ELEN0037
Microelectronics
Tutorials

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Tutorial 8: Noise Analysis and Modeling

Exercise 1 (1st, P4.2/2nd, P9.5)

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,[1] (b) $C = 0.3$,[2] (c) $C = +1$,[3] and (d) $C = -1$.[4] Use the following formula:

$$V_n^2 = V_{n1}^2 + V_{n2}^2 + 2CV_{n1}V_{n2},$$

or

$$P_n = P_{n1} + P_{n2} + 2C\sqrt{(P_1P_2)},$$

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[1] (a) $P_n = -18.24\,dBm$
[2] (b) $P_n = -17.16\,dBm$
[3] (c) $P_n = -15.35\,dBm$
[4] (d) $P_n = -30.67\,dBm$

Exercise 2 (1st, P4.3/2nd, P9.6)

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?[5] Find the root spectral density in $^{V}/\sqrt{Hz}$.[6][7]

[5] $V^2_{no-10Hz} = -44.77\,dBm$

[6] Spectral density $V_n^2(f) = 0.0033\,{}^{(mV)^2}/_{Hz}$

[7] Root spectral density $V_n(f) = 0.058\,{}^{mV}/\sqrt{Hz}$

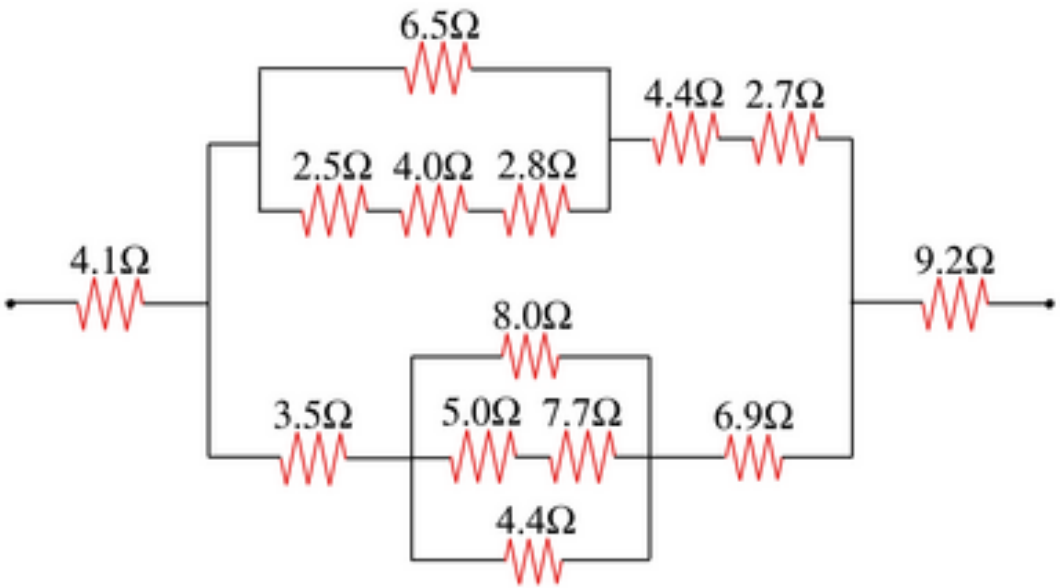
Exercise 3 (1st, P4.4/2nd, P9.7)

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 $1\,Hz$?[8]

[8] $P_n = -31.6\,dBm$

Exercise 4 (1st, P4.5/2nd, P9.14)

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 $R_1 + R_2$. Also compute the power spectral density across each resistance, as well as their serial combination. Repeat the problem for parallel resistances. What is the total power spectral density across the following resistance network?



Exercise 5 (1st/2nd, Example 9.5)

Consider a noise signal, $V_{ni}(f)$, that has a white root spectral density of $20\,{}^{nV}/\sqrt{Hz}$. Find the total noise RMS value between DC and $100\,kHz$.[9] What is the total noise RMS value if it is filtered by a RC filter with a cutoff frequency $f_0 = 1000\,Hz$, where it is assumed the RC filter is noise free?[10]

[9] $V_{ni} = 6.3\,\mu V$

[10] $V_{no} = 0.79\,\mu V$

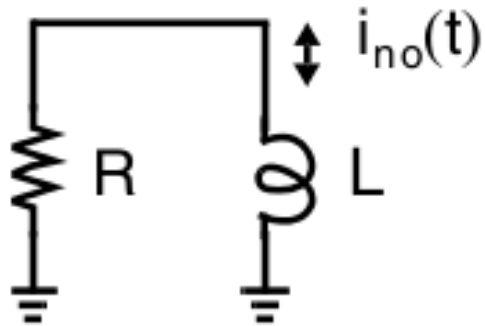
Exercise 6 (1st, P4.6/2nd, P9.15)

Sketch the spectral density of voltage noise across a $100\,pF$ capacitor when it is in parallel with a $1\,k\Omega$ resistor. Make another sketch for the same capacitor but with a $1\,M\Omega$ resistance in parallel. What can you say about the area under the curves of the two sketches?[11]

[11] Whereas the curves are different, the area are the same: $V_{no}^2 = \frac{kT}{C}$

Exercise 7 (1st, P4.9/2nd, P9.19)

Consider an inductor of value L and an arbitrary resistor in parallel, as shown in the following figure.



Show that the current noise is given by

$$I_{no}^2 = \frac{kT}{L}$$

Exercise 8 (2nd, Example 9.9)

Two voltage amplifiers (each having very large input impedance and small output impedance) are available: one with a gain of $3\,V/v$ and $3\,\mu V$ noise observed at the output; the other with a gain of $8\,V/v$ and $6\,\mu V$ noise observed at its output. What is the input-referred noise of each amplifier?[12] If the two amplifiers are to be placed in series to realize a gain of $24\,V/v$, in what order should they be placed in order to obtain the best noise performance?[13] What is the resulting input-referred noise of the overall system?[14]

[12] $V_{ni1} = 1\,\mu V,\ V_{ni2} = 0.75\,\mu V$

[13] The second first

[14] $V_{ni} = 0.76\,\mu V$