very useful in expressing gains (or) any ratios.

(P.T.O.)

Decibel dB.

① 'Bel' is derived from the Telephone inventor, Alexander Graham Bell. The unit 'Bel' is defined relating two power levels P_1 and P_2 as

$$G = \log_{10}\left(\frac{P_2}{P_1}\right) \text{ Bel}$$

② But, in practice, it was found that Bel is a very large unit for measurement. hence "decibel" (dB) is defined where

$$\boxed{10 \text{ decibels} = 1 \text{ Bel.}}$$

$$\boxed{\therefore G_{dB} = 10 \log_{10}\left(\frac{P_2}{P_1}\right) \text{ dB}}$$

where P_2 & P_1 are the output and i/p powers of a given circuit. ~~expressed gain as a ratio of voltage or current~~

~~③ Often we~~ normalized/standardized or

③ Often the input power is kept constant at 1 milliwatt then the gain is represented as dBm

$$\boxed{\therefore G_{dB} = 10 \log\left(\frac{P_2}{1mW}\right) \text{ dBm}}$$

④ If the gain is expressed in terms of voltage or current then

$$G_{dB} = 10 \log\left(\frac{V_0^2/R_0}{V_i^2/R_i}\right) \text{ dB}$$

when it is set $R_i = R_0 = $ unity

$$\boxed{G_{dB} = 20 \log\left(\frac{V_0}{V_i}\right) \text{ dB or } = 20 \log\left(\frac{I_0}{I_i}\right) \text{ dB}}$$

P.T.O.

(5) For n-stage cascaded amplifier the gain in dB is as below

$$A_V = A_{V_1} * A_{V_2} * A_{V_3} * \cdots * A_{V_n}$$

$$\therefore 20 \log_{10} A_V = 20 \log A_{V_1} + 20 \log_{10} A_{V_2} + \cdots + 2 \log_{10} A_{V_n}$$

$\therefore$ Total gain in dB = Sum of all gains in dB.

(6) If $A_V = 1$ then

$$20 \log_{10} 1 = 0 \text{ dB}$$

(7) If $A_V = 0.1$ i.e. $V_0 = 0.1 \times V_i$ means o/p is smaller than input such a ckt is called as an attenuator, then the gain dB is

$$20 \log_{10} A_V = 20 \log_{10} 0.1 = 20 \log_{10} 10^{-1}$$

$$= -1 \text{ dB}$$

the gain in dB is negative

-ve ← dB → Positive

... -4 -3 -2 -1 0 1 2 3 4 ....

gain line in dB

← Attenuation

$A < 1 \Rightarrow$ o/p < i/p

Amplification →

i.e. $A > 1 \Rightarrow$ o/p > i/p

(8) At 3dB frequencies the gain is $\frac{1}{\sqrt{2}}$ of maximum gain

$$\therefore \cancel{20 \log_{10} A_V \Big|_{3dB} = 2}$$

$$A \Big|_{3dB\,freq} = \frac{A_{max}}{\sqrt{2}}$$

(P.T.O.)

$$\therefore 20\log A_v\Big|_{3dB\ freq} = 20\log_{10}\frac{A_{max}}{\sqrt{2}}$$
$$= 20\log_{10} A_{max} - 20\log_{10}\sqrt{2}$$
$$= (A_{max} \text{ in dB}) - 10\log_{10} 2$$
$$= (A_{max} \text{ in dB}) - 3.010\,dB$$

$\therefore$ At 3dB frequencies the gain is 3dB smaller than that of the maximum gain in dB.

Prob: (1) Determine the linear gain if gain is 1dB.

Sol: $20\log_{10} A = 1\ dB$

$\therefore \log_{10} A = \frac{1}{20} = \cancel{0.005}\ 0.05$

$\therefore A = 10^{0.05}$

$\boxed{\therefore A = 1.12}$

(2) An amplifier has a voltage gain of 15 dB. If the input signal voltage is 0.8V determine the o/p voltage.

Sol: we know that gain in dB is given as 15 dB

$\therefore 20\log_{10}\frac{V_0}{V_i} = 15$

$\therefore \log_{10}\frac{V_0}{V_i} = \frac{15}{20} = \frac{3}{4} = 0.75$

$\therefore \frac{V_0}{V_i} = 10^{0.75} = 5.6234$

$\therefore V_0 = 4.5\ V$

End

(P.T.O.)

Note ⑤ **Validity of Hybrid-π model.**

(a) The Hybrid-π model is valid ~~for small~~ for base incremental current I_B is small compared with collector incremental current I_C.

(b) The Hybrid-π model is valid for frequencies upto approximately $\boxed{\frac{f_T}{3}}$.

Question Bank on
ANALOG CIRCUITS AND APPLICATIONS.

Questions for 2 marks.

1. The absolute gain of an amplifier is 30; find its decibel in gain.
2. The absolute gain of an amplifier is 40; find its decibel in gain.
3. The input power to an amplifier is 10 mw while output power is 1.5 W. Find the gain of the amplifier.
4. The input power to an amplifier is 20 mw while output power is 2.5 W. Find the gain of the amplifier.
5. A multistage amplifier employs 4 stages each of which has a power gain of 20. What is the total gain of the amplifier in db?
6. A multistage amplifier employs 3 stages each of which has a power gain of 30. What is the total gain of the amplifier in db?
7. The gain of the second amplifier in case of two-stage amplifier is low. Comment.
8. What do you understand by multistage transistor amplifier?
9. What is need to of multistage transistor amplifier?
10. Explain the term frequency response with respect to two-stage transformer-coupled amplifier.
11. What are the advantages of frequency with respect to two-stage amplifier?
12. What are the disadvantages of frequency with respect to two-stage transformer-coupled amplifier?
13. Explain the term gain.
14. What is the application of two stage RC coupled amplifier?
15. Draw the block diagram of multistage amplifier.
16. Why do we prefer to express the gain in db?

Questions for 3 marks.

1. We are to match a 16 Ω speaker load to an amplifier so that the effective load resistance is 10KΩ. What should be the transformer turn ratio?
2. We are to match a 24 Ω speaker load to an amplifier so that the effective load resistance is 12 KΩ. What should be the transformer turn ratio?
3. A single stage amplifier has collector load Rc=10KΩ, input resistance Rin=1KΩ and β=100. If RL=100Ω find the voltage gain.
4. A single stage amplifier has collector load Rc=20KΩ, input resistance Rin=2KΩ and β=100. If RL=75Ω find the voltage gain.
5. A multistage amplifier consists of three stages; the voltage gain of the stages are 60,100 and 160 calculate the overall gain.
6. With the neat diagram explain the application of two-stage transformer-coupled amplifier
7. Explain the term frequency response.
8. Explain the term decibel gain.
9. Explain the term bandwidth.
10. Why does transformer coupling give poor frequency response?

Questions for 4 marks.

1. A multistage amplifier consists of four stages; the voltage gain of the stages are 60,80, 100 and 160 calculate the overall gain.
2. Explain the terms of amplifier I) frequency response and II) decibel gain.
3. Explain the terms of amplifier I) frequency response and II) bandwidth.
4. Explain the terms of amplifier I) decibel gain and II) bandwidth.
5. Explain the frequency response of two-stage RC coupled amplifier.
6. A multistage amplifier consists of three stages; the voltage gain of the stages are 60,100 and 160 calculate the overall gain.
7. How will you achieve impedance matching with transformer coupling?
8. What are the merits of two-stage transformer coupled amplifier over RC coupled amplifier?
9. Draw the neat-labeled diagram of two-stage RC coupled amplifier and two-stage transformer coupled amplifier.

Questions for 6 marks.

1. With the neat diagram explain the working of two-stage RC coupled amplifier
2. Explain the terms of amplifier I) frequency response II) decibel gain and III) bandwidth.
3. Explain RC coupled transistor amplifier with special reference to frequency response, advantages, disadvantages and application.
4. With neat diagram explain the working of transformer coupled transistor amplifier.