Additional end-of-chapter problems for Chapter 8 – Electrical Noise: An Overview

*CMOS: Circuit Design, Layout, and Simulation*

**A8.1** The units for power spectral density (PSD) are *V*2/*Hz*. We know PSD is the measured power in a bandwith. What is known when we use units of *V*2 for power? Specify other units acceptable for a PSD measurement or spectrum (okay to look at the specifications for a spectrum analyzer and list the possible units used by the unit).

**A8.2** In the example on page 217 we said that the first point, when using a SA to measure the signal (1 + cos 2π∙4.05 kHz∙t), occurs when n = 0 so that the input signal is applied directly to the lowpass filter. The output of the filter, 1 V, is applied directly to the power meter. What is the mean-squared value of this signal (and thus what is the RMS value). While the discussion in the second paragraph is valid for sinusoids is it valid for DC signals? Why or why not? Repeat the example if a bandpass filter is used that has a center frequency of 1 kHz and a bandwith of 100 Hz.

1 V

100 S

10 kΩ

**Figure A8.3** Estimate the PSD of the noise on the output of the circuit.

Out

In

Noiseless resistor

**A8.3** Estimate, and verify with SPICE, the output noise PSD for the following circuit. Note that the voltage-controlled current source models a noiseless resistor. What is the output signal when the input signal is 1 V?

**A8.4** Estimate the input-referred and output noise PSDs for the following circuits. Verify your answers with SPICE. Note that a voltage-controlled voltage source behaves like an ideal voltage amplifier (infinite input resistance and zero output resistance).

**Figure A8.4** Estimate the PSD of the noise on the output of these circuits.

1 V

100 V/V

10 kΩ

Out

In

Voltage amplifier with a gain of 100.

1 V

100 V/V

10 kΩ

Out

In

Voltage amplifier with a gain of 100.

**A8.5** Estimate, and verify with SPICE, the output noise PSD for the following circuit, the NEB, and the RMS value of the circuits’ output noise. (Hint: see Fig. 8.23 on page 237.)

**A8.6** Repeat problem A8.5 if the voltage-controlled current source is replaced by a 10k resistor.

1 V

100 S

10 kΩ

**Figure A8.5** Estimate the PSD of the noise on the output of the circuit.

Out

In

10 pF

**A8.7** Suppose an amplifier has an input capacitance of 10 pF. If the source voltage driving the amplifier has a 75 Ω source resistance then estimate the signal-to-noise ratio on the input, *SNRin* when the input signal peak amplitude is 1 V. Use SPICE to verify your answer. Repeat if the input capacitance of the amplifier is shunted with 75 Ω (the input resistance of the amplifier is 75 Ω).

**A8.8** How does Eq. (8.36) simplify if the circuits’ bandwidth, *B*, is dominated by a single pole roll-off caused by an input time constant of ?

**A8.9** In simple terms why is the RMS value of the output noise in the forward-biased diode circuit of Ex. 8.12 so much lower than the output noise of the reverse-biased diode circuit in Ex. 8.13?

**A8.10** Using a voltage-controlled voltage source for the op-amp in Fig. 8.29 (see Fig. 8.37) verify, with SPICE, the results of Ex. 8.14 (the RMS output noise increases as one over the root of the lower frequency, *fL* (=1/*TL*).)

**A8.11** Repeat Ex. 8.17 using the LT1364 high-speed op-amp (see page 261). Include both the input-referred noise current and noise voltage (see page 260). What is the critical component in the circuit for low-noise performance? Note the gain-bandwidth product of the op-amp is 70 MHz.

**A8.12** Compare the noise performances of the TLC220 and LT1364 op-amps in amplifier configurations with a gain of +2 using 10k resistors. Comment on the bandwidths of the two circuits and how bandwidth affects the RMS noise calculations.

**A8.13** For the op-amp circuit seen in Fig. A8.13 estimate the input-referred and output noise PSDs. Calculate the input-referred and output RMS noise voltages. Verify your hand calculations using SPICE. Assume the op-amp is ideal. Does the input-referred PSD have meaning? Why or why not? How do you estimate the input-referred RMS voltage (hint: you use the output RMS voltage)?

**A8.14** Suppose the op-amp in Fig. A8.13 has an input-referred thermal noise voltage spectral density of 50 n*V*/ and a flicker noise numerator, *FNN*, of 100 × 1015 *V*2. Estimate the output noise PSD and corresponding input-referred and output RMS noise voltages. Assume the op-amp has infinite open-loop gain.

1 V

peak

10 kΩ

**Figure A8.13** Estimate the output and input noise PSDs. Also, estimate the RMS input and output noise voltages.

Out

In

10 pF

1k

**A8.15** Determine the RMS value of the input-referred noise in the following circuit (hint: see how kT/C noise is derived). Use SPICE, and numerical values, to verify your result over some bandwidth.

**A8.16** Repeat problem A8.13 for the circuit seen in Fig. A8.16. Does the 10k resistor affect the noise performance of the circuit? Use SPICE to verify your answers. Note that the input-referred noise is a noise current in parallel with the current input signal.

100 µA, peak

20 kΩ

**Figure A8.16** Estimate the output and input noise PSDs. Also, estimate the RMS input and output noise voltages.

Out

In

100 pF

10k

**A8.17** Discuss the design techniques used to maximize the *SNRout* of both voltage and transimpedance amplifiers using an op-amp.

*Vin*

*L*

**Figure A8.15** RMS value of the input-referred noise in an *RL* circuit.

Out

In

*R*