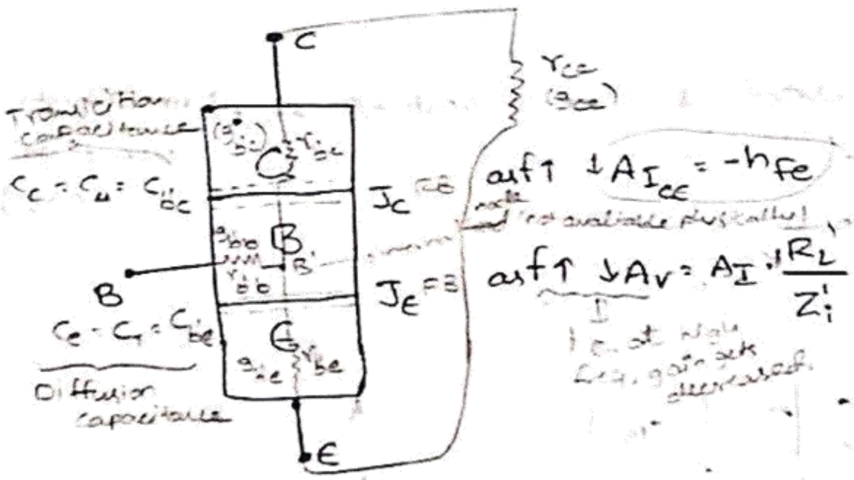
UNIT-3:- HIGH FREQUENCY RESPONSE OF BJT & FET:-

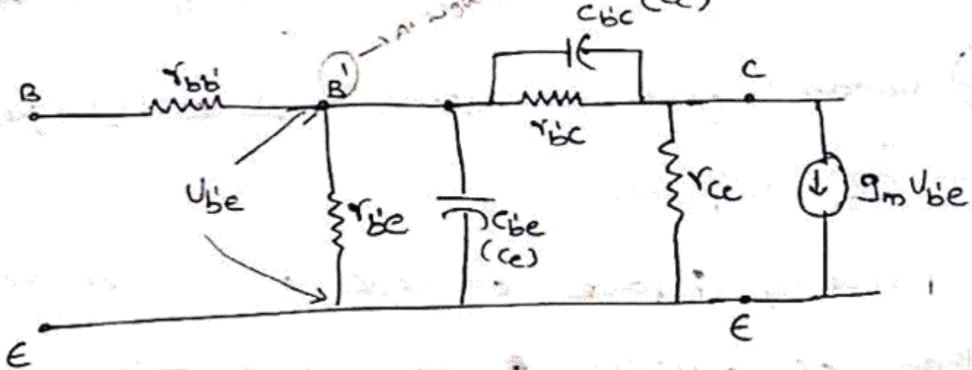
* BJT acts as Amplifier in Active region(J_E FB & J_C RB)
* gain of an amplifier falls at LF & HF.
* gain falls at LF due to coupling (μF) capacitors.
* gain falls at HF due to internal (or) Junction capacitances (pF capacitances)



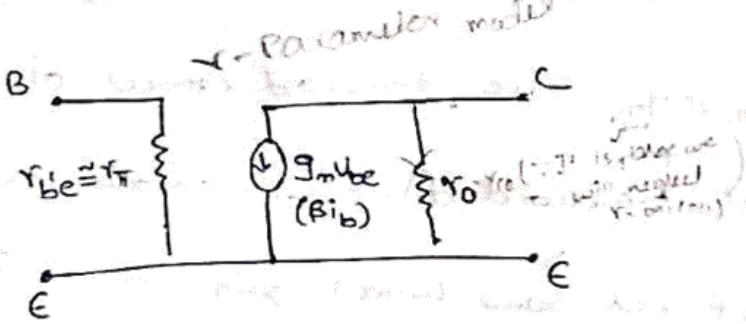
as $f\uparrow$ $\downarrow A_{I_{ce}} = -h_{fe}$ — constant
mode ... not available physically ... only A_V is available physically
as $f\uparrow$ $\downarrow A_V = A_I \cdot \frac{R_L}{Z_i'}$
i.e. at high freq. gain gets decreased.

BJT high frequency model

— at high freq. internal node is more effective



r-parameter model



$r_\pi \cong r_{b'e}$

$h_{ie} = r_\pi + r_{bb'}$

* All parameters in the high frequency model are assumed to be independent of frequency.

* They may vary with Q-Pt. i.e., if Q-point is constant all parameters are treated constant for small signal analysis.

* The resistive components of the circuit can be obtained ~~to~~ from the low frequency model.

* B' = Internal ~~load~~ node in base region which is not physically accessable

* $r_{bb'}$ = ohmic base spreading resistance b/w External & internal base.

$g_m V_{b'e}$ = Small signal collector current with collector shorted to Emitter.

$g_{b'e} = \frac{1}{r_{b'e}}$ = Input conductance b/w Internal base and Emitter

$g_{b'c} = \frac{1}{r_{b'c}}$ = feedback conductance b/w internal base & collector.

g_{ce} = o/p conductance b/w collecter and Emitter.

$C_{b'e} = C_e = C_\pi$ = diffusion capacitance across internal base & Emitter.

$C_{b'c} = C_c = C_\mu$ = Transicition (or) Junction capacitance b/w internal base & collector.

→ Typical values of HF BJT Model:-

(at room temperature & for $I_C = 1.3\,mA$)

$g_m = 50\,mA/V$ $\qquad$ $r_{b'c} = 4\,M\Omega$

$r_{ce} = 80\,k\Omega$ $\qquad$ $C_c = 3\,pF$

$r_{bb'} = 100\,\Omega$ $\qquad$ $C_e = 100\,pF$

$r_{b'e} = r_\pi = 1\,k\Omega$

Important Equations:-

* g_m = transconductance

1) $g_m = \frac{I_C}{V_T} = \frac{\beta}{r_\pi} = \frac{\alpha}{r_e}$ $\qquad$ $r_\pi = \frac{V_T}{I_B}$

2) $r_{b'e} = r_\pi = \frac{\beta}{g_m} = \frac{h_{fe}}{g_m}$

(or)

$g_{b'e} = \frac{g_m}{\beta} = \frac{g_m}{h_{fe}}$

3) $g_{b'c} = h_{re} \cdot g_{b'e}$

(or)

$r_{b'e} = h_{re} \cdot r_{b'c}$

(or)

$r_\pi = h_{re} \cdot r_{b'c}$

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

(or)

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

5) $g_{ce} = h_{oe} - g_m h_{re}$

(or)

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

6) $C_c = \frac{\epsilon A}{W}$ where $W = \left[\frac{2\epsilon V}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)\right]^n$

where $n = \frac{1}{2}$ for step graded

$n = \frac{1}{3}$ for linear graded

7. $C_e = \frac{g_m}{2\pi f_T} = g_m \cdot \frac{W_B^2}{2 D_B}$ $\qquad$ D_B → Base diffusion constant ↓ minority carriers

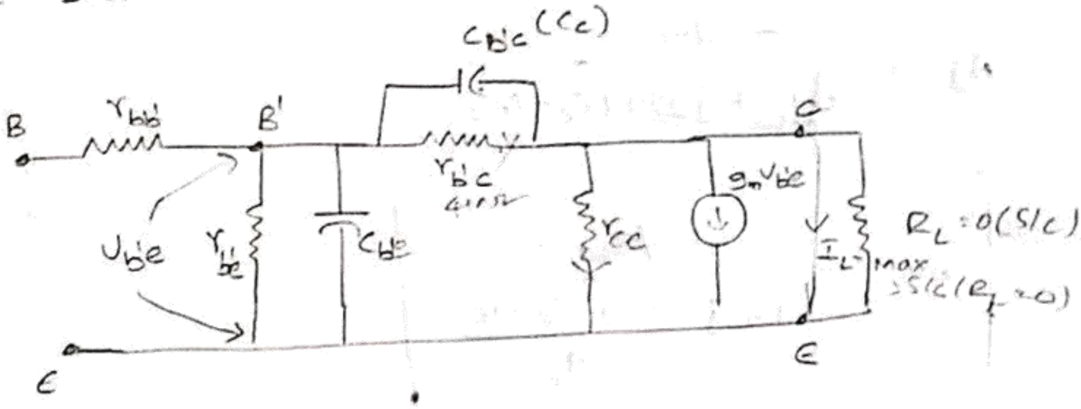
where

W_B = Base width & $D_B = D_n$ (e^- diffusion constant) for NPN

& $D_B = D_p$ (hole diffusion constant) for PNP.

CE short circuit current gain ($R_L = 0\,\Omega$)

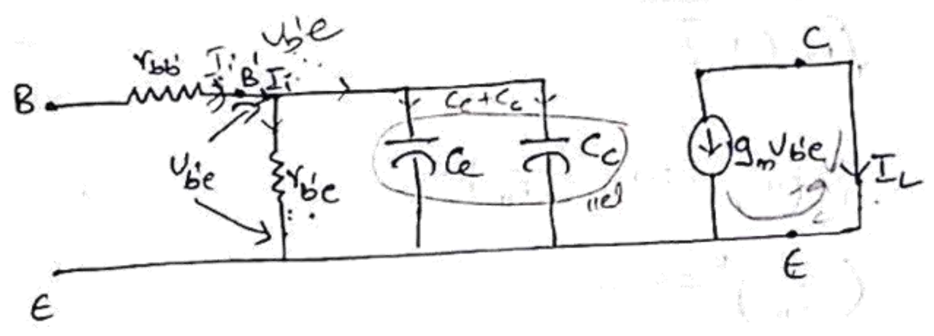
Calculation of current gain when collector & Emitter are shorted



1. Effect of r_{ce} is neglected as it is in shunt (‖el) with S/c.

2. Effect of $r_{b'c}$ is neglected as it is very high ($4M\Omega$)

$r_{b'c}$ = resistance across collector base Junction ($4M\Omega$)
(J_c RB)
↳ more resistance less current



Current gain = $A_{I_{R_L=0}} = \frac{I_L}{I_i}$ —— ①

$I_L = -g_m V_{b'e}$ —— ②
(opp. direction)

KCL

$$I_i = \frac{V_{b'e}}{r_{b'e}} + \frac{V_{b'e}}{X_{C_e+C_c}} = V_{b'e}\left[\frac{1}{r_{b'e}} + \frac{1}{\frac{1}{j2\pi f(C_c+C_e)}}\right]$$

$I_i = V_{b'e}\left[g_{b'e} + j2\pi f(C_c+C_e)\right]$ —— ③

now

$$A_I = \frac{I_L}{I_i} = \frac{-g_m \cancel{V_{b'e}}}{\cancel{V_{b'e}}\left[g_{b'e} + j2\pi f(C_c + C_e)\right]}$$

$$A_I = \frac{-g_m}{g_{b'e} + j2\pi f(C_c + C_e)}$$

$$\boxed{A_I = \frac{(-g_m/g_{b'e})}{1 + j\,\dfrac{2\pi f(C_c + C_e)}{g_{b'e}}}}$$

formula ② $g_{b'e} = \frac{g_m}{\beta} = \frac{g_m}{h_{fe}}$

$$A_I = \frac{-h_{fe}}{1 + j\,\dfrac{2\pi(C_c + C_e)}{g_{b'e}} \cdot f}$$

f → input signal freq

$$A_I = \frac{-h_{fe}}{1 + j\left(\frac{f}{f_H}\right)}$$

where $f_H = \frac{g_{b'e}}{2\pi(C_c + C_e)}$ = constant

f_H = upper cut off frequency

f = input signal frequency

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

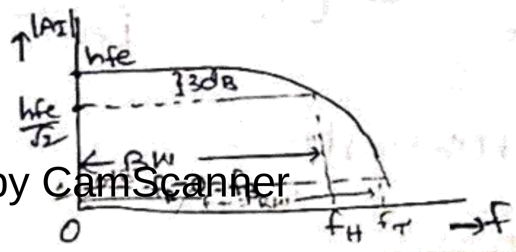
*(a) if $f < f_H$ then $\left(\frac{f}{f_H}\right) < 1$

$$\left(\frac{f}{f_H}\right)^2 << 1$$

so $|A_I| \cong h_{fe}$ //

**(b) if $f > f_H$ then $\left(\frac{f}{f_H}\right) > 1$ & $\left(\frac{f}{f_H}\right)^2 >> 1$

so $|A_I| = \frac{h_{fe}}{(f/f_H)} = \frac{f_H \cdot h_{fe}}{f}$ = gain ↓ses when $f > f_H$ //



f_H when Collector & Emitter are shorted, it is defined as f_β = Bandwidth of CE when C & E are shorted.

f_T = Unity gain cut-off frequency

f_T = unity gain B.W product.

f_T : It is the frequency at which CE s/c A_I reaches (or) reduces to unity.

$$|A_I| = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f}{f_\beta}\right)^2}}$$

$\because f > f_\beta$, $\left(\frac{f}{f_\beta}\right)^2 >> 1$

$$|A_I| \cong \frac{h_{fe}}{(f/f_\beta)}$$

W.K.T at $f = f_T$ then $A_I = 1$

$$1 = \frac{h_{fe}}{(f_T/f_\beta)} \Rightarrow \boxed{f_T = h_{fe} \cdot f_\beta.}$$

$\boxed{f_T = h_{fe} \cdot f_\beta}$ $\boxed{f_T = \text{gain}\uparrow_{\downarrow} \times BW\downarrow_{\uparrow}}$

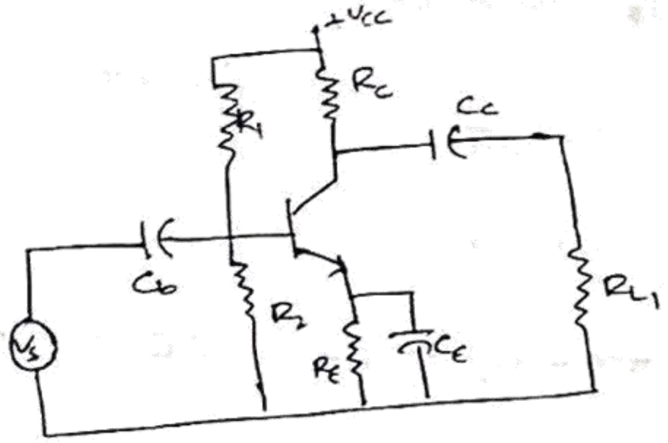
product is constant

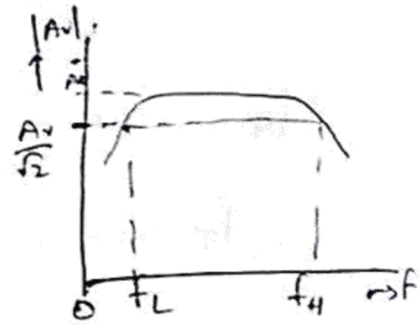
$\Downarrow$

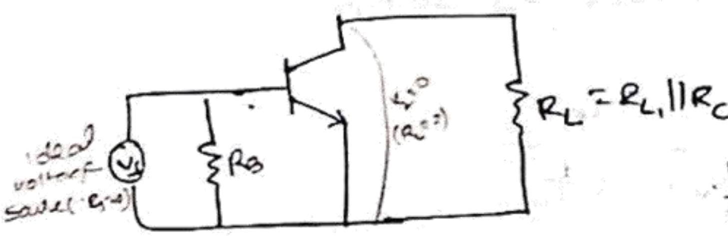
low freq. Current gain $\times$ $\underline{BW}$ of CE amp with $R_L = 0\Omega$

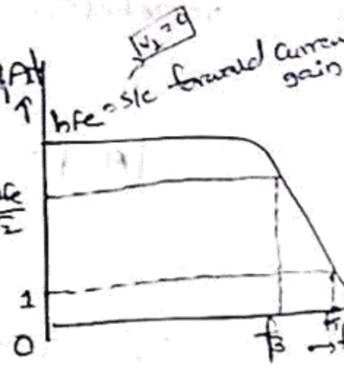
if current gain = 1 $\Rightarrow$ f_T = BW at $A_I = 1$

BJT high frequency response

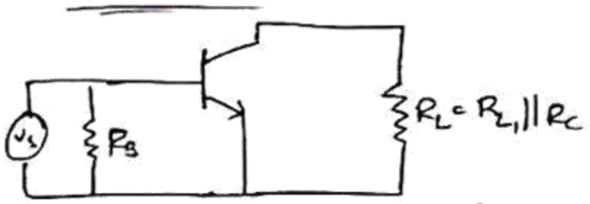






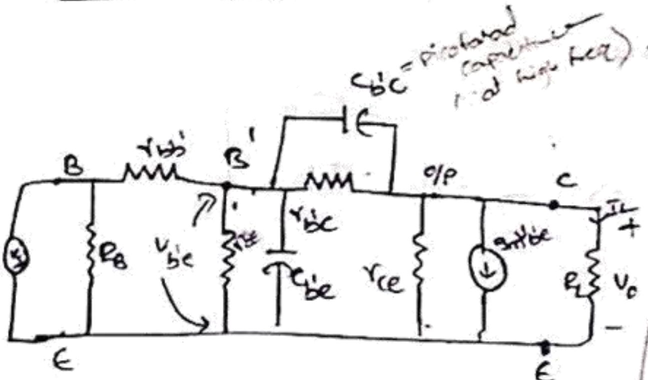


RL into Effect



$$A_I = \frac{-h_{fe}}{1 + j(f/f_\beta)}$$

$$|A_I| = \frac{h_{fe}}{\sqrt{1 + (f/f_\beta)^2}}$$



f_β = BW of CE amplifier with s/c o/p

f_β = β - cutt of frequency

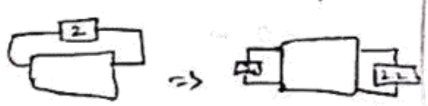
$$f_T : \frac{g_{b'e}}{2\pi(C_c + C_e)} = \frac{1}{2\pi r_{b'e}(C_c + C_e)}$$

$\boxed{f_T = h_{fe} \cdot f_\beta}$ = gain × BW

= gain BW product

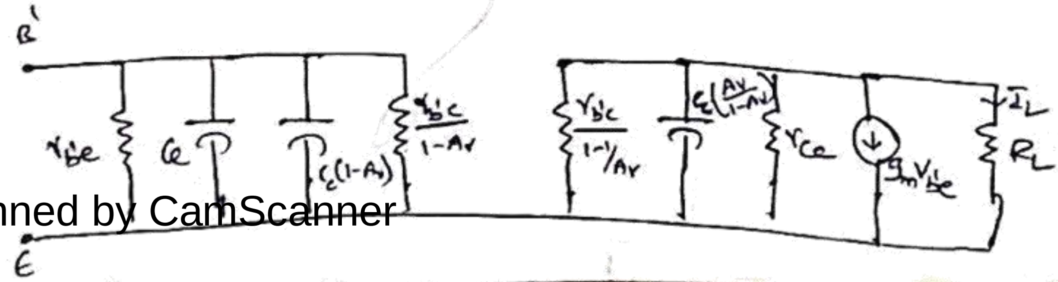
f_T = unity gain BW

using miller's theorem,



$$Z_1 = \frac{Z}{1 - A_v} = \frac{\frac{1}{j\omega c}}{1 - A_v} = \frac{1}{j\omega C_c(1 - A_v)}$$

$$Z_2 = \frac{Z}{1 - 1/A_v}$$ where A_v = MF voltage gain



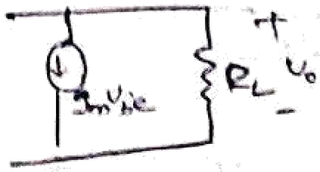
A_v = voltage gain at MF $= \frac{V_o}{V_{b'e}} = \frac{V_{ce}}{V_{b'e}}$

at MF, all PF capacitances (C_c, C_e) act as o/c

$V_o = -g_m V_{b'e} R_L$

$\frac{V_o}{V_{b'e}} = A_v = -g_m R_L$ (50mA/V, $\rightarrow 2k\Omega$)

$\simeq (50mA/V)(2k)$



$A_v = -100$

Input side

1. $\frac{r_{b'c}}{1-A_v} = \frac{4M\Omega}{1-(-100)} = \frac{4M\Omega}{101} \simeq 40k\Omega$

$\frac{r_{b'c}}{1-A_v}$ can be neglected as it is in ‖el with $r_{b'e}$ ($\cong 1k\Omega$)

Output side

1. $\frac{r_{b'c}}{(1-1/A_v)} \cong r_{b'c} = 4M\Omega$

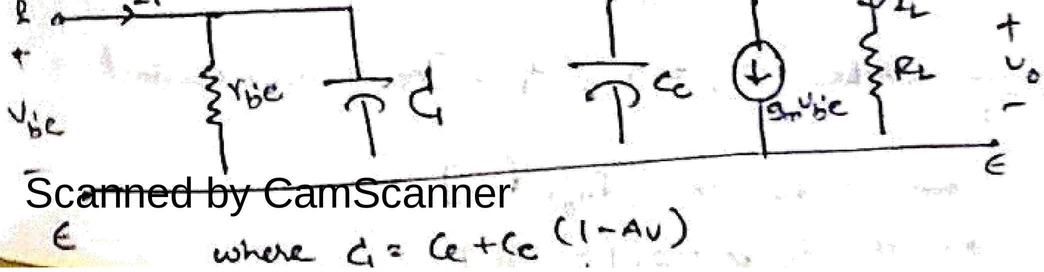
This can be neglected as it is in ‖el with R_L ($\cong 2k\Omega$)

2. $r_{ce} = 80k\Omega$ ($>> R_L$)

r_{ce} can be neglected as it is in ‖el with R_L ($\cong 2k\Omega$)

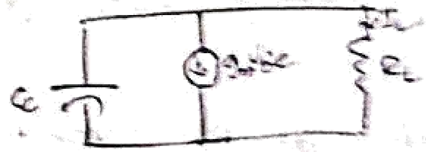
3. $C_c\left(\frac{A_v}{A_v - 1}\right) \cong C_c$

KCL (C) $= I_L = g_m V_{b'e} \times \frac{\frac{1}{j\omega C_c}}{\frac{1}{j\omega C_c} + R_L}$

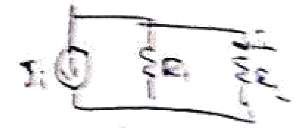


where $C_i = C_e + C_c(1-A_v)$

$$I_L = -g_m V_{b'e} \times \frac{\frac{1}{j\omega C_c}}{\frac{1}{j\omega C_c} + R_L}$$



$$I_L = \frac{-g_m V_{b'e}}{1 + j\omega R_L C_c} = \frac{-g_m V_{b'e}}{1 + j2\pi f R_L C_c}$$



$$I_L = \frac{-g_m V_{b'e}}{1 + j\left(f/f_{H_o}\right)} \quad \text{where } f_{H_o} = \frac{1}{2\pi R_L C_c} \text{ —— (1)}$$

$$f_{H_o} = \frac{1}{2\pi \tau_o} = \text{upper cut off freq. due to o/p.}$$

where $\tau_o = R_L C_c$ = o/p time constant

$$I_i = \frac{V_{b'e}}{r_{b'e}} + \frac{V_{b'e}}{\left(1/j\omega C\right)} = V_{b'e}\left[\frac{1}{r_{b'e}} + j\omega C\right]$$

$$I_i = V_{b'e}\left[\frac{1 + j\omega r_{b'e} C_i}{r_{b'e}}\right] \text{ —— (2)}$$

$$A_{I \text{ with } R_L} = \frac{I_L}{I_i}$$

$$A_{I \text{ with } R_L} = \frac{-g_m r_{b'e}}{\left(1 + jf/f_{H_o}\right)\left(1 + j\omega r_{b'e} C_i\right)}$$

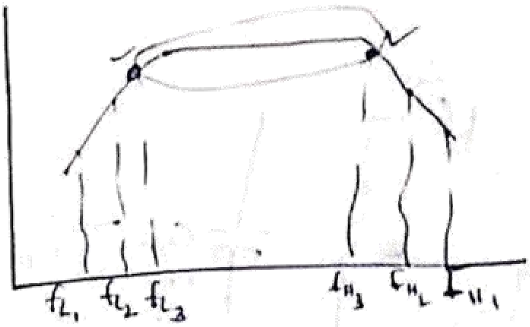
$$= \frac{-g_m r_{b'e}}{\left(1 + j f/f_{H_o}\right)\left(1 + j f/f_{H_i}\right)}$$

where $f_{H_i} = \dfrac{1}{2\pi r_{b'e} C_i}$ = upper cut off freq. due to i/p side

$$f_{H_i} = \frac{1}{2\pi \tau_i} \quad \text{where } \tau_i = r_{b'e} C_i = \text{Input time constant}$$

overall $f_H = \text{Min}[f_{H_o}, f_{H_i}]$

overall $f_H \propto \text{Max}[\tau_o, \tau_i]$



f_L = highest $(f_{L_1}, f_{L_2}, f_{L_3})$

$f_H \approx$ Lowest $(f_{H_1}, f_{H_2}, f_{H_3})$

~~Overall~~ $\tau_i = r_{b'e} \cdot C_i = r_{b'e}\left[C_e + C_c(1-A_v)\right]$

$\tau_i = 1K\Omega\left[100PF + 3PF(1+100)\right]$

$\boxed{\tau_i = 403\, n\,sec}$

nano

$\tau_o = R_L \cdot C_c = 2K\Omega \times 3PF$

$\boxed{\tau_o = 6 n sec}$

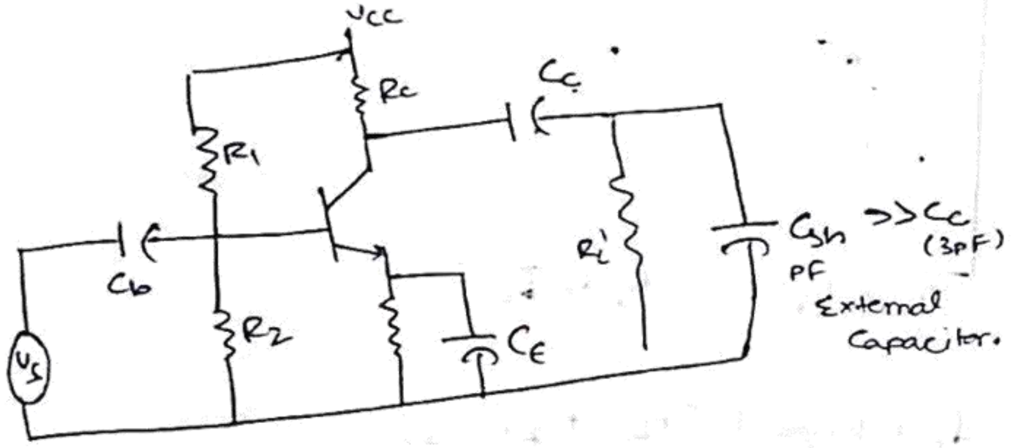
Since $\tau_o < \tau_i$ So $f_{H_i} < f_{H_o}$

$\boxed{\text{Hence } f_{H\,\text{overall}} = f_{H_i} = \dfrac{1}{2\pi r_{b'e} \cdot C_i}}$

Disadvantage: overall $f_H = f_{H_i}$ is Constant for given CE amplifier which can't be modified once the amplifier ckt is designed.

to avoid this disadv., we go for Remedy.

Remedy:-

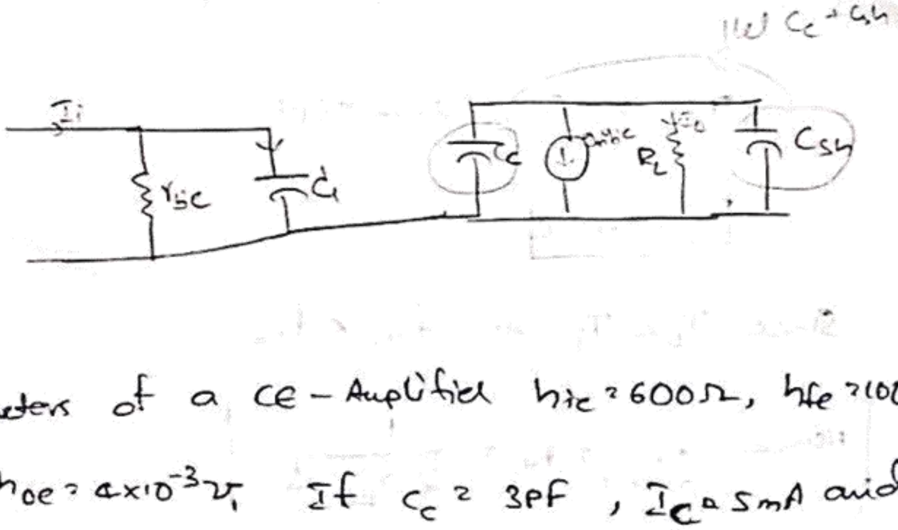


$$f_{H_i} = \frac{1}{2\pi r_{b'e} C_i} \quad \& \quad f_{H_o} = \frac{1}{2\pi R_L C_{sh}}$$

$\boxed{f_{H_o} < f_{H_i}}$ so $f_{H\,\text{overall}} \simeq f_{H_o}$

choose C_{sh} such that

$\tau_o > \tau_i$



Problem:-

The h-parameters of a CE-Amplifier $h_{ie} = 600\Omega$, $h_{fe} = 100$, $h_{re} = 10^{-4}$, $h_{oe} = 4\times10^{-3}$ Ʊ. If $C_c = 3pF$, $I_C = 5mA$ and $A_I = 10$ at 10MHz. find f_β, f_T, $r_{b'e}$, $r_{bb'}$, C_e.

Sol:

$$r_{b'e} = \frac{\beta}{g_m}$$

$$g_m = \frac{I_C}{V_T} = \frac{5A}{26mV} = \frac{5}{26}$$

$$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{100\times26}{5} = 520\Omega$$

$$A_I = \frac{-h_{fe}}{1 + j\,f/f_\beta}$$

$$|A_I| = \frac{h_{fe}}{\sqrt{1+(f/f_\beta)^2}}$$

Given $|A_I| = 10$ at $f = 10MHz$

$f_\beta = 10^6\ Hz$

$f_T = \beta f_\beta = h_{fe}\cdot f_\beta = 10^8\ Hz$

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

$= 600 - 520$

$= 80\,\Omega$

$f_T = \dfrac{g_m}{2\pi(C_c + C_e)}$

$10^8\,Hz = \dfrac{5}{26(3.14)(3\times10^{-12} + C_e)}$

$3\times10^{-12} + C_e = \dfrac{5\times10^{-8}}{26(3.14)\times2}$

$= \dfrac{6.12}{2}\times10^{-10}$

$C_e = \dfrac{6.07}{2}\times10^{-10}$

$\boxed{C_e = \dfrac{607}{2}\,PF}$

p) S/C, CE A_I of a transistor is 25 at a freq of 2 MHz if $f_\beta = 200\,kHz$. Calc h_{fe}, f_T & A_I at 10 MHz

Sol: $|A_I| = 25$ at $f = 2\,MHz$

$f_\beta = 200\,kHz$

$|A_I| = \dfrac{h_{fe}}{\sqrt{1+(f/f_\beta)^2}}$

$25 = \dfrac{h_{fe}}{\sqrt{1+\left(\frac{2\times10^6}{200\times10^3}\right)^2}}$

$h_{fe} = 251.2$

$f_T = \beta f_\beta$

$= 251 \times (200 \times 10^3)$

$= 50.2 \times 10^6$

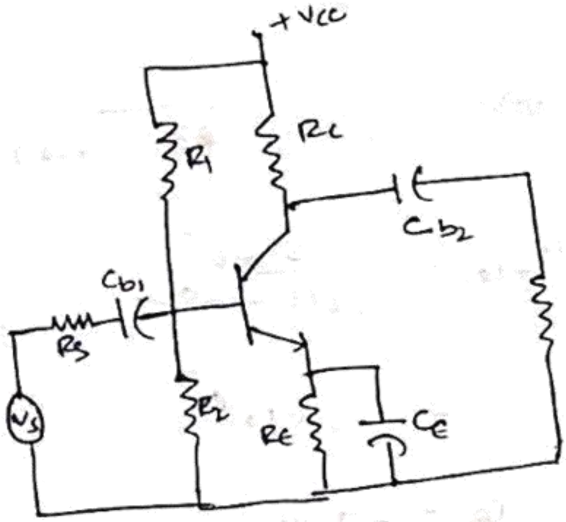
$\boxed{f_T = 50.2\,MHz}$

at $f = 10\,MHz$

$|A_I| = \dfrac{h_{fe}}{\sqrt{1+(f/f_\beta)^2}}$

$= \dfrac{251}{\sqrt{1+\left(\frac{10M}{200k}\right)^2}} = 5.023$

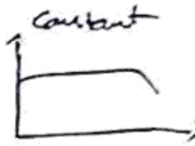
CE Amplifier at HF with practical voltage source (V_s with $R_s \neq 0$)



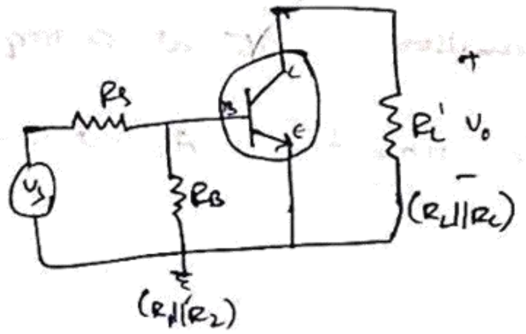
$h_{fe} = \beta =$ CE S/C current gain

at high freq reduces

at low & MF constant



→ Replaced with high freq equivalent model.



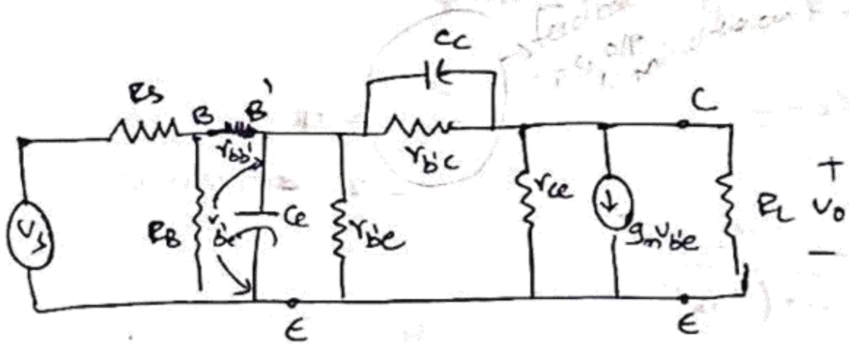
(i) CE Amp with $R_L = 0$ (V_s with $R_s = 0$) ideal source

(ii) CE Amp with $R_L \neq 0$ (V_s with $R_s \neq 0$)

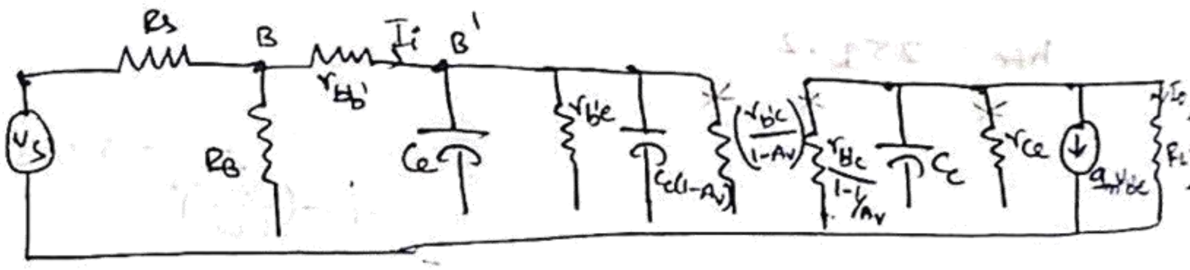
(iii) CE Amp with $R_L \neq 0$ (V_s with $R_s \neq 0$)

→ voltage gain, A_V

→ f_H

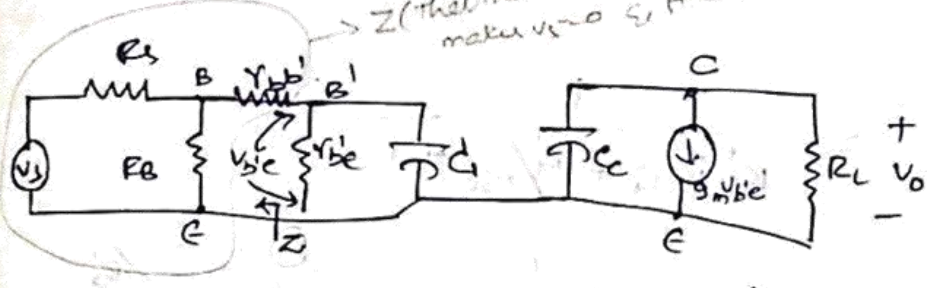


Using Miller Theorem



A_v = Mid frequency voltage gain

$$A_v = -g_m R_L >> 1$$



where $C_1 = C_e + C_c(1 + g_m R_L)$

$$v_o = -g_m v_{b'e}\left[R_L \| \frac{1}{j\omega C_c}\right]$$

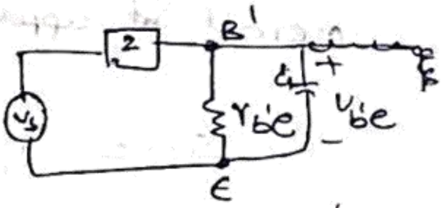
$$= -g_m v_{b'e}\left[\frac{R_L \cdot \frac{1}{j\omega C_c}}{R_L + \frac{1}{j\omega C_c}}\right]$$

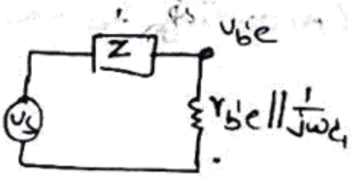
$$v_o = \frac{-g_m R_L v_{b'e}}{1 + j\omega R_L C_c}$$

$$\frac{v_o}{v_{b'e}} = \frac{-g_m R_L}{1 + j\left(f/f_{H_o}\right)}$$

where $f_{H_o} = \frac{1}{2\pi R_L C_c}$ = upper cut off frequency due to o/p node.

$$A_v = \frac{v_o}{v_s} = \frac{v_o}{v_{b'e}} \times \frac{v_{b'e}}{v_s}$$





where $Z = R_s \| R_B + r_{bb'}$

$\simeq \boxed{R_s + r_{bb'} = R_s'}$

VDR:
$V = V_T \times \frac{\text{that resistance}}{\text{Sum of resistance}}$

VDR

$$v_{b'e} = \frac{\left[r_{b'e} \| \frac{1}{j\omega C_1}\right]}{\left[R_s' + r_{b'e} \| \frac{1}{j\omega C_1}\right]} v_s$$

total voltage

$$\frac{v_{b'e}}{v_s} = \frac{r_{b'e}\left(\frac{1}{j\omega C_1}\right)}{R_s'\left(r_{b'e} + \frac{1}{j\omega C_1}\right) + r_{b'e}\left(\frac{1}{j\omega C_1}\right)}$$

$$\frac{v_{b'e}}{v_s} = \frac{(r_{b'e}/j\omega C_i)}{\left[R_s' r_{b'e} + \frac{R_s'}{j\omega C_i}\right) + \left(\frac{r_{b'e}}{j\omega C_i}\right)}$$

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

$$= \frac{1}{R_s'(j\omega C_i + g_{b'e}) + 1} \cong \frac{1/R_s'}{(j\omega C_i + g_{b'e}) + \frac{1}{R_s'}}$$

$$= \frac{G_s'}{j\omega C_i + g_{b'e} + G_s'}$$

$$A_v = \frac{v_o}{v_{b'e}} \times \frac{v_{b'e}}{v_s} = \left(\frac{-g_m R_L}{1 + j(f/f_{Lb})}\right) \cdot \left(\frac{G_s'}{j\omega C_i + g_{b'e} + G_s'}\right)$$

$f_{Hi} = \dfrac{1}{2\pi R_i C_i}$ = upper cutt off frequency due to i/p node.

$\boxed{f_{Hi} = \frac{1}{2\pi T_i}}$

then $R_i = R_s' \| r_{b'e}$

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

overall ~~of~~ upper cutoff frequency $= f_H = \text{Min}(f_{Hi}, f_{Ho})$

Since $T_i >> T_o$ (According to standard value)

$$f_{Hi} < f_{Ho}$$

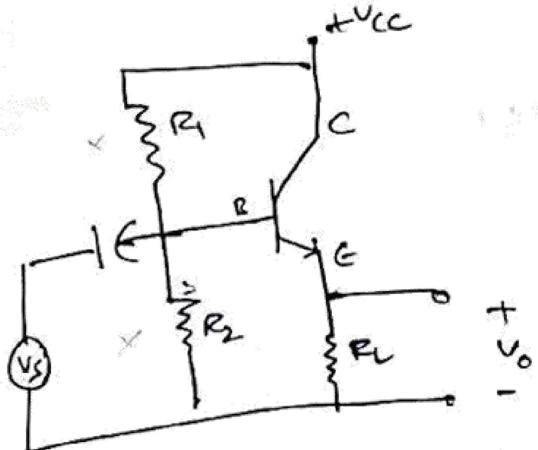
Hence $f_H = f_{Hi} = \dfrac{1}{2\pi R_i C_i}$

<u>Disadv:-</u> f_{Hi} = constant.

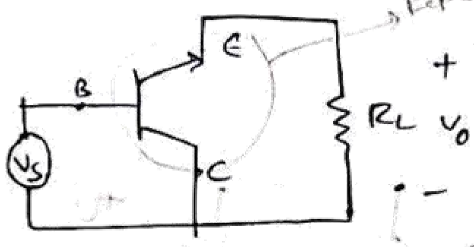
→ Emitter follower (common collector) at HF :-

↦ A_v of CC & f_H of CC

* $A_{v_m} \simeq 1$ (unity voltage gain) for CC

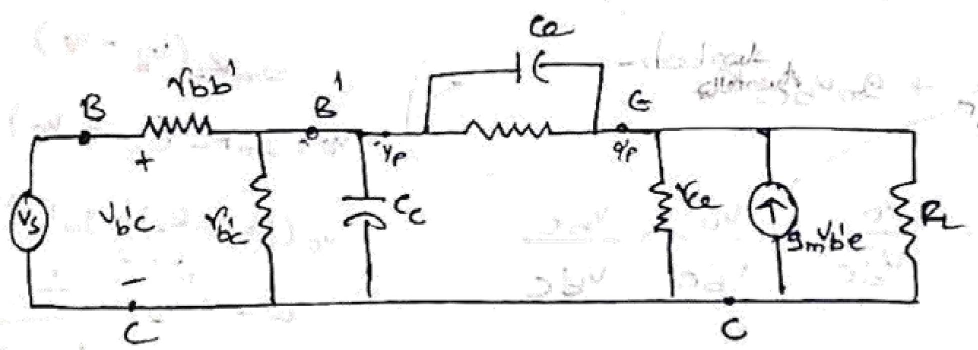


→ Replacing with Equivalent HF model.



R_E is not considered because it's value is high

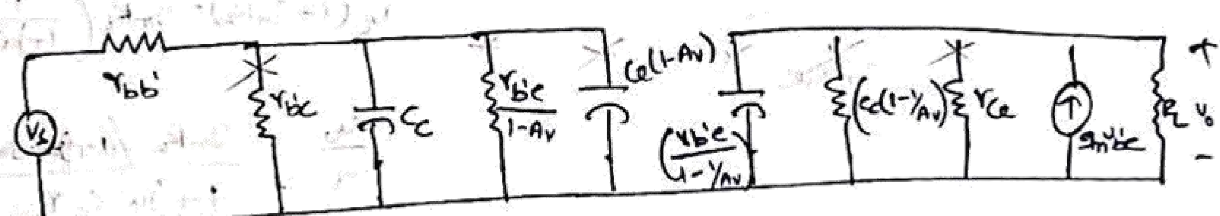
B' = internal base node



→ current direction is always from collector to Emitter

$$\boxed{A_v = \frac{V_o}{V_{b'c}}}$$

use Miller's theorem



At MF CC $\boxed{A_v = 1}$

i/p side

1) $\frac{r_{b'e}}{1-A_v} = \frac{r_{b'e}}{0} = \infty$ (O/C)

2) $C_e(1-A_v)$
$= 0$

$X_{C_e} = \frac{1}{j\omega C_e} = \frac{1}{0} = \infty$ (O/C)

3) $r_{b'c}$ = ...

O/P side:-

1) $\frac{r_{b'c}}{1 - 1/A_v} = \infty$ (o/c)

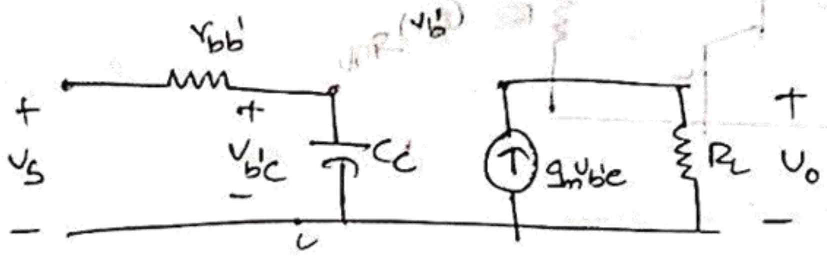
2) $C_e(1 - 1/A_v) \simeq 0$

$X_{Ce} = \frac{1}{j\omega C_e} = \frac{1}{0} = \infty$ (o/c)

3) $r_{ce} = 80K\Omega >> R_L$

r_{ce} can be removed

Equivalent circuit:-



$V_o = + g_m V_{b'e} R_L$

$\Rightarrow V_o = g_m R_L (V_{b'} - V_e)$

$V_o = g_m R_L (V_{b'} - V_o)$

$V_o(1 + g_m R_L) = g_m R_L V_{b'}$

$A_v = \frac{V_o}{V_{b'c}} = \frac{V_o}{V_{b'e}} \times \frac{V_{b'e}}{V_{b'c}}$

where V.D.R $V_{b'} = \frac{\frac{1}{j\omega C_c}}{r_{bb'} + \frac{1}{j\omega C_c}} \times V_s$

$\times f_H = \frac{1}{2\pi r_{bb'} C_c}$ = upper cut off frequency

$\Rightarrow V_{b'} = \frac{V_s}{1 + j\omega C_c r_{bb'}}$

get ratio of $\frac{V_{b'e}}{V_{b'c}}$ by using KCL at B' node.

$g_m V_{b'e}$

$V_o(1 + g_m R_L) = g_m R_L \left(\frac{1}{1 + j\omega C_c r_{bb'}}\right) V_s$

$\frac{V_o}{V_s} = \frac{g_m R_L / (1 + g_m R_L)}{1 + j\omega C_c r_{bb'}}$

$A_v = \frac{V_o}{V_s} = \frac{(g_m R_L / (1 + g_m R_L))}{1 + j(f/f_H)}$

where

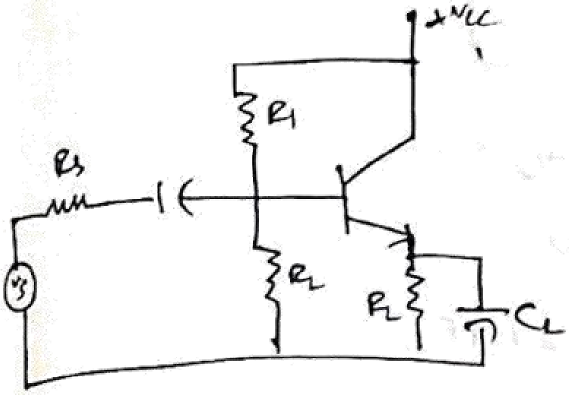
$f_H = \frac{1}{2\pi r_{bb'} C_c}$

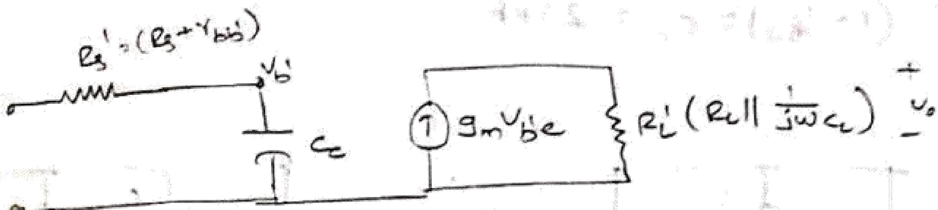
since $g_m R_L >> 1$

$$\boxed{A_v = \frac{1}{1+j(f/f_H)}}$$

for $f > f_H$ $\boxed{A_v < 1}$

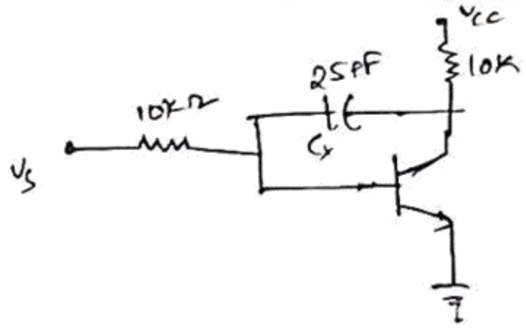
* problem:- CC amp with C_L





$V_o = g_m R_L' (V_{b'} - V_e)$

P1)



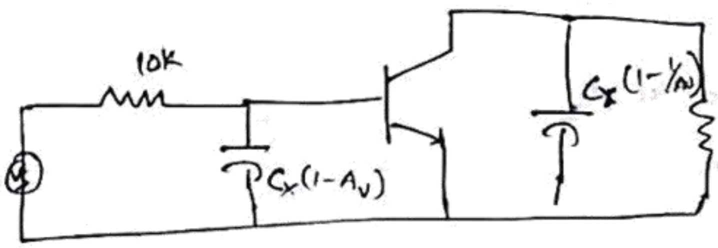
find f_H if $g_m = 5mA/V$

$r_\pi = 20K\Omega$ ↓ $r_{b'e}$

$C_\pi = 1.5pF$

$C_\mu = 0.5pF$

miller theorm

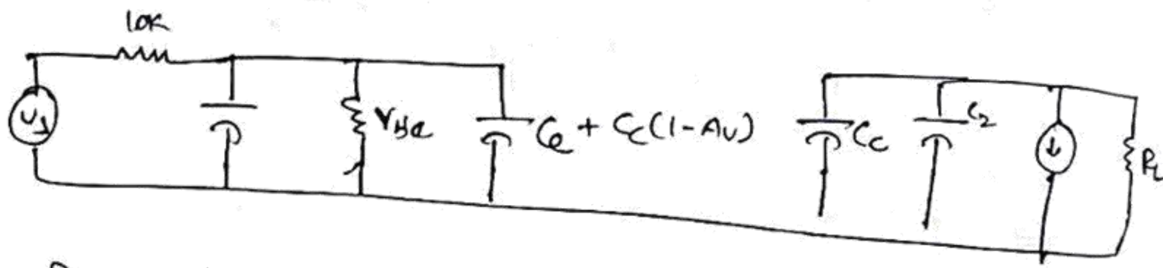


where $A_V = -g_m R_L = -5mA/V \times 10K$

$= -50$

$C_x(1-A_V) = 25 \times 51 = 1275pF$

$C_x(1-\frac{1}{50}) \simeq C_x = 25pF$



$f_{H_i} = \frac{1}{2\pi \tau_i}$

where $\tau_i = R_i C_i$

where $R_i = 10 || r_{b'e}$

$= 10||20$

$C_i = C_1 + C_e + C_c(1-A_V)$

$= 1275 + 1.5 + 0.5(51)$

$f_{H_o} = \frac{1}{2\pi \tau_o}$

$\tau_o = R_o C_o$

where

$R_o = R_L = 10K\Omega$

$C_o = C_c + C_2$

$= 0.5 + 25$

$\tau_i \gg \tau_o$ So $f_H = f_i$

An NPN Transistor with $C_\pi = 0.3pF$ & unity gain cut off freq. $f_T = 400MHz$ at a DC bias current of $I_C = 1mA$.

find $C_c = ?$ $C_\mu = ?$

$$f_T = \frac{g_m}{2\pi(C_e + C_c)} = \frac{g_m}{2\pi(C_\pi + C_\mu)} = \frac{1}{26 \times 2\pi(0.3pF + C_\mu)}$$

where $g_m = \frac{I_C}{V_T} = \frac{1mA}{26mV} = \frac{1}{26}$

$$\cancel{400\times10^6}$$

$$0.3pF + C_\mu = \frac{1}{26 \times 2\pi \times 400 \times 10^6}$$

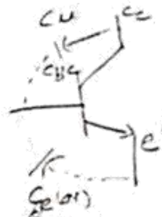
$$C_\mu = 1.53 \times 10^{-11} - 0.3 \times 10^{-12}$$

$$\boxed{C_\mu = 1.5 \times 10^{-11}}$$

→ for a NPN BJT $g_m = 38mA/V$ & $\underset{C_c}{\overset{\parallel}{C_\mu}} = 10^{-14}F$ $\underset{C_e}{\overset{\parallel}{C_\pi}} = 4\times10^{-13}F$

$\beta = h_{fe} = 90$ find f_T & f_β

C_μ & C_π are internal (pF) capacitances exists at high freq.



$$f_T = \frac{g_m}{2\pi(C_c + C_e)}$$

$$= \frac{38 \times 10^{-3}}{2 \times 3.14(10^{-14} + 4\times10^{-13})}$$

$$\boxed{f_T = 1.47 \times 10^{10}}$$

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

$$\frac{1.47\times10^{10}}{90} = f_\beta$$

$$f_\beta = 1.63 \times 10^{8}$$