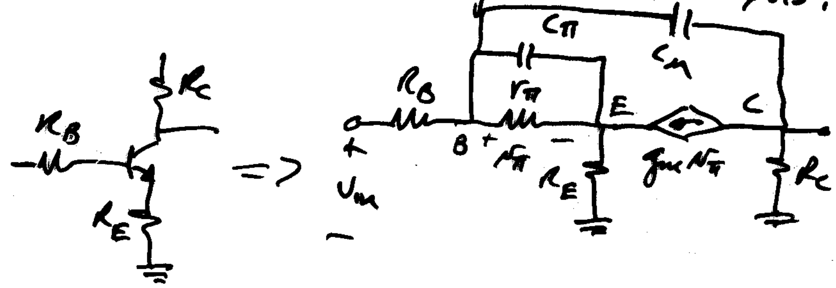
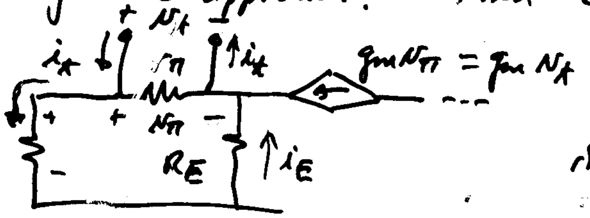
Question: What about non-CE config. for HF analysis?

Answer:



Using OTC approach: find $R_{C\pi O}$ and $R_{C\mu O}$



First ignore r_π (it is in // with the answer)

$i_E + g_m v_x = i_x$

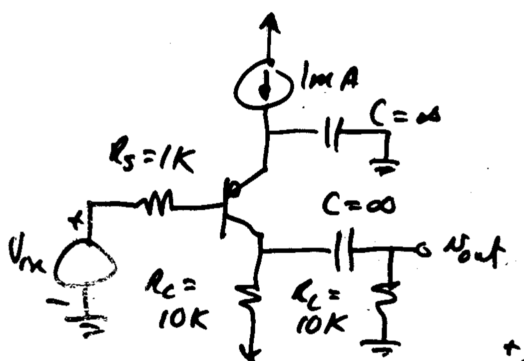
$$v_x = i_x R_B + R_E(i_x - g_m v_x)$$

$$v_x[1 + g_m R_E] = i_x(R_B + R_E)$$

$$\frac{v_x}{i_x} = \frac{R_B + R_E}{1 + g_m R_E} \rightarrow R_{C\pi O} = r_\pi \,\Big|\Big|\, \left[\frac{R_B + R_E}{1 + g_m R_E}\right]$$

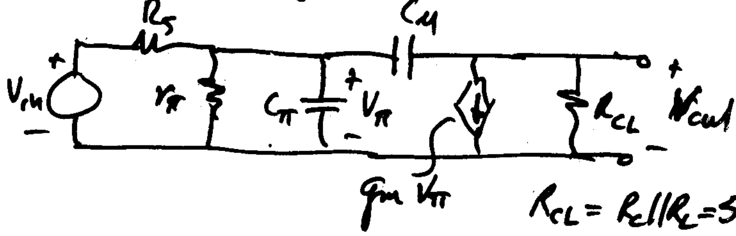
BJT HF Example

$$C_\pi = \frac{2\pi f_T}{g_m} - C_\mu$$



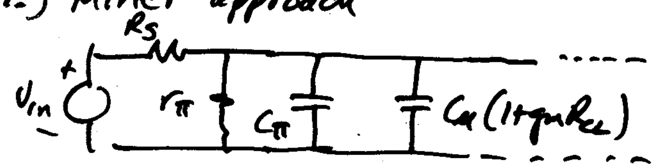
$\beta = 100$, $C_\mu = 2pF$, ~~$f_T = 560 MHz$~~, $r_x = 0$ and $r_o = \infty$. If $r_\pi = 1K$, $g_m = 0.01 A/V$ and $C_\pi = 10pF$, find f_H.

Small-signal model:



$R_{CL} = R_C || R_L = 5K$

1.) Miller approach



$$K = \frac{V_{out}}{V_\pi} \cong -g_m R_{CL} \text{ if } \frac{1}{\omega_H C_\mu} >> R_{CL}$$

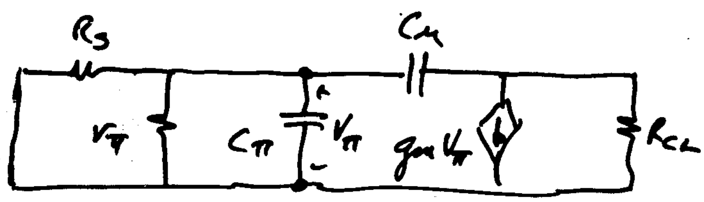
Continuing -

$$C_\mu(1+g_mR_{CL}) = 2pF(1+10\cdot5) = 102pF \qquad C_{eq} = 112pF$$

$$\omega_H = \frac{1}{(R_s \| r_\pi)C_{eq}} = \frac{1}{500\,(112pF)} = 17.86\ \text{Mrads/sec}$$

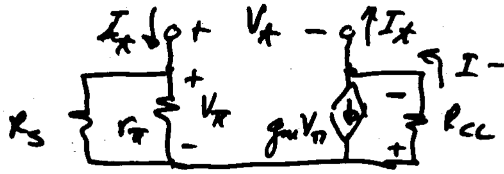
$$f_H = f_{-3dB}(\text{upper}) = \frac{\omega_H}{2\pi} = \underline{\underline{2.842\ MHz}}$$

2.) OTC



$R_{C\pi o}$: $\quad R_{C\pi o} = r_\pi \| R_s$

$R_{C\mu o}$:



$I = I_x + g_mV_\pi$

$V_\pi = I_x(r_\pi \| R_s)$

$\therefore I = I_x[1 + g_m(r_\pi \| R_s)]$

$$V_x = I_x[r_\pi \| R_s] + IR_{CL}$$

$$V_x = I_x[r_\pi \| R_s] + I_xR_{CL}[1 + g_m(r_\pi \| R_s)]$$

$$R_{C\mu O} = \frac{V_x}{I_x} = (r_\pi \| R_s)(1 + g_mR_{CL}) + R_{CL}$$

$$= 5k + (1+10\cdot5)(500) = 30.5k\Omega$$

check Assumption:

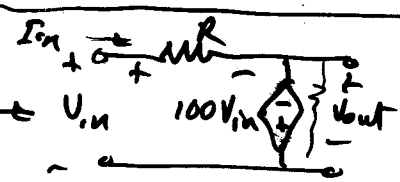
$\frac{1}{\omega_H 2pF} = 28k\Omega$

$28k > 5k$

$$\omega_H = \frac{1}{R_{C\pi o}C_\pi + R_{C\mu o}C_\mu} = \frac{1}{(0.5k)(10pF) + (30.5k)(2pF)} \simeq 15\ \frac{\text{Mrads}}{\text{sec}}$$

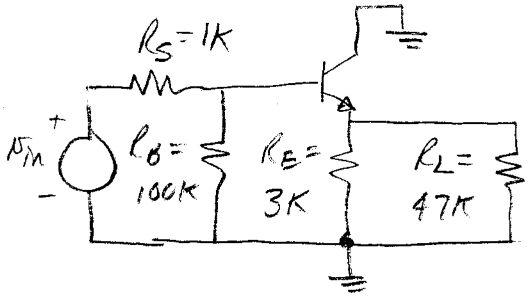
$$f_H = \frac{15\times10^6}{2\pi} = \ldots$$

$R_{in} = ?$



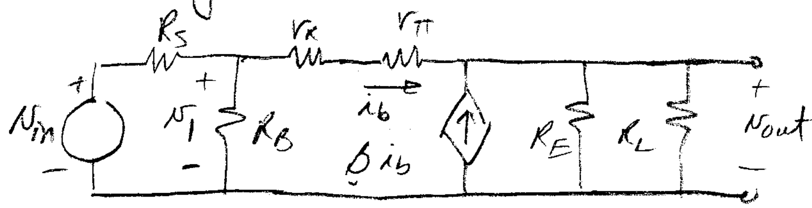
$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{\frac{V_{in} - (-100V_{in})}{R}} = \frac{R}{101}$$

Dominant Pole for Emitter Follower (Common Collector)



If $\beta = 100$, $I_C = 1.5mA$, $r_x = 150\Omega$, $C_\mu = 0.5pF$ and $f_T = 500MHz$, find the midband gain and ω_H.

Midband gain:



$$g_m = \frac{1.5}{25} = 60mS$$

$$r_\pi = \frac{100}{60} \times 10^3 = 1667\Omega$$

$$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{i_b}\right)\left(\frac{i_b}{v_1}\right)\left(\frac{v_1}{v_{in}}\right)$$

$$\frac{v_{out}}{i_b} = (1+\beta)\, R_E \| R_L = 101\,(3K \| 47K) = 101(2.82K) = 284.82K$$

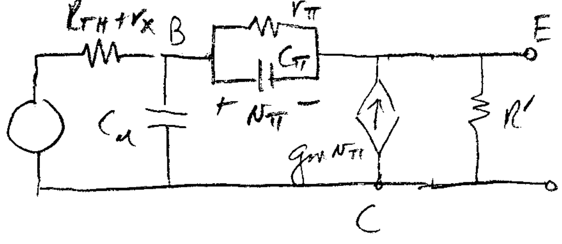
$$\frac{i_b}{v_1} = \frac{1}{r_x + r_\pi + (1+\beta)R_E\|R_L} = \frac{1}{0.150K + 1.667K + 101(2.82K)} = \frac{1}{286.64K}$$

$$\frac{v_1}{v_{in}} = \frac{R_B \| \left[\frac{v_1}{i_b}\right]}{R_S + R_B \| \left[\frac{v_1}{i_b}\right]} = \frac{100K \| 286.64K}{1K + 100K \| 286.64K} = \frac{74.14K}{75.14K}$$

$$\therefore \frac{v_{out}}{v_{in}} = (284.82K)\left(\frac{1}{286.64K}\right)\left(\frac{74.14}{75.14}\right) = 0.974 \text{ V/V}$$

ω_H:

$$C_\pi = \frac{g_m}{\omega_T} - C_\mu = \frac{60 \times 10^{-3}}{\pi \times 10^9} - 0.5pF = 18.6pF$$

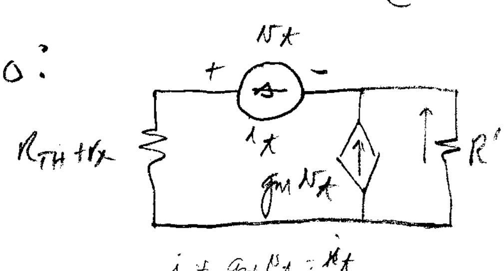


$$R_{TH} = R_S \| R_B = 0.99K$$

$$R_{TH} + r_x = 1.149K$$

$$R' = R_E \| R_L = 2.82K$$

$R_{\pi 0}$:



$i + g_m v_x = i_x$

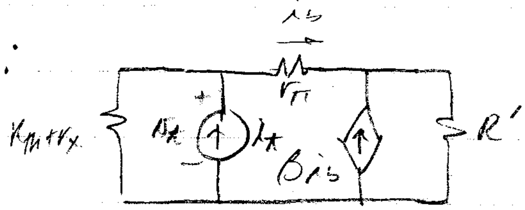
$$v_x = i_x (R_{TH} + r_x) + (i_x - g_m v_x) R'$$

$$v_x (1 + g_m R') = i_x (R_{TH} + r_x + R')$$

$$R_{\pi 0} = r_\pi \| \frac{R_{TH} + r_x + R'}{1 + g_m R'} \approx \frac{R_{TH} + r_x + R'}{1 + g_m R'} = 22.4\Omega$$

Common-Collector - Cont'd

$R_{\mu o}$:



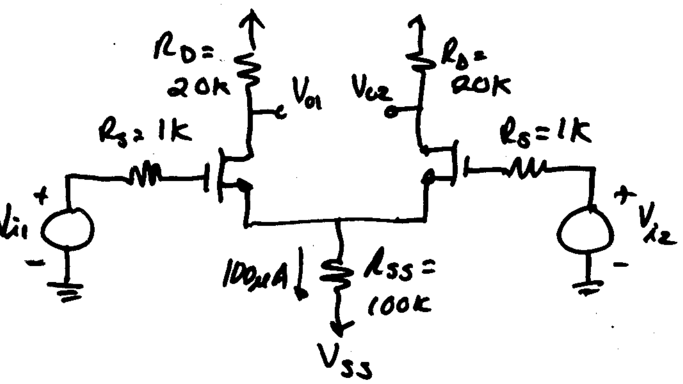
$$i_x = \frac{v_x}{R_{th}+r_x} + \frac{v_x}{r_\pi + (1+\beta)R'} \rightarrow R_{\mu o} = \frac{v_x}{i_x} = \frac{1}{\frac{1}{R_{th}+r_x} + \frac{1}{r_\pi + (1+\beta)R'}}$$

$$R_{\mu o} = \frac{1}{\frac{1}{1.149K} + \frac{1}{286.487K}} = 1.144\,K\Omega$$

$$\therefore \omega_H \approx \frac{1}{R_{\pi o}C_\pi + R_{\mu o}C_\mu} = \frac{1}{(0.0224K)(18.6pF) + (1.144K)(0.5pF)}$$

$$= 1.01 \times 10^9 \text{ rad/sec} \longrightarrow \underline{\underline{161\text{ MHz}}}$$

High-Frequency Response of a Diff. Amp.

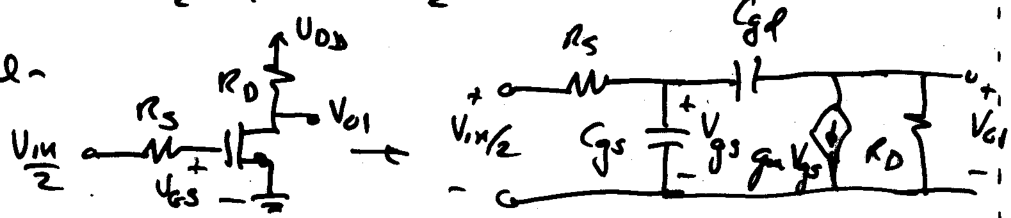


If $K_N' = 1mA/V^2$ and $V_{TN} = 1V$ find MBG and ω_H for the differential and common mode responses assuming that $C_{gs} = 5pF$ and $C_{gd} = 1pF$.

Differential Mode –

$$\frac{V_{o1}}{V_{id}} = ? \qquad V_{i1} = \frac{V_{in}}{2} \;\; \& \;\; V_{i2} = -\frac{V_{in}}{2}$$

S.S model –



$$MBG = \frac{V_{o1}}{V_{in}} = ? \qquad V_{o1} = -g_m R_D V_{gs} = -g_m \frac{R_D}{2} V_{in}$$

$$MBG = -\frac{g_m R_D}{2} = ? \qquad g_m = \sqrt{2 \cdot K_N' I_{D1}} = \sqrt{2 \cdot 1\frac{mA}{V^2} \cdot 50\mu A}$$

$$= -\frac{316\times10^{-6}\; 20\times10^{3}}{2} = \underline{\underline{-3.162 V/V}} \qquad g_m = 316\mu S$$

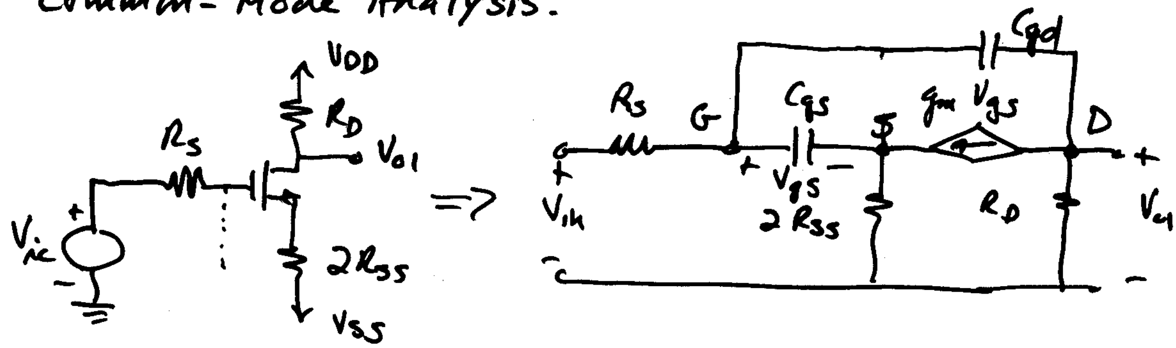
ω_H (Miller Approach) –

$$\omega_H \approx \frac{1}{C_{eq} R_S}, \quad C_{eq} = C_{gs} + C_{gd}(1 + g_m R_D) \text{ if } \frac{1}{\omega_H C_{gd}} \gg R_D$$

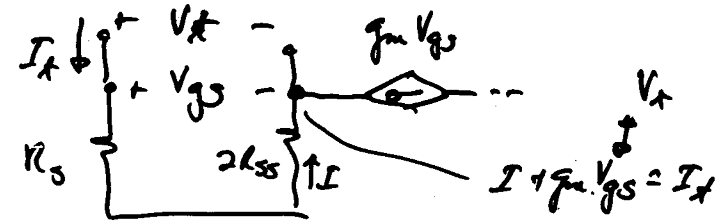
$$C_{eq} = 5pF + 1pF(1 + 6.32) = 12.3pF$$

$$\omega_H = \frac{1}{(1K)(12.3pF)} = 81.2\times10^{6} \frac{rad}{sec} \rightarrow \underline{\underline{f_H = 12.9 MHz}}$$

Commom-Mode Analysis:



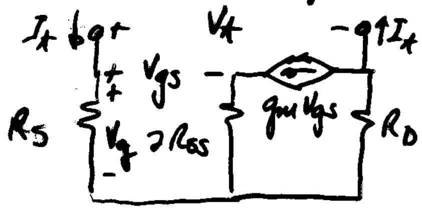
R_{cgso}:



$$V_x = I_x R_S + (I_x - g_m V_x) 2R_{SS}$$

$$\frac{V_x}{I_x} = R_{cgso} = \frac{R_S + 2R_{SS}}{1 + g_m 2R_{SS}} = 3.13K$$

R_{cdgo}:



$$V_x = I_x R_S + (I_x + g_m V_{gs}) R_D$$

$$V_{gs} = V_g - V_s = V_g - g_m 2R_{SS} V_{gs}$$

$$\therefore V_{gs} = \frac{V_g}{1 + g_m 2R_{SS}} = \frac{I_x R_S}{1 + g_m 2R_{SS}}$$

Thus, $V_x = I_x R_S + I_x R_D + g_m R_D \left(\frac{R_S I_x}{1 + 2 g_m R_{SS}} \right)$

or $\frac{V_x}{I_x} = R_{cdgo} = R_S + R_D + \frac{g_m R_D R_S}{1 + 2 g_m R_{SS}} = 21K + \frac{6.32K}{64.2} = 21.1K$

$$\omega_H = \frac{1}{R_{cgso} C_{gs} + R_{cdgo} C_{gd}} = \frac{1}{1.565 \times 10^{-8} + 4.22 \times 10^{-8}} = 17.29 \text{ Mrads/sec}$$

$f_H = \underline{\underline{2.75 \, MHz}}$

$$MBG = \frac{g_m R_D}{1 + 2 g_m R_{SS}} \cong \frac{\cancel{g_m} R_D}{2 \cancel{g_m} R_{SS}} = \frac{20}{200} = \underline{\underline{0.1 \, V/V}}$$

CMRR ? $\rightarrow 31.6 \left(\frac{\frac{s}{\omega_H(cm)} + 1}{\frac{s}{\omega_H(diff)} + 1} \right)$

Chap. 18 next