Exam in TSTE14, Analog Filters

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

Place: U1 and U3

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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. Derive the expressinos for the lowpass to bandpass transformation of the filter specification, resistors, inductors, and capacitors. **(10 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. The squared magnitude function for a Chebyshev I filter can be written as

$$|H(j\omega)|^2 = \frac{1}{1+\varepsilon^2 T_N^2(\frac{\omega}{\omega_c})}$$

   where

$$T_N(x) = \begin{cases} \cos(N\text{acos}(x)) & |x| \leq 1 \\ \cosh(N\text{acosh}(x)) & |x| > 1. \end{cases} \quad (1)$$

   At the passband edge ω_c and the stopband edge ω_s, the filter has attenuations A_{max} and A_{min}, respectively. Derive the formula to estimate the order of the filter. **(10 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

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

   (a) How should the values of a, b, and c be selected in order to realize second order highpass and bandpass filters? **(3 p)**

(b) Considering $c = G$ and $a = b = 0$, what is the value of G if we want to have $|H(0)| = 1$? **(1 p)**

(c) Considering $c = G$ and $a = b = 0$, determine the angular frequency, say ω_{peak}, at which the magnitude function is maximum. Determine the values of Q for which ω_{peak} is real. **(6 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)**