

E4215: Analog Filter Synthesis and Design: HW8

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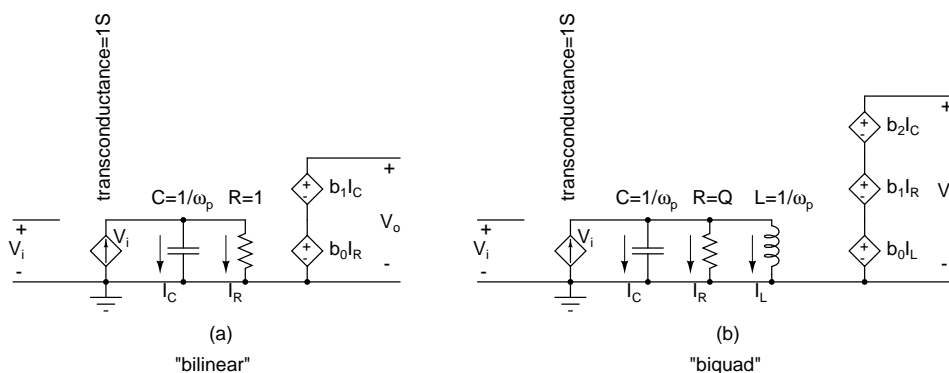


Figure 1:

- (a) (5 pts.) Compute the transfer functions V_o/V_i in terms of the parameters (Q , ω_p , b_0 , b_1 , b_2) for the circuits in Fig. 1(a, b).
 (b) Turn these circuits into parameterized subcircuits "bilinear" and "biquad" in cadence¹ with the required parameters. You can then use these subcircuits to realize ideal cascade realizations of any transfer function.

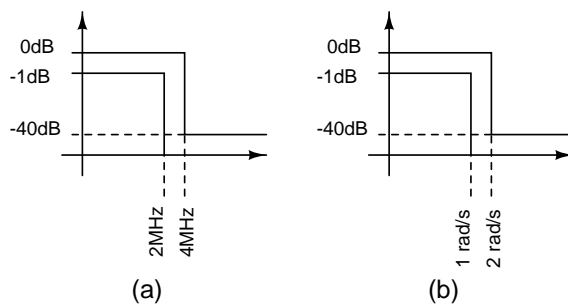


Figure 2:

- You are required to realize a filter that meets the specifications shown in Fig. 2(a). You are given (Table 1)

¹In cadence, to realize a current controlled voltage source, you also need to have a 0 V voltage source through which the desired current is flowing. See the example subcircuit "lpf" in the library "E4215_examples".

the poles and zeros of 4 types (Excluding Bessel) of filters which satisfy the prototype specifications in Fig. 2(b).

- (a) (4 pts.) Tabulate the order, the resonant frequencies, the quality factors of the poles, and the location of transmission zeros (if present) of the different types of filters that satisfy the specs. in Fig. 2(a).
- (b) (7 pts.) Using the parameterized subcircuits for the bilinear and the biquadratic filters, simulate the four filters (using the cascade structure) in cadence. Use the rules of cascading discussed in the class. You do not have to submit the schematics. Clearly state the order of cascade and the pole zero pairing.
Plot their magnitude and phase responses², and the group delay (for this, you can use the function “groupDelay” in the calculator in cadence).
- (c) (4 pts.) For each filter, determine the maximum transfer function magnitude from the input to each of the stage (first or second order) outputs. If each output were limited to 1 V, what is the maximum input voltage that could be applied to each without having distortion?
- (d) (4 pts.) Simulate the transfer function of the Bessel filter prototype (last column of Table 1) using the same technique as above. If this filter were scaled such that it had an attenuation $A_s = 40$ dB at 4 MHz (the stopband edge), what would be its attenuation at the passband edge (2 MHz)?³ Does it meet the specs in Fig. 2(a)?
- (e) (4 pts.) For each of the 4 filters that satisfies the specs in Fig. 2(a), list the maximum quality factor of the biquad stages used, the maximum resonant frequency, and the maximum group delay variation in the passband (< 2 MHz).
(2 pts.) Repeat³ for the Bessel filter. To find its maximum resonant frequency, calculate the maximum resonant frequency in the prototype and multiply it by the scaling factor determined above.

Table 1: Prototype zeros and poles

Butterworth	Chebyshev	Inverse Chebyshev		Elliptic		Bessel
poles	poles	zeros	poles	zeros	poles	poles
$-1.1031 \pm j0.2194$	$-0.0895 \pm j0.9901$	$\pm j3.0671$	$-0.2811 \pm j1.1013$	$\pm j3.5251$	$-0.3643 \pm j0.4786$	$-0.3868 \pm j1.0991$
$-0.9351 \pm j0.6248$	$-0.2342 \pm j0.6119$	$\pm j1.8956$	$-0.9461 \pm j0.8751$	$\pm j1.6095$	$-0.1053 \pm j0.9937$	$-0.6127 \pm j0.8548$
$-0.6248 \pm j0.9351$	-0.2895		-1.4202			$-0.7547 \pm j0.6319$
$-0.2194 \pm j1.1031$						$-0.8453 \pm j0.4179$
						$-0.8964 \pm j0.2080$
						-0.9129

²Plot the magnitude responses of the 4 filters in the same plot; same for the phase response and the group delay. Plot the magnitude response (in dB) twice—once showing the whole picture and once zoomed in on the passband. Use sensible scales so that the details of the response can be seen. e.g. with notches, the response goes down to $-\infty$ dB and the default scale may be totally unsuitable.

³You don't need to rescale the filter and simulate. You should be able to answer this by looking at the prototype response.