Electrical Engineering
EECE2210 — Fall 2020
Final Take–Home Exam

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General Rules (New for Exam 2, so please read carefully):

- Please submit your solutions on Canvas in a single .pdf file by 14 December at 23:59:59 Eastern United States Standard Time (GMT-5). You are encouraged to type your solutions, but it is not mandatory. Solutions can be written clearly and neatly on A4 or US 8.5 by 11 white papers and scanned. If you do not have a scanner, use scan apps to capture your answer sheets. Do not use the camera app of your device. Adobe scan app works well, available for ios and android (you may use other scanner apps). Please check the readability and quality of your file before submission carefully.

- **New:** To simplify grading, please submit your answers to each problem in the following way: Page 1 contains the short answer to each lettered question. Page 2 includes any plots requested. Remaining pages consist of your description of how you solved each problem.

- You may use any material you find in books, journal articles, or websites. Please cite any that you use. You may use calculator or software (e.g., Matlab). Provide sufficient details of your solving procedure.

- Avoid any appearance of academic dishonesty. Do not consult other students or outside experts about the exam.

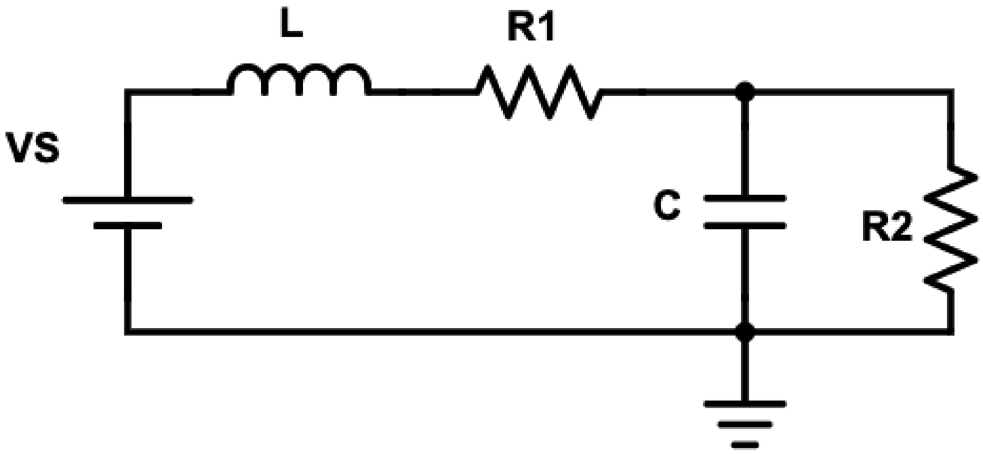

Figure 1.1: Figure for Problem 1. Here $V_s = 12$ V, $R_1 = 100$ kΩ, $R_2 = 10$ MΩ, $L = 150$ mH $C1 = 1$ mF.

1 Transients

Consider the circuit in Figure 1.1. I want to connect this circuit to a +12 V power source for a period of time and then disconnect it and use the charge in the capacitor to power the load, $R_2 = 10$ MΩ. Hopefully, because the load resistance is large and the current will thus be small, I can provide power for a very long time. Let's see how practical it is.

a. Assume the circuit has been connected to the power for a long time. What is the voltage, v_a on the load?

b. After the source is removed, what is the equation for the voltage, v_a? Plot it carefully with correct labels, using Matlab or other appropriate software.

c. What is the time constant for the circuit after it is removed from the power source? Put a small circle on your plot at the appropriate time and voltage.

d. To test our hypothesis, for how long will the voltage, v_a, be greater than 8 volts? Put a star on the plot at the appropriate time and voltage.

e. How much energy is stored in the capacitor?

f. What are the maximum and minimum instantaneous powers delivered to the load during this time?

g. Now let's see how practical this is. Assume the dielectric in the capacitor has $\epsilon_r = 7$ and the thickness of the dielectric is 10 μm. Calculate the area and the volume of the capacitor. Now assume we can interleave the layers so that we use both sides of the metal sheets and arrange the capacitor to be a cube. What is the size of the cube?

2 Power

The nameplate on a pump motor states

Voltage	120 V RMS
Current	1.25 A RMS
Frequency	60 Hz
Power	80 W

a. What is the power factor and associated angle, θ, in degrees?

b. We can assume that the motor is adequately described as an inductor with series resistance. What are the resistance and inductance?

Now we connect the motor to an electric outlet, which we can model as a 120 V_{RMS} source with a series resistance of 8 Ω accounting for the resistance in the transmission wires.

c. Carefully plot the current and voltage as functions of time for 2 cycles. Hint: If you choose the units carefully you can put them on the same vertical axis.

d. Plot the power consumed by the motor as a function of time.

e. What is the average power? Hint: If you used a computer and plotted sufficiently dense points over exactly 2 cycles you can simply take the mean of the plot in part d.

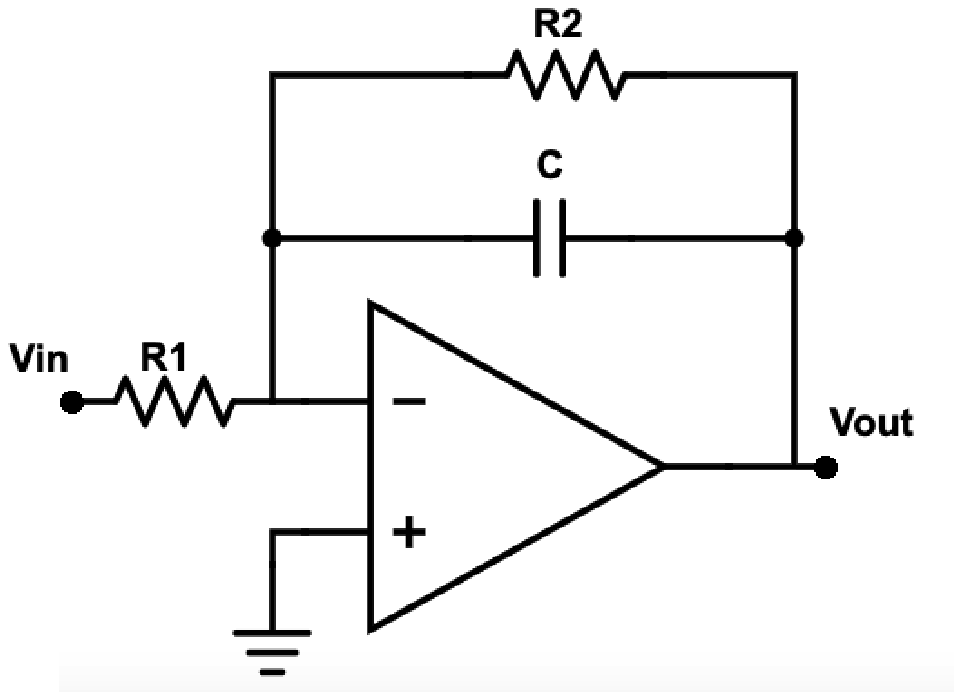

Figure 3.1: Figure for Problem 3. Here $R_1 = 50\ \Omega$, $R_2 = 1\ \text{k}\Omega$, $C1 = 50$ nF.

3 Transfer Function

Consider the amplifier circuit in Figure 3.1, which will provide gain and act as a filter.

a. Write the equation for the gain as a function of frequency.

b. What is the maximum gain?

c. Plot exactly the amplitude of the gain in decibels and the phase in degrees for frequencies from 100 Hz to 100 kHz. Use a logarithmic scale on the frequency axis. Use Matlab or appropriate software to generate the plot.

d. From your plot or from your data, determine the cutoff frequency, at which the gain is reduced to 3 decibels below the peak gain.

e. Now connect the output of this circuit to the input of an identical circuit. On the same set of axes as in part c, repeat the plots for this cascaded amplifier circuit.

f. What is the cutoff frequency for this cascaded circuit?

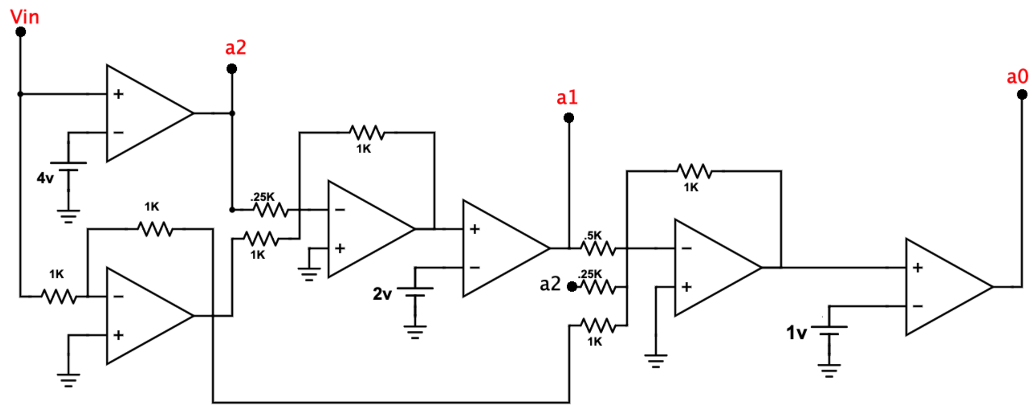

Figure 4.1: Circuit for Problem4

4 Amplifier Circuit

The circuit shown in Figure4.1 is a combination of several circuits that we already have studied in the class. Assume V_{in} is the input and $a2$, $a1$ and $a0$ are the outputs. The input value is supposed to be integer values from 0 to 7 Volts.

In all opamps, the high saturation voltage is 1 V and low saturation voltage is zero volt (Reminder: In an opamp circuit, if there is no connection (either by a resistor or just a wire) between output and inverting input terminals, the opamp will be saturated and the output will be either the high saturation voltage (if $V_+ > V_-$ in input terminals) or the low saturation voltage (if $V_+ < V_-$ in input terminals)). Typically we would create this situation by applying +1 and 0 Volts to the power connections of the amplifier.

a. Find the output for input values of 3, 4, and 7 Volts. Provide a clear and sufficient explanation.

b. Can you say what is the mathematical operation done by this circuit?

c. Can you create an inverse circuit? By "inverse circuit" we mean a circuit whose inputs are $a2$, $a1$, and $a0$ and the output is a value that, if applied to circuit Figure4.1 as input, will produce the same number of $a2$, $a1$ and $a0$.

Please note:

- You will find a red and a black a2. The red one is where this output is created, and the black one is the same value that is an input to another parts of the circuit.
- All intersections are junctions, not wires crossing over each other.