ECE 3050 Analog Electronics Quiz 3

January 28, 2009

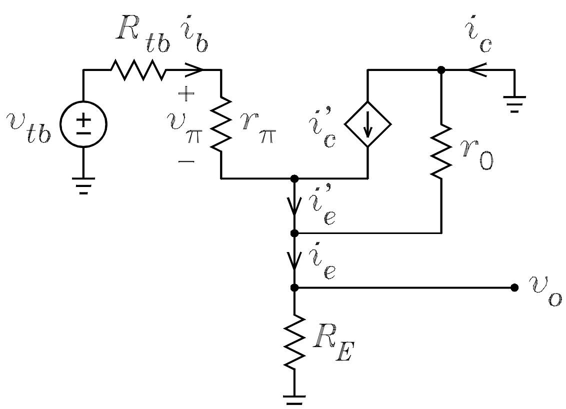
Professor Leach Last Name:____________________________First Name:____________________________

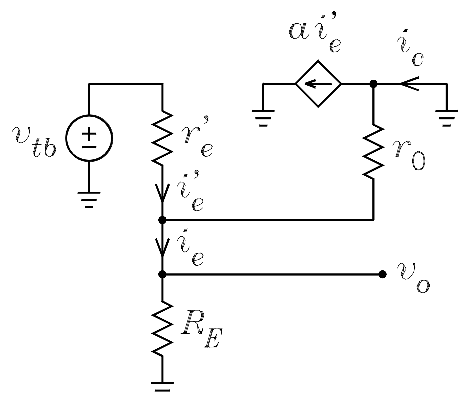
Instructions. Print your name in the spaces above. Place a box around any answer. **Honor Code Statement:** *I have neither given nor received help on this quiz.* Initials ____________

1. The circuit on the left below shows the hybrid-π model for a common-collector amplifier. The circuit on the right shows the common-collector amplifier with the simplified T model. For each circuit, it is given that $R_{tb} = 1\,\text{k}\Omega$, $R_E = 2\,\text{k}\Omega$, $r_0 = 20\,\text{k}\Omega$, $\beta = 99$, $\alpha = 0.99$, $I_C = 1\,\text{mA}$, and $V_T = 0.025\,\text{V}$. Relevant equations are

$$i'_c = g_m v_\pi = \beta i_b = \alpha i'_e \qquad r'_e = \frac{R_{tb}}{1+\beta} + r_e \qquad g_m = \frac{I_C}{V_T}$$

$$r_\pi = \frac{V_T}{I_B} \qquad r_e = \frac{V_T}{I_E} \qquad I_C = \beta I_B = \alpha I_E \qquad \beta = g_m r_\pi$$





(a) Solve for v_o/v_{tb} using the hybrid-π model.

(b) Solve for v_o/v_{tb} using the T model.

See next 2 pages for solutions.

$V_T := 0.025 \quad \beta := 99 \quad \alpha = 0.99 \quad I_C := 0.001 \quad I_B := \frac{I_C}{\beta} \quad I_E := \frac{I_C}{\alpha}$

$r_0 := 20000 \quad R_{tb} := 1000 \quad R_E := 2000 \quad r_\pi := \frac{V_T}{I_B} \quad r_\pi = 2.475 \cdot 10^3$

$r_e := \frac{V_T}{I_E} \quad r_e = 24.75 \quad r'_e := \frac{R_{tb}}{1+\beta} + r_e \quad r'_e = 34.75 \quad v_{tb} := 1 \quad g_m := \frac{I_C}{V_T}$

With v_{tb} = 1, the voltage gain is the value of v_o.

Part (a)

Solution using $i'_c = \beta \cdot i_b$

$$i_b = \frac{v_{tb}}{R_{tb} + r_\pi + R_p(r_0, R_E)} - \beta \cdot i_b \cdot \frac{R_p(r_0, R_E)}{(R_{tb} + r_\pi) + R_p(r_0, R_E)}$$

$$i_b := \frac{\dfrac{v_{tb}}{R_{tb} + r_\pi + R_p(r_0, R_E)}}{1 + \beta \cdot \dfrac{R_p(r_0, R_E)}{(R_{tb} + r_\pi) + R_p(r_0, R_E)}} \qquad i_b = 5.397 \cdot 10^{-6}$$

$$v_o := v_{tb} \cdot \frac{R_p(r_0, R_E)}{R_{tb} + r_\pi + R_p(r_0, R_E)} + \beta \cdot i_b \cdot R_P(R_{tb} + r_\pi, r_0, R_E) \qquad v_o = 0.981$$

or $\quad v_o := (i_b + \beta \cdot i_b) \cdot R_p(r_0, R_E) \qquad v_o = 0.981$

Part (b)

$$v_o := v_{tb} \cdot \frac{R_p(R_E, r_0)}{r'_e + R_p(R_E, r_0)} \qquad v_o = 0.981$$

First Alternate for Part (a)

$$i'_e = \frac{v_{tb}}{R_{tb} + r_\pi + R_p(r_0, R_E)} + \alpha \cdot i'_e \cdot \frac{R_{tb} + r_\pi}{R_{tb} + r_\pi + R_p(r_0, R_E)}$$

$$i'_e := \frac{\dfrac{v_{tb}}{R_{tb} + r_\pi + R_p(r_0, R_E)}}{1 - \alpha \cdot \dfrac{R_{tb} + r_\pi}{R_{tb} + r_\pi + R_p(r_0, R_E)}} \qquad i'_e = 5.397 \cdot 10^{-4}$$

$$v_o := i'_e \cdot R_p(r_0, R_E) \qquad v_o = 0.981$$

Second Alternate for Part (a)

$$v_\pi = v_{tb} \cdot \frac{r_\pi}{R_{tb} + r_\pi + R_p(r_0, R_E)} - g_m \cdot v_\pi \cdot \frac{R_p(r_0, R_E)}{R_{tb} + r_\pi + R_p(r_0, R_E)} \cdot r_\pi$$

$$v_\pi := \frac{v_{tb} \cdot \dfrac{r_\pi}{R_{tb} + r_\pi + R_p(r_0, R_E)}}{1 + g_m \cdot \dfrac{R_p(r_0, R_E)}{R_{tb} + r_\pi + R_p(r_0, R_E)} \cdot r_\pi} \qquad v_\pi = 0.013$$

$$v_o := v_{tb} \cdot \frac{R_p(r_0, R_E)}{R_{tb} + r_\pi + R_p(r_0, R_E)} + g_m \cdot v_\pi \cdot R_P(R_{tb} + r_\pi, r_0, R_E) \qquad v_o = 0.981$$