Exam in TSTE14, Analog Filters

Time: 2013-03-14, 08:00-12:00

Place: TER2

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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, 36, and 48 points are needed to, respectively get 3, 4, and 5. For each problem, motivate your answer to get the maximum number of points.

1. A bound on the deviation, in attenuation, for a doubly resistively terminated LC filter because of the element errors is given as

$$\Delta A(\omega) \leq 8.69\varepsilon \frac{|\rho(j\omega)|}{|H(j\omega)|^2} \omega \tau_g(\omega).$$

Here, $\varepsilon = \frac{\Delta L}{L} = \frac{\Delta C}{C}$ is the tolerance of the inductors and capacitors where $\tau_g(\omega)$ stands for the group delay. Furthermore, $\rho(j\omega)$ is the reflection function. What options does a designer have to reduce $\Delta A(\omega)$? Explain four of them. **(10 p)**

2. Determine the transfer function of an analog filter $H(s)$ when the zeros are $s_{z_{1,2}} = \pm j2$rad/s and $s_{z_3} = +8$rad/s with the poles being $s_{p_{1,2}} = 0.5 \pm j0.9$rad/s and $s_{p_3} = 0.5$rad/s. Can this filter be used in practice? Explain your reasons. **(10 p)**

3. Assume a zero at $s_z = +\infty$. Where is this zero mapped if we do

   (a) LP to HP transformation.

   (b) LP to BP transformation.

   (c) LP to BS transformation.

   Derive the exact location of the new zeros. **(10 p)**

4. Assume a two-port with the incident and reflected voltage waves x and y where the input currents and voltages are, respectively, represented with I and V. For ports 1 and 2, we have

$$\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} = P \begin{bmatrix} V_1 \\ I_1 \end{bmatrix}, \quad \begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = Q \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}.$$

   If the transmission matrix T is defined as

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = T \begin{bmatrix} V_2 \\ I_2 \end{bmatrix},$$

   Determine the wave transmission matrix F where

$$\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} = F \begin{bmatrix} x_2 \\ y_2 \end{bmatrix}.$$

   As you can see, the wave variables x and y are linear combinations of the input currents and voltages. **(10 p)**

5. Determine the order and type (LP, HP, BP, BS) of the filters with the pole-zero plots shown in Fig. 1. Which one (ones) of these filters has (have) a monotonic stopband? Motivate your answer. **(10 p)**

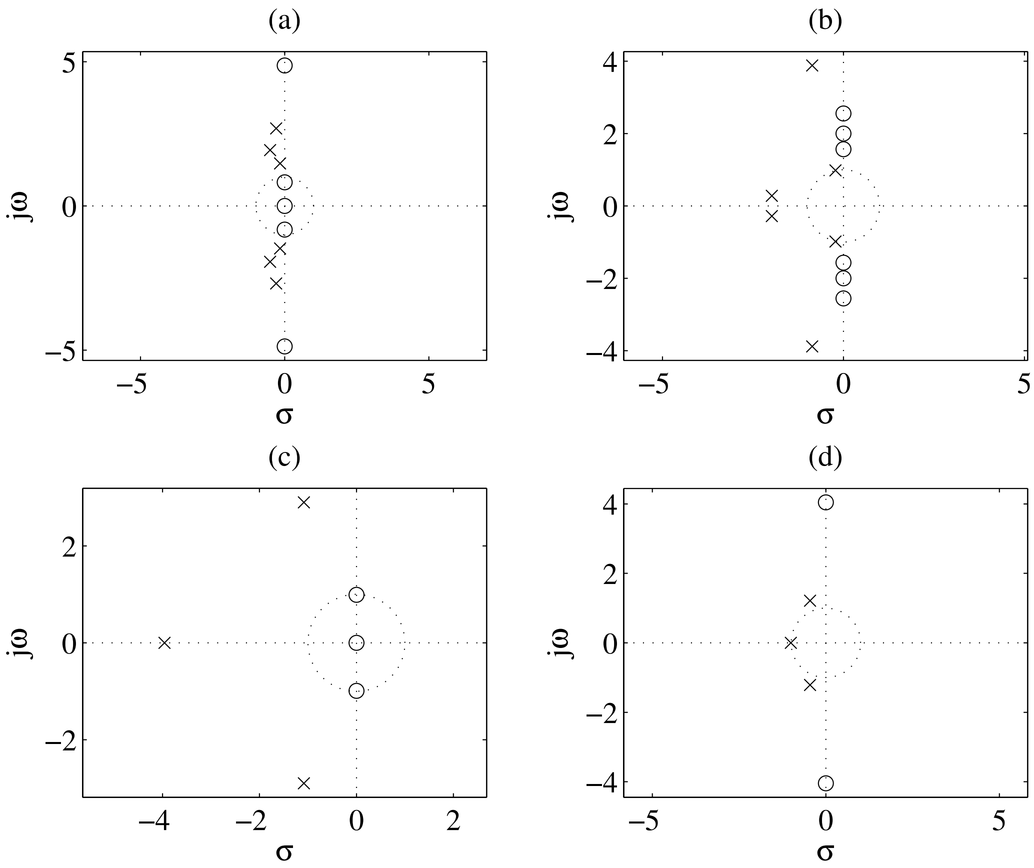

Figure 1: Pole-zero plot.

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)**