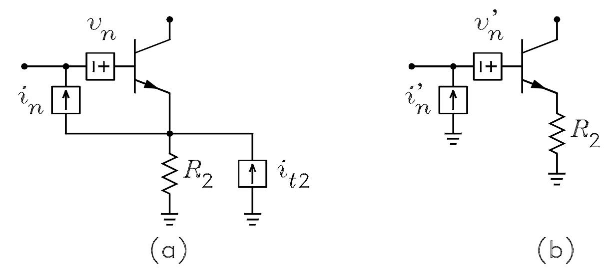
ECE 6416 Assignment 4

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

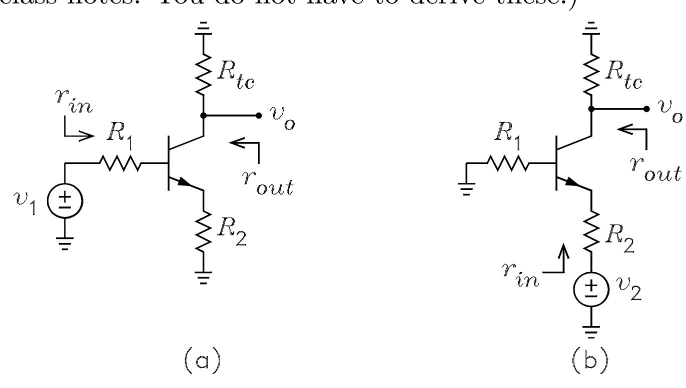
   (a) If flicker noise can be neglected, what amplifier gain would be required to amplify the diode noise to a voltage of 100 mV in the band from 20 Hz to 20 kHz? Answer: $A_v = 7.91 \times 10^5$.

   (b) If the diode has a flicker noise corner frequency of 2 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 $v_n = 130\,\mathrm{mV}$ rms.

2. 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 $r_0 = 50\,\mathrm{k}\Omega$. Assume $V_T = 25\,\mathrm{mV}$. Use the results derived in Chapter 4 of the class notes to solve for v_n', i_n', and ρ' for the circuit of Fig. (b). Answers: $v_n' = 2.4\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$, $i_n' = 7\,\mathrm{pA}/\sqrt{\mathrm{Hz}}$, $\rho' = 0.63$.



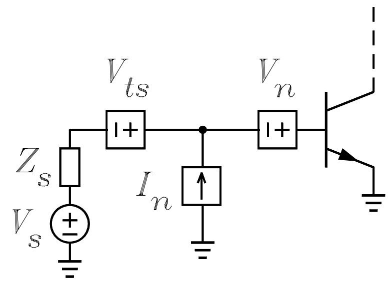
3. The figure shows the ac signal circuits for single stage CE and CB amplifiers. The transistor parameters are $\beta = 100$, $r_x = 40\,\Omega$, $r_0 = 50\,\mathrm{k}\Omega$, and $V_T = 25\,\mathrm{mV}$. (The formulas for the voltage gain, input resistance, and output resistance of the CE and CB amplifiers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



   (a) 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 $I_C = I_{C(opt)}$, show that $v_o/v_1 = -51.4$, $r_{in} = 16.2\,\mathrm{k}\Omega$, $r_{out} = 8.76\,\mathrm{k}\Omega$, $v_{ni}/\sqrt{\Delta f} = 4.4\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$, $F = 1.21$, and $NF = 0.829\,\mathrm{dB}$.

(b) For the CB amplifier of Fig. (b), it is given that $R_1 = 50\,\Omega$, $R_2 = 50\,\Omega$, $R_{tc} = 10\,\text{k}\Omega$. Show that $I_{C(opt)} = 1.78\,\text{mA}$. For $I_C = I_{C(opt)}$, show that $v_o/v_2 = 146$, $r_{in} = 67.7\,\Omega$, $r_{out} = 9.55\,\text{k}\Omega$, $v_{ni}/\sqrt{\Delta f} = 1.58\,\text{nV}/\sqrt{\text{Hz}}$, $F = 3.11$, and $NF = 4.93\,\text{dB}$.

4. 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 formulas 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.

(h) For the source impedance specified, show that the collector output impedance is $Z_{out} = 73.6 - j77.8\,\Omega$.

(i) If the external load impedance on the collector is Z_{out}^*, show that the base input impedance is $Z_{ib} = 3.25 - j41.7\,\Omega$ and the voltage gain is $V_o/V_s = 23.0\angle 77.5^\circ$ (27.2 dB).