EECE 2150 – Circuits and Signals: Biomedical Applications
Final Exam ---- Sec 1
Fall 2014

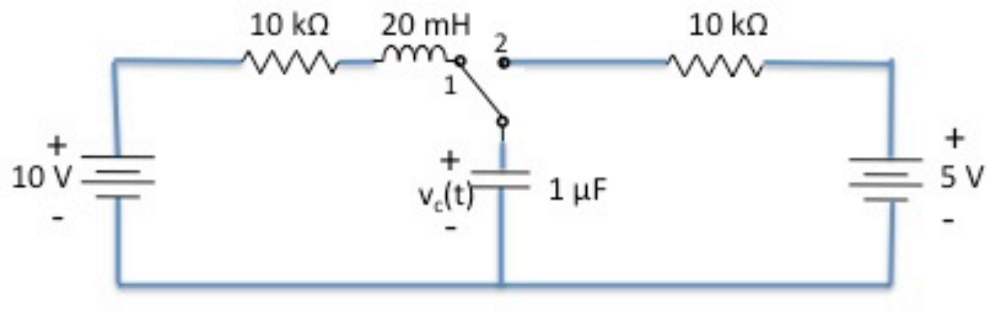
Name:

Instructions:

- This exam is closed book and closed notes, except for the tables of Fourier Transforms provided.
- Computers, and cell phones are NOT allowed. Calculators are allowed as long as they are not communication devices.
- There are 5 problems. Point values for each problem are given. The problems are not necessarily meant to be in order of difficulty. Try problems that you can solve first. In some cases, especially in longer problems, you may be able to solve some parts even if you cannot solve previous parts so look carefully at all parts of the problem.
- Write your name on all pages
- You may write on both sides of the pages but please be clear about what part of what problem you are solving when you do so.
- Show all work clearly for full credit and **place a box around all your final answers**. The more clear you make both your final answer and your solution procedure, the more likely a grader is to be able to grade it correctly and give partial credit appropriately.

Question 1 (12 Points) **Name:**

The switch in the circuit below is at position 1, as shown, for a long time before t=0.
At t=0 it moves to position 2. Solve for $v_c(t)$ for $t > 0$.



Question 2 (22 Points) **Name:**

Part (a) of this problem is independent from parts (b) and (c) which are all independent of part (d).

(a) Sketch the signal given by the following expression: $x(t) = 2u(t+2) – u(t) + u(t-1) – 2u(t-3)$. Be sure to label your sketch clearly for full credit.

(b) An analog-to-digital converter (also called ADC or A/D) uses a sampling rate of F_s = 6000 samples/second , An audio signal is transduced by a microphone to produce the electrical signal $x(t) = 3\sin(4000\pi t + \pi/3) + 4\cos(9000\pi t – \pi/6)$ volts and is then sampled by this ADC and stored on a computer.

(b-1) What is the resulting discrete time (DT) sinusoid? (You can ignore any quantization effects for this part of the problem.) The frequencies of the DT sinusoid should be converted to the lowest equivalent frequency.

(b-2) If this DT sinusoid is played through speakers connected to a computer using the same sampling rate F_s to reconstruct the signal, what frequencies (pitches) will be heard in the sound?

(b-3) Do these frequencies match those in the original signal? Why or why not?

(c) This ADC has a dynamic range of -3 to 3 volts and quantizes numbers to 10 bit accuracy.

(c-1) What is the amplitude resolution of this ADC in volts (that is, what is the equivalent in volts to a difference of one quantization level in the quantized signal)? Reasonable approximations are acceptable as long as you explain them.

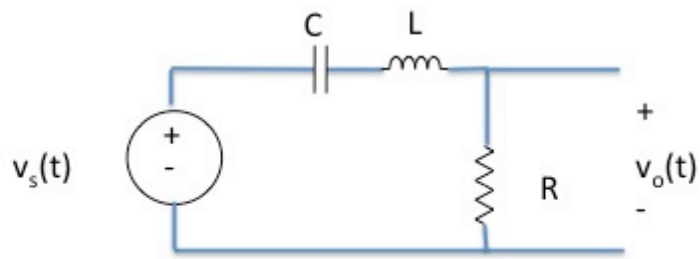
(c-2) Based on your answer to (c-1), for the first component of x(t), $3\sin(4000\pi t + \pi/3)$ volts , what is the maximum quantization error in volts?

(c-3) For the second component of x(t), $4\cos(9000\pi t - \pi/6)$ volts , what is the maximum quantization error in volts?

(d) What is the Fourier Transform of $x(t) = 2e^{-(t-2)}u(t-2)$? Hint: Reduce this problem to one that can be solved just using the tables of Fourier Transform pairs and properties provided, without doing any integration yourself.

Question 3 (24 Points) **Name:**

(a) For the circuit below, if $v_s(t) = 3\cos(\omega t)$, based directly on the DC (0 frequency) and high-frequency limit behavior of the circuit elements, what will $v_o(t)$ be at DC and as $\omega \rightarrow \infty$? Argue directly from the behavior of the circuit elements without writing a full impedance equation.



(b) What is the impedance seen by the voltage source?

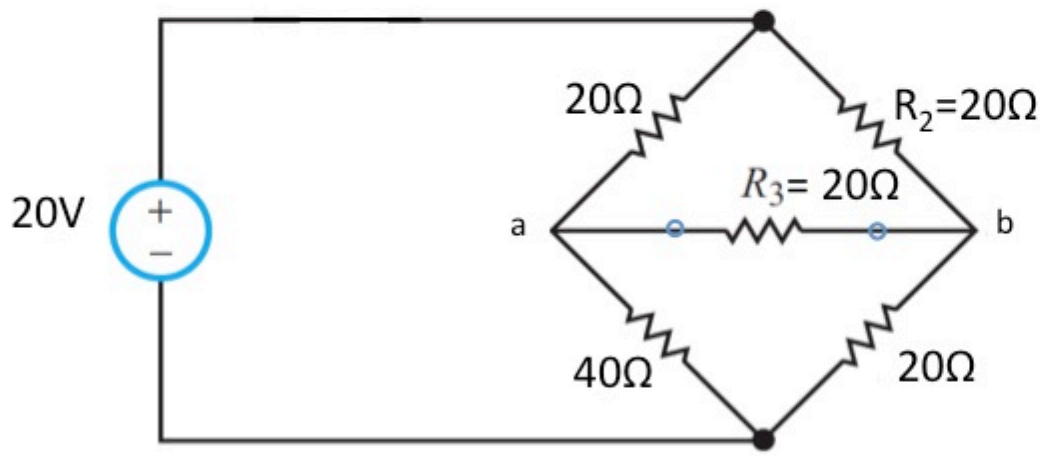
(c) Now derive an expression for the phasor representation of $v_o(t)$ in terms of the circuit elements, frequency ω, and the phasor representation of $v_s(t)$.

(d) Are your answers to **(b)** and **(c)** consistent with your answer to (a)? Explain mathematically in a clear and well-organized way so that a grader can understand your reasoning. You can use the answer to **(b)**, the answer to **(c)**, or both, as you find most convenient.

(e) If R = 20kΩ, L = 20mH and C = 2μF, and ω= 10^4, find an equivalent circuit as seen by the voltage source **at that frequency** which contains only two circuit elements. Give the **actual values** (not just the impedances) of those two elements.

Question 4 (22 Points) **Name:**

For the circuit below:

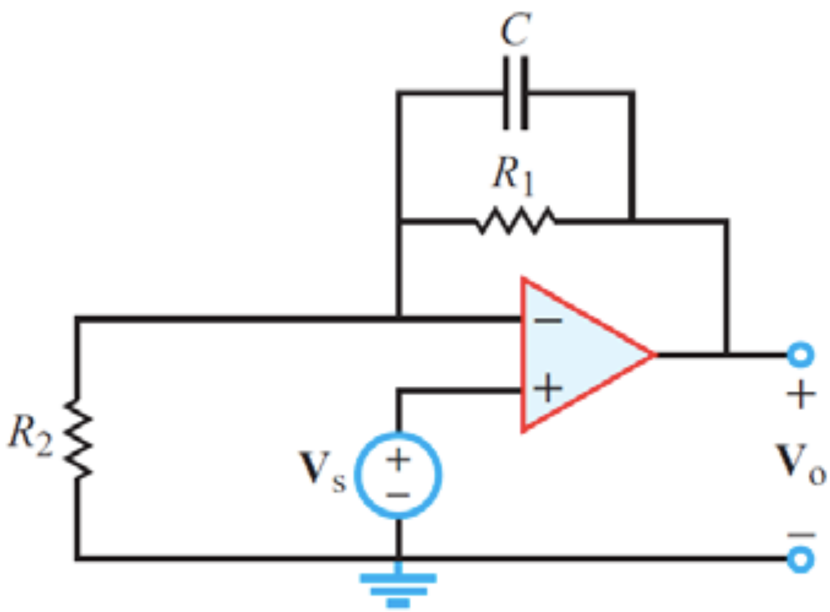


(a) Write node-voltage equations for this circuit. Simplify these equations and then put the system of equations in matrix form. You do not need to solve for the values of the node voltages.

(b) Write mesh current equations for this same circuit. Simplify these equations and then put the system of equations in matrix form. You do not need to solve for the values of the node voltages

(c) Find the Thevenin equivalent circuit seen by the resistor R_3 at terminals a and b.

Question 5 (20 Points) **Name:**



(a) In the circuit above, if $\mathbf{V_s}$ and $\mathbf{V_o}$ are phasor voltages, find the ratio $\mathbf{V_o}/\mathbf{V_s}$ as a function of frequency by using the ideal op-amp model and expressions for the impedances of the circuit element. Put a box around your final answer so it can easily be found by a grader.

(b) If $v_s(t)$ is a general signal with Fourier Transform $V_s(\omega)$, give an expression for $V_o(\omega)$, the Fourier Transform of $v_o(t)$ as a function of ω in terms of the values in the circuit, ω , and $V_s(\omega)$. Hint: use your result from part **(a)**. If you could not solve part **(a)** use a general expression to answer this part.

(c) Using the expression you obtained in part (a), if $R_1 = 20k\Omega$, $R_s = 5k\Omega$, and $C = 1\mu F$, what is $v_o(t)$ if $v_s(t) = 2 + 2\cos(250t + \pi/3)$? If you could not obtain any expression for part (a) explain in as much detail as you can how you would solve this problem in order to get partial credit.

(d) How will this circuit, with the element values given, amplify or attenuate the frequency content of inputs at different frequencies? That is, will low frequencies be amplified more, or attenuated less, than high frequencies, or vice-versa, or some other outcome? Explain your answer based on any techniques or results you have at your disposal. Feel free to use a sketch of frequency response magnitude if that will be helpful.