Exam in TSEI10, Filter

Time: 2014-03-20, 08-12

Place: TER4

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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. Assume the following transfer functions:

$$H_1(s) = \frac{s^2+4s}{s^3+2s^2+5s+7} \tag{1}$$

$$H_2(s) = \frac{s^2+4s}{s^3-2s^2+5s-7} \tag{2}$$

$$H_3(s) = \frac{s+4}{s^3+2s^2+7} \tag{3}$$

$$H_4(s) = \frac{s+4}{s^3+5s+7}. \tag{4}$$

$$H_5(s) = \frac{s^2+4s}{-s^3-2s^2-5s-7} \tag{5}$$

   - Which one of these transfer functions represents a realizable analog filter? Explain your reasons. **(2 p)**
   - Which one of these transfer functions has infinite zeros? Explain your reasons. **(2 p)**
   - For $H_1(s)$, derive the expressions for phase response, group delay, and the phase delay. **(6 p)**

2. Consider a transformer with a chain matrix as

$$K = \begin{bmatrix} n & 0 \\ 0 & \frac{1}{n} \end{bmatrix}, \quad n > 0 \text{ and real.} \tag{6}$$

   - Is this a symmetric element? **(1 p)**
   - Is this a lossless element? **(1 p)**
   - Compute the power absorbed by this transformer. **(4 p)**
   - Assume a load of $Z_2 = Ls$ at port two, what is the input impedance at port one? **(4 p)**

3. Assume the reference filter in Fig. 1. Separate the branches using minimal number of unit elements. Determine the specifications of the unit elements and the circuit components. **(10 p)**

4. Consider the filter in Fig. 2.

   - Determine the type of this filter, i.e., lowpass, highpass, bandpass, or bandstop. **(2 p)**

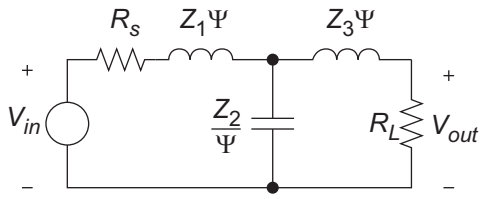

Figure 1: Reference filter.

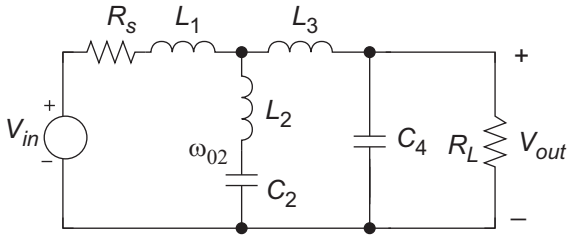

Figure 2: Fifth-order filter.

- Use Bruton's method and determine a suitable transfer function $g(s)$ in a way that the circuit is simulated without inductors. Sketch the final circuit diagram and determine the new element values. **(8 p)**

5. We want to realize a Cauer filter with $\rho = 15\%$, $A_{min} = 45$ dB, $\omega_c = 5.95$ Mrad/s, $\omega_s = 3.5$ Mrad/s, and minimum number of inducters.

   (a) What is the minimum required filter order? **(1 p)**

   (b) What ladder structure should be chosen? **(1 p)**

   (c) At each stage of the design procedure, what are the values of the poles and zeros? **(3 p)**

   (d) At each stage of the design procedure, what are the values of circuit elements? **(3 p)**

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

6. Assume a doubly resistively terminated third-order T ladder structure with circuit elements as R_S, L_1, C_2, L_3, and R_L.

   (a) Determine the transfer function. **(6 p)**

   (b) If $R_S \rightarrow kR_S$, $L_1 \rightarrow kL_1$, $L_3 \rightarrow kL_3$, and $C_2 \rightarrow \frac{C_2}{k}$, how does the transfer function change? **(2 p)**

   (c) If $L_1 \rightarrow \frac{L_1}{k}$, $L_3 \rightarrow \frac{L_3}{k}$, and $C_2 \rightarrow \frac{C_2}{k}$, how does the transfer function change? **(2 p)**