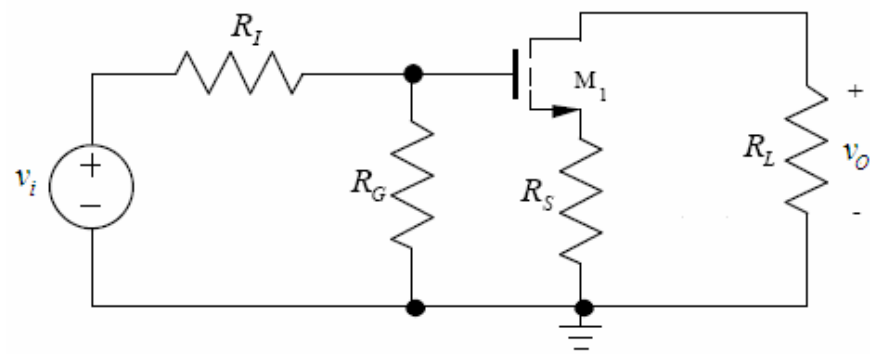
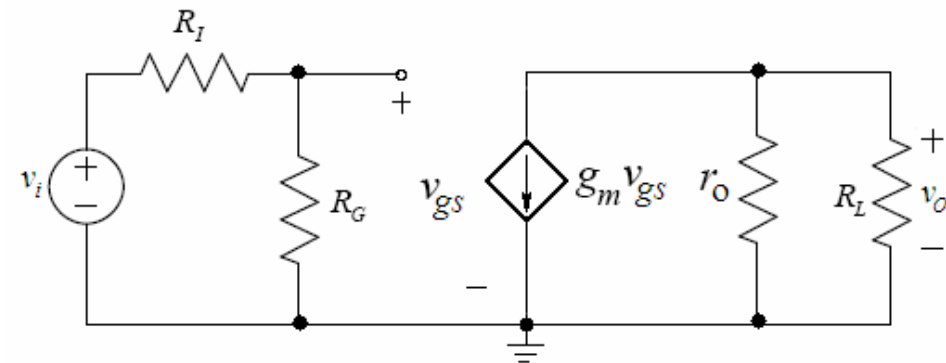




(b)  $R_S$  is bypassed



$$A_v = -g_m (R_L \parallel r_o) \left( \frac{R_G}{R_I + R_G} \right)$$

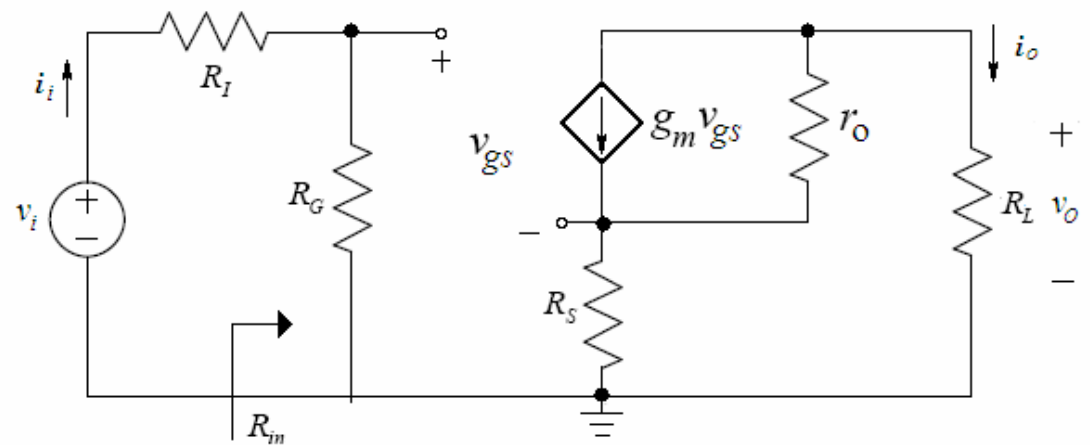
$$A_v = -(0.005\text{S})(2\text{k}\Omega \parallel 10\text{k}\Omega) \left( \frac{1\text{M}\Omega}{75\text{k}\Omega + 1\text{M}\Omega} \right) = -7.75$$

$$R_{in} = R_G = 1\text{M}\Omega \quad | \quad R_{out} = r_o = 10.0\text{ k}\Omega$$

$$i_o = -g_m v_{gs} \quad | \quad i_i = \frac{v_{gs}}{R_G}$$

$$A_i = \frac{i_o}{i_i} = -R_G g_m = -1\text{M}\Omega (0.005\text{S}) = -5000$$

(a) AC Equivalent Circuit with the MOSFET Replaced by Small Signal Model



Neglecting  $r_o$ :

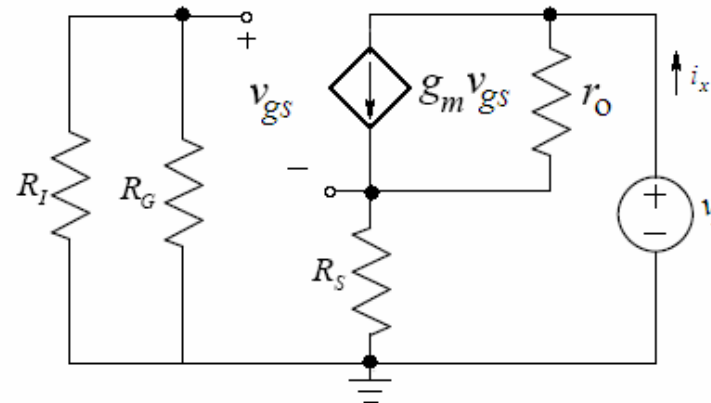
$$\frac{v_o}{v_{gs}} = -g_m R_L \quad | \quad \frac{v_{gs}}{v_i} = \frac{R_G}{(R_I + R_G)(1 + g_m R_S)}$$

$$A_v = \frac{v_{gs}}{v_i} \times \frac{v_o}{v_{gs}} = -\frac{1\text{M}\Omega (0.005\text{S})(2000\Omega)}{(75\text{k}\Omega + 1\text{M}\Omega) \left( 1 + (0.005\text{S})(200\Omega) \right)} = -4.65$$

$$i_o = -g_m v_{gs} \quad | \quad i_i = \frac{v_{gs} + g_m v_{gs} R_S}{R_G}$$

$$A_i = \frac{i_o}{i_i} = -R_G \frac{g_m}{1 + g_m R_S} = -1\text{M}\Omega \frac{0.005\text{S}}{1 + (0.005\text{S})(200\Omega)} = -2500$$

Including  $r_o$ :



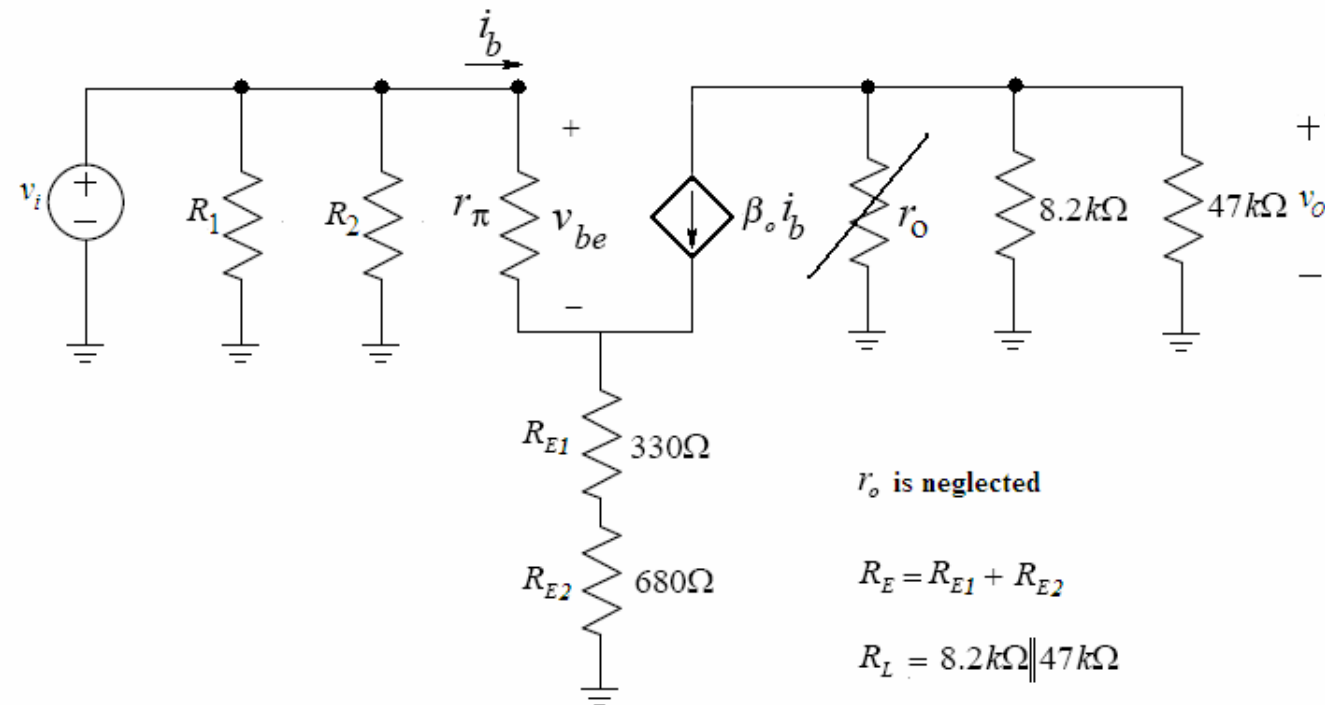
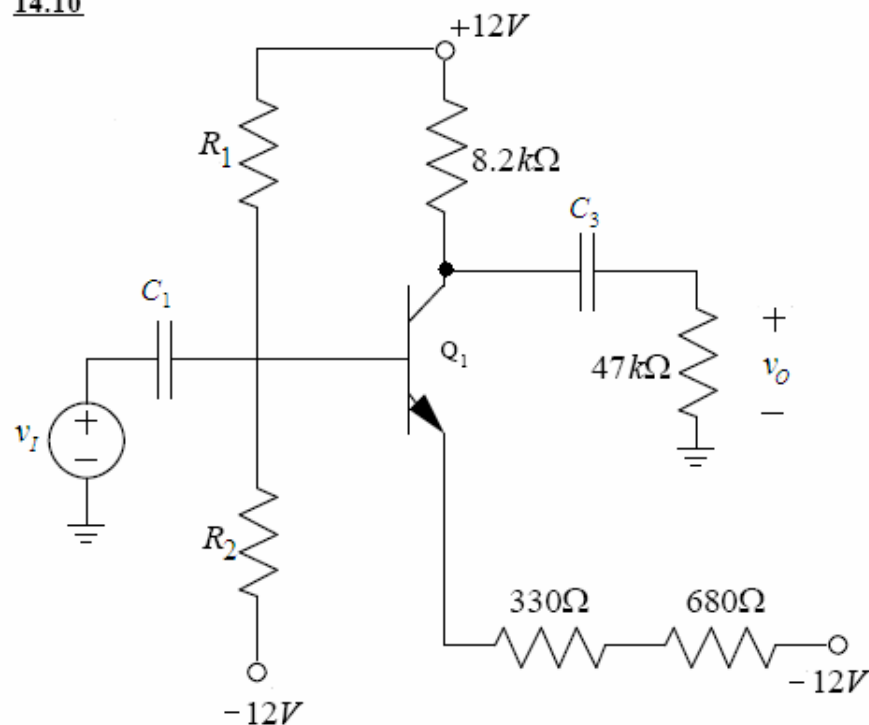
$$v_x = i_x R_S + (i_x + g_m i_x R_S) r_o \quad (r_o \gg R_S)$$

$$R_{out} = \frac{v_x}{i_x} = r_o (1 + g_m R_S)$$

$$R_{out} = 10\text{k}\Omega [1 + (0.005\text{S})(200\Omega)]$$

$$R_{out} = 20.0\text{ k}\Omega$$

$$R_{in} = R_G = 1\text{M}\Omega$$



(a)  $v_o = -\beta_o i_b R_L \mid v_i = i_b r_\pi + i_b (\beta_o + 1) R_E$

$$A_v = \frac{v_o}{v_i} = -\frac{\beta_o i_b R_L}{i_b r_\pi + i_b (\beta_o + 1) R_E} \quad \text{For large } \beta_o : A_v \cong -\frac{R_L}{R_E} = -\frac{8.2k\Omega \parallel 47k\Omega}{330\Omega + 680\Omega} = -6.91$$

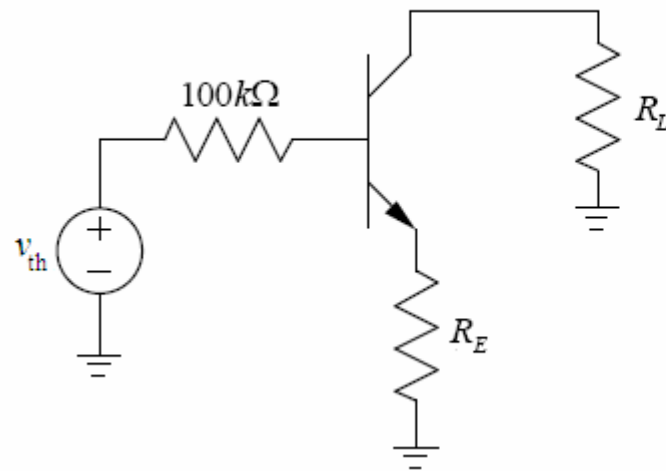
(b) Place a bypass capacitor in parallel with the 330  $\Omega$  resistor. Then  $A_v \cong -\frac{R_L}{R_E} = -\frac{8.2k\Omega \parallel 47k\Omega}{680\Omega} = -10.3$

(c) Place a bypass capacitor in parallel with the 680  $\Omega$  resistor. Then  $A_v \cong -\frac{8.2k\Omega \parallel 47k\Omega}{330\Omega} = -21.2$

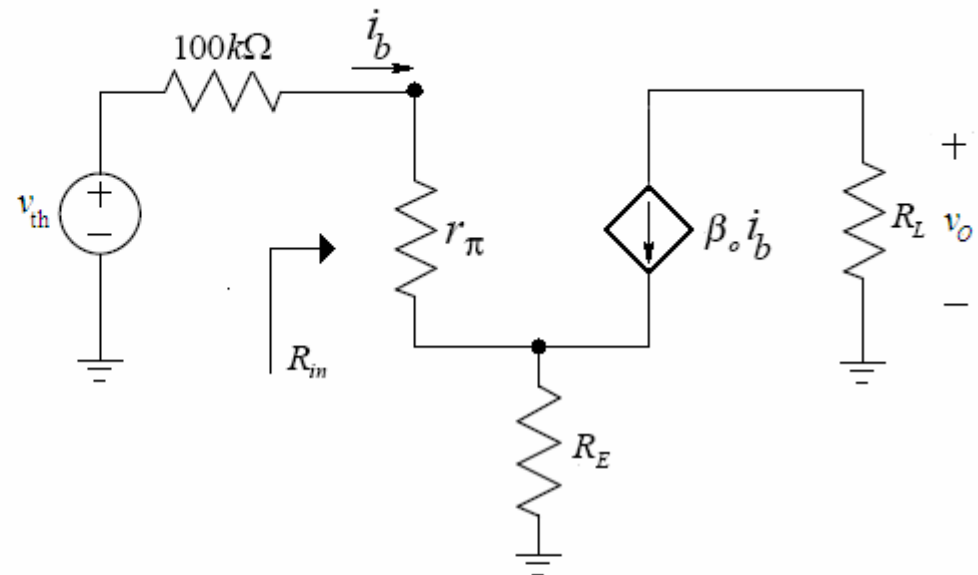
(d) Place a bypass capacitor from the emitter to ground.

(e)  $A_v \cong -10(V_{CC} + V_{EE}) = -240$ . (look at the page 903 section 13.6.3 from the course book)

14.11



AC Equivalent Circuit with BJT replaced by Small Signal Model

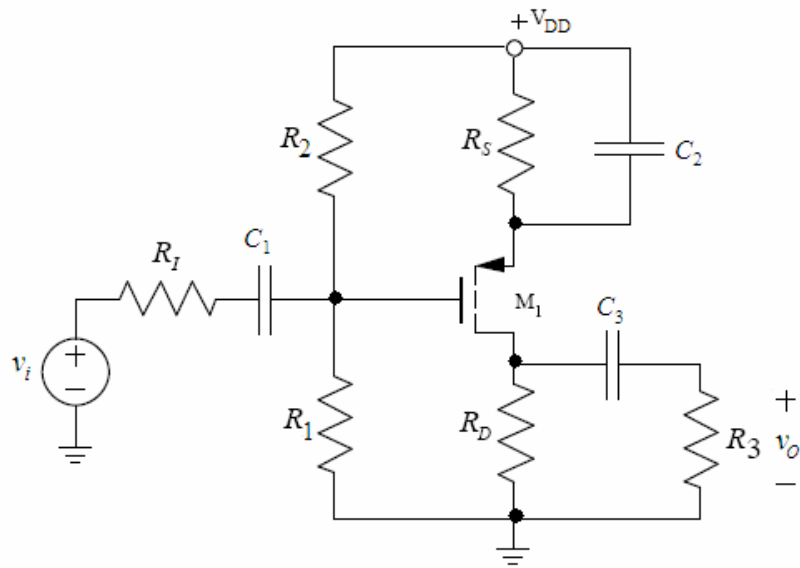


$$R_{in} = r_{\pi} + (\beta_o + 1)R_E = 500 \text{ k}\Omega$$

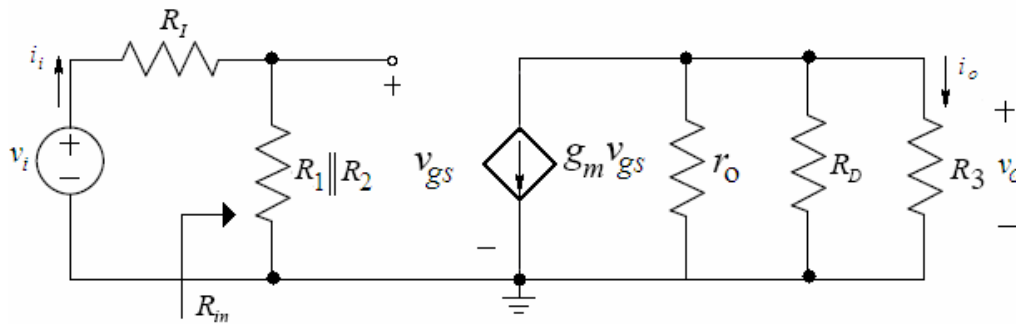
$$A_v = \frac{v_o}{v_{th}} = -\frac{\beta_o R_L}{r_{\pi} + (\beta_o + 1)R_E} = -\frac{75 R_L}{500 \text{ k}\Omega} = -10 \rightarrow R_L = 66.7 \text{ k}\Omega$$

Assuming  $(\beta_o + 1)R_E \gg r_{\pi}$ ,

$$R_E \cong \frac{500 \text{ k}\Omega}{\beta_o + 1} = \frac{500 \text{ k}\Omega}{76} = 6.58 \text{ k}\Omega$$



AC Equivalent Circuit with Mosfet replaced by Small Signal Model



$$R_L = r_o \parallel R_D \parallel R_3 = r_o \parallel 18k\Omega \parallel 470k\Omega \approx 18k\Omega \parallel 470k\Omega = 17.3k\Omega$$

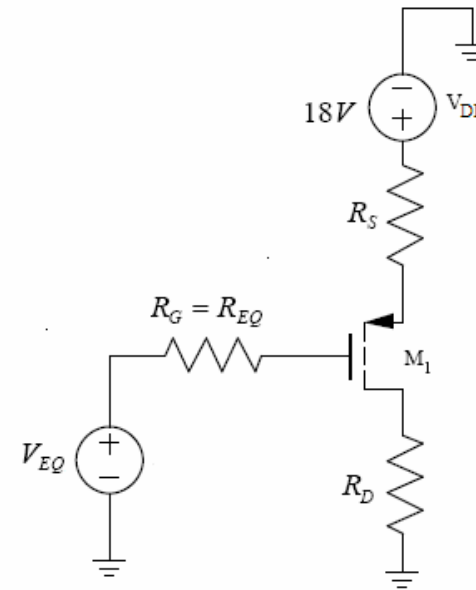
$$R_{in} = R_1 \parallel R_2 = 1.10M\Omega \quad | \quad R_{out} = r_o \parallel 18k\Omega = 18k\Omega$$

$$A_v = -g_m R_L \left( \frac{R_{in}}{R_I + R_{in}} \right) = -(0.496mS)(17.3k\Omega) \frac{1.1M\Omega}{1k\Omega + 1.1M\Omega} = -8.57$$

$$A_i = -g_m R_{in} \frac{R_D}{R_D + R_3} = -0.496mS(1.1M\Omega) \frac{18k\Omega}{18k\Omega + 470k\Omega} = -18.3$$

$$v_{gs} = v_i \frac{R_{in}}{R_I + R_{in}} = v_i \frac{1.1M\Omega}{1k\Omega + 1.1M\Omega} = 0.999v_i$$

$$v_{gs} \leq 0.2(V_{GS} - V_{TN}) \quad | \quad v_i \leq 0.2 \left( \frac{1.24V}{0.999} \right) = 0.248V$$



$$V_{EQ} = 18 \frac{2.2M\Omega}{2.2M\Omega + 2.2M\Omega} = 9.00V \quad | \quad R_G = R_{EQ} = 2.2M\Omega \parallel 2.2M\Omega = 1.10M\Omega$$

Assume Transistor Operates in Saturation Region;

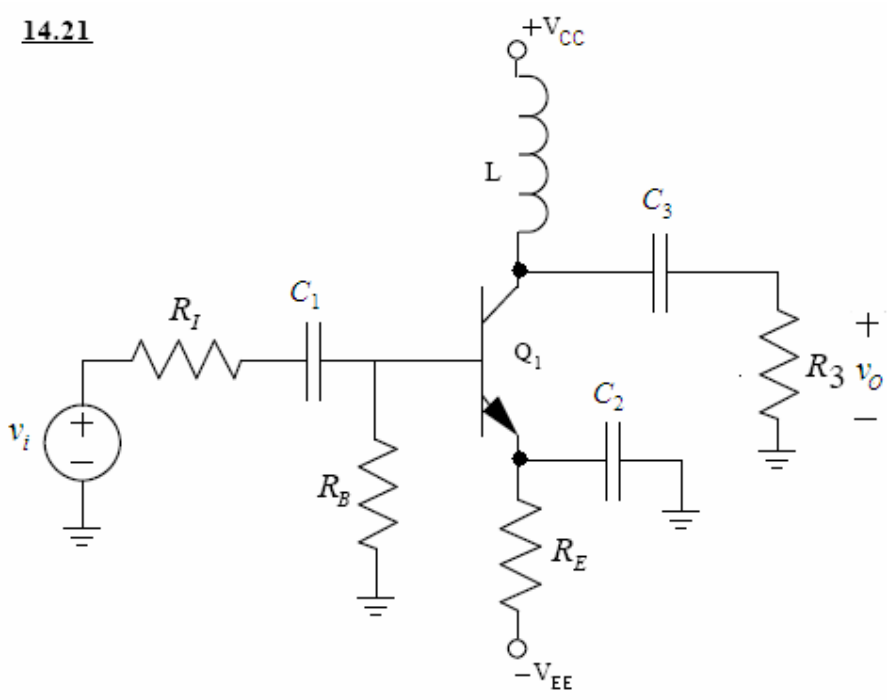
$$18 = 22000I_D - V_{GS} + 9 \quad | \quad 9 = 22000I_D + 1 + \sqrt{\frac{2I_D}{400 \times 10^{-6}}} \rightarrow I_D = 307\mu A$$

$$V_{DS} = -[18 - I_D(22k\Omega + 18k\Omega)] = -5.72V$$

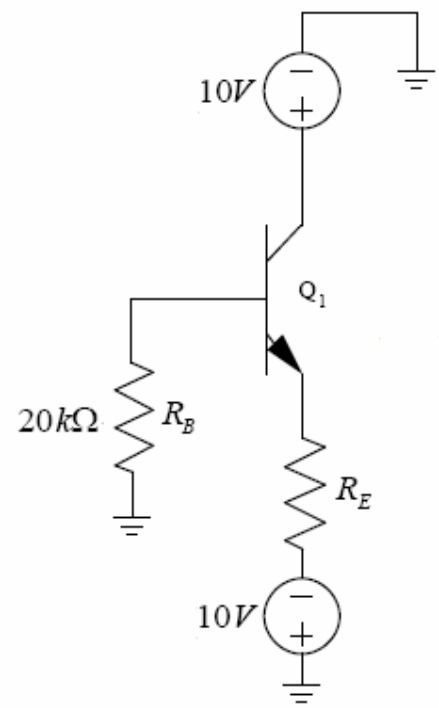
$$|(V_{GS} - V_{TP})| = \sqrt{\frac{2(307\mu A)}{400\mu A/V^2}} = 1.24V \quad | \quad |V_{DS}| > |(V_{GS} - V_{TP})|$$

Assumption is Correct

$$g_m = \sqrt{2(400 \times 10^{-6})(307 \times 10^{-6})} = 0.496mS \quad \text{Assume } \lambda = 0, r_o = \infty$$



DC Equivalent Circuit



Assume Transistor Operates in Forward Active Region ;

$$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta_o + 1)R_E} = \frac{(10 - 0.7)V}{20k\Omega + (80 + 1)9.1k\Omega} = 12.3\mu A$$

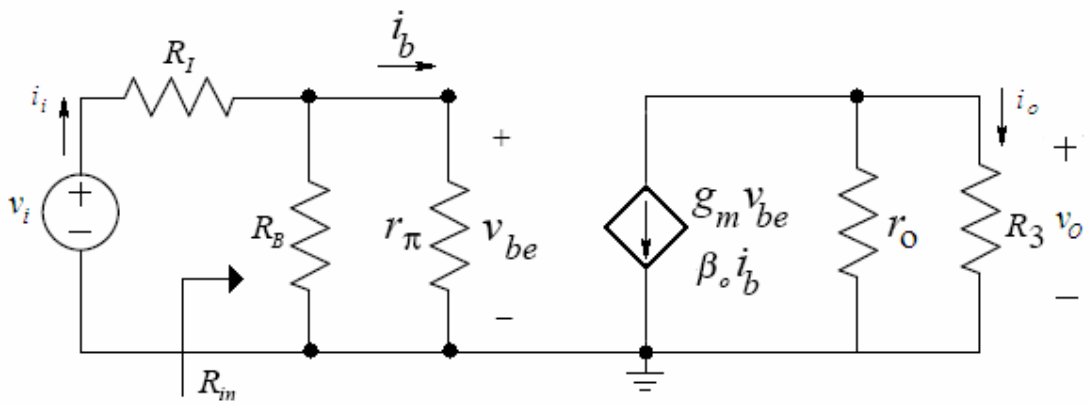
$$I_C = 983\mu A \mid V_{CE} = (V_{CC} + V_{EE}) - R_E I_E = 20 - 9100I_E = 11.0V$$

$$V_{BE} = 0.7 \quad V_{BC} = 0.7 - 11 = -10.3V$$

Assumption is Correct

$$r_\pi = \frac{80(0.025V)}{983\mu A} = 2.04k\Omega \mid r_o = \frac{(100 + 11.0)V}{983\mu A} = 113k\Omega$$

AC Equivalent Circuit with BJT replaced by Small Signal Model



$$R_L = r_o \parallel 1M\Omega = 113k\Omega \parallel 1M\Omega = 102k\Omega$$

$$R_{in} = R_B \parallel r_\pi = 20k\Omega \parallel 2.04k\Omega = 1.85k\Omega \mid R_{out} = r_o = 113k\Omega$$

$$A_v = \frac{v_o}{v_i} = -g_m R_L \left( \frac{R_{in}}{R_I + R_{in}} \right) = -40(983\mu A)(102k\Omega) \frac{1.85k\Omega}{250\Omega + 1.85k\Omega} = -3530$$

$$i_i = i_b \left( \frac{R_B + r_\pi}{R_B} \right) \mid i_o = -\beta_o i_b \left( \frac{r_o}{r_o + R_3} \right)$$

$$A_i = \frac{i_o}{i_i} = -80 \left( \frac{20k\Omega}{20k\Omega + 2.04k\Omega} \right) \left( \frac{113k\Omega}{113k\Omega + 1M\Omega} \right) = -7.37$$

$$v_{be} = v_i \left( \frac{R_{in}}{R_I + R_{in}} \right) = v_i \frac{20k\Omega}{250\Omega + 20k\Omega} = 0.988v_i \mid v_i \leq \frac{5.00mV}{0.988} = 5.06mV$$