Spring 2004; E4215: Analog Filter Synthesis and Design; HW5

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For 1-5, give the schematic of the passive filter with all the element values. For 1-3, give the the transfer function in the normalized form which is

$$\frac{b_0 + b_1(s/Q/\omega_n) + b_2(s/\omega_n)^2}{1 + s/Q/\omega_n + (s/\omega_n)^2}$$

where ω_n is an appropriate normalizing frequency. For 3-5, give the expression for the frequency transformation along with the numerical values for the parameters in the transformation. For 6, give the final schematic and explain very briefly the purpose of each feedforward component[1].
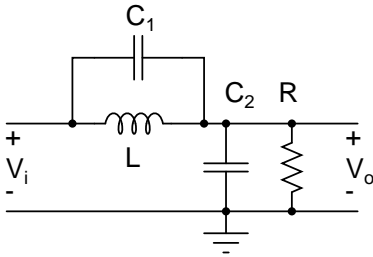
1. (1 pt.) Assume that you have a lowpass notch

Figure 1:

filter (Fig. 1) with $Q = 1/\sqrt{2}$, $\omega_p = 2\pi \times 10^6$ rad/s, and a notch at 10 MHz. (Use the filter from HW4, P3). What is the attenuation (in dB) at 1 MHz? Call this A_p.

2. (3 pts.) Scale the filter in (1) so that it uses $R = 1\,\Omega$ and has a notch at 10 rad/s. What is the frequency Ω_p at which the attenuation is A_p? What is the smallest frequency[2] at which the attenuation is $A_s = -20\,\text{dB}$? Call this Ω_s.

3. (4 pts.) Transform the prototype in (2) to a passive RLC highpass filter with an attenuation A_p (determined in (1)) at 10 Mrad/s and a termination resistance $R = 10\,\text{k}\Omega$. What is the frequency of the notch in this filter? Draw the schematic replacing the inductors with capacitively terminated gyrators whose gyration resistance[3] is $10\,\text{k}\Omega$.

4. (4 pts.) Transform the prototype in (2) to a passive RLC bandpass filter whose attenuation is A_p at $\omega_{p1} = 100\,\text{Mrad/s}$ and $\omega_{p2} = 121\,\text{Mrad/s}$. The termination resistance should be $2\,\text{k}\Omega$. What are the "stopband" edges ω_{s1} and ω_{s2} where the attenuation is A_s? What is the gain of the filter at 110 Mrad/s? If one of the notches of the filter is at 47 Mrad/s, where is the other notch?

5. (4 pts.) Transform the prototype in (2) to a passive RLC bandstop filter whose attenuation is at least A_s in the range $8.1\,\text{Mrad/s} \leq \omega \leq 10\,\text{Mrad/s}$. Use a termination resistance of $10\,\text{k}\Omega$. What are the "passband" edges ω_{p1}

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[1]Elements from the input to various opamps.

[2]You can calculate this analytically-you'll get a 2nd order equation in Ω^2; or use a numerical tool such as MATLAB.

[3]The gyration resistance is $1/g_m$ where g_m is the transconductance of the two transconductors in the gyrator.

and ω_{p2} where the attenuation is A_p? What is the filter's attenuation at 9 Mrad/s?

6. (3 pts.) Realize an an opamp-RC version of the highpass filter in (3). Use the Tow-Thomas biquad with feedforward technique to realize the zeros at the output of the first opamp. Use $C = 100\,\mathrm{pF}$ for the 2 integrators.

7. (1 pt.) Realize a bandpass filter whose attenuation is A_p at $f_{p1} = 10\,\mathrm{MHz}$ and $f_{p2} = 12.1\,\mathrm{MHz}$. (Hint: You don't have to go through the whole synthesis again. Use the result from (4)).