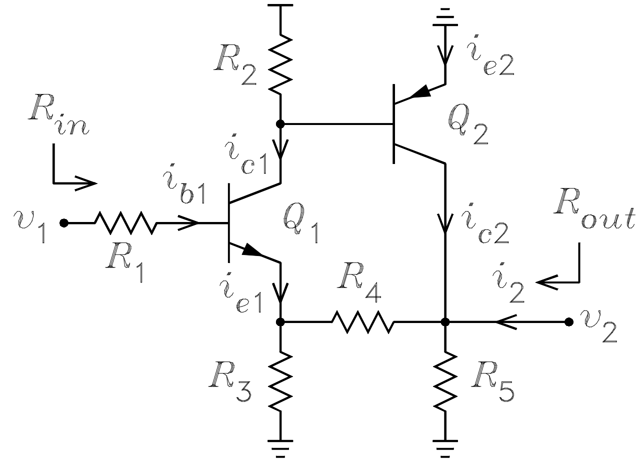
ECE 6416 Assignment 4

1. The figure shows the signal circuit of a series-shunt feedback amplifier. The circuit element values are $R_1 = 620\,\Omega$, $R_2 = 24\,\text{k}\Omega$, $R_3 = 1.2\,\text{k}\Omega$, $R_4 = 16\,\text{k}\Omega$, $R_5 = 1.5\,\text{k}\Omega$, $I_{C1} = 1.2\,\text{mA}$, $I_{C2} = 3\,\text{mA}$, $r_x = 0$, $r_0 = \infty$, $\beta = 149$, and $a = \beta/(1+\beta)$. Assume $V_T = 25\,\text{mV}$.



   (a) Looking out of the emitter of Q_1, form a Thévenin equivalent circuit with respect to v_2. Answer: a voltage source $0.0698v_2$ in series with $1116\,\Omega$.

   (b) Looking to the left through R_4 from the v_2 node, form the Norton equivalent circuit with respect to i_{e1}. Answer: a current source $0.0698i_{e1}$ in parallel with $17.2\,\text{k}\Omega$.

   (c) Solve for i_{c1}, i_{e1}, and i_{b1} as a function of v_1 and the Thévenin source $0.0658v_2$. Answers: $i_{c1} = 8.705 \times 10^{-4}(v_1 - 0.0698v_2)$, $i_{e1} = 8.763 \times 10^{-4}(v_1 - 0.0698v_2)$, $i_{b1} = 5.842 \times 10^{-6}(v_1 - 0.0698v_2)$.

   (d) Solve for i_{c2} as a function of i_{c1}. Answer: $i_{c2} = 141.7i_{c1}$.

   (e) Solve for v_2 as a function of i_{c2}, i_2, and i_{e1}. Answer: $v_2 = 1380(i_{c2} + i_2) + 96.26i_{e1}$.

   (f) Set $i_2 = 0$ and solve the equations for $A_v = v_2/v_1$. Answer: $A_v = 13.22$.

   (g) Set $i_2 = 0$ and solve the equations for $R_{in} = v_1/i_{b1}$. Answer: $R_{in} = 2.204\,\text{M}\Omega$.

   (h) Set $v_1 = 0$ and solve the equations for $R_{out} = v_2/i_2$. Answer: $R_{out} = 107.1\,\Omega$.

2. A diode is biased at a current of $1\,\text{mA}$. The ideality factor or emission coefficient is $\eta = 2$.

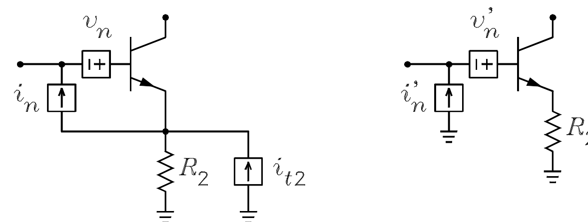
   (a) If flicker noise can be neglected, what amplifier gain would be required to amplify the diode noise to a voltage of $100\,\text{mV}$ in the band from $20\,\text{Hz}$ to $20\,\text{kHz}$? Answer: $A_v = 7.91 \times 10^5$.

   (b) If the diode has a flicker noise corner frequency of $2\,\text{kHz}$, what is the flicker noise coefficient and the new total rms noise voltage at the amplifier output? Answers: $K_f = 6.4 \times 10^{-16}$ and $v_n = 130\,\text{mV}$ rms.

3. Fig. (a) shows the noise model of a CE BJT with a resistor R_2 connected in series with its emitter. Fig. (b) shows an equivalent circuit where R_2 is considered a noiseless resistor. It is given that $v_n/\sqrt{\Delta f} = 0.5\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$, $i_n/\sqrt{\Delta f} = 7\,\mathrm{pA}/\sqrt{\mathrm{Hz}}$, $\rho = 0.2$, and $R_2 = 200\,\Omega$. The transistor is biased at a current $I_C = 1\,\mathrm{mA}$ and has the parameters $r_x = 50\,\Omega$, $\beta = 100$, and $r_0 = \infty$. Assume $V_T = 25\,\mathrm{mV}$.
(a) Following the derivation for $I_{c(sc)}$ in Chapter 7 of the class notes, solve for V_{ni} and show that V_n' and I_n' are given by

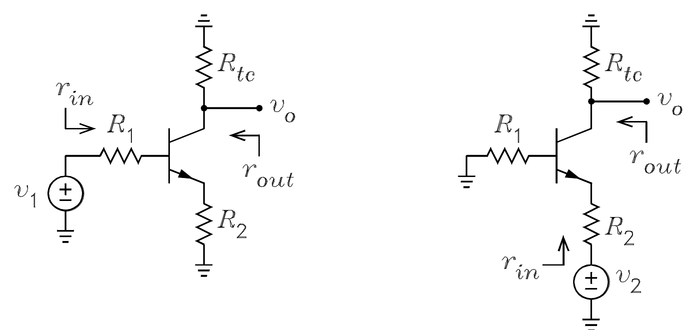
$$V_n' = V_n - (I_{t2} - I_n)\,R_2 \qquad I_n' = I_n$$

(b) Show that $v_n' = 2.4\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$, $i_n' = 7\,\mathrm{pA}/\sqrt{\mathrm{Hz}}$, $\rho' = 0.63$.



(a) (b)

4. The figure shows the ac signal circuits for single stage CE and CB amplifiers. The transistor parameters are $\beta = 100$, $r_x = 40\,\Omega$, $r_0 = 50\,\mathrm{k}\Omega$, and $V_T = 25\,\mathrm{mV}$. (The equations for the voltage gain, input resistance, and output resistance of the CE and CB amplifiers are given in Section 7.6 of the class notes. You do not have to derive these.)

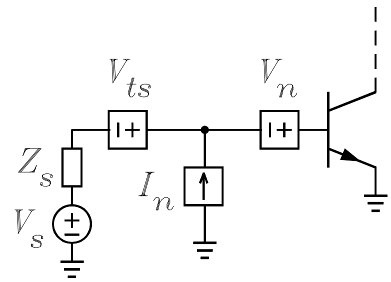


(a) (b)

(a) For the CE amplifier of Fig. (a), it is given that $R_1 = 1\,\mathrm{k}\Omega$, $R_2 = 50\,\Omega$, and $R_{tc} = 10\,\mathrm{k}\Omega$. Show that $I_{C(opt)} = 228\,\mu\mathrm{A}$. For $I_C = I_{C(opt)}$, use the r_0 approximations to show that $v_o/v_1 = -51.4$, $r_{in} = 17.0\,\mathrm{k}\Omega$, $r_{out} = 8.76\,\mathrm{k}\Omega$, $v_{ni}/\sqrt{\Delta f} = 4.4\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$, $F = 1.21$, and $NF = 0.829\,\mathrm{dB}$.

(b) For the CB amplifier of Fig. (b), it is given that $R_1 = 50\,\Omega$, $R_2 = 50\,\Omega$, $R_{tc} = 10\,\mathrm{k}\Omega$. Show that $I_{C(opt)} = 1.78\,\mathrm{mA}$. For $I_C = I_{C(opt)}$, use the r_0 approximations to show that $v_o/v_2 = 146$, $r_{in} = 64.8\,\Omega$, $r_{out} = 9.55\,\mathrm{k}\Omega$, $v_{ni}/\sqrt{\Delta f} = 1.58\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$, $F = 3.11$, and $NF = 4.93\,\mathrm{dB}$.

5. For the common-emitter amplifier shown, it is given that $Z_s = R_s + jX_s = 50 + j100\,\Omega$, $I_C = 10\,\text{mA}$, $V_{CB} = 10\,\text{V}$, $V_A = 30\,\text{V}$, $V_T = 25\,\text{mV}$, $\beta = 99$, $\alpha = 0.99$, $r_x = 10\,\Omega$, $c_{jc} = 10\,\text{pF}$, $c_{je} = 15\,\text{pF}$, $\tau_F = 0.5625\,\text{ns}$, and $f = 10\,\text{MHz}$. (The equations for working this problem are given in Section 7.13 of the Class Notes. You do not have to derive these.)



(a) Show that $v_n/\sqrt{\Delta f} = 0.431\,\text{nV}/\sqrt{\text{Hz}}$, $i_n/\sqrt{\Delta f} = 6.11\,\text{pA}\,/\sqrt{\text{Hz}}$, and $\gamma = 0.173 - j0.117$.

(b) Show that the optimum source impedance is $Z_{opt} = 70.0 + j8.21\,\Omega$.

(c) Show that the minimum noise figure is $F_{min} = 1.38$.

(d) Show that F can be written

$$F = 1.38 + \frac{1}{428R_s}\left[(R_s - 70.0)^2 + (X_s - 8.21)^2\right]$$

(e) For the source impedance specified, show that $F = 1.80$.

(f) A capacitor is to be put in series with Z_s to make $X_s = X_{opt}$. Show that the required value of the capacitor is $C = 173\,\text{pF}$.

(g) Show that $F = 1.40$ with the capacitor.