Exam 2

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Instructions

- Exam duration: **2 hours and 30 minutes.**
- Please show your derivation for each question. A response given without details will not be considered.
- The exam is open-book. Open-book exam means the students can have access to their lectures, homework solutions, personal notes, whether they are on paper or on laptop/computer/tablets. However, browsing internet and/or posting questions on blogs and/or forum are not allowed.

Exercise 1 (35%)

An RCL series circuit has the transfer function

$$H(s) = \frac{R}{sL + 1/(sC) + R}$$

where $R = 1k\Omega$, $L = 1mH$ and $C = 1nF$.

1. Give the Direct Form I topology of the system.
2. Give the Direct Form II topology of the system.
3. Find the response to a ramp function, in time domain.
4. Derive $H(\omega)$ in a standard form as

$$H(\omega) = \frac{K\left(j\omega/\omega_c\right)}{1 + 2\xi\left(j\omega/\omega_c\right) + \left(j\omega/\omega_c\right)^2},$$

   and determine K, ω_c and ξ.

5. Plot by hand the magnitude of $H(\omega)$ in dB and its phase in degrees versus ω in log-scale.

Exercise 2 (20%)

If $x(t)$ is bandlimited to 5 kHz, what is the Nyquist sampling rate for

$$y(t) = x^3(t) + x(t)?$$

Exercise 3 (25%)

For a sixth-order Butterworth lowpass filter with a cutoff frequency of 1 rad/s, compute the following:

1. The locations of the poles.
2. The transfer function $H(s)$.
3. The corresponding LCCDE description.

Exercise 4 (20%)

1. At work, your colleague claims he can design an active third order LPF by concatenating three active first-order LPF with the same cutoff frequency and different DC gains.

   (a) This is impossible.

   (b) This is possible only if the DC gains satisfy a certain condition.

   (c) This is possible.

2. The same colleague pursues that his active third-order LPF will have the same cutoff frequency as that of each active first-order LPF.

   (a) His claim is correct and coincides with what we learned in ECE 103 class.

   (b) The overall cutoff frequency will be reduced.

   (c) the overall cutoff frequency will be increased.

3. A band-reject filter can be easily designed by cascading an LPF and an HPF.

   (a) Yes, if the bandwidths of the LPF and the HPF are properly chosen.

   (b) No, that is not possible.

   (c) Not sure.

4. You are asked to write the Fourier series of a periodic rectangular waveform. You plot the series representation of the signal with 5 terms. Do you expect to see the Gibbs phenomenon?

   (a) No

   (b) Yes, irrespective of the number of terms

5. For AM modulation, to guarantee a successful envelope detection, one has to choose the modulation index m smaller than one. For a given signal $x(t)$ to be transmitted, one can add a DC component A as large as possible with no effect on the required energy budget.

   (a) True

   (b) False

   (c) Neither true nor false.