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 $\beta_0 = 100$, $V_T = 25\text{mV}$, and $V_A = \infty$. Assume that $I_{CQ} = 0.5\text{mA}$ and find the numerical values of voltage gain, $v_{out}/v_{in}$, $R_{in}$, and $R_{out}$.

(b.) Replace the transistor in the circuit shown with a NMOS FET that has a $K_n = 1\text{mA/V}^2$ and $\lambda = 0$. Assume that $I_{DQ} = 0.5\text{mA}$ 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 $\infty$.)

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 ($R_B = R_1 || R_2$).

\[ R_{in} = R_s + R_B || r_{\pi} = 1\text{k}\Omega + 100\text{k}\Omega || 5\text{k}\Omega = 1\text{k}\Omega + 4.762\text{k}\Omega = 5.762\text{k}\Omega \]
\[ R_{out} = R_3 = 20\text{k}\Omega \]
\[ \frac{v_{out}}{v_{in}} = (-g_m \cdot R_3 || R_L) \left( \frac{r_{\pi} || R_B}{R_s + R_B || r_{\pi}} \right) = (-10 \text{K}) \left( \frac{4.762\text{K}}{50} \right) = -200 \cdot 0.826 = -165.3 \text{V/V} \]

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

\[ g_m = \sqrt{2K_n I_{DQ}} = \sqrt{2 \cdot 1 \cdot 0.5} = 1\text{mS} \]
\[ R_{in} = R_s + R_B = 1\text{k}\Omega + 100\text{k}\Omega = 101\text{k}\Omega \]
\[ R_{out} = R_3 = 20\text{k}\Omega \]
\[ \frac{v_{out}}{v_{in}} = (-g_m \cdot R_3 || R_L) \left( \frac{R_B}{R_s + R_B} \right) = (-1 \cdot 10) \left( \frac{100}{101} \right) = -0.9 \text{V/V} \]

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).