

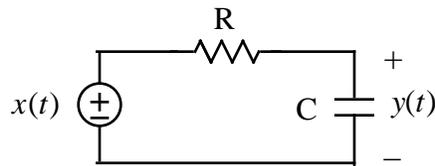
ECE 306L - FOURIER SERIES - LAB 1 FREQUENCY RESPONSES AND SPECTRAL PLOTS

FALL 2006

FELZER/KANG

OBJECTIVE

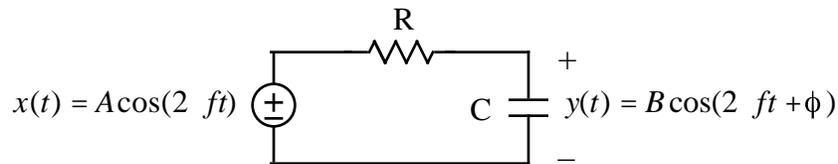
The objective of this lab is to see how the sinusoidal steady state response $y(t)$ of a lowpass filter like the following



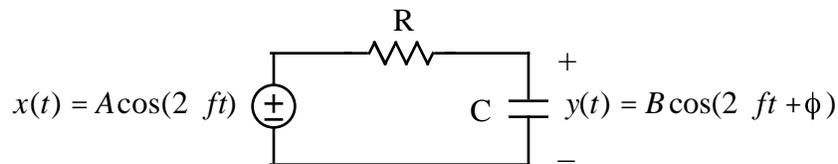
depends on the frequency of the sinusoid together with the frequency response of the filter

PRELAB

1. What do we mean by the frequency response of a linear circuit like the lowpass filter above
2. Given our first order lowpass filter above with a sinusoidal input as follows



- a. Make use of time domain arguments - the amount of time the charge has to accumulate on the capacitor's plates - to explain why B decreases as the frequency f increases
 - b. Sketch $x(t)$ for a low frequency. And then below it sketch $y(t)$
 - c. Sketch $x(t)$ for a high frequency. And then below it sketch $y(t)$. Draw your graph so that the higher frequency sinusoid looks like a higher frequency sinusoid
 - d. Confirm that your results in parts (b) and (c) are consistent with your result in part (a)
3. The objective of this problem is to do some calculations to confirm your results in Problem (2) for our filter as follows

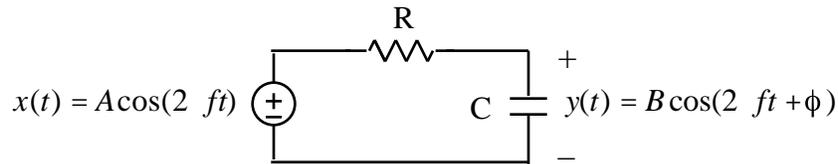


- a. Draw the phasor circuit
- b. Analyze your phasor circuit to show that its transfer function is equal to

$$G(j2 f) = \frac{1}{1 + j2 fRC}$$

- c. Make use of your transfer function in part (b) to find the sinusoidal steady state of $y(t)$ to $x(t) = 5\cos(2 1000t)$ when $R = 1\text{K}$ and $C = 0.1\mu\text{f}$. Use Matlab to calculate $G(j2 f) = G(j2 1000)$

- d. Use Matlab to plot $x(t)$ and $y(t)$ from part (c) on the same graph
 - e. Repeat parts (c) and (d) for the higher frequency input $x(t) = 5\cos(2 \ 3000t)$
 - f. Confirm that your results for low and high frequency sinusoids are consistent with your results in Problem (2)
4. The objective of this problem is to get a graph of the frequency response of our first order RC circuit - in particular a graph of how B/A varies as a function of frequency



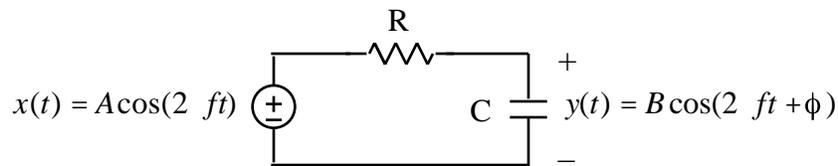
- a. Make use of your results in Problems (2) and (3) to sketch the frequency response of this circuit as follows

$$|G(j2 \ f)| = \frac{B}{A}$$
 as a function of f
 - b. Describe your sketch in part (a)
 - e. Now make use of Matlab to obtain a *full page* plot of the magnitude of the transfer function $G(j2 \ f)$ with $|G(j2 \ f)|$ plotted on a **linear scale** and f plotted on a **log scale**
 - f. Confirm that your graph in part (e) is consistent with your sketch in part (a)
5. The objective of this problem is to make use of your frequency response plots to calculate the amplitudes of the steady state outputs of your circuit
- a. Explain in words how we can make use of a frequency response plot $|G(j2 \ f)|$ to find the amplitude B of the steady state response to $x(t) = A\cos(2 \ ft)$ at a given frequency f
 - b. Make use of your Matlab graph in Problem (4) to calculate the amplitude of the sinusoidal steady state response to $x(t) = 5\cos(2 \ 1000t)$
 - c. Repeat part (b) for the higher $x(t) = 5\cos(2 \ 3000t)$
 - d. Verify that your results in parts (b) and (c) are about the same as you calculated in Problem (3). As always make use of a Table for such a comparison
6. The objective of this problem is to draw one-sided spectral plots of our sinusoids in the previous problems
- a. Sketch the one-sided spectral plot of the amplitude of $x(t) = 5\cos(2 \ 1000t)$
 - b. Make use of your plot of the frequency response $|G(j2 \ f)|$ to sketch the one-sided spectral plot of $y(t)$
 - c. Repeat parts (a) and (b) for $x(t) = 5\cos(2 \ 3000t)$
7. The objective of this problem is to draw two-sided spectral plots of our sinusoids in the previous problems
- a. Sketch the two-sided spectral plot of the amplitude of $x(t) = 5\cos(2 \ 1000t)$
 - b. Make use of your plot of the frequency response $|G(j2 \ f)|$ to sketch the two-sided spectral plot of $y(t)$
 - c. Repeat parts (a) and (b) for $x(t) = 5\cos(2 \ 2 \times 10^4 t)$

8. Now for a sum of sinusoids as follows $x(t) = 2\cos(2000t) + 3\cos(4000t)$
 - a. Draw the one-sided spectral plot of $x(t)$
 - b. Make use of Matlab to obtain a graph of $x(t)$
 - c. Make use of superposition to calculate the steady state response to $x(t)$
 - d. Draw the two-sided spectral plot of $y(t)$
 - e. Make use of Matlab to plot $y(t)$
 - f. How come $y(t)$ doesn't look like $x(t)$
9. Is it possible for $x(t) = 2\cos(2000t) + 3\cos(4000t)$ to be the sum of any other sinusoids. Come up with an experiment that makes use of bandpass filters to test your hypothesis
10. Here's some math we'll be needing. Given the single sinusoid $x(t) = \cos(2000t)$
 - a. Find the rms voltage
 - b. Find the rms voltage in $dBV = 20\log_{10}(V_{rms})$
 - c. Find the rms voltage in $dBm = 20\log_{10} \frac{V_{rms}}{0.22361}$. Note that when $V_{rms} = 0.22361$ then 1mw will be dissipated in a 50 Ω load
11. Calculate the amplitudes of the $x(t)$'s and $y(t)$'s in this prelab in dBV

LAB

1. Measure $|G(jf)| = B/A$ for at least ten frequencies f for the circuit analyzed in Prelab Problem (2) as follows



Then plot your data points on the graph of Prelab Problem (4).

2. Display $x(t) = \cos(2000t)$ from the signal generator on the scope. Then
 - a. Measure the peak-to-peak amplitude, peak amplitude and frequency of $x(t)$
 - b. Display 5 to 10 cycles on the scope and then use the FFT function on the scope to measure the one-sided spectrum of the sinusoid. Use the Hanning window to measure the frequency. And use the flattop window to measure the amplitude in dBV. See the instructions below for using the HP scope as a spectrum analyzer. Save a screen capture for your report
3. Measure the steady state responses $y(t)$ of your RC circuit to each of the following sinusoids. Save screen captures for your report
 - a. $x(t) = 5\cos(2000t)$
 - b. $x(t) = 5\cos(4000t)$
4. Use the HP scope to obtain spectral plots of $x(t)$ and $y(t)$ for your RC circuit for each of the following sinusoids. Save screen captures for your report
 - a. $x(t) = 5\cos(2000t)$
 - b. $x(t) = 5\cos(4000t)$

5. Use Simulink to simulate the response of your RC circuit to each of the following inputs. Use the transfer function block. Save screen captures of your inputs and outputs for your report
 - a. $x(t) = 5\cos(2\ 1000t)$
 - b. $x(t) = 5\cos(2\ 3000t)$
 - c. $x(t) = 2\cos(2\ 1000t) + 3\cos(2\ 3000t)$

POSTLAB

1. Compare the calculated and measured values of $|G(j2\ f)| = \frac{B}{A}$. Put your results in a Table with a column for percentage differences. What can you conclude
2. Compare your calculated and measured spectrums of the sinusoid $x(t) = \cos(2\ 1000t)$. Put your results in a Table that includes the percentage differences between the calculated and measured frequencies and the amplitudes in dBV. How well did the Hanning and flattop windows do.
3. Describe and explain your Simulink results

USING AN HP DIGITAL SCOPE TO OBTAIN THE FFT

The FFT is an algorithm for efficiently calculating the spectrum of a signal - the frequencies and amplitudes of the harmonics. To obtain the single-sided FFT of a sinusoid with an HP scope:

1. Display 5 to 10 cycles of the sinusoid on the scope
2. Press the \pm key between Channel 1 and Channel 2
3. Press ON under Function 2
4. Press Menu under Function 2
5. Keep pressing Operation until FFT is selected
6. Press FFT Menu
7. Press Center Frequency and turn the dial until the center frequency is zero
8. Press Frequency Span
9. Turn the dial to set the span at minimum (12.21 kHz). Each horizontal division now represents $12.21\ \text{kHz}/10 = 1.221\ \text{kHz}$
10. Select Hanning as a window function to measure the frequency of the sinusoid
11. Press Previous Menu
12. Set the reference level (at the top of the screen) to 0dBV
13. Set the units at 5 dBV
14. Press cursor
15. Set the Source to F2
16. Select f1 for Active Cursor
17. Move the first cursor to the leftmost spectrum (near 0 Hz)
18. Select f2 for Active Cursor
19. Move the second cursor to the peak
20. Read $f(F2)$
21. Press the \pm key between Channel 1 and Channel 2 to get back to the FFT menu
22. Go back to FFT and change the window to Flattop to measure the amplitude of the sinusoid
23. Use voltage cursors to measure the amplitude of the sinusoid in dBV