Exam in TSTE14, Analog Filters

Time: 2014-03-20, 14-18

Place: G35

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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 a loaded transmission line as in Fig. 1. At a distance x, from the source, the voltages and currents can be represented as

$$\begin{cases} V(x) = \frac{A_1 e^{-\gamma x} + B_1 e^{\gamma x}}{2} \\ I(x) = \frac{A_1 e^{-\gamma x} - B_1 e^{\gamma x}}{2Z_0}. \end{cases} \tag{1}$$

Here, γ and Z_0 are the propagation constant and the characteristic impedance, respectively. Determine the values of A_1 and B_1 as functions of V_1, I_1, and Z_0. Which of A_1 and B_1 refers to the reflected wave? **(10 p)**

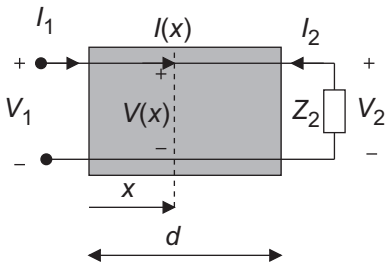

Figure 1: Loaded transmission line.

2. The group delay of a lowpass filter is given as $\tau_{gLP}(\Omega)$.

   (a) Determine the group delay of the corresponding bandpass filter in terms of $\tau_{gLP}(\Omega)$, ω_I, and ω. **(5 p)**

   (b) Determine the group delay of the corresponding highpass filter in terms of $\tau_{gLP}(\Omega)$, ω_I, and ω. **(5 p)**

3. Assume the fifth-order T ladder filter of Fig. 2. Derive the resulting Leapfrog filter composed of integrators, adders, and inverters. **(10 p)**

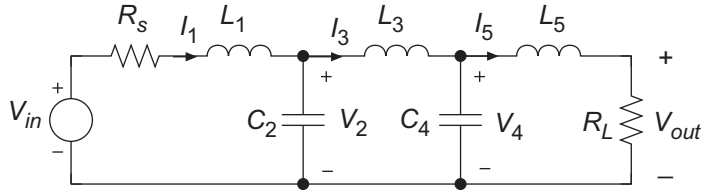

Figure 2: Fifth-order T ladder.

4. A lowpass Butterworth filter of order N, with a passband edge of ω_c and a positive ε, has a characteristic function as

$$|H_{LP}(j\omega)|^2 = \frac{1}{1+\varepsilon^2(\frac{\omega}{\omega_c})^{2N}}. \tag{2}$$

   (a) Determine the characteristics function of the corresponding highpass filter $|H_{HP}(j\omega)|^2$. **(3 p)**

   (b) Select a suitable ε such that $|H_{LP}(j\omega_c)|^2 = |H_{HP}(j\omega_c)|^2 = 0.5$. **(2 p)**

   (c) With the selected ε, show that $|H_{LP}(j\omega)|^2 + |H_{HP}(j\omega)|^2 = 1$. This property is called power complementary. **(5 p)**

   Hint: Select $\omega_I^2 = \omega_c^2$.

5. We want to realize a filter, having ripples in both passband and stopband, with $\rho = 15\%$, $A_{min} = 42$ 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. 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 lowpass, highpass, and bandpass filters? **(2 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. **(4 p)**

   (d) Considering $c = G$ and $a = b = 0$, determine the group delay of the filter. **(3 p)**