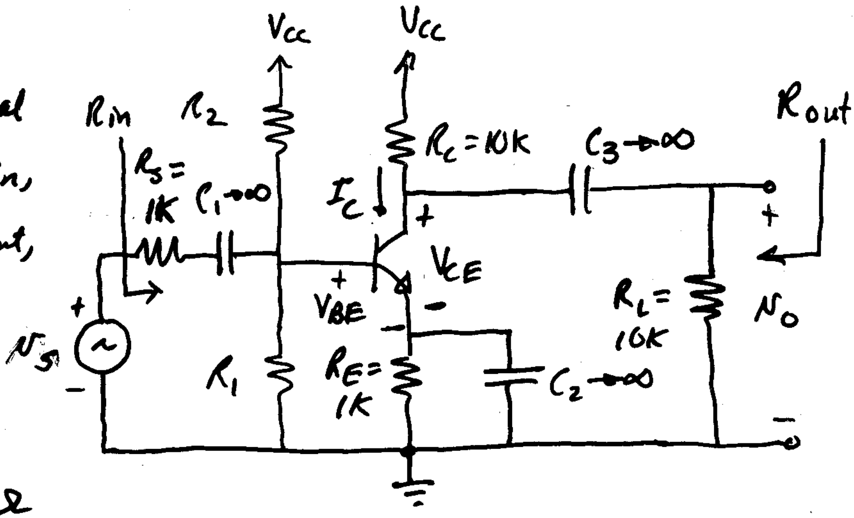
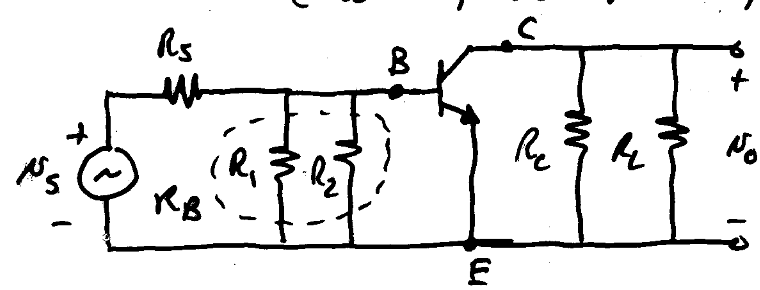
BJT Example

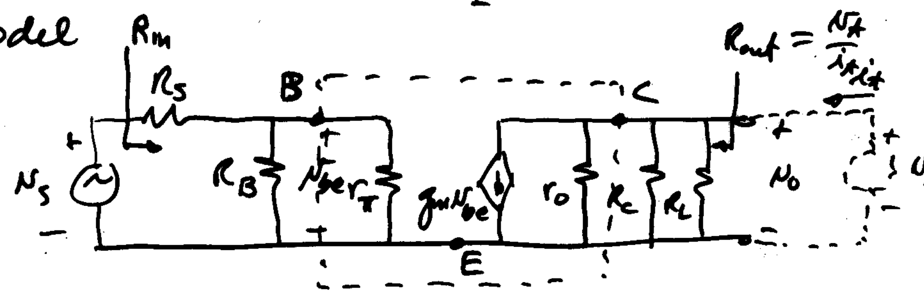
Find the small-signal input resistance, R_{in}, output resistance, R_{out}, and $\frac{v_o}{v_s}$ when $I_C = 1mA$, $\beta_o = 100$, $V_A = 100V$ and $R_B = R_1 || R_2 = 20k\Omega$



1.) Quasi-ac model ($V_{cc} = 0$ & C's replaced by shorts)



2.) AC-model



4.) Perform the analysis – R_{in}, R_{out}, $\frac{v_o}{v_s}$

$$R_{in} = R_S + R_B || r_\pi = 1k + 20k || 2.5k\Omega$$

$$R_{in} = 3.22k\Omega$$

$$\frac{v_o}{v_s} = \left(\frac{v_o}{v_{be}}\right)\left(\frac{v_{be}}{v_s}\right)$$

3.) Find g_m, r_π & r_o

$$g_m = \frac{I_C}{V_t} = \frac{1mA}{25mV} = 40mS$$

$$r_\pi = \frac{\beta_o}{g_m} = 25 \cdot 100 = 2.5k\Omega$$

$$g_o = \frac{I_C}{V_A + V_{CE}} \approx \frac{I_C}{V_A} = \frac{1mA}{100V} = \frac{1}{100K}$$

$$r_o = 100k\Omega$$

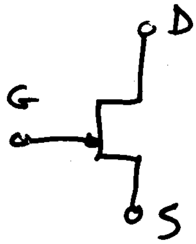
4.) Cont'd

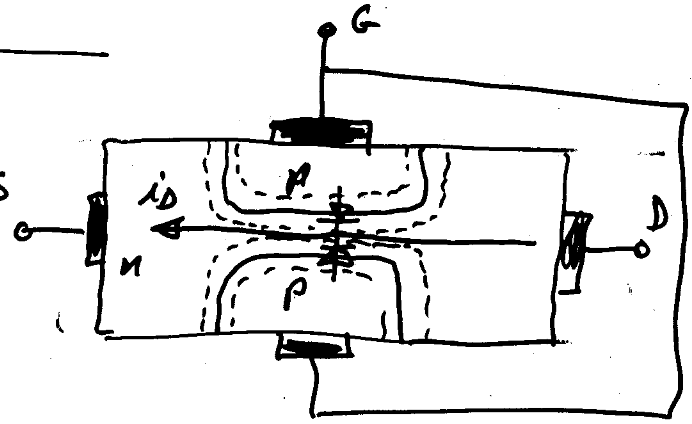
$$\frac{v_o}{v_{be}} = -g_m\left(r_o \| R_C \| R_L\right), \quad \frac{v_{be}}{v_s} = \frac{R_B \| r_\pi}{R_S + R_B \| r_\pi}$$

$$\therefore \frac{v_o}{v_s} = \frac{-g_m(r_o\|R_C\|R_L)(R_B\|r_\pi)}{R_S + R_B\|r_\pi} = \frac{(-40mS)(4.76K)(2.22K)}{3.22K} = \underline{\underline{-131.3 \tfrac{V}{V}}}$$

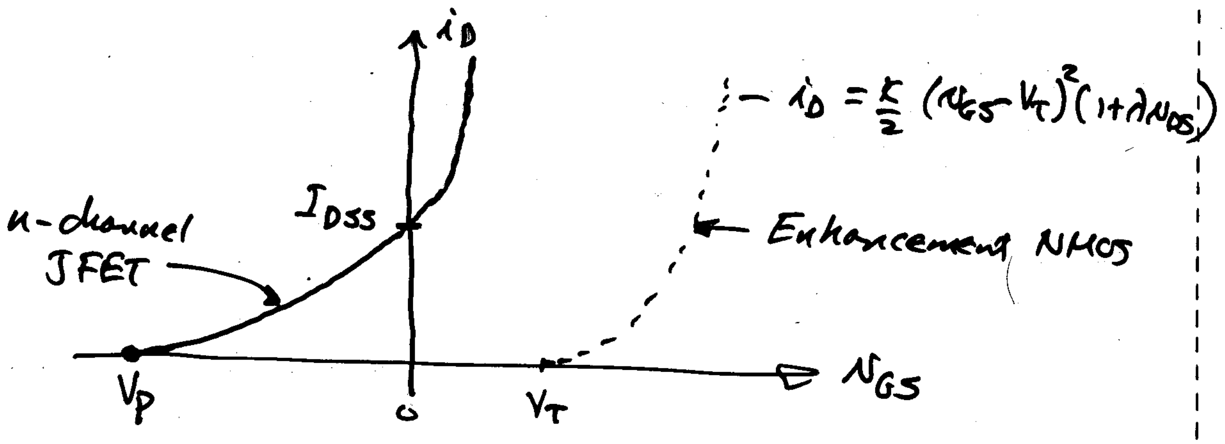
$$R_{out} = \left.\frac{v_x}{i_x}\right|_{v_s=0} = r_o\|R_C\|R_L = 100K\|5K = \underline{\underline{4.76K}}$$

JFET S.S Model -





Transconductance Characteristics.

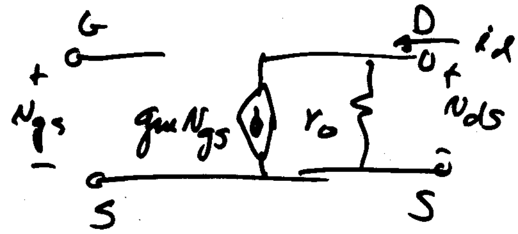


Q_{ABC} notation: A = terminal w. highest mag. of potential
B = " " lowest " " "
C = condition of the remaining terminal w.r.t. terminal B.

JFET Large signal model: $i_D = I_{DSS}\left[1 - \frac{v_{GS}}{V_P}\right]^2(1+\lambda v_{DS}), \quad v_{DS} \geq v_{GS} - V_P$

Small signal model:

$$i_d = k_1 v_{gs} + k_2 v_{ds} = g_m v_{gs} + g_o v_{ds}$$



$$g_m = \left.\frac{i_d}{v_{gs}}\right)_{v_{ds}=0} = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = -\frac{2 I_{DSS}}{V_P}\left(1 - \frac{V_{GS}}{V_P}\right)(1+\lambda V_{DS})$$

Note that:

$$\left(1 - \frac{V_{GS}}{V_P}\right) = \sqrt{\frac{I_D}{I_{DSS}(1+\lambda V_{DS})}}$$

$$g_m = \frac{2}{|V_P|}\sqrt{I_D I_{DSS}(1+\lambda V_{DS})} \approx \frac{2}{|V_P|}\sqrt{I_D I_{DSS}}$$

or,
$$g_m = -\frac{2 I_{DSS}}{V_P^2}(V_P - V_{GS}) = \frac{2 I_{DSS}}{V_P^2}(V_{GS} - V_P)$$

$$g_o = \left.\frac{i_d}{v_{ds}}\right|_{v_{gs}=0} \cong \left.\frac{\partial i_D}{\partial v_{DS}}\right)_Q = \lambda I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2 = \frac{\lambda I_D}{1+\lambda V_{DS}} \approx \lambda I_D$$

if $\lambda V_{DS} \ll 1$

$$g_m \cong \frac{2}{|V_P|}\sqrt{I_D I_{DSS}} \qquad g_o \cong \lambda I_D$$

(Table 13.4)