NAME ______________________________________

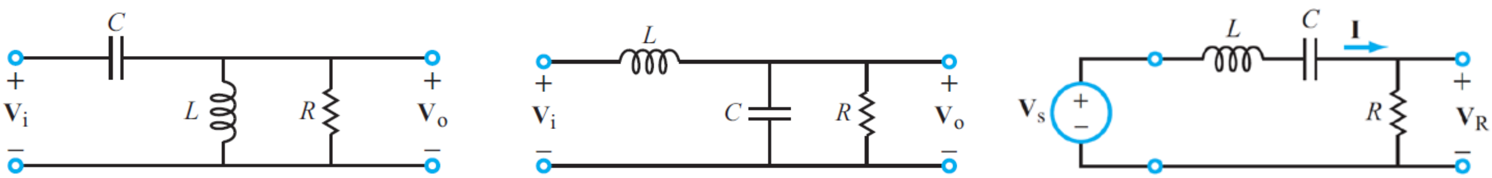
ELEC 226
Prof. Rich Kozick
May 6-12, 2011

# FINAL EXAM

Your solution to this exam is due by Thursday, May 12 at 11:00 AM. You may use books, notes, Matlab, and your calculator to solve the problems, **but you must work alone**. Please show your work neatly, and clearly indicate your final results. You can submit your solutions to Prof. Kozick's office or to Judy in the EE office. You can also submit all or part of your exam electronically. Good luck and have a great summer!

**Problem 1:** (20 points)

In this problem, you are asked to design a low-pass, high-pass, and band-pass filter to meet given specifications. You will also use Matlab to produce Bode plots (magnitude and phase response) for each filter, and also evaluate the sinusoidal time waveform output from each filter at a specific frequency. The filter circuits that will be used are shown in (a), (b), and (c).




(a) (b) (c)

The filter specifications are as follows.

- Low-pass: cutoff frequency 500 Hz and "maximally flat" magnitude response.
- High-pass: cutoff frequency 2,000 Hz and "maximally flat" magnitude response.
- Band-pass: Upper and lower cutoff frequencies 500 and 2,000 Hz, respectively.

Please note that the frequencies are in hertz, while in Homework 3 we worked with rad/sec. Also note that we are *not* adding the filter outputs as in Homework 3, but instead each filter is used independently.

Please answer the following questions.

a) Use Matlab to produce Bode plots of the magnitude (in dB) and the phase (in degrees) response of each filter for frequencies from 10 to 100,000 Hz. Be sure that the frequency axis in your plots is scaled and labeled in Hz. Explain how you produced the Bode plots, and specify which filter in (a), (b), (c) is low-pass, high-pass, and band-pass.

b) If the sinusoidal voltage $v(t) = 10\cos(2\pi 1200\, t)$ V is applied to each filter, then find the sinusoidal steady-state output from each filter (specify the time function, not the phasor). Explain your approach and how the answer is related to the Bode plots. Also, match your answers with the corresponding time waveforms on page 2. That is, specify the color in the plot (red, black, blue) that corresponds to each filter output.

c) Assume that R = 100 ohms in each filter, and find values for L and C in each filter that achieve the specifications. Use values for L in the range from 1 mH to 500 mH. Clearly explain how you obtained the values for L and C in each filter.

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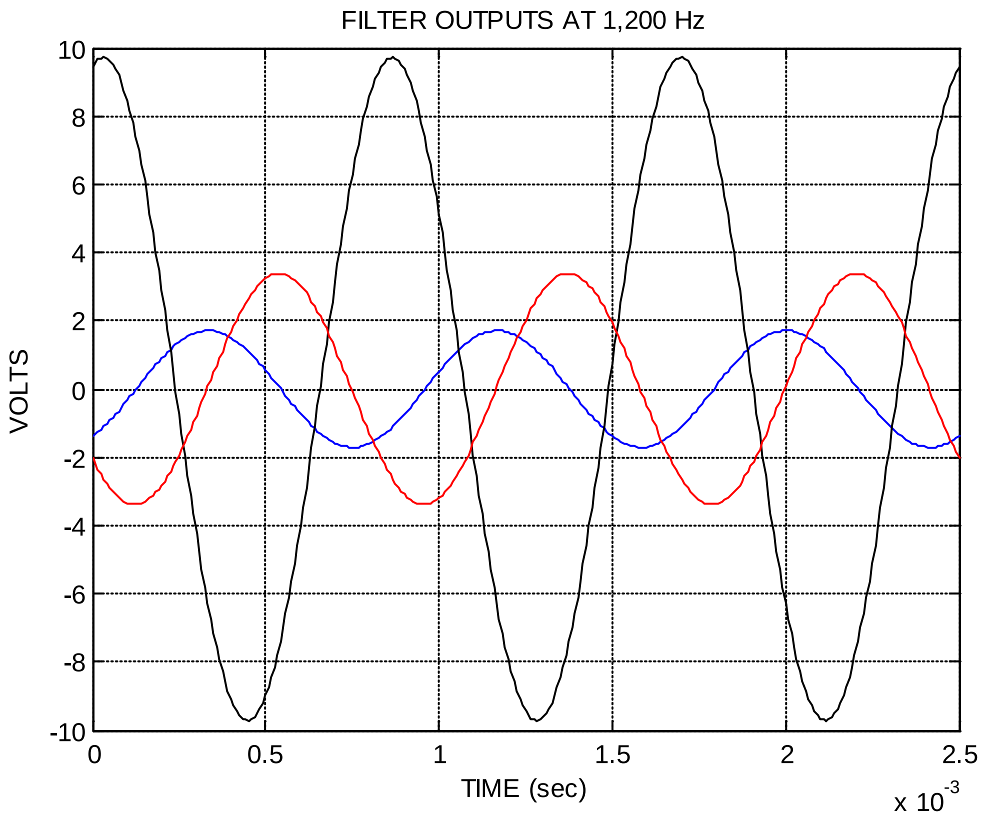
Please submit the Matlab code that you use to answer this question, either printed out or by email. It may be convenient for you to paste your Matlab plots into a Word file, along with your code, and then email the Word document to me. Your analysis may be handwritten and submitted separately on paper.

Plots of filter output waveforms with input voltage $v(t) = 10\cos(2\pi 1200\, t)$ V (you can use these plots to check your work!):



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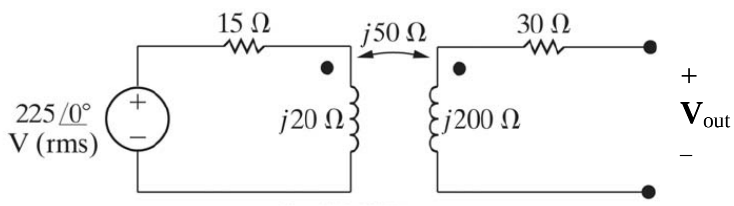
**Problem 2:** (12 points)

Please answer the following for the sinusoidal steady-state circuit shown below

(a) Find an expression for the output voltage time waveform $v_{out}(t)$ (not the phasor $\mathbf{V}_{out}$).
Assume that the sinusoidal frequency is 60 Hz.
Note that the voltage source amplitude is specified by its RMS value.

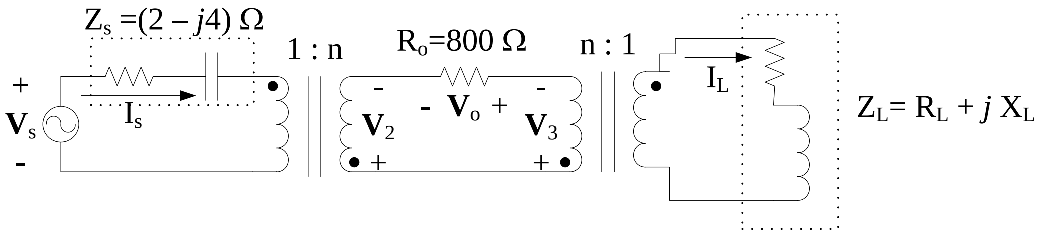
(b) Find the *average power* delivered by the source.

(c) Find the average power absorbed by the 15 ohm resistor.



**Problem 3:** (20 points)

Consider the circuit shown below with ideal transformers and sinusoidal source phasor $\mathbf{V}_s = 50\angle 0^\circ \quad V$ (rms).




The transformer turns ratio $n$ may be chosen in the range $1 \le n \le 20$ and the load impedance $Z_L$ is unrestricted, so $R_L$ and $X_L$ may be set to any values.

Choose values for $n$ (in the range 1 to 20), $R_L$, and $X_L$ so that the **average power** absorbed by the load impedance $Z_L$ is **maximum**.
**Show your work on a separate page and write your answers on this page.**

$n$ = ________ $R_L$ = ______________ $X_L$ = ______________

Then for your chosen values of $n$, $R_L$, and $X_L$, compute the following quantities (with units).

Load current phasor (rms), $\boldsymbol{I}_L$ =

Load complex power, $\boldsymbol{S}_L$ =

Load average power, $P_L$ =

Load reactive power, $Q_L$ =

Load apparent power, $S_L$ =

Load power factor (include leading/lagging) =

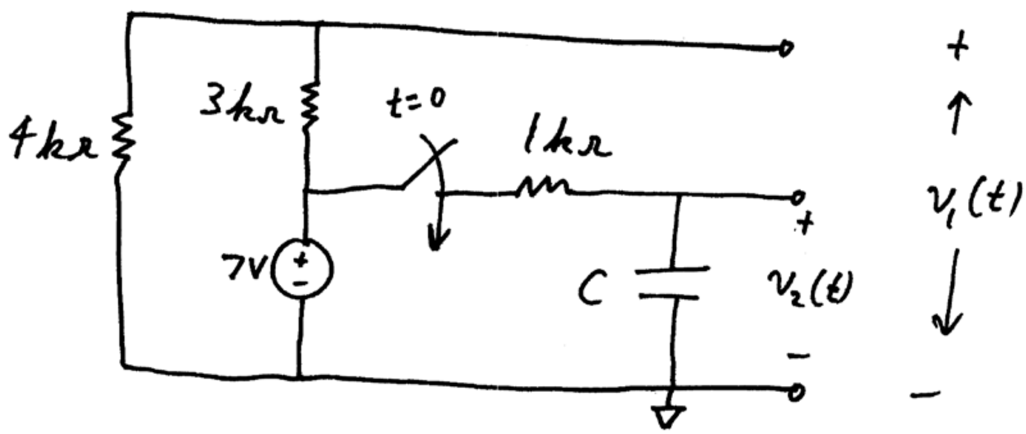
Source current phasor (rms), $\boldsymbol{I}_S$ =

Average power delivered by voltage source, $P_S$ =

**Problem 4:** (20 points)

The switch in the circuit below closes at time t=0, and the capacitor is initially uncharged. Find the value for the capacitance, C, so that $v_2(0.01) = v_1(0.01)$. That is, the voltage across the capacitor should equal $v_1$ at time t = 0.01 sec.

The resistor values in the circuit are 1 kΩ, 3 kΩ, 4 kΩ and the source is 7 V (in case the writing is unclear).



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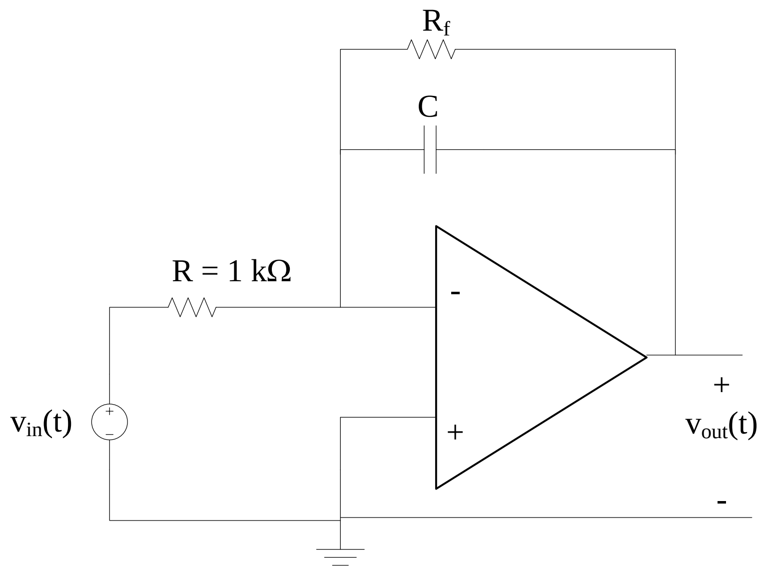
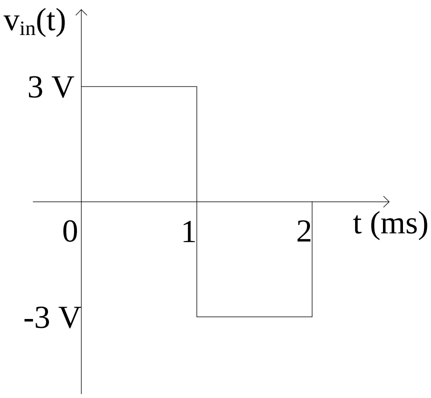
**Problem 5:** (15 points)




Consider the practical integrator circuit shown above, where the op amp is powered with +10 V and -10 V. Choose a value for C so that the output waveform has $|v_{out}(t)|$ with maximum value 5 V, and sketch $v_{out}(t)$ versus $t$ for your chosen value of C. Note that the time axis is labeled in milliseconds and assume that $v_{out}(0) = 0$ V. (Assume that $R_f$ is infinite to answer this part.)

How much current flows in/out of the op amp output node from 0 to 2 ms? Is this current reasonable for a 741 op amp? (Again assume that $R_f$ is infinite.)

Next, specify a value for the resistor $R_f$ so that $R_f$ has negligible impact on the integrator, but $R_f$ will allow the capacitor to discharge on a longer time scale than the changes in $v_{in}(t)$. Explain your reasoning in choosing $R_f$. Why is it necessary to include $R_f$ in a practical integrator circuit?

**Problem 6:** (13 points)

Consider the oscillator circuit shown below. Assume that the op amp is a 741 that is powered with +10 V and -10 V. Choose values for $R_a$, $R_b$, R, and C so that the voltage waveforms in the plot are produced. The waveforms are periodic, but only one period is shown in the plot.
The capacitor voltage varies between +1 V and -1 V (indicated by the black dotted lines), and the period is 0.40 μsec.
Calculate the maximum current out of the op amp in your design, and produce a design with maximum current in the range 1 mA to 5 mA to avoid overloading the op amp.