Spring 2004; E4215: Analog Filter Synthesis and Design; HW3

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Problem 1 below is the same as HW2, problem 4. It is reprinted here for convenience.

1. (a) (3 pts.) Design a second order opamp-RC Butterworth lowpass filter with dc gain=2 and -3dB bandwidth=1 MHz. Assume that all capacitors are of equal value of 100 pF. Give the transfer function and all the component values in the opamp-RC filter schematic.

   (b) (2 pts.) Sketch the magnitude and phase response of the transfer function from the input to the output of each of the opamps.

2. (6 pts.) Design a lowpass notch filter with a notch at $\sqrt{10}$ MHz. The dc gain and the poles of this filter should be the same as that obtained in 1(a). Use the feedforward technique with the Tow Thomas biquad to realize the lowpass notch transfer function at (a) the output V_1[1]. and (b), the output V_2.

3. (a) (3 pts.) Design a g_m-C Butterworth lowpass filter with a dc gain=10 and a -3 dB bandwidth=3 MHz. Assume that the smallest g_m in the circuit is 10 μS. Give the transfer function and the values of the components in the g_m-C filter schematic.

   (b) (3 pts.) Turn this into a lowpass notch filter with a notch at 10 MHz while preserving the dc gain and the poles. Show the schematic of a g_m-C filter that realizes this transfer function. Use the voltage summing technique.

4. (a) (1 pt.) Design a 100 H inductor using transconductors and a 100 pF capacitor.

   (b) (2 pts.) Derive the (passive) equivalent circuit of the previously designed inductor if the capacitor had a 1 MΩ resistor across it.

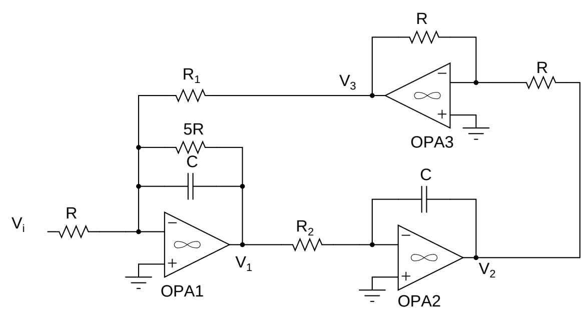

Figure 1:

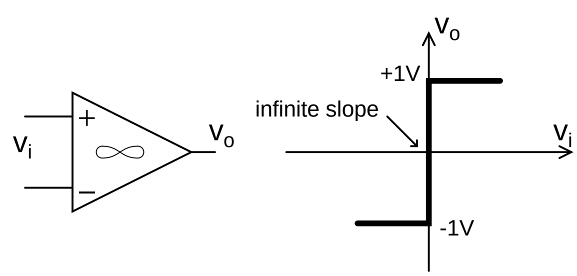

Figure 2:

5. (5 pts.) In Fig. 1 consider two cases (i) $R_1 = R_2 = R$ and (ii) $R_1 = 3R, R_2 = R/3$.

[1]output of OPA1; in the handout "Transfer functions realizable in a biquad".

For each of these, (a) Find $V_1(s)/V_i(s)$. Is there a difference? (b) Evaluate $V_k(s)/V_i(s)$, $k = \{2, 3\}$. Is there a difference? What is the maximum of $|V_k(j\omega)/V_i(j\omega)|$? (c) The input is a sinusoid $v_i(t) = V_{ip}\cos(\omega t)$ where ω can be anything. If the opamps have a swing limit of 1V (This means that the opamp behaves ideally if $-1\text{V} \leq v_o \leq 1\text{V}$. See Fig. 2), what is the largest V_{ip} that can be applied while maintaining all the opamps in the linear region?