

EE40 Homework #7

Due Oct 22 (Thursday), 12:00 noon in Cory 240

Reading Assignments

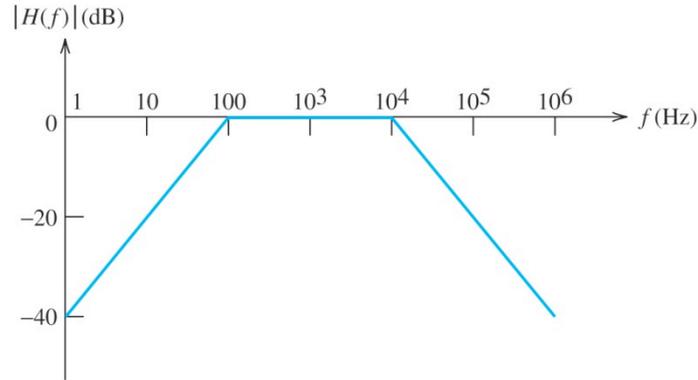
Sections 6.6–6.8 of Hambley textbook. Section 6.9 on DSP will be discussed later in course.

Section 14.10 of Hambley (active filters)

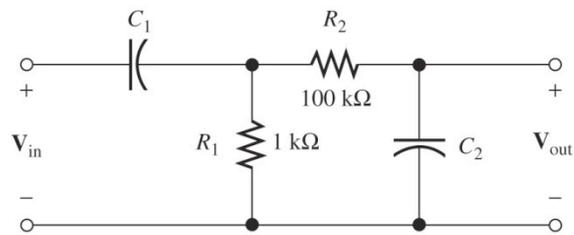
Problem 1: Band Pass Filter Design (Hambley P6.71)

Suppose that we need a filter with the Bode plot shown in Figure (a) below. We decide to cascade a highpass circuit and a lowpass circuit as shown in Figure (b). So that the second (i.e., right-hand) circuit looks like an approximate open circuit across the output of the first (i.e., left-hand) circuit, we choose $R_2 = 100 R_1$.

- a) Which of the components form the highpass filter? Which form the lowpass filter?
- b) Compute the capacitances needed to achieve the desired break frequencies, making the approximation that the left-hand circuit has an open-circuit load.
- c) Write expressions that can be used to compute the exact transfer function $H(f) = V_{out}/V_{in}$ and use the computer program of your choice to produce a Bode magnitude plot for f ranging from 1 Hz to 1 MHz. The result should be a close approximation to the desired plot shown in Figure (a).



(a)

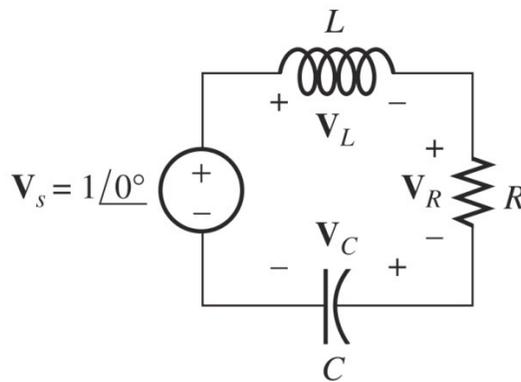


(b)

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Problem 2: Series Resonance (Hambley 6.75)

Consider the series resonant circuit shown in the figure below. Compute the resonant frequency, the bandwidth, and the half-power frequencies. Assuming that the frequency of the source is the same as the resonant frequency, find the phasor voltages across the elements and sketch a phasor diagram.

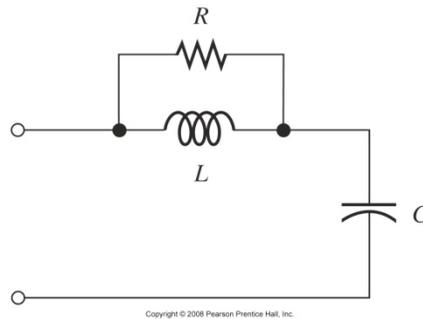


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Problem 3: Another RLC Combination (Hambley P6.80)

Other combinations of R, L and C have behaviors similar to that of the series circuit. For example, consider the circuit shown in the figure below.

- Derive an expression for the resonant frequency of this circuit. (We have defined the resonant frequency to be the frequency for which the impedance is purely resistive.)
- Compute the resonant frequency, given:
- Using the computer program of your choice, obtain a plot of the impedance magnitude of this circuit for f ranging from 0.95 to 1.05 times the resonant frequency. Compare the result with that of a series RLC circuit.



Problem 4: Example Applications of Filters (Hambley P6.92, P6.93)

- Each AM radio signal has components ranging from 10 kHz below its carrier frequency to 10 kHz above. Various radio stations in a given geographical region are assigned different carrier frequencies so that the frequency ranges of the signals do not overlap.
Suppose that a certain AM radio transmitter has a carrier frequency of 980 kHz. What type of filter should be used if we want the filter to pass the components from this transmitter and reject the components of all other transmitters? What are the best values for the cutoff frequencies?
- In an electrocardiograph, the heart signals contain components with frequencies ranging from dc to 100 Hz. During an exercise on a treadmill, the signal obtained from the electrodes also contains noise generated by muscle contraction. Most of the noise components have frequencies exceeding 100 Hz. What type of filter should be used to reduce the noise? What cutoff frequency is appropriate?

Problem 5: Another Perspective of RLC Resonant Circuits (Hambley P6.97)

Consider the filter shown in the figure below.

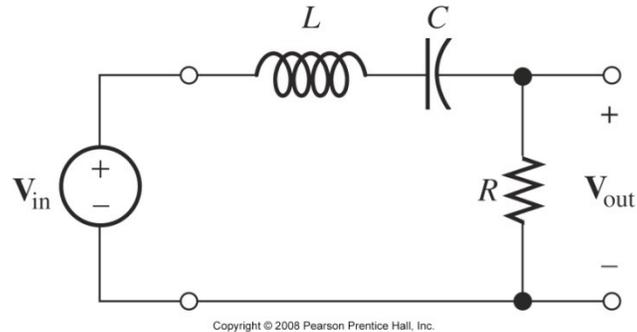
- Derive an expression for the transfer function $H(f) = V_{out}/V_{in}$.
- Use the computer program of your choice to obtain a Bode plot of the transfer function magnitude for:

Allow the frequency to range from 1 kHz to 100 kHz.

- At very low frequencies, the capacitance becomes an open circuit and the inductance becomes a short circuit. For this case, determine an expression for

the transfer function and evaluate for the circuit parameters of part (b). Does the result agree with the value plotted in part (b)?

- d) At very high frequencies, the capacitance becomes a short circuit and the inductance becomes an open circuit. In this case, determine an expression for the transfer function and evaluate for the circuit parameters in part (b). Does the result agree with the value plotted in part (b)?

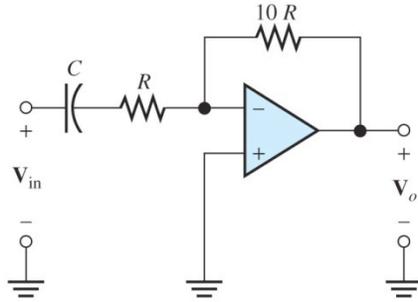


Problem 6: Active Filter (Hambley P14.78)

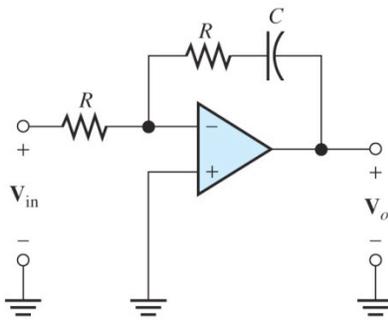
This problem counts as two problems in your homework score.

Do all magnitude Bode plots by hand, using straight line segments. You should count on having to hand-sketch Bode plots on the next exam.

Assume that the op amps in the figure below are ideal. Derive an expression for the voltage transfer ratio of each circuit. Also, sketch the magnitude Bode plots to scale (phase plots are not necessary).



(a)

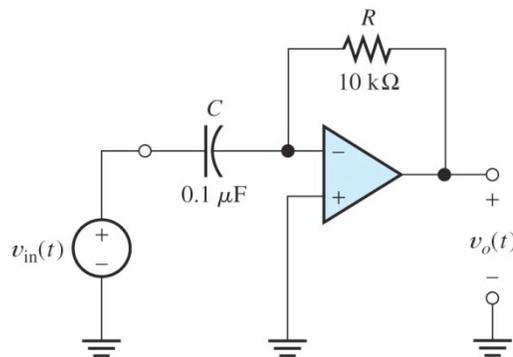


(b)

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Problem 7: The Differentiator as a Filter (Hambley P14.80)

It is interesting to look at the differentiator circuit as a filter. Derive the transfer function of the differentiator in the figure below, and sketch the magnitude Bode plot to scale.



Problem 8: More Bode Plot Practice

Sketch by hand the Bode Magnitude and Phase plots for

$$H(\omega) = \frac{j100\omega}{(100 + j5\omega)(100 + j\omega)^2}$$