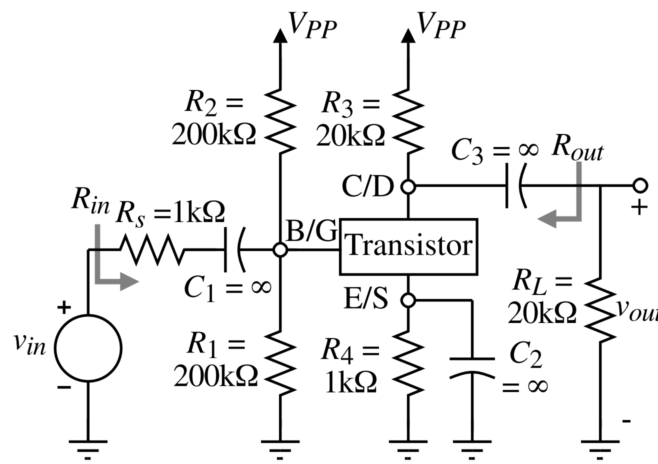
# QUIZ NO. 4 - SOLUTION

(Average score = 7.5/10 of those taking the quiz)

(a.) Replace the transistor in the circuit shown with a npn BJT that has a $\beta_o$ = 100, $V_T$ = 25mV, and $V_A = \infty$. Assume that $I_{CQ}$ = 0.5mA and find the numerical values of voltage gain, $v_{out}/v_{in}$, $R_{in}$. and $R_{out}$.



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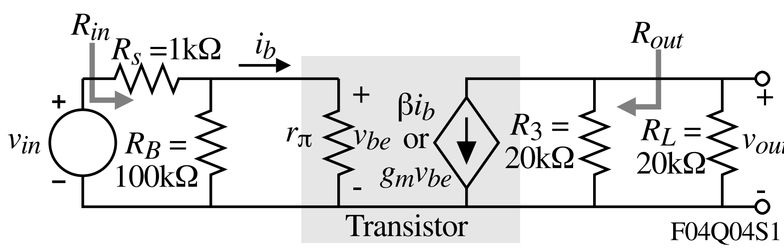
(b.) Replace the transistor in the circuit shown with a NMOS FET that has a $K_n$ = 1mA/V$^2$ and $\lambda$ = 0. Assume that $I_{DQ}$ = 0.5mA and find the numerical values of voltage gain, $v_{out}/v_{in}$, $R_{in}$. and $R_{out}$.. (Hint: let $r_\pi$ of part (a.) be ∞.)

c.) In your own words tell why the small-signal voltage gain of the BJT CE amplifier is greater (roughly x10) than the small-signal voltage gain of the NMOS CS amplifier when the currents are the same and the external circuit is the same.

*Solution*

a.) The small-signal model for the case of the BJT is shown below ($R_B = R_1 || R_2$).



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$$g_m = \frac{I_{CQ}}{V_T} = \frac{0.5\text{mA}}{25\text{mV}} = \frac{1}{50}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = 100\cdot 50 = 5\text{k}\Omega$$

$(r_o = \infty)$

$R_{in} = R_s + R_B || r_\pi$ = 1kΩ + 100kΩ||5kΩ = 1kΩ+4.762kΩ = <u>5.762kΩ</u> $R_{out} = R_3$ = <u>20kΩ</u>

$$\frac{v_{out}}{v_{in}} = (-g_m \cdot R_3 || R_L)\left(\frac{r_\pi || R_B}{R_s + R_B || r_\pi}\right) = \left(\frac{\text{-10K}}{50}\right)\left(\frac{4.762\text{K}}{50}\right) = -200\cdot 0.826 = \underline{-165.3 \text{ V/V}}$$

b.) If we let $r_\pi = \infty$, then the above results are applicable to the MOSFET.

$$g_m = \sqrt{2K_N I_{DQ}} = \sqrt{2\cdot 1\cdot 0.5} = 1\text{mS}$$

$R_{in} = R_s + R_B$ = 1kΩ + 100kΩ = <u>101kΩ</u> $R_{out} = R_3$ = <u>20kΩ</u>

and $$\frac{v_{out}}{v_{in}} = (-g_m \cdot R_3 || R_L)\left(\frac{R_B}{R_s + R_B}\right) = (-1\cdot 10)\left(\frac{100}{101}\right) = \underline{-9.9 \text{ V/V}}$$

c.) The difference is due to the small-signal transconductances. The transconductance is the slope of the collector/drain current as a function of base-emitter/gate source voltage. This function for the BJT is an exponential and for the MOSFET is a parabola. At any equivalent value of collector/drain current the slope of the exponential is at least 10 times that of a parabola. One could also say that it is due to the difference between diffusion current (BJT) and drift current (FET).