

ECE 6416 Quiz 1

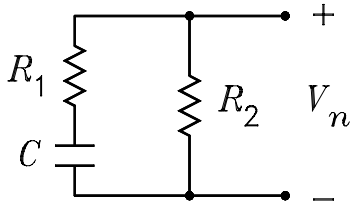
October 9, 2006

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Name _____

Instructions. Print your name in the space above and at the top of all other pages in your quiz. Place a box around each answer. Express each numerical answer as a decimal number. Numerical values are $4kT_0 = 1.6 \times 10^{-20}$ J and $q = 1.6 \times 10^{-19}$ C. **Honor Code:** *I have neither given nor received help on this quiz.* Initials _____

- The figure shows an RC network. Use the generalized Nyquist formula to solve for the expression for the mean-square noise voltage v_n^2 in the frequency band Δf .



$$\begin{aligned} Z &= R_2 \frac{R_1 + 1/j\omega C}{R_1 + R_2 + 1/j\omega C} = R_2 \frac{1 + j\omega R_1 C}{1 + j\omega (R_1 + R_2) C} \\ &= R_2 \frac{1 + \omega^2 R_1 (R_1 + R_2) C - j\omega R_2 C}{1 + [\omega (R_1 + R_2) C]^2} \end{aligned}$$

$$v_n^2 = 4kTR_2 \frac{1 + \omega^2 R_1 (R_1 + R_2) C}{1 + [\omega (R_1 + R_2) C]^2} \Delta f$$

- A particular BJT amplifier is driven from a source having an output resistance R_S . The equivalent noise input voltage is found to be given by

$$V_{ni} = V_{ts} + V_{tx} + I_{shb} (R_S + r_x) + \frac{I_{shc}}{g_m} \left(\frac{R_S + r_x}{r_\pi} + 1 \right)$$

where V_{ts} is the thermal noise generated by R_S and the noise sources V_{tx} , I_{shb} , and I_{shc} are internal to the amplifier. What are the expressions for V_n and I_n in the $V_n - I_n$ amplifier noise model?

$$V_n = V_{tx} + I_{shb} r_x + \frac{I_{shc}}{g_m} \left(\frac{r_x}{r_\pi} + 1 \right)$$

$$I_n = I_{shb} + \frac{I_{shc}}{g_m r_\pi}$$

- An amplifier has the spot noise parameters $v_n = 2 \text{ nV} / \sqrt{\text{Hz}}$, $i_n = 1.5 \text{ pA} / \sqrt{\text{Hz}}$, and $\gamma = 0.2 + j0.1$. The amplifier is driven from a source having the resistive output impedance $R_S = 50 \Omega$.

(a) Calculate the noise factor F and the noise figure NF .

$$v_{ni}^2 = 4kT_0R_S + v_n^2 + 2v_ni_n \operatorname{Re}(\gamma R_S) + i_n^2 R_S^2 = 5.963 \times 10^{-18} \frac{\text{V}}{\sqrt{\text{Hz}}}$$

$$v_{ts}^2 = 4kT_0R_S = 8 \times 10^{-19} \frac{\text{V}}{\sqrt{\text{Hz}}}$$

$$F = \frac{v_{ni}^2}{v_{ts}^2} = 7.4531 \quad NF = 10 \log(F) = 8.723 \text{ dB}$$

(b) Calculate the optimum source impedance Z_{opt} that minimizes F .

$$Z_{opt} = \left(\sqrt{1 - \gamma_i^2} - j\gamma_i \right) \frac{v_n}{i_n} = 132.7 - j13.33 \Omega$$

(c) A series impedance $Z_1 = Z_{opt} - R_S$ is inserted between the source and the amplifier so that the source impedance seen by the amplifier is Z_{opt} . Calculate the new noise factor and the new noise figure. Note – The correct answer is not F_{\min} .

$$v_{ni}^2 = 4kT_0R_S + v_n^2 + 2v_ni_n \operatorname{Re}(\gamma Z_{opt}) + i_n^2 |Z_{opt}|^2 = 1.180 \times 10^{-17} \frac{\text{V}}{\sqrt{\text{Hz}}}$$

$$v_{ts}^2 = 4kT_0R_S = 8 \times 10^{-19} \frac{\text{V}}{\sqrt{\text{Hz}}}$$

$$F = \frac{v_{ni}^2}{v_{ts}^2} = 14.7433 \quad NF = 10 \log(F) = 11.69 \text{ dB}$$