E4215: Analog Filter Synthesis and Design: HW10

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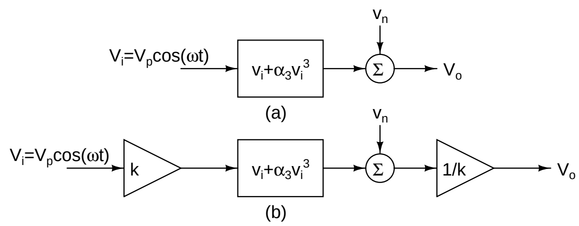

Figure 1:

1. (4+2+3 pts.) Fig. 1 shows a block that has third order distortion and an output noise v_n (rms volts). It could represent a filter or any other circuit that has distortion and noise. The input is a sinusoid with a peak V_p.

   (a) In Fig. 1(a, b) calculate the following quantities at the output: Peak value of the fundamental sinusoid, amplitude of the third harmonic, rms output noise, ratio of the third harmonic peak to the fundamental peak, ratio of rms noise to rms fundamental. Neglect the contribution from the v_i^3 term while calculating the output fundamental amplitude.

   (b) How does k affect the noise/signal[1] and distortion/signal ratios? What would you do with k to (a) minimize noise/signal, (b) distortion/signal? Give a very brief intuitive explanation. Compute k such that noise/signal and distortion/signal ratios are equal.

   (c) If $\alpha_3 = 0.002\,\mathrm{V}^{-2}, v_n = \sqrt{2}$mV, rms, $V_p = 1\,\mathrm{V}$, calculate k for equal noise/signal and distortion/signal ratios. With these numerical values, calculate the noise/signal and distortion/signal ratios in Fig. 1(a, b). How do the two circuits compare?

2. (2+3+2+1+2 pts.) $C = 1/2\pi$ nF, $R = 1\,\mathrm{k}\Omega, L = 10/2\pi\,\mu$H.

   (a) Calculate the output noise voltage of the circuit in Fig. 2(a).

   (b) Simulate the noise in Fig. 2(a). To compute the mean squared noise, integrate the spectral density from i) $1/10$ the -3 dB bandwidth to 10 times the -3 dB bandwidth, and ii) $1/100$ the -3 dB bandwidth to 100 times the -3 dB bandwidth. How different are the two values?

[1]"signal" implicitly means "desired signal", in this case the fundamental.

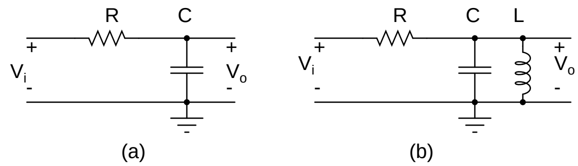

Figure 2:

(c) Simulate the noise in Fig. 2(a). To compute the mean squared noise, integrate the spectral density in the range $f_0 \pm 10 f_B$ where f_0 is the center frequency and f_B is the -3 dB bandwidth of the bandpass filter.

(d) Set $L = 0.1/2\pi$ μH and repeat the previous simulation.

(e) Compare the noise in the three cases above. What is the bandwidth of the circuit in the three cases? Does the value of the mean squared noise make sense, considering that it is the spectral density integrated over a certain bandwidth?

3. (1+4+4+2 pts.) The input referred noise voltage of a transconductor g_m is $\gamma 4kT/g_m$.

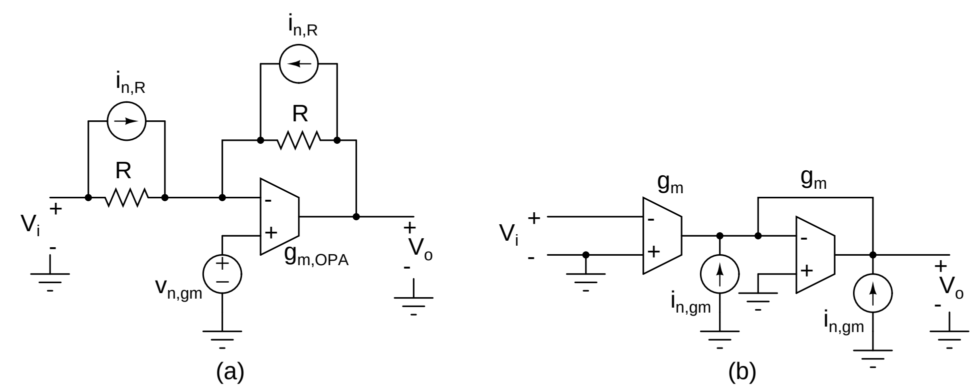

Figure 3:

(a) Calculate $g_{m,OPA}$ in Fig. 3(a) if the loop gain has to be 100 (HW2 had problems related to the use of a transconductor as an opamp).

(b) Calculate[2] the noise spectral density at the output in Fig. 3(a, b) in terms of $kT, g_m, g_{m,OPA}, R, \gamma$.

(c) In the expression for Fig. 3(a) substitue the value of $g_{m,OPA}$ calculated in (i). In the expression for Fig. 3(b) substitute $g_m = 1/R$. What can you say about the relative values of noise in Fig. 3(a) and Fig. 3(b) assuming e.g. $\gamma = 5$. The comparison is typically true for opamp-RC and g_m-C filters.

(d) If $V_i = V_p \cos(\omega t)$ what is the peak current driven by each active component in Fig. 3(a)?

[2] It is easiest if you represent the noise of different components as shown. While analyzing Fig. 3(a), you can assume an opamp with infinite gain.