MAE 140 – Linear Circuits – Winter 2008
Final

Instructions

1) This exam is open book. You may use whatever written materials you choose, including your class notes and textbook. You may use a hand calculator with no communication capabilities.

2) You have 170 minutes.

3) On the questions for which we have given the answers, please provide detailed derivations.

Question 1 — Equivalent Circuits

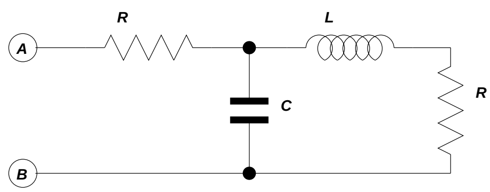

Figure 1: Circuit for Question 1 (i)

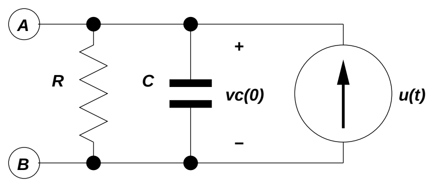

Figure 2: Circuit for Question 1 (ii)

Part (i) [5 marks] Assuming zero initial conditions, find the impedance equivalent to the circuit in Figure 1 as seen from terminals A and B. The answer should be given as a ratio of two polynomials.

Part (ii) [5 marks] Assuming that the initial condition of the capacitor is as indicated in the diagram, redraw the circuit shown in Figure 2 in s-domain. Then use source transformations to find the s-domain Norton equivalent to the circuit as seen from terminals A and B.

Question 2 — Laplace Domain Circuit Analysis

Part (i) [2 marks] Consider the circuit depicted in Figure 3. The voltage sources are constant. The switch is kept in position A for a very long time. At $t = 0$ it is moved to position B. Show that the initial capacitor voltage is given by

$$v_C(0^-) = 1.5V.$$

[Show your working.]

Part (ii) [2 marks] Use this initial condition to transform the circuit into the s-domain for $t \geq 0$. Use an equivalent model for the capacitor in which the initial condition appears in a current source.
[Show your working.]

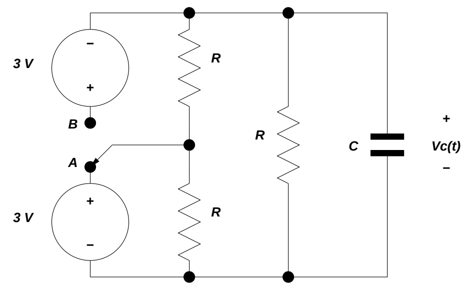

Figure 3: RC circuit for Laplace analysis.

Part (iii) [3 marks] Use s-domain circuit analysis and inverse Laplace transforms to show that the capacitor voltage satisfies,

$$v_C(t) = 3\left(e^{-2t/(RC)} - 1/2\right)u(t)$$

Hint: simplify the circuit, transform all voltage sources into equivalent current sources and use nodal-analysis.

[Show your working.]

Part (iv) [3 marks] Use the final value theorem to show that the voltage on the capacitor after the switch is kept in position B for a very long time is given by

$$v_C(\infty) = -1.5V.$$

Verify whether the same solution is obtained from the answer to the previous question.

[Show your working.]

Question 3 — Active Filter Analysis and Design

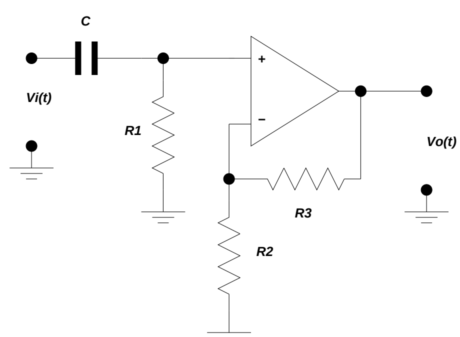

Figure 4: Filter for analysis

Part (i) [4 marks] Assuming zero initial conditions, transform the circuit in the Figure 4 into the s-domain and compute the transfer function from $V_i(s)$ to $V_o(s)$.

Part (ii) [3 marks] Showing your reasoning, determine the nature of this filter's frequency response. Further, determine the gain of the filter and its cut-off frequency.

Part (iii) [3 marks] If $C = 100$nF, find values of R_1, R_2 and R_3 so that the cutoff frequency is 10 KHz and the filter gain is 2.

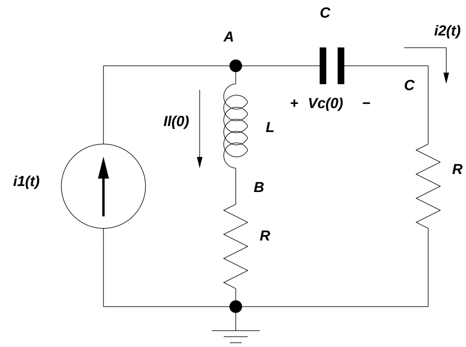

Figure 5: Frequency Response Circuit

Question 4 — Laplace Domain Circuit Analysis

[6 marks] Formulate node-voltage equations for the circuit in Figure 5. Use the reference node and other labels as shown in the figure. Do not assume zero initial conditions!

Question 5 — Frequency Response

[4 marks] Let $L = (1/\pi)$ H, $C = (25/\pi)$ μF and $R = 200$ Ω. Using what you known about frequency response, find the steady state current $i_2(t)$ in the circuit given in Figure 5 when the input current is $i_1(t)$ is a cosine function with amplitude '1' A and frequency 100 Hz.

Question 6 — Op-Amp Analysis and Application (Bonus)

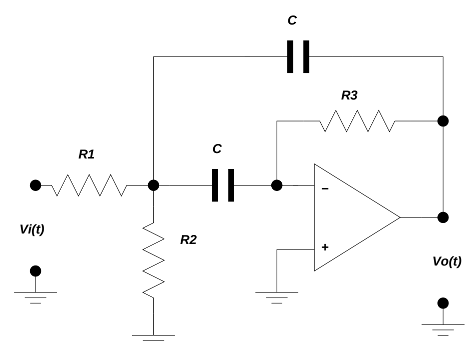

Figure 6: Op-Amp Circuit

Part (i) [4 marks] Using the fundamental op-amp relationships, find the transfer function from $V_i(s)$ to $V_o(s)$ in Figure 6. Assume zero initial conditions.

Part (ii) [3 marks] Calculate the input and the output impedances of this circuit.

Part (iii) [3 marks] Set $R_1 = 1100$ Ω, $R_2 = 1200$ Ω, $R_3 = 150$ K Ω, $C = .01$ μF. Tell me as much as you can about this circuit's function.