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4.6 PROBLEMS

Unless otherwise stated, assume dBm values are referenced to $50\ \Omega$.

4.1 If a signal is measured to have $V_{(rms)}$ volts, what is the difference in db if it is expressed in dBm referenced to $50\ \Omega$ as opposed to being referenced to $75\ \Omega$?

4.2 Consider the sum of two noise sources of values -20 dBm and -23 dBm. Find the total noise power in dBm for the cases in which the two noise sources are (*a*) uncorrelated, (*b*) $C = 0.3$, (*c*) $C = +1$, and (*d*) $C = -1$.

4.3 The output noise of a circuit is measured to be -40 dBm around 100 kHz when a resolution bandwidth of 30 Hz is used. What is the expected dBm measurement if a resolution bandwidth of 10 Hz is used? Find the root spectral density in $V/\sqrt{Hz}$.

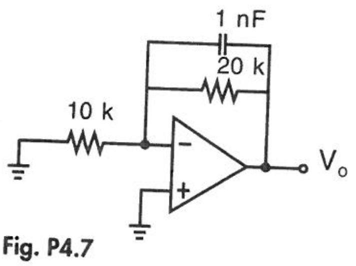
4.4 At 0.1 Hz, a low-frequency measurement has a noise value of -60 dBm when a resolution bandwidth of 1 mHz is used. Assuming 1/f noise dominates, what would be the expected noise value (in dBm) over the band from 1 mHz to 1 Hz?

4.5 Show that, when two resistors of values R_1 and R_2 are in series, their noise model is the same as a single resistance of value $R_1 + R_2$. Repeat the problem for parallel resistances.

4.6 Sketch the spectral density of voltage noise across a 100-pF capacitor when it is in parallel with a 1-kΩ resistor. Make another sketch for the same capacitor but with a 1-MΩ resistance in parallel. What can you say about the area under the curves of the two sketches?

4.7 Consider the circuit shown in Fig. P4.7 on p. 218, where the opamp has a unity-gain frequency of 1 MHz and equivalent input voltage and current noise sources of $V_n(f) = 20\ nV/\sqrt{Hz}$ and $I_n(f) = 10\ pA/\sqrt{Hz}$, respectively. Estimate the total rms noise voltage at V_o.

4.8 Assuming an ideal noiseless opamp, find the noise level at V_x and V_o for the opamp circuit shown in Fig. P4.8. By what factor is the noise value at V_o larger (or smaller) than $kT/1\ nF$? How do you account for this increase (or decrease)? Also explain why the noise value at V_x is smaller than $kT/1\ nF$.



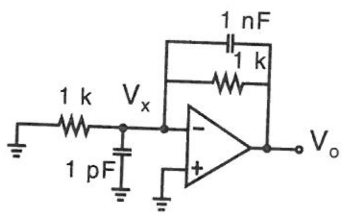
Opamp

$V_n(f) = 20\ nV/\sqrt{Hz}$

$I_{n+}(f) = I_{n-}(f) = 10\ pA/\sqrt{Hz}$

$f_t = 1\ MHz$

Fig. P4.7



Ideal noiseless opamp

Fig. P4.8

4.9 Consider an inductor of value L and an arbitrary resistor in parallel, as shown in Fig. P4.9. Show that the current noise, $i_{no}(t)$, has a noise value given by

$$I^2_{no(rms)} = \frac{kT}{L}$$

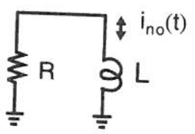


Fig. P4.9

4.10 The two circuits shown in Fig. P4.10 realize a first-order, low-pass filter. Assume the opamps are ideal and noiseless.

(*a*) Show that the two circuits have the same input-output transfer function.

(*b*) Estimate the total output noise for circuit I, using only dominant noise sources.

(*c*) Repeat (*b*) for circuit II.

4.11 Modify circuit I in Fig. P4.10 such that the new circuit has the same transfer function but uses an 80-pF capacitor instead of an 80-nF capacitor. If the opamp is ideal and noiseless, what is the new total output noise?

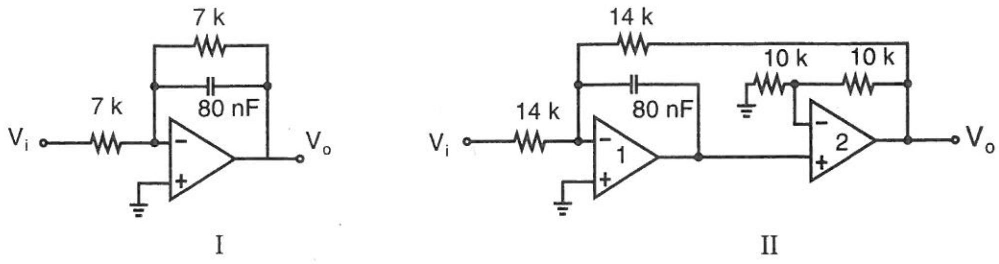


Fig. P4.10

4.12 Using the 1/f tangent principle, estimate the total noise above 0.1 Hz for the spectral density shown in Fig. 4.3.

4.13 Consider a bandpass amplifier that has equivalent input noise root spectral density and amplifier response, as shown in Fig. P4.13. Sketch the root spectral density for the output signal. Estimate the total output rms noise value by applying the 1/f tangent principle.

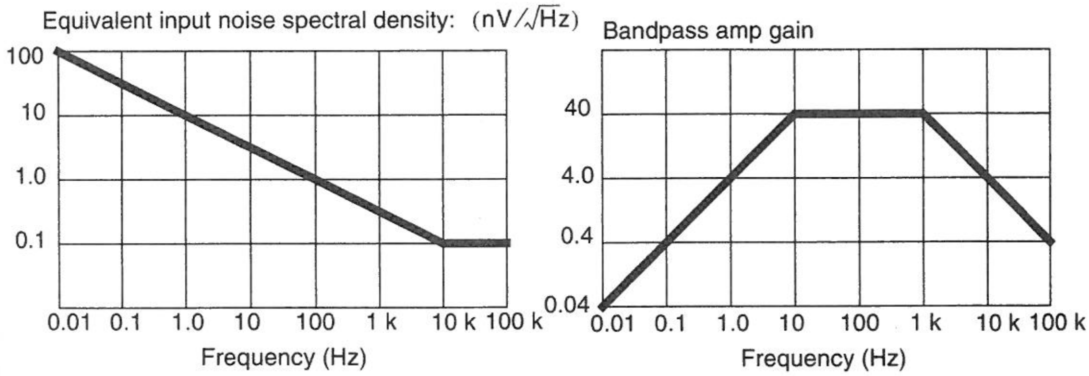


Fig. P4.13

4.14 Consider the noise root spectral density of the signal shown in Fig. P4.14. Find the total rms noise value using a graphical approach for 0.01 to ∞ Hz. Compare your result with that obtained when using the 1/f tangent principle.

4.15 We saw on page 193, Eq. (4.36), that the noise bandwidth of a first-order, low-pass filter is $(\pi/2)f_0$. Show that the noise bandwidth of a second-order, low-pass filter given by

$$A(s) = \frac{A_o}{\left(1 + \frac{s}{(2\pi f_0)}\right)^2}$$

is equal to $(\pi/4)f_o$.

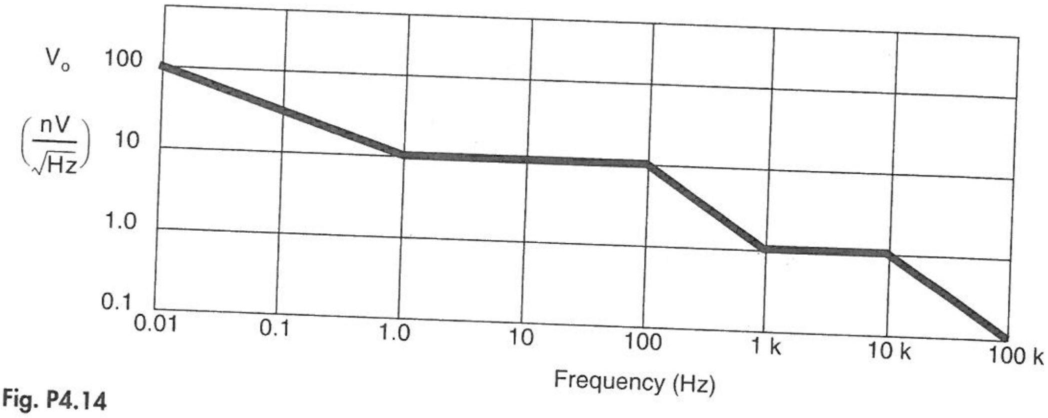


Fig. P4.14

4.16 Consider the two bipolar current mirrors shown in Fig. P4.16, where I_{in} is a 1-mA bias current plus a 100-μA(rms) signal current. Assuming that the base resistance for each transistor is $r_b = 330\ \Omega$ and dominates the output noise, estimate the resulting SNR (in dB) for the two current mirrors over a 50-MHz bandwidth (also assume the output noise is white).

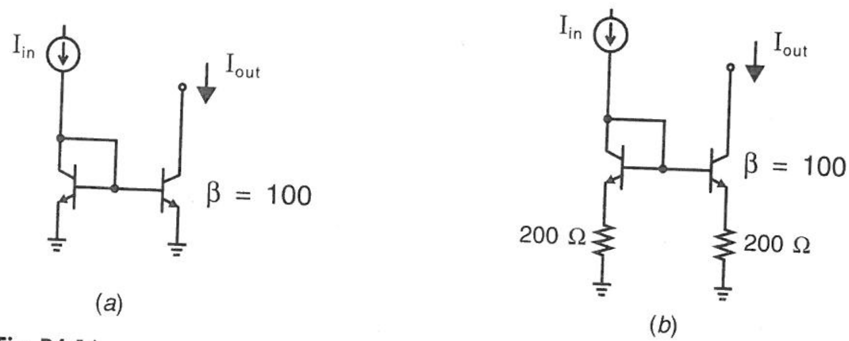


Fig. P4.16

4.17 Estimate the total output noise rms value for a low-pass filter, as shown in Fig. 4.15, when $C_f = 1\ \text{nF}$, $R_f = 16\ \text{k}$, $R_1 = 1.6\ \text{k}$, and $R_2 = 0$. Also, find the SNR for an input signal equal to 100 mV rms. Assume that the noise voltage of the opamp is given by $V_n(f) = 20\ \text{nV}/\sqrt{\text{Hz}}$, that both its noise currents are $I_n(f) = 0.6\ \text{pA}/\sqrt{\text{Hz}}$, and that its unity-gain frequency equals 2 MHz.

4.18 Consider the CMOS differential input stage shown in Fig. 4.17, where Q_5 supplies a bias current of 100 μA, resulting in $g_{m1} = g_{m2} = 1\ \text{mA/V}$ and $g_{m3} = g_{m4} = 0.5\ \text{mA/V}$. Find the equivalent input noise spectral density associated with thermal noise. If the bias current is doubled, how does the equivalent input noise density change?