E4215: Analog Filter Synthesis and Design: HW7

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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 a convenient 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.) Design a second order passive low-

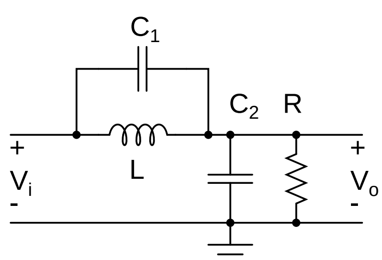

Figure 1:

pass RLC notch filter with $Q = 1/\sqrt{2}$, $\omega_p = 1\,$Mrad/s and a transmission zero at $\omega_z = 10\,$Mrad/s. Use the topology in Fig. 1 with $C_1 + C_2 = 10\,$nF. What is the attenuation in dB at 1 Mrad/s? Call this A_p.

2. (2 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 $A_s = -20\,$dB? Call this Ω_s.

3. (3 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 impedance $10\,\mathrm{k}\Omega$. What is the frequency of the notch in this filter? Draw the schematic replacing the inductors with capacitively terminated gyrators whose gyration resistance is $10\,\mathrm{k}\Omega$.

4. (4 pts.) Transform the prototype in (2) to a passive RLC bandpass filter whose attenuation is A_p at $\omega_{p1} = 10\,$Mrad/s and $\omega_{p2} = 12.1\,$Mrad/s. The termination impedance should be $10\,\mathrm{k}\Omega$. What are the "stopband" edges ω_{s1} and ω_{s2} where the attenuation is A_s? What is the gain of the filter at 11 Mrad/s? If one of the notches of the filter is at 4.7 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 $81\,$Mrad/s $\leq \omega \leq 100\,$Mrad/s. Use a termination impedance of $1\,\mathrm{k}\Omega$. What are the "passband" edges ω_{p1} and

[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 determine it using simulation-be sure to use a sufficiently small frequency step.

ω_{p2} where the attenuation is A_p? What is the filter's attenuation at 90 Mrad/s?

6. (2 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 $R = 10\,\text{k}\Omega$ in the resonator core.

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

8. (2 pt.) Simulate the magnitude response of the passive circuits in 1, 3 (not the part with the gyrator), 4, 5. (Plot all 4 magnitude responses in 4 subwindows of the same plot for submission. Use appropriate ranges for x and y axes to show all points of interest). In each, mark the frequency of the notch(es).

9. (1 pt.) Simulate the magnitude response of the opamp-RC filter in 6. For the opamps use ideal voltage controlled voltage sources with gain=10^6.