Exam in TSEI10, Filter

Time: 2012-03-08, 8:00-12:00

Place: U3 and U4

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Aid: Tables and Formulas for Analog and Digital Filters; Calculator; Physics Handbook for Science and Engineering

Instructions: Maximum 60 points where 25 points are needed to pass the exam. For each problem, motivate your answer in order to get the maximum number of points.

1. (a) Describe the characteristics of the magnitude function, in the passband and stopband, for the following filters: Butterworth, Chebyshev I, Chebyshev II, Cauer. **(5 p)**

   (b) Assume that a frequency response is represented as

   $$H(j\omega) = H_R(\omega) + jH_I(\omega) = |H(j\omega)|e^{j\Phi(\omega)}.$$

   What are the definitions for the attenuation function, the phase function, the group delay, and the phase delay? **(5 p)**

2. Assume a lowpass doubly resistively terminated T ladder of order two. The source and load resistors are, respectively, R_S and R_L whereas the LC ladder is composed of inductors and capacitors L_1 and C_2, respectively. Using chain matrices, compute the transfer function. **(10 p)**
   Hint: The chain matrix for a series impedance Z is

   $$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}.$$

   Hint: The chain matrix for a shunt admittance Y is

   $$\begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}.$$

3. A lowpass specification is met using a third-order symmetric doubly resistively terminated ladder with element values $R_S = R_L = 600\ \Omega$, $L_1 = 600$ mH, $C_2 = 3.3\ \mu$F, and $L_3 = 600$ mH.

   (a) Is this a T ladder or a π ladder? **(2 p)**

   (b) If we increase the load resistance by a factor of 3 and if we want to meet the same specifications, what are the new element values? **(4 p)**

   (c) If we increase the passband edge by a factor of 3, what are the new element values? **(4 p)**

4. Using proper Kuroda-Levy identities, determine the Richards structure that corresponds to a series resonance circuit in the Ψ domain. The series resonance circuit consists of an inductor $R_1\Psi$ and a capacitor $\frac{R_2}{\Psi}$. **(10 p)**
   Hint: A capacitor or an inductor can be obtained by properly terminating a lossless transmission line.

5. The transfer function for a section is given as

   $$H(s) = \frac{G}{s^2 + \frac{r_p}{Q}s + r_p^2}.$$

(a) What is the order of this section? **(1 p)**

(b) Is this a lowpass, highpass, bandpass, or bandstop filter? **(1 p)**

(c) What is the value of G if we want to have $|H(0)| = 1$? **(1 p)**

(d) Determine the angular frequency, say ω_{peak}, at which the magnitude function is maximum. **(6 p)**

(e) For ω_{peak} to be real, what is the range of Q? **(1 p)**

6. We want to realize a fifth-order Cauer filter with $\rho = 15\%$, $A_{min} = 45$ dB, $\omega_c = 5.5$ Mrad/s, and $\omega_s = 3.5$ Mrad/s.

(a) At each stage of the design procedure, what are the values of the poles and zeros? **(4 p)**

(b) At each stage of the design procedure, what are the values of circuit elements if a T ladder is used? **(4 p)**

(c) Suggest a suitable grouping of the poles and zeros. **(2 p)**