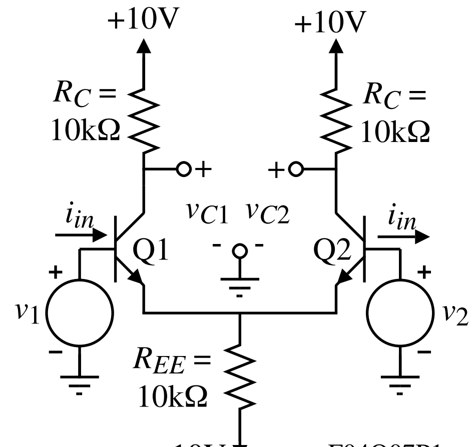
QUIZ NO. 7 - SOLUTION

(Average score = 8.8/10 of those taking the quiz)

Assume that Q1 and Q2 and the resistors R_C of the differential amplifier shown are matched. If $\beta_F = 100$, $V_t = 25\text{mV}$, $V_{BEQ} = 0.6\text{V}$, and $V_A = \infty$, find (a.) the numerical value of I_{C1} and I_{C2} if $v_1 = v_2 = 0$. (b.) For the rest of the problem assume that $I_{C1} = I_{C2} = 0.5\text{mA}$ and find the numerical value of v_{C1}/v_{id} where $v_{id} = v_1 - v_2$. (c.) Find the numerical value of v_{C1}/v_{ic} where $v_{ic} = v_1 = v_2$. (d.) Find the numerical value of the differential input resistance defined as,

$$R_{id} = v_{id}/i_{in} .$$



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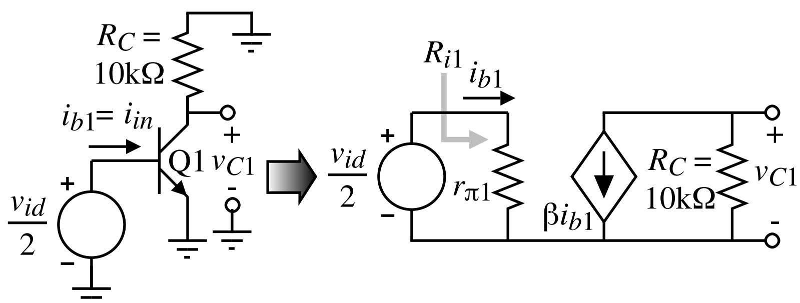
Solution

(a.) $$I_{C1} = I_{C2} = 0.5\, I_{EE} = 0.5\left(\frac{10\text{V} - 0.6\text{V}}{10\text{k}\Omega}\right) = 0.5(0.96\text{mA}) = \underline{\underline{0.48\text{mA}}}$$

(b.) Simplifying the circuit for differential mode analysis gives the model shown.



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$$g_m = \frac{I_{C1}}{V_t} = \frac{0.5\text{mA}}{25\text{mV}} = 20\text{mS}$$

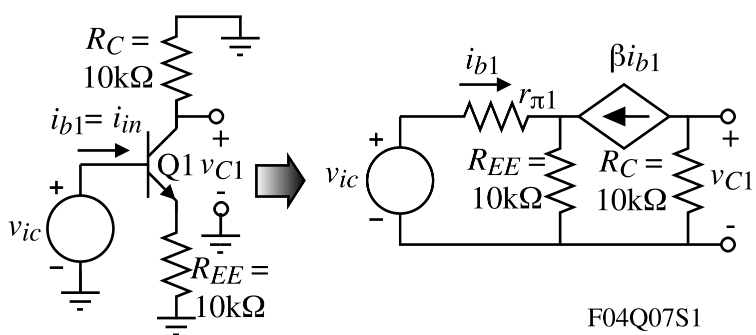
and

$$r_\pi = \frac{\beta_F}{g_m} = 100\cdot 50 = 5\text{k}\Omega$$

$$R_{i1} = (v_{id}/2)/i_{b1} = r_{\pi1} = 5\text{k}\Omega$$

$$\frac{v_{C1}}{v_{id}} = \frac{1}{2}\frac{v_{C1}}{v_{id}/2} = \frac{1}{2}\left(\frac{v_{C1}}{i_{b1}}\right)\left(\frac{i_{b1}}{v_{id}/2}\right) = \frac{1}{2}\left(\frac{v_{C1}}{i_{b1}}\right)\left(\frac{1}{R_{i1}}\right) = \frac{-\beta R_C}{2R_{i1}} = \frac{-100\cdot 10\text{k}\Omega}{2\cdot 5\text{k}\Omega} = \underline{\underline{-100\text{ V/V}}}$$

(c.) The simplifying circuit for the common mode analysis is shown.



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$$\frac{v_{C1}}{v_{id}} = \frac{1}{2}\frac{v_{C1}}{v_{id}/2} = \frac{1}{2}\left(\frac{v_{C1}}{i_{b1}}\right)\left(\frac{i_{b1}}{v_{id}/2}\right)$$

$$= 0.5(-\beta_F R_C)\left(\frac{1}{r_{\pi1}+(1+\beta_F)R_{EE}}\right)$$

$$= \left(\frac{0.5(-100\cdot 10\text{k}\Omega)}{5\text{k}\Omega+(101\cdot 10\text{k}\Omega)}\right) = \underline{\underline{-0.493\text{ V/V}}}$$

(d.) $$R_{id} = \frac{v_{id}}{i_{in}} = \left(\frac{2}{2}\right)\frac{v_{id}}{i_{b1}} = 2\,\frac{v_{id}/2}{i_{b1}} = 2R_{id} = 2(5\text{k}\Omega) = \underline{\underline{10\text{k}\Omega}}$$