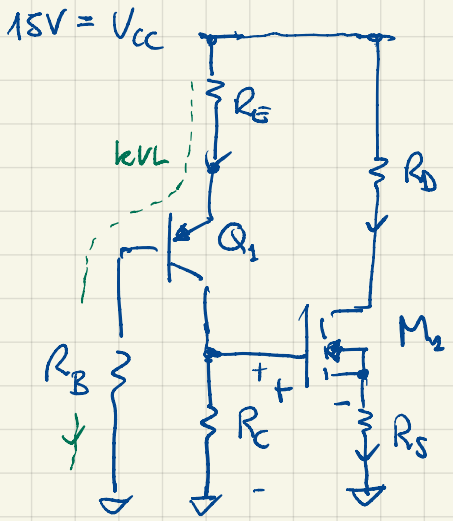
13 - 1 - 2023

BIAS POINT ANALYSIS



$R_E = 1.2\ k\Omega$

$R_D = 6.8\ k\Omega$

$R_S = 1\ k\Omega$

$R_C = 10\ k\Omega$

$R_B = 1.8\ M\Omega$

$\beta_{F_1} = 100 \simeq \beta_0$

$V_{BE_1} = -0.7\ V$

$I_{DSS} = 0.2\ mA$

$V_t = 2\ V$

KVL: $V_{CC} = R_E \cdot I_{B_1}(\beta_{F_1}+1) - V_{BE_1} + R_B \cdot I_{B_1}$

$$I_{B_1} = \frac{V_{CC} + V_{BE_1}}{R_B + R_E(\beta_{F_1}+1)} = \frac{14.3}{1.8\cdot 10^6 + 1.2\cdot(101)\cdot 10^3} \simeq 7.44\ \mu A$$

$$I_{C_1} = \beta_{F_1} \cdot I_{B_1} = 0.74\ mA$$

$$V_{CE} = -V_{CC} + R_C \cdot I_{C_1} + R_E \cdot I_{B_1}(\beta_{F_1}+1) \simeq -6.65\ V$$

$$V_{G_1} = R_C \cdot I_{C_1} = 7.44\ V$$

$$\begin{cases} V_{GS_1} = V_{G_1} - R_S \cdot I_D \\ I_D = I_{DSS}\left(\frac{V_{GS}}{V_t} - 1\right)^2 \end{cases}$$

$$V_{G1} - R_S I_{DSS}\left[\left(\frac{V_{GS}}{V_t}\right)^2 + 1 - 2\frac{V_{GS}}{V_t}\right] - V_{GS_1} = 0$$

$$a = \frac{R_S I_{DSS}}{V_t^2} = 0.05 \qquad c = R_S I_{DSS} - V_{G1} = -7.24$$

$$b = \frac{2R_S I_{DSS}}{V_t} - 1 = -0.8$$

$$V_{GS_{1,2}} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \begin{cases} +6.45\ V > V_t \\ \dots < V_t \end{cases}$$

$$I_D = I_{DSS}\left(\frac{V_{GS_1}}{V_t} - 1\right)^2 \simeq 1\ mA$$

$V_{CE_1} < -0.2V$ $\left(V_{CE\,SAT}\ pnp\right)$ F.A.R OK.

$$V_{DS} = V_{CC} - (R_D + R_S) I_D = 7.27V > V_{GS} - V_t$$

$\Rightarrow$ Q_2 IS IN THE SATURATION REGION

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$$g_{m_1} = \frac{I_{C1}}{V_T} = 0.03\ \Omega^{-1} = 30\ mS$$

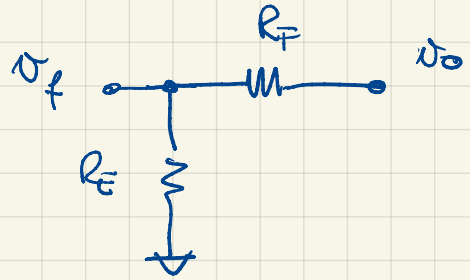
$$g_{m_2} = \frac{2}{V_t}\sqrt{I_D I_{DSS}} = 0.45\ mS$$

$$r_{\pi_1} = \frac{\beta_{01}}{g_{m_1}} = 3.36\ k\Omega$$

SMALL SIGNAL ANALYSIS

TOPOLOGY: VOLTAGE AMPLIFIER

β - NETWORK

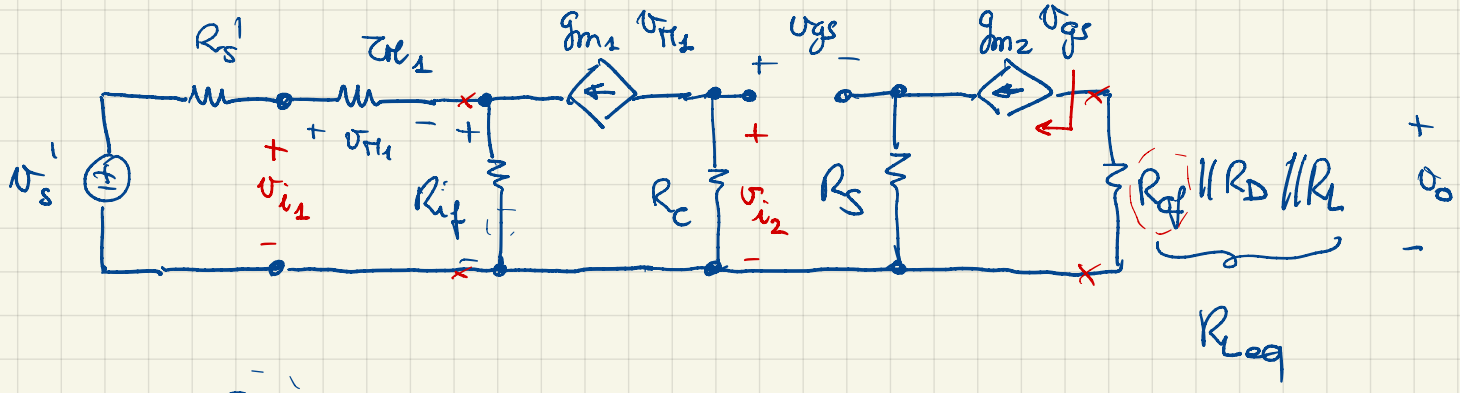


$$\beta = \frac{R_E}{R_E + R_F} = 0.353$$

$$R_{if} = R_E \,//\, R_F$$

$$R_{of} = R_E + R_F$$

SMALL SIGNAL EQUIVALENT CIRCUIT $\beta = \emptyset$



$$v_s' = \frac{R_B}{R_g + R_B} \cdot v_s \qquad R_{L_{eq}} = R_{gf} // R_D // R_L$$

$$R_s' = R_B // R_g$$

$$A_2 = \frac{v_o}{v_{i_2}} = - \frac{g_{m_2} R_{L_{eq}}}{1 + g_{m_2} R_S} = -6.627$$

$$A_1 = \frac{v_{o_1}}{v_{i_1}} = \frac{v_{i_2}}{v_{i_1}} = - \frac{\beta_{o_1} R_C}{r_{\pi_1} + (\beta_{o_1} + 1) R_{if}} = -10.9$$

$$k_s' = \frac{v_{i_1}}{v_s} = \frac{r_{\pi_1} + (\beta_{o_1} + 1) R_{if}}{R_s' + r_{\pi_1} + (\beta_{o_1} + 1) R_{if}} \approx 1$$

$$A_a = k_s' \cdot A_1 \cdot A_2 = +6.84$$

$$A_F = \frac{A_a}{1 + \beta A_a} = +2 \qquad T \simeq 2...$$

$$A_V = \frac{v_o}{v_s} = \underbrace{\frac{v_o}{v_s'}}_{A_F} \cdot \frac{v_s'}{v_s} = 1.99$$

$$R_{out_a} = R_{L_{eq}} \longrightarrow R_{out_F} = \frac{R_{L_{eq}}}{1 + \beta A_a} = 596\ \Omega$$

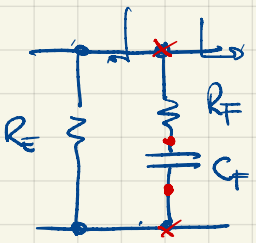
$$R_{out} = \frac{1}{\frac{1}{R_{out_F}} - \frac{1}{R_L}} = 615\ \Omega$$

f_L SCTC METHOD

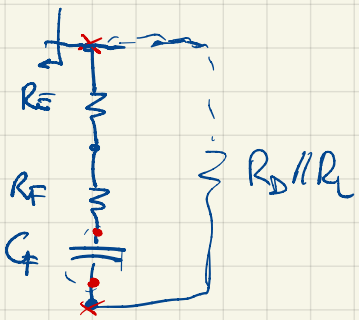
$$R_{cg} = R_g + R_B // \left[r_{\pi_1} + (\beta_{o_1} + 1) R_{if} \right] = 88\ k\Omega$$

$$R_{cL} = R_L + R_D // R_{of} = 22.3\ k\Omega$$

z_{if} =



z_{of}



R_{CF_1} R_{CF_2}

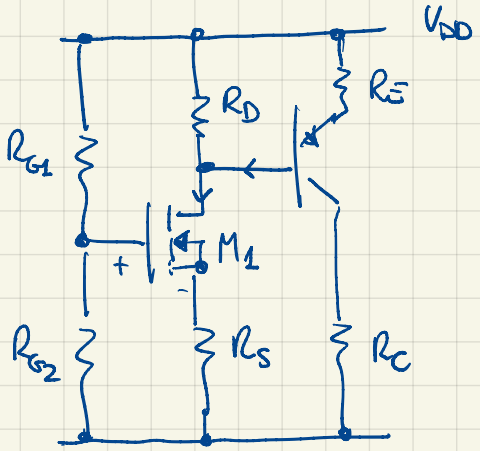
$$+ \cdots \frac{1}{2\pi C_F R_{CF_1}} + \frac{1}{2\pi C_F R_{CF_2}} + \cdots$$

$$\frac{1}{2\pi C_F} \cdot \left(\frac{1}{R_{CF_1}} + \frac{1}{R_{CF_2}} \right) = \frac{1}{2\pi C_F} \cdot \frac{1}{R_{CF_1} // R_{CF_2}}$$

$$R_{CF_1} \cong R_F + R_E // \frac{1}{g_{m_1}} \left(= R_F + R_E // \frac{r_{\pi_1} + R_S'}{\beta_{o_1} + 1} \right) = 2.32\ k\Omega$$

$$R_{CF_2} = R_D // R_L + (R_E + R_F) = 8.47\ k\Omega$$

$$f_L = \frac{1}{2\pi} \cdot \left(\frac{1}{1 + \beta A_a} \right) \cdot \sum_i \frac{1}{R_i C_i} = \underline{57\ Hz}$$



$$V_{G_1} = V_{DD} \cdot \frac{R_{G2}}{R_{G_1} + R_{G2}}$$

$$\begin{cases} V_{GS_1} = V_{G_1} - R_S \cdot I_D \\ I_D = I_{DSS}\left(\frac{V_{GS_1}}{V_t} - 1\right)^2 \end{cases}$$

$$a = \frac{R_S I_{DSS}}{V_t^2} \qquad b = \frac{2 R_S I_{DSS}}{V_t} - 1$$

$$c = -V_{G_1} + R_S I_{DSS}$$

$$V_{GS} = \frac{-b + \sqrt{b^2 - 4ac}}{2a} = 4.16\,V > V_t = 3V$$

$$I_D = I_{DSS}\left(\frac{V_{GS}}{V_t} - 1\right)^2 = 3.4\ mA$$

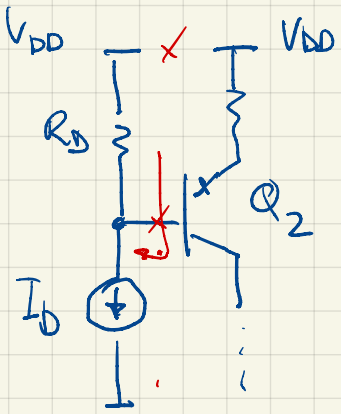
$A_a = 6$

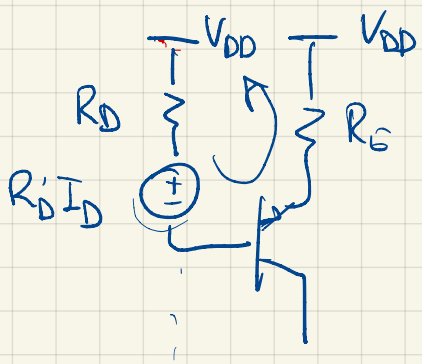
$A_f = 4.66$

$A_V = 4.57$

$f_L \simeq 324\ Hz$!!

NO EFFECT OF FEEDBACK





$$I_{B_2} = \frac{R_D I_D + V_{BE_2}}{R_D + R_E\left(\beta_{F_2} + 1\right)} = 5.23\ \mu A$$

$$I_C = \beta_{F_2} I_{B_2} = 0.52\ mA$$

$$V_{DS} = V_{DD} - R_S I_D - R_D\left(I_D - I_{B_2}\right) = 6.8V > V_{GS} - V_t$$

$$V_{CE} = V_{DD} - R_C \cdot I_{C_2} - R_E\left(\beta_{F_2} + 1\right) I_{B_2} = -2.61\,V < 0.2V$$

BOTH TRANSISTORS OPERATE IN THE LINEAR REGION.