1. The figure shows the ac signal circuit for a differential amplifier. For each BJT, it is given that $\alpha = 0.99$, $\beta = 99$, $r_x = 0$, $g_m = 49.5 \, \text{mS}$, $r_\pi = 2 \, \text{k}\Omega$, $r_e = 20 \, \Omega$, $r_0 = \infty$, $R_B = 1 \, \text{k}\Omega$, $R_E = 70 \, \Omega$, $R_Q = 50 \, \text{k}\Omega$, and $R_C = 12 \, \text{k}\Omega$.

(a) Replace $v_{s1}$ and $v_{s2}$ with differential inputs. Solve for the differential gain $A_{v(d)} = v_{o1}/v_{id}$.

(b) Replace $v_{s1}$ and $v_{s2}$ with common-mode inputs. Solve for the common-mode gain $A_{v(cm)} = v_{o1}/v_{icm}$.

(c) What is the common-mode rejection ratio?

Solutions on next page.
\[ a := 0.99 \quad \beta := 99 \quad g_m := 49.5 \times 10^{-3} \quad r_\pi := 2000 \quad r_e := 20 \quad R_B := 1000 \]

\[ R_E := 70 \quad R_Q := 50000 \quad R_C := 12000 \quad r_e' := \frac{R_B}{1 + \beta} + r_e \quad r_e' = 30 \]

You were expected to use the small-signal models to arrive at the following answers:

(a) \[ v_{i1} = \frac{v_{id}}{2} \quad v_{i2} = -\frac{v_{id}}{2} \quad v_{o1} = -\mu c_1 \cdot R_C = -\alpha \cdot i' \cdot R_C = -\alpha \cdot \frac{2}{r_e' + R_E} \cdot R_C \]

\[ A_{vd} = \frac{v_{o1}}{v_{id}} \quad A_{vd} := \frac{-\alpha \cdot R_C}{2} = \frac{-\alpha \cdot R_C}{r_e' + R_E} \quad A_{vd} = -59.4 \]

(b) \[ v_{i1} = v_{icm} \quad v_{i2} = v_{icm} \quad v_{o1} = -\mu c_1 \cdot R_C = -\alpha \cdot i' \cdot R_C = -\alpha \cdot \frac{v_{icm}}{r_e' + R_E + 2R_Q} \cdot R_C \]

\[ A_{vcm} = \frac{v_{o1}}{v_{icm}} \quad A_{vcm} := \frac{-\alpha \cdot R_C}{r_e' + R_E + 2R_Q} \quad A_{vcm} = -0.119 \]

(c) \[ \text{CMRR} := \left| \frac{A_{vd}}{A_{vcm}} \right| \quad \text{CMRR} = 500.5 \]

\[ \text{CMRR}_{\text{dB}} := 20 \cdot \log(\text{CMRR}) \quad \text{CMRR}_{\text{dB}} = 53.988 \]