E4215: Analog Filter Synthesis and Design: Midterm

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90 minutes; 3 problems; 25 pts.; Closed book; No calculators;

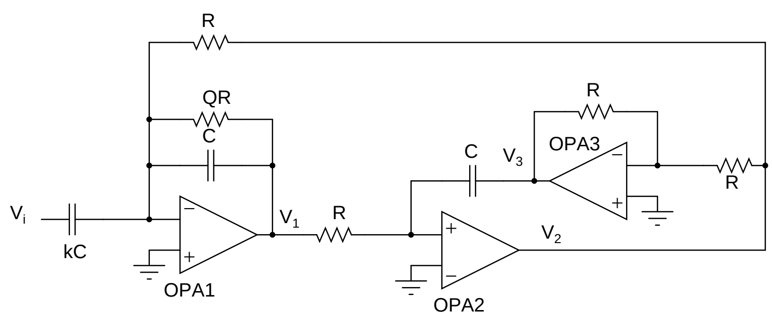

Figure 1: Circuit for problem 1.

1. (a) (4 pts.) Derive the transfer functions $V_1(s)/V_i(s)$ and $V_2(s)/V_i(s)$ for the circuit in Fig. 1. Assume ideal opamps.

   (b) (3 pts.) Sketch the magnitude and phase responses of $V_1(s)/V_i(s)$ and $V_2(s)/V_i(s)$ for $Q = 5, k = 2$.

   (c) (3 pts.) How would you modify the circuit so that a second order low pass filter with dc gain=1 is realized between V_i and V_3? What is the transfer function $V_3(s)/V_i(s)$ for this modified circuit?

2. A filter with an input $V_{in}(t) = \cos(1\,\text{Grad/s}\,t) + \cos(10\,\text{Grad/s}\,t) + \cos(100\,\text{Grad/s}\,t)$ should have an output $V_{out}(t) = a_1 \cos(1\,\text{Grad/s}\,t + \phi_1) + a_{10}\cos(10\,\text{Grad/s}\,t + \phi_{10}) + a_{100}\cos(100\,\text{Grad/s}\,t + \phi_{100})$ where $a_1 \ll a_{10}, a_{100} \ll a_{10}$.

   (a) (1 pt.) What is the required type of filter?

   (b) (1 pt.) Give a second order transfer function (with general parameters) which realizes a filter of the required type.

   (c) (2 pts.) Choose the parameter(s) of the transfer function such that $a_1/a_{10} = 10^{-2}$.

   (d) (4 pts.) Using a 2 nH inductor, design a passive second order filter which realizes the transfer function determined above. Assume that the voltage source driving this filter has an output resistance of 50 Ω.

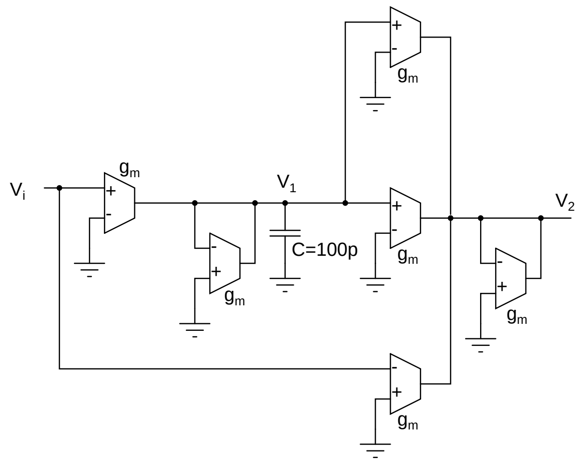

Figure 2: Circuit for problem 3. All transconductances are of an identical value; g_m=1 mS.

(e) (2 pts.) What is the ratio a_{100}/a_{10} with the filter designed above?

3. (a) (3 pts.) Derive the transfer functions $V_1(s)/V_i(s)$ and $V_2(s)/V_i(s)$ for the circuit in Fig. 2. All transconductances are of an identical value; g_m=1 mS.

   (b) (2 pts.) Where are the poles and zeros of $V_2(s)/V_i(s)$ (give the correct signs)? Sketch the magnitude and phase responses of $V_2(s)/V_i(s)$.

Notes:

- It is generally less confusing to carry out the calculations analytically and to substitute the numerical values at the end.
- Use judicious approximations to simplify numerical calculations. e.g. $1 + \delta \approx 1$ if δ is small, say 0.01. You can then verify if the approximation is valid by substituting back the answer so obtained.