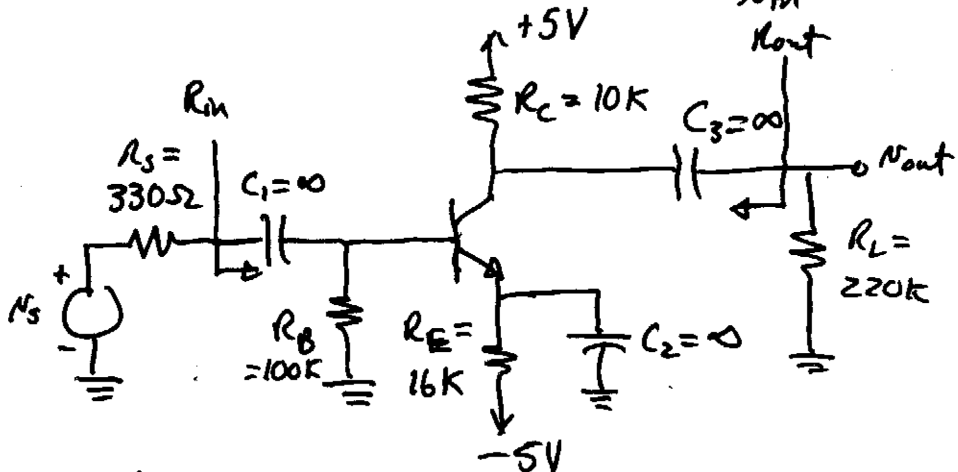
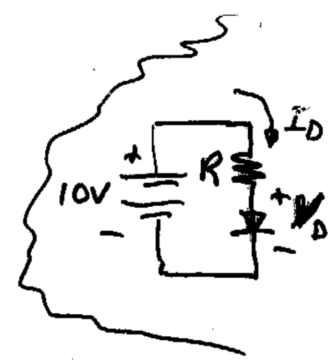
Example 1

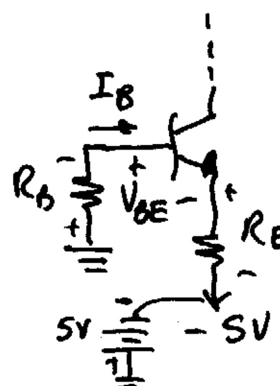
1.) BJT, NPN CE Inverting Amplifier

$\beta_F = 65$, $V_A = 50$ Find $\frac{v_{out}}{v_{in}}$, R_{in}, and R_{out}.





a.) Find the Q point.



Assume $V_{BE} \approx 0.7V$

$$0 = I_B R_B + V_{BE} + (1+\beta) I_B R_E - 5V = 0$$

$$I_B = \frac{5 - V_{BE}}{R_B + (1+\beta) R_E} = \frac{4.3}{100K + 66(16K)} = 3.72\mu A$$

$$I_C = 65 \cdot 3.72\mu A = \underline{242\mu A}$$

$$V_{CE} \cong 10 - I_C (R_C + R_E) = \underline{3.71V}$$

b.) Calculate g_m and r_o (and r_π)

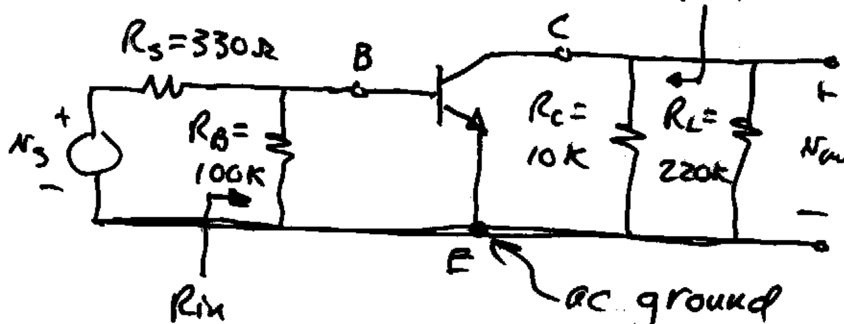
$$g_m = \frac{I_C}{V_T} = \frac{242\mu A}{25mV} = 9.68mS$$

$$r_\pi = \frac{\beta_F}{g_m} = \frac{65}{9.68mS} = 6.71K\Omega$$

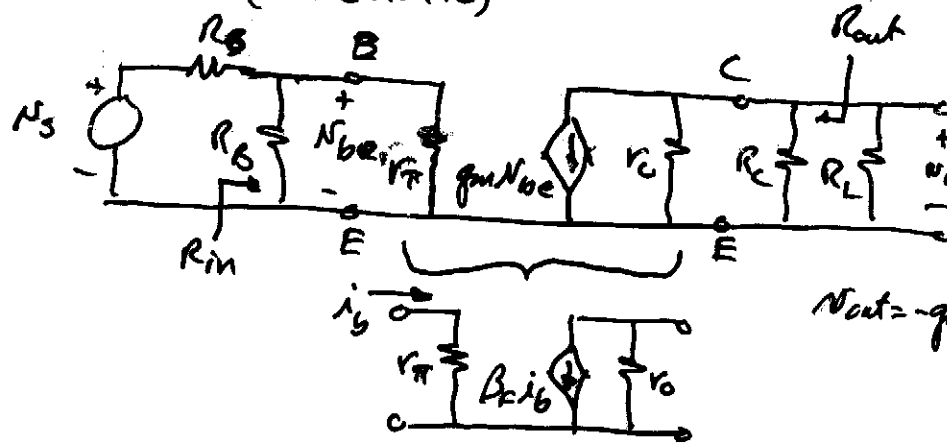
$$r_o = \frac{V_A + V_{CE}}{I_C} = \frac{50V + 3.71V}{242\mu A} = 222k\Omega$$

Example 1 - Cont'd

c.) S.S. circuit



d.) SS model (schematic)



$v_{out} = -g_m(r_o \| R_C \| R_L) v_{be}$

$g_m v_{be} = g_m (r_\pi i_b) = g_m r_\pi i_b = \beta_F i_b$

$R_{in} = R_B \| r_\pi = \underline{6.288 k\Omega}$ $\quad R_{out} = r_o \| R_C = \underline{9.17 k\Omega}$

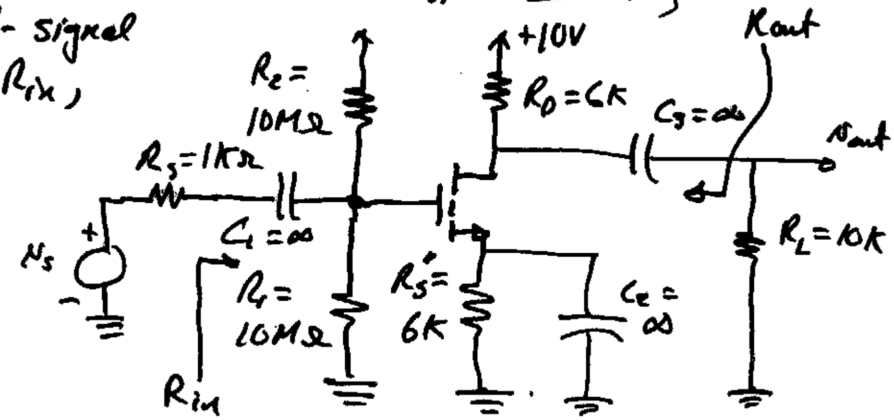
$$\frac{v_{out}}{v_s} = \left(\frac{v_{out}}{v_{be}}\right)\left(\frac{v_{be}}{v_s}\right) = \left(-g_m R_L \| R_C \| r_o\right)\left(\frac{R_B \| r_\pi}{R_s + R_B \| r_\pi}\right)$$

($R_B \| r_\pi$ ← R_{in})

$$\frac{v_{out}}{v_s} = \left(-9.68 \times 9.170\right)\left(\frac{6.29K}{0.33K + 6.29K}\right) = \underline{-84.3\ V/V}$$

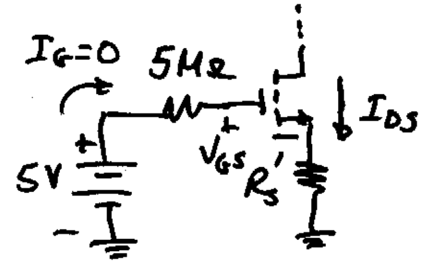
2.) **Example 2 - CS, NMOS Inverting Amplifier**

If $k_n = 0.5 mA/V^2$, $V_{TN} = 1V$, and $\lambda = 0.01\ V^{-1}$, find the small-signal voltage gain, R_{in}, and R_{out}.



a.) Find Q point

Thevenin eq. from gate

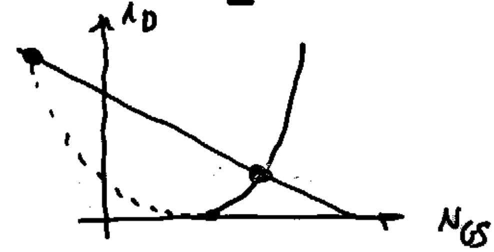


$5 = V_{GS} + I_{DS}R_S'$

Assume saturation and replace IDS

$5 = V_{GS} + R_S'\left[\frac{k_n}{2}(V_{GS}-V_T)^2\right] \rightarrow 5 = V_{GS} + (6K)\left(\frac{.5mA}{2V^2}\right)(V_{GS}-1)^2$

Finally, $V_{GS}^2 - \frac{5}{3}V_{GS} - \frac{2}{3} = 0$



$V_{GS} = \frac{5}{6} \pm 1.667 = 2V$

$I_D = \frac{0.5}{2}(2-1)^2 = \underline{0.5mA}$

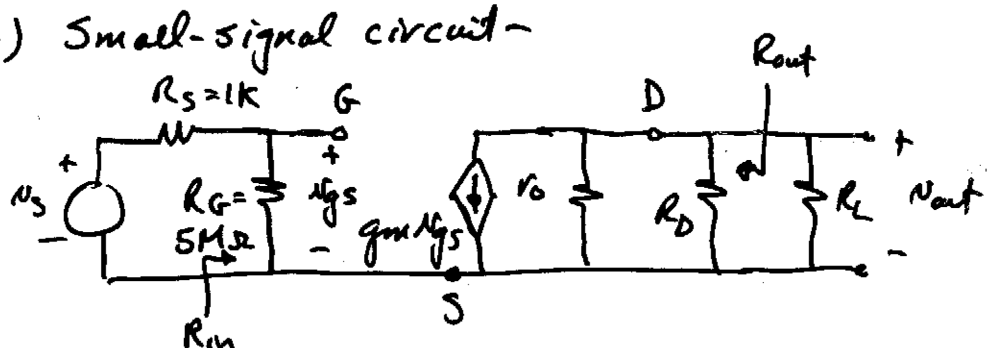
$V_{DS} = 10 - I_{DS}(R_D + R_S') = \underline{4V} \Rightarrow V_{DS} > V_{GS} - V_T = 1V$

b.) Small signal model parameters

$g_m = \sqrt{2k_n I_{DS}(1+\lambda V_{DS})} = \sqrt{2\cdot\frac{1}{2}\cdot\frac{1}{2}(1+0.04)} \simeq 0.721mS$

$r_o = \frac{V_{DS}+\frac{1}{\lambda}}{I_{DS}} = \frac{4+100}{0.5}K = 208k\Omega$

c.) Small-signal circuit -



d.) $R_{in} = R_G = \underline{5M\Omega}$ $R_{out} = r_o \| R_D = \underline{5.83k\Omega}$

$\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_s}\right) = \left(-g_m r_o \| R_D \| R_L\right)\left(\frac{R_G}{R_S+R_G}\right)$

$\frac{v_{out}}{v_{in}} = (-2.13)\left(\frac{5}{5.001}\right) = \underline{-2.13 V/V}$