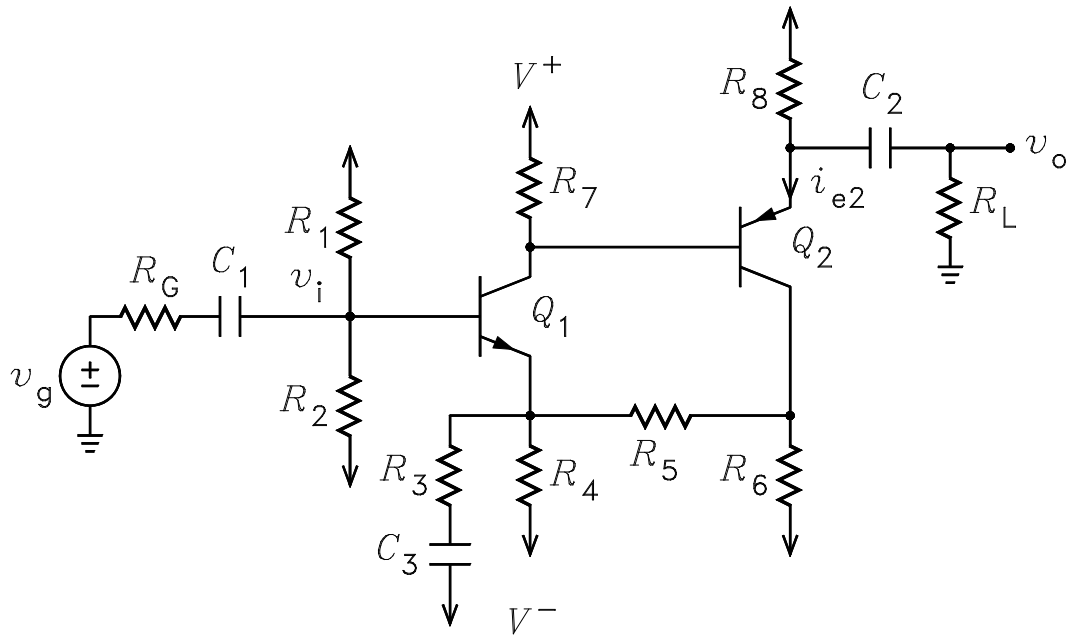


Series Series Feedback



$$V_{\text{plus}} := 15\text{V} \quad V_{\text{minus}} := -15\text{V} \quad V_{\text{BE}} := 0.65\text{V} \quad V_{\text{EB}} := 0.65\text{V} \quad V_{\text{T}} := 25.9\text{mV}$$

$$\beta := 10^{307} \quad R_{\text{p}}(A, B) := \frac{A \cdot B}{A + B} \quad R_1 := 53\text{k}\Omega \quad R_2 := 13\text{k}\Omega \quad R_3 := 1.94\text{k}\Omega$$

$$R_4 := 10\text{k}\Omega \quad R_5 := 1.3\text{k}\Omega \quad R_6 := 1.25\text{k}\Omega \quad R_7 := 26\text{k}\Omega \quad R_8 := 3.0875\text{k}\Omega$$

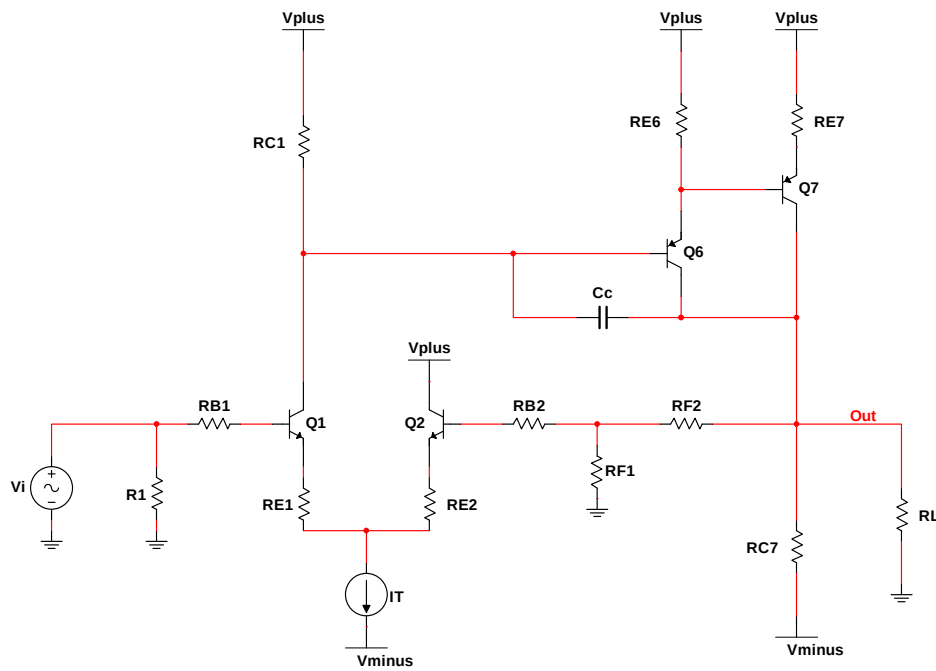
$$R_{\text{L}} := 10\text{k}\Omega \quad V_{\text{B1}} := V_{\text{plus}} \frac{R_2 - R_1}{R_2 + R_1} = -9.091\text{V} \quad V_{\text{E1}} := V_{\text{B1}} - V_{\text{BE}} = -9.741\text{V}$$

$$\begin{pmatrix} I_1 \\ I_2 \end{pmatrix} := \begin{bmatrix} \frac{R_4 \cdot (R_5 + R_6)}{R_4 + R_5 + R_6} & \frac{R_4 \cdot R_6}{R_4 + R_5 + R_6} \\ R_7 & -R_8 \end{bmatrix}^{-1} \cdot \begin{pmatrix} V_{\text{E1}} - V_{\text{minus}} \\ V_{\text{EB}} \end{pmatrix} = \begin{pmatrix} 0.525 \\ 4.209 \end{pmatrix} \cdot \text{mA}$$

$$r_{\text{e1}} := \frac{V_{\text{T}}}{I_1} \quad r_{\text{e2}} := \frac{V_{\text{T}}}{I_2} \quad R_{\text{F2}} := R_{\text{p}}(R_3, R_4) \quad R_{\text{F1}} := R_5 \quad R_{\text{C2}} := R_6$$

$$R_{\text{te1}} := R_{\text{p}}(R_{\text{F2}}, R_{\text{F1}} + R_{\text{C2}}) \quad R_{\text{te2}} := R_{\text{p}}(R_8, R_{\text{L}}) \quad R_{\text{C1}} := R_7$$

Series Shunt Feedback Amplifier Diff Amp Input



$$I_T := 1.5\text{mA} \quad SR := 5 \frac{\text{V}}{\mu\text{s}} \quad f_x := 5\text{MHz}$$

Use the formulas for the resistive load on the diff amp

$$SR = \frac{I_T}{2C_c} \quad f_x = \frac{1}{4\pi \left(R_E + 2 \frac{V_T}{I_T} \right) C_c} \quad V_T := 25.49\text{mV} \quad V_{BE} := 0.65\text{V} \quad \beta := 10^{300}$$

$$I_{SO} := \frac{1\text{mA}}{\exp\left(\frac{V_{BE}}{V_T}\right)} = 8.422 \times 10^{-15} \text{A} \quad V_{EB} := 0.65\text{V} \quad \alpha := \frac{\beta}{\beta + 1}$$

Pick

$$\beta := 10^{300} \quad \alpha := \frac{\beta}{\beta + 1} = 1 \quad I_6 := 0.2\text{mA} \quad I_7 := 1.8\text{mA}$$

$$V_{out} := 0\text{V} \quad R_{F1} := 10\text{k}\Omega \quad R_B := 100\Omega \quad R_L := 10^{300}\text{k}\Omega$$

$$R_1 := 10\text{k}\Omega \quad V_{plus} := 15\text{V} \quad V_{minus} := -15\text{V} \quad R_{F2} := 10^{300}\text{k}\Omega \quad \text{To get Open Loop Gain}$$

Gain of Q6-Q7 to be -100 Q6 is an emitter follower with a gain of approx 1 so

$$A_{67} = \frac{-R_{C7}}{r_{e7} + R_{E7}} \quad A_{67} := -100$$

Then

$$C_c := \frac{I_T}{2SR} = 150 \cdot \text{pF}$$

$$I_1 := \frac{I_T}{2} \quad r_e := \frac{V_T}{I_1}$$

$$R_E := \frac{1}{4 \cdot \pi \cdot f_X \cdot C_c} - r_e = 72.117 \Omega$$

$$R_{C7} := \frac{0V - V_{\text{minus}}}{I_6 + I_7} = 7.5 \cdot \text{k}\Omega$$

$$r_{e7} := \frac{V_T}{I_7} = 14.161 \Omega$$

$$r_{e6} := \frac{V_T}{I_6} = 127.45 \Omega \quad R_{E7} := \frac{-R_{C7}}{A_{67}} - r_{e7} = 60.839 \Omega \quad R_p(A, B) := \frac{A \cdot B}{A + B}$$

$$R_{E6} := \frac{I_7 \cdot R_{E7} + V_{EB}}{I_6} = 3.798 \cdot \text{k}\Omega$$

$$R_{C1} := \frac{I_6 \cdot R_{E6} + V_{EB}}{I_1} = 1.879 \cdot \text{k}\Omega$$

Eqn 11.39 page 159

$$A := \frac{1}{2 \cdot (r_e + R_E)} \cdot (-R_{C1}) \cdot \left(\frac{-R_{E6}}{r_{e6} + R_{E6}} \right) \cdot \left(\frac{1}{R_{E6}} + \frac{1}{r_{e7} + R_{E7}} \right) \cdot R_p(R_{C7}, R_{F2} + R_{F1}) = 873.787$$

Now change $R_{F1} := 10 \text{k}\Omega$ $R_{F2} := 90 \text{k}\Omega$

$$A := \frac{1}{2 \cdot (r_e + R_E)} \cdot (-R_{C1}) \cdot \left(\frac{-R_{E6}}{r_{e6} + R_{E6}} \right) \cdot \left(\frac{1}{R_{E6}} + \frac{1}{r_{e7} + R_{E7}} \right) \cdot R_p(R_{C7}, R_{F2} + R_{F1}) = 812.825$$

$$b := \frac{R_{F1}}{R_{F1} + R_{F2}} \quad \frac{1}{b} = 10 \quad A_v := \frac{A}{1 + b \cdot A} = 9.878$$

$$r_{\text{out}} := \frac{R_p[R_{C7}, (R_{F1} + R_{F2})]}{1 + b \cdot A} = 84.79 \Omega$$

$$V_U := V_{\text{plus}} \cdot \frac{R_p(R_{C7}, R_L)}{R_{E7} + R_p(R_{C7}, R_L)} + V_{\text{minus}} \cdot \frac{R_p(R_{E7}, R_L)}{R_{C7} + R_p(R_{E7}, R_L)} = 14.759 \text{ V}$$

$$V_L := V_{\text{minus}} \cdot \frac{R_L}{R_L + R_{C7}} = -15 \text{ V}$$

Fig. 11.12 VBE Multiplier to Bias Output Stage

$$I_{67} := I_6 + I_7 = 2 \cdot \text{mA}$$

$$V_{BE10} = V_{CE10} \cdot \frac{R_3}{R_2 + R_3} \quad V_{CE10} = V_{BE10} \left(1 + \frac{R_2}{R_3} \right)$$

$$V_{CE10} = I_8 \cdot R_{E8} + I_9 \cdot R_{E9} + V_{BE8} + V_{BE9}$$

$$(R_2 + R_3) \cdot I_{23} = V_{CE10} = V_{BE10} \left(1 + \frac{R_2}{R_3} \right)$$

Pick $I_8 := 2 \text{ mA}$ $I_9 := 2 \text{ mA}$ $R_{E8} := 100 \Omega$ $R_{E9} := 100 \Omega$

$$I_{23} := I_{67} \cdot 0.2 = 0.4 \cdot \text{mA}$$

Then

$$V_{CE10} := I_8 \cdot R_{E8} + I_9 \cdot R_{E9} + 2 \cdot V_{BE} = 1.7 \text{ V} \quad R_3 := \frac{V_{BE}}{I_{23}} = 1.625 \cdot \text{k}\Omega$$

$$R_2 := \frac{V_{CE10}}{I_{23}} - R_3 = 2.625 \cdot \text{k}\Omega$$

Current Mirror Load on Diff Amp

$$SR = \frac{I_T}{C_c} \quad f_x = \frac{1}{2\pi \left(R_E + 2 \frac{V_T}{I_T} \right) C_c}$$

$$C_c := \frac{I_T}{SR} = 300 \cdot \text{pF}$$

$$R_E := \frac{1}{2 \cdot \pi \cdot f_x \cdot C_c} - r_e = 72.117 \Omega \quad I_{11} := I_6 + I_7 = 2 \cdot \text{mA}$$

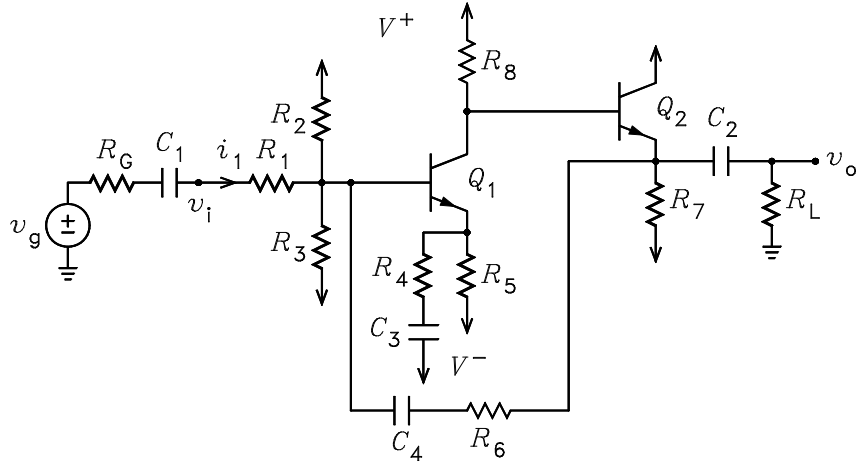
Pick $R_{E11} := 600 \Omega$ $R_{E7} := 600 \Omega$ $I_{R4} := 0.1 \cdot I_{11} = 0.2 \cdot \text{mA}$

$$R_4 := \frac{V_{\text{plus}} - (V_{\text{BE}} + I_{11} \cdot R_{\text{E11}} + V_{\text{minus}})}{I_{\text{R4}}} = 140.75 \cdot \text{k}\Omega$$

$$R_5 := \frac{V_{\text{BE}} + I_{11} \cdot R_{\text{E11}}}{I_{\text{R4}}} = 9.25 \cdot \text{k}\Omega$$

$$R_{\text{E6}} := \frac{I_7 \cdot R_{\text{E7}} + V_{\text{EB}}}{I_6} = 8.65 \cdot \text{k}\Omega$$

Shunt-Shunt Amplifier



$$\begin{aligned} V_{\text{plus}} &:= 15\text{V} & V_{\text{minus}} &:= -15\text{V} & \beta &:= 10^{200} & R_G &:= 0\Omega & R_1 &:= 10\text{k}\Omega \\ R_2 &:= 487\text{k}\Omega & R_3 &:= 109\text{k}\Omega & R_4 &:= 100\Omega & R_5 &:= 10\text{k}\Omega & R_6 &:= 120\text{k}\Omega \\ R_7 &:= 5\text{k}\Omega & R_8 &:= 18\text{k}\Omega & R_L &:= 10\text{k}\Omega & V_{\text{BE}} &:= 0.65\text{V} & V_T &:= 25.9\text{mV} \end{aligned}$$

$$V_{\text{B1}} := \frac{R_3 - R_2}{R_2 + R_3} \cdot V_{\text{plus}} = -9.513\text{V} \quad V_{\text{E1}} := V_{\text{B1}} - V_{\text{BE}} = -10.163\text{V}$$

$$I_{\text{E1}} := \frac{V_{\text{E1}} - V_{\text{minus}}}{R_5} = 0.484\text{mA} \quad I_{\text{C1}} := I_{\text{E1}} \quad V_{\text{C1}} := V_{\text{plus}} - I_{\text{C1}} \cdot R_8 = 6.294\text{V}$$

$$V_{\text{B2}} := V_{\text{C1}} \quad V_{\text{E2}} := V_{\text{B2}} - V_{\text{BE}} = 5.644\text{V} \quad I_{\text{E2}} := \frac{V_{\text{E2}} - V_{\text{minus}}}{R_7} = 4.129\text{mA}$$

$$r_{\text{e1}} := \frac{V_T}{I_{\text{E1}}} = 53.55\Omega \quad r_{\text{e2}} := \frac{V_T}{I_{\text{E2}}} = 6.273\Omega \quad R_{\text{p}}(A, B) := \frac{A \cdot B}{A + B}$$

$$G_{\text{m1}} := \frac{1}{r_{\text{e1}} + R_{\text{p}}(R_4, R_5)} \quad G_{\text{m2}} := \frac{1}{r_{\text{e2}} + R_{\text{p}}(R_7, R_{\text{p}}(R_L, R_6))}$$

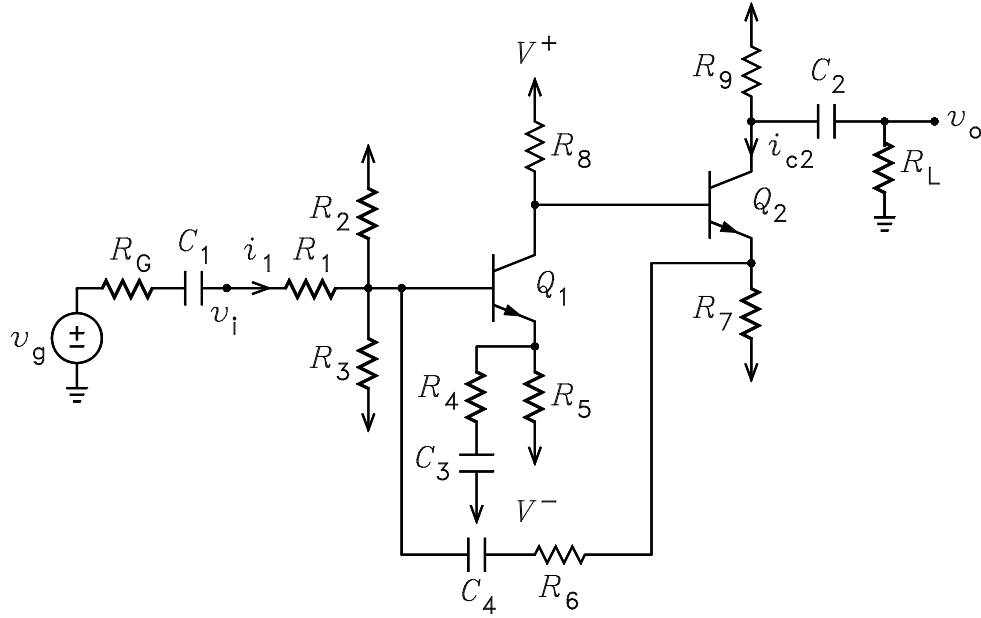
$$R_{23} := R_{\text{p}}(R_2, R_3) \quad R_1 := R_{\text{p}}(R_1, R_{23}) \quad R_{\text{E2}} := R_{\text{p}}(R_7, R_L) = 3.333\text{k}\Omega$$

$$A := R_{\text{p}}(R_1, R_6) \cdot \left[G_{\text{m1}} \cdot (-R_8) \cdot \frac{R_{\text{p}}(R_{\text{E2}}, R_6)}{r_{\text{e2}} + R_{\text{p}}(R_{\text{E2}}, R_6)} + \frac{R_{\text{p}}(r_{\text{e2}}, R_{\text{E2}})}{R_6 + R_{\text{p}}(r_{\text{e2}}, R_{\text{E2}})} \right] = -9.849 \times 10^5 \Omega$$

$$b := \frac{-1}{R_6} \qquad \frac{1}{b} = -120 \cdot k\Omega$$

$$A_r := \frac{A}{1 + A \cdot b} = -106.967 \cdot k\Omega$$

Shunt Series



$$V_{\text{plus}} := 15\text{V} \quad V_{\text{minus}} := -15\text{V} \quad R_1 := 10\text{k}\Omega \quad R_2 := 500\text{k}\Omega \quad R_3 := 100\text{k}\Omega$$

$$R_4 := 100\Omega \quad R_5 := 8.7\text{k}\Omega \quad R_6 := 21.0375\text{k}\Omega \quad R_7 := 2.3375\text{k}\Omega \quad R_8 := 40\text{k}\Omega$$

$$R_9 := 2.5\text{k}\Omega \quad R_L := 10\text{k}\Omega \quad V_{\text{BE}} := 0.65\text{V} \quad V_T := 25.9\text{mV}$$

$$R_p(A, B) := \frac{A \cdot B}{A + B} \quad V_{\text{B1}} := V_{\text{plus}} \cdot \frac{R_3 - R_2}{R_3 + R_2} = -10\text{V} \quad V_{\text{E1}} := V_{\text{B1}} - V_{\text{BE}} = -10.65\text{V}$$

$$R_G := 0\Omega \quad I_1 := \frac{V_{\text{E1}} - V_{\text{minus}}}{R_5} = 0.5\text{mA} \quad V_{\text{C1}} := V_{\text{plus}} - I_1 \cdot R_8 = -5\text{V}$$

$$V_{\text{E2}} := V_{\text{C1}} - V_{\text{BE}} = -5.65\text{V}$$

$$I_2 := \frac{V_{\text{E2}} - V_{\text{minus}}}{R_7} = 4\text{mA} \quad \beta := 10^{307}$$

$$r_{\text{e1}} := \frac{V_T}{I_1} \quad r_{\text{e2}} := \frac{V_T}{I_2}$$

$$R_{67} := R_p(R_6, R_7)$$

$$G_{\text{m1}} := \frac{1}{r_{\text{e1}} + R_p(R_4, R_5)}$$

$$G_{\text{m2}} := \frac{1}{r_{\text{e2}} + R_p(R_7, R_6)}$$

$$R_F := R_6 \quad R_{\text{E2}} := R_{67}$$

$$R_{\text{C1}} := R_8$$

$$R_{23} := R_p\big(R_2,R_3\big) \qquad R_1 := R_p\big(R_1,R_{23}\big)$$

$$A := R_p\big(R_1,R_F+R_{E2}\big)\cdot \left[G_{m1}\cdot \big(-G_{m2}\cdot R_{C1}\big)-\frac{G_{m2}\cdot R_{E2}}{R_F+R_{E2}}\right] = -810.856$$

$$b := -\frac{R_{E2}}{R_F+R_{E2}} = -0.091 \qquad \frac{1}{b} = -11$$

$$A_i := \frac{A}{1+b\cdot A} = -10.853$$

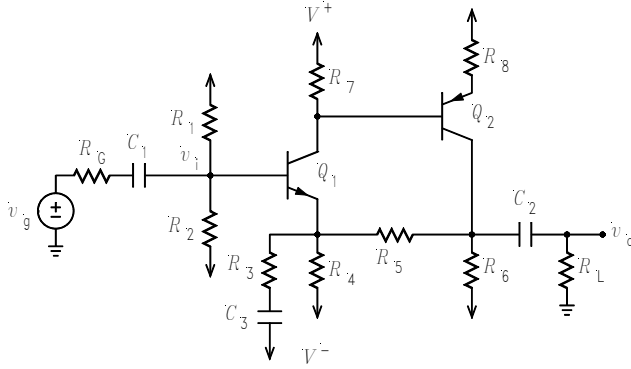
$$R_{nb1} := R_p\big(R_1,R_6+R_7\big) = 6.461 \times 10^3 \Omega \qquad R_{tc2} := R_p\big(R_L,R_9\big) = 2 \times 10^3 \Omega$$

$$R_{te2} := R_p\big(R_6,R_7\big) = 2.104 \times 10^3 \Omega$$

$$n := \frac{R_{nb1}}{R_{te2}} = 3.071$$

$$n_b := \frac{R_1}{R_{te2}} = 4.244$$

Series Shunt Amplifier



$$R_p(A, B) := \frac{A \cdot B}{A + B}$$

$$V_T := 25.9 \text{ mV}$$

$$V_{BE} := 0.65 \text{ V}$$

$$V_{EB} := 0.65 \text{ V}$$

$$R_L := 10 \text{ k}\Omega$$

$$V_{\text{plus}} := 15 \text{ V}$$

$$V_{\text{minus}} := -15 \text{ V}$$

$$R_g := 0$$

$$R_1 := 28 \text{ k}\Omega$$

$$R_2 := 15 \text{ k}\Omega$$

$$R_3 := 1.8 \text{ k}\Omega$$

$$R_4 := 13 \text{ k}\Omega$$

$$R_5 := 20 \text{ k}\Omega$$

$$R_6 := 5.1 \text{ k}\Omega$$

$$R_7 := 1.8 \text{ k}\Omega$$

$$R_8 := 100 \Omega$$

$$V_{B1} := V_{\text{plus}} \cdot \frac{R_2 - R_1}{R_1 + R_2} = -4.535 \text{ V} \quad V_{E1} := V_{B1} - V_{BE} = -5.185 \text{ V}$$

$$\begin{pmatrix} I_1 \\ I_2 \end{pmatrix} := \begin{pmatrix} R_p(R_4, R_5 + R_6) & \frac{R_6}{R_4 + R_5 + R_6} \cdot R_4 \\ R_7 & -R_8 \end{pmatrix}^{-1} \cdot \begin{pmatrix} V_{E1} - V_{\text{minus}} \\ V_{EB} \end{pmatrix} = \begin{pmatrix} 0.53 \\ 3.034 \end{pmatrix} \cdot \text{mA}$$

$$V_{E1} := I_1 \cdot R_p(R_4, R_5 + R_6) + I_2 \cdot \left(\frac{R_6}{R_4 + R_5 + R_6} \cdot R_4 \right) + V_{\text{minus}} = -5.185 \text{ V}$$

$$V_{C1} := V_{\text{plus}} - I_1 \cdot R_7 = 14.047 \text{ V} \quad V_{B2} := V_{C1} = 14.047 \text{ V} \quad V_{E2} := V_{B2} + V_{EB} = 14.697 \text{ V}$$

$$V_{C2} := I_2 \cdot R_p(R_6, R_4 + R_5) + I_1 \cdot \frac{R_4}{R_4 + R_5 + R_6} \cdot R_6 + V_{\text{minus}} = -0.678 \text{ V}$$

$$r_{e1} := \frac{V_T}{I_1}$$

$$G_{m1} := \frac{1}{r_{e1} + R_p(R_5, R_p(R_3, R_4))}$$

$$r_{e2} := \frac{V_T}{I_2}$$

$$G_{m2} := \frac{1}{r_{e2} + R_8}$$

$$A := G_{m1} \cdot \left(G_{m2} \cdot R_7 \cdot R_p(R_p(R_6, R_L), R_5 + R_p(R_3, R_4)) + \frac{R_p(R_3, R_4) \cdot R_p(R_6, R_L)}{R_p(R_3, R_4) + R_5 + R_p(R_6, R_L)} \right) = 32.128$$

$$b := \frac{R_p(R_3, R_4)}{R_5 + R_p(R_3, R_4)} = 0.073 \quad \frac{1}{b} = 13.65 \quad A_v := \frac{A}{1 + b \cdot A} = 9.58$$

Put cap to ground from emitter of Q2

$$G_{m2} := \frac{1}{r_{e2}}$$

$$A := G_{m1} \cdot \left(G_{m2} \cdot R_7 \cdot R_p(R_6, R_L), R_5 + R_p(R_3, R_4) \right) + \frac{R_p(R_3, R_4) \cdot R_p(R_6, R_L)}{R_p(R_3, R_4) + R_5 + R_p(R_6, R_L)} = 406.789$$

$$b := \frac{R_p(R_3, R_4)}{R_5 + R_p(R_3, R_4)} = 0.073 \quad A_v := \frac{A}{1 + b \cdot A} = 13.206$$

$$G_{m1} := \frac{1}{r_{e1} + R_{te1}} \qquad G_{m2} := \frac{1}{r_{e2} + R_{te2}}$$

$$A := G_{m1} \cdot \frac{R_{C1}}{r_{e2} + R_{te2}} = 0.011 \frac{1}{\Omega} \qquad b := \frac{R_{C2} \cdot R_{F2}}{R_{C2} + R_{F1} + R_{F2}} = 486.489 \Omega$$

$$\frac{1}{b} = 2.056 \times 10^{-3} \frac{1}{\Omega} \qquad A_m := \frac{A}{1 + b \cdot A} = 1.72 \times 10^{-3} \frac{1}{\Omega}$$