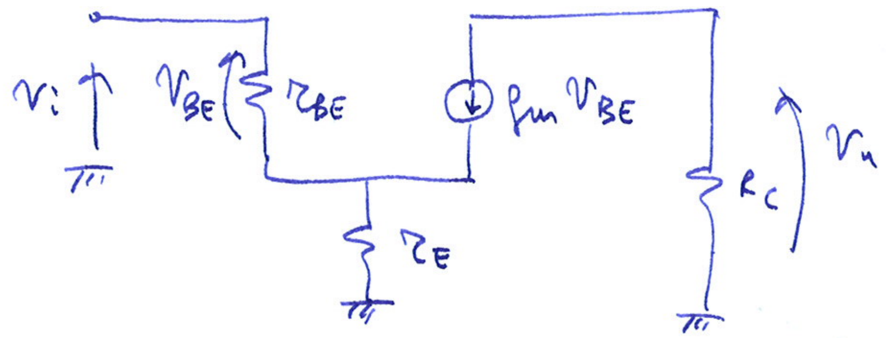
1) $I_{C0} = \dfrac{V_{CC} - V_{u0}}{R_C} = \dfrac{3.5 - 2}{750} = 2\ mA \Rightarrow I_{E0} = 2.04\ mA$

La resistenza differenziale del bipolo non lineare è quindi:

$r_E = R_0 + 3\alpha I_{E0}^2 = 46.2\ \Omega$

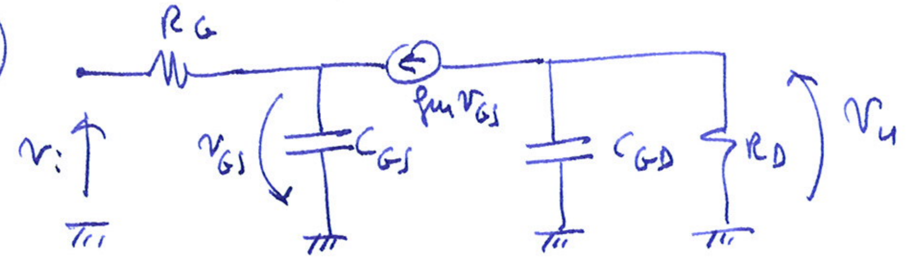
$r_{BE} = \dfrac{V_T \beta_F}{I_{C0}} = 650\ \Omega$

$g_m = \dfrac{I_{C0}}{V_T} = 76.9\ mS$



$$\begin{cases} v_u = -g_m v_{BE} R_C \\ v_i = v_{BE} + r_E \left(g_m + \frac{1}{r_{BE}} \right) v_{BE} \end{cases} \Rightarrow \frac{v_u}{v_i} = \frac{-g_m R_C}{1 + r_E \left(g_m + \frac{1}{r_{BE}} \right)} = -12.5$$

2)



$$\begin{cases} v_u = -g_m v_{GS} \cdot \dfrac{R_D / sC_{GD}}{R_D + \frac{1}{sC_{GD}}} = -\dfrac{g_m R_D}{1 + sC_{GD} R_D} \cdot v_{GS} \\ \dfrac{v_i + v_{GS}}{R_G} = -g_m v_{GS} - sC_{GS} v_{GS} \end{cases}$$

$$\Rightarrow \frac{v_u}{v_i} = \frac{g_m R_D}{(1 + sC_{GD} R_D)(1 + R_G g_m + R_G s C_{GS})}$$

$f_{p1} = \dfrac{1}{2\pi} \cdot \dfrac{1}{R_D C_{GD}} = 1.89\ GHz$ $\qquad f_{p2} = \dfrac{1 + R_G g_m}{2\pi R_G C_{GS}} = 63.7\ GHz$

3) $$\begin{cases} V^+ = \dfrac{R_4}{R_u+R_3+\dfrac{1}{sC}} V_u = \dfrac{sCR_4}{1+sC(R_3+R_4)} \cdot V_u \\[2ex] V^- = V_i - \dfrac{V_i - V_u}{R_1+R_2} \cdot R_1 \\[2ex] V_d = V^+ - V^- = \dfrac{V_u}{A_d} \end{cases}$$

$$\Rightarrow \frac{sCR_4}{1+sC(R_3+R_4)} \cdot V_u - \frac{R_2}{R_1+R_2} \cdot V_i - \frac{R_1}{R_1+R_2} \cdot V_u = \frac{V_u}{A_d}$$

$$\Rightarrow V_u \left(1 + \frac{R_1 A_d}{R_1+R_2} - \frac{sCR_4 A_d}{1+sC(R_3+R_4)}\right) = - V_i \frac{R_2 A_d}{R_1+R_2}$$

$$\Rightarrow \frac{V_u}{V_i} = - \frac{R_2 A_d \left(1+sC(R_3+R_4)\right)}{(R_1+R_2)(1+sC(R_3+R_4)) + R_1 A_d \left(1+sC(R_3+R_4)\right) - sCR_4 A_d (R_1+R_2)}$$

$$\Rightarrow f_z = \frac{1}{2\pi} \cdot \frac{1}{C(R_3+R_4)} = 15.9 \text{ kHz}$$

4) $$H_d H_2 = \frac{A_0 e^{-j\omega\tau_2}}{1+j\omega\tau_1} \Rightarrow \begin{cases} |H_d H_2| = \dfrac{A_0}{\sqrt{1+(\omega\tau_1)^2}} \\[2ex] \arg(H_d H_2) = -\omega\tau_2 - \arctan(\omega\tau_1) \end{cases}$$

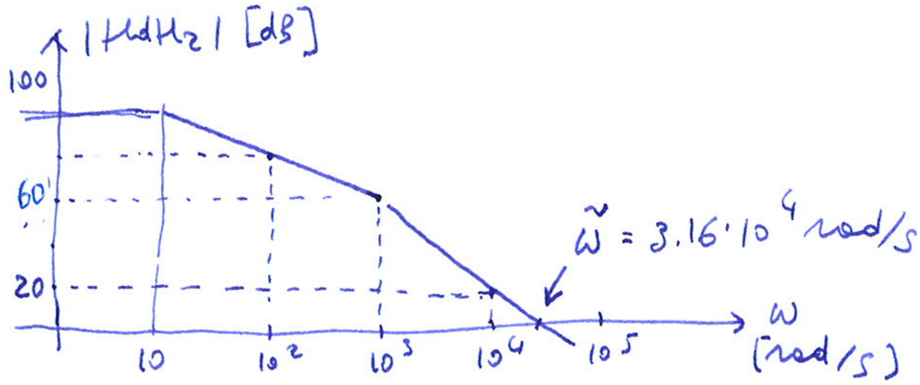
Perché sia MA = 20 dB, deve aversi $\arg(H_d H_2) = -\pi$ dove $|H_d H_2| = -20$ dB.
Poiché $\omega_p = \frac{1}{\tau_1} = 10$ rad/s, si ha $|H_d H_2| = -20$ dB per $\omega^* = 10^6$ rad/s.

$$\arg(H_d H_2)\big|_{\omega=\omega^*} = -\omega^*\tau_2 - \arctan(\omega^*\tau_1) = -\pi$$

$$\Rightarrow \tau_2 = \frac{1}{\omega^*}\left(\pi - \arctan(\omega^*\tau_1)\right) = 1.57\ \mu s$$

5) $H_2 = \frac{V^-}{V_u} = \frac{R_3}{R_2+R_3}$; $H_d H_2 = \frac{\frac{A_0 R_3}{R_2+R_3}}{(1+j\,\omega/\omega_{p1})(1+j\,\omega/\omega_{p2})}$

$$\frac{A_0 R_3}{R_2+R_3} = 10^5 = 100 \text{ dB}$$

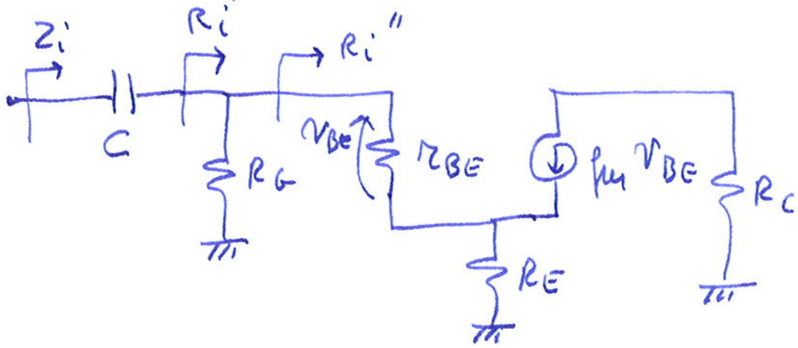


$$\arg(H_d H_2)\Big|_{\omega=\tilde{\omega}} = -\arctan\left(\frac{\tilde{\omega}}{\omega_{p1}}\right) - \arctan\left(\frac{\tilde{\omega}}{\omega_{p2}}\right) =$$

$$= -89.98^\circ - 88.19^\circ = 178.2^\circ$$

$\Rightarrow$ MF $= 1.8^\circ$

6)



$Z_i = \frac{1}{sC} + R_i'$

$R_i' = R_G // R_i''$

$R_i'' = r_{BE} + (\beta_F + 1) R_E$

$$I_{B0} + \frac{V_{CC} - (\beta_F I_B R_E + V_\gamma)}{R_G} = I_B \Rightarrow I_B = \frac{R_G I_{B0} + V_{CC} - V_\gamma}{R_G + \beta_F R_E} = 14.5\,\mu A$$

$\Rightarrow r_{BE} = 1.79\ k\Omega$

$\Rightarrow R_i'' = 3.61\ k\Omega \qquad \Rightarrow R_i' = 3.58\ k\Omega$

$$Z_i = R_i' - \frac{j}{\omega C} \Rightarrow |Z_i| = \sqrt{(R_i')^2 + \frac{1}{(2\pi f C)^2}} = 3.73\ k\Omega$$

7) $\frac{1}{2}(\mu_p C_{ox})\left(\frac{W}{L}\right)_1 (V_{SG1}+V_{Tp})^2 = \frac{V_{SS}-V_{SG1}}{R}$

$\Rightarrow 6\cdot10^{-4}\cdot V_{SG1}^2 - 1.2\cdot10^{-3}\cdot V_{SG1} + \cancel{6\cdot10^{-4}} = \cancel{6\cdot10^{-4}} - 2\cdot10^{-4}\cdot V_{SG1}$

$\Rightarrow V_{SG1}\left(6\cdot10^{-4}\cdot V_{SG1} - 10^{-3}\right) = 0$

$\Rightarrow V_{SG1} =$ 0 V : soluzione da scartare

1.67 V : soluzione accettabile

$\Rightarrow I_{D1} = 266\ \mu A \quad \Rightarrow \quad I_{D2} = \frac{1}{4} I_{D1} = 66.5\ \mu A$

$\Rightarrow I_{D3} = \frac{1}{2}(\mu_n C_{ox})\left(\frac{W}{L}\right)_3 (V_{GO}-V_{Tn})^2(1+\lambda_3\cdot V_o) = I_{D2}$

$\Rightarrow V_o = \frac{1}{\lambda_3}\left(\frac{I_{D2}}{\frac{1}{2}(\mu_n C_{ox})\left(\frac{W}{L}\right)_3 (V_{GO}-V_{Tn})^2} - 1\right) = 1.93\ V$

8) $V_o = R_o\,(I_{E2} - I_{C1})$

$I_{C1} = \beta_F \cdot I_{B1} = \beta_F \cdot \frac{V_{B1}-V_\gamma}{R_{B1}} = 2.5\ mA$

$I_{E2} = (\beta_F+1)\,I_{B2} = (\beta_F+1)\,\frac{V_{B2}-V_\gamma-V_o}{R_{B2}}$

$\Rightarrow V_o = R_o\left((\beta_F+1)\frac{V_{B2}-V_\gamma-V_o}{R_{B2}} - \beta_F\cdot\frac{V_{B1}-V_\gamma}{R_{B1}}\right)$

$\Rightarrow V_o\left(1+(\beta_F+1)\frac{R_o}{R_{B2}}\right) = R_o\left((\beta_F+1)\frac{V_{B2}-V_\gamma}{R_{B2}} - \beta_F\frac{V_{B1}-V_\gamma}{R_{B1}}\right)$

$\Rightarrow V_o = 1.39\ V$