LINKÖPING UNIVERSITY

Exam in TSEI10 Filters

Exam code:	TEN1
Date:	2017-06-08 **Time:** 14–18
Place:	U1
Examiner:	Håkan Johansson
Department:	ISY
Allowed aids:	Pocket calculator Wanhammar: Tables and formulas for analog and digital filters Söderkvist: Formler och Tabeller Ingelstam, Rönngren, Sjöberg: Tefyma Ekbom: Tabeller och Formler NT Nordling: Physics Handbook for Science and Engineering Strid: Formler och Lexikon Mathematical tables
Number of tasks:	7
Grading:	Maximum 70 points, 30 points required to pass the exam. **Note** that a **motivation/solution** is required to get the maximal number of points for a problem. **Note** that 10, 8, 6, 4, or 2 points obtained at the **seminars** means that you do not have to solve Problem 1, 1(a)-(d), 1(a)-(c), 1(a)-(b), or 1(a), respectively.
Solutions:	Will be published no later than three days after the exam at http://www.commsys.isy.liu.se/en/student/kurser/TSTE14/
Result:	Available 2017-06-22

1

a. What is the difference between passive and active components and filters? (2 p)

b. What is the potential disadvantage of using frequency transformations when synthesizing bandpass and bandstop filters? (2 p)

c. Why do doubly resistively terminated LC-filters have lower sensitivity than singly terminated LC filters? (2 p)

d. What is characteristic for the frequency response of a distributed-element filter, as opposed to a lumped-element filter? (2 p)

e. What is an inverting amplifier? How can it be realized using an OP amplifier and resistors? (2 p)

2 Synthesize a Chebyshev-I filter that meets the following specification: $\omega_c = 2\pi \times 120$ krad/s, $\omega_s = 2\pi \times 40$ krad/s, $A_{\max} = 0.5$ dB, and $A_{\min} = 40$ dB. Determine the poles and zeros, and indicate their locations in the s-plane. The filter order should not be higher than necessary. (10 p)

3 Realize a Cauer filter that meets the following specification: $\omega_c = 2\pi \times 60$ krad/s, $\omega_s = 2\pi \times 300$ krad/s, $A_{\max} = 0.1$ dB ($\rho = 15\%$), and $A_{\min} = 42$ dB. Use a T-type ladder structure. Determine the capacitor and inductor values assuming source and load resistors with the same value according to $R_S = R_L = 50\ \Omega$. (10 p)

4 Assume two normalized filters with transfer functions as:

$$H_1(s) = \frac{s}{s^2 + 24s + 169}, \quad H_2(s) = -\frac{s}{s^2 + 10s + 169}$$

a. Compute the poles and zeros of the overall filter $H(s)$ when $H_1(s)$ and $H_2(s)$ are cascade connected, i.e., $H(s) = H_1(s)H_2(s)$. (4 p)

b. Compute the poles and zeros of the overall filter $H(s)$ when $H_1(s)$ and $H_2(s)$ are parallel connected, i.e., $H(s) = H_1(s) + H_2(s)$. (4 p)

c. For each of the two cases above, determine $H(j\omega)$ for $\omega = 0$ and $\omega = \infty$ and state the type of filter (lowpass, highpass, bandpass, or bandstop). (2 p)

5 The transfer function of a second-order filter section is given as

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

a. Is this a lowpass, highpass, bandpass, or bandstop filter section? Motivate the answer by sketching the principle behaviour of the magnitude response. (2 p)

b. Determine the gain constant G so that the magnitude response $|H(j\omega)|$ equals unity at DC (zero-frequency). (1 p)

c. Express in terms of r_p and Q, the angular frequency ω (say ω_{peak}) at which the magnitude response $|H(j\omega)|$ is maximum. (6 p)

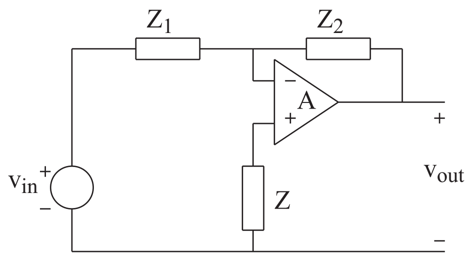
d. For ω_{peak} to be real-valued, what is the range of values for Q? (1 p)

6 **a.** Derive the transfer function $H(s) \triangleq V_{\text{out}}(s)/V_{\text{in}}(s)$ for the active circuit below, expressed in terms of $Z_1(s)$, $Z_2(s)$ and $A(s)$, where $A(s)$ is the transfer characteristics of the OP amplifier. The OP amplifier is thus non-ideal, but its input impedance can be assumed to be infinite in the derivations. (5 p)

b. Assume that $Z_2(s)/Z_1(s) = G$, with $Z_1(s)$ and $Z_2(s)$ being real-valued constants, and thus G being a real-valued constant. This means that the circuit is an inverting amplifier. However, due to the non-ideal OP amplifier, $H(s)$ has a lowpass filter frequency response. Determine the 3dB angular frequency for $H(s)$. Use reasonable approximations if necessary. For a lowpass filter $H(s)$, the 3dB angular frequency, say ω_{3dB}, is defined by $|H(j\omega_{3dB})| = |H(j0)|/\sqrt{2}$. Assume that

$$A(s) = \frac{A_0}{1 + \frac{s}{\omega_0}}$$

with $A_0 = 10^5$ and $\omega_0 = 2\pi \times 10$ rad/s. Also assume that $A_0 >> G$. (5 p)



7 Assume that $H(S)$ is a first-order prototype lowpass filter according to

$$H(S) = \frac{G}{S - P}$$

where G is a gain constant and P is the pole, and assume that $H(S)$ is frequency transformed into bandpass and bandstop filters.

a. Determine the zeros and poles of the bandpass and bandstop filters, expressed in terms of P and the parameter ω_I^2 which is used in the transformations. (6 p)

b. Assume that we realize the prototype lowpass filter with a first-order π-type ladder structure, and that we transform this realization into the bandpass filter realization. Show that the capacitor in the lowpass filter, with the capacitance C, is transformed into a parallel connection consisting of a capacitor, with the capacitance C, and an inductor, with the inductance $1/(\omega_I^2 C)$. (4 p)