

ECE 306L - FOURIER SERIES - LAB 1

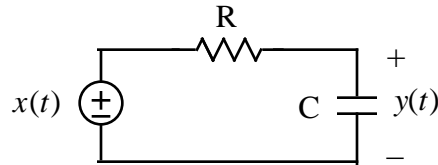
FREQUENCY RESPONSES AND SPECTRAL PLOTS

SPRING 2007

FELZER/KANG

OBJECTIVE

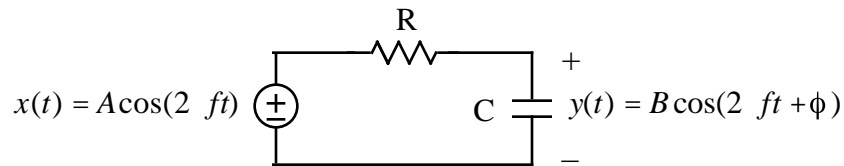
The objective of this lab is to see how the sinusoidal steady state response $y(t)$ of a lowpass filter like the following



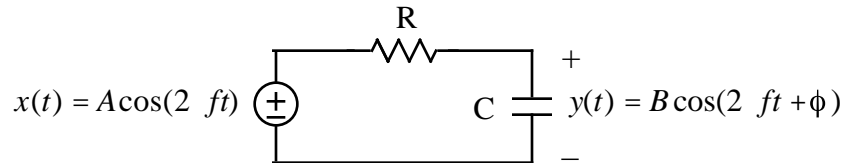
depends on the frequency of the sinusoid together with the frequency response of the filter

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



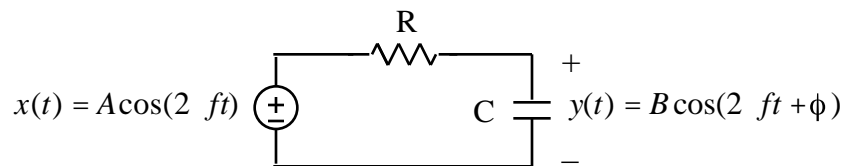
- a. Draw the phasor circuit
- b. Analyze your phasor circuit to show that its transfer function is equal to

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

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

$$|G(j2\ 1000)| = \text{abs}(G)$$

- 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. Are your results for low and high frequency sinusoids consistent with your results in Problem (2). How can you tell
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



when $R = 1\text{K}$ and $C = 0.1\mu\text{f}$

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

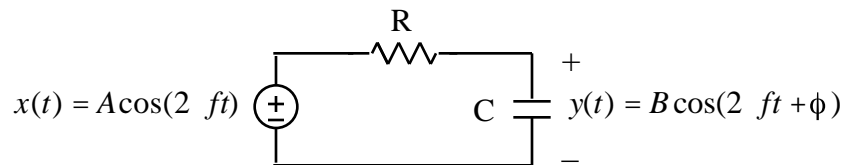
$$|G(j2\ f)| = \frac{B}{A}$$
 - b. Describe your sketch in part (a)
 - c. Now make use of Matlab to obtain a *full page* plot of the magnitude of the transfer function $G(j2\ f)$ with $|G(j2\ f)|$ plotted on a **linear scale** and f plotted on a **log scale**
 - d. Confirm that your graph in part (c) 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 $|G(j2\ f)| = B/A$ 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 frequency input $x(t) = 5\cos(2\ 3000t)$
 - 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 $x(t) = 5\cos(2 \times 10^4 t)$
8. Now for a sum of sinusoids as follows $x(t) = 2\cos(2 \times 1000t) + 3\cos(2 \times 2000t)$
 - 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 of your RC circuit 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. Here's some math we'll be needing. Given the single sinusoid $x(t) = \cos(2 \times 1000t)$
 - 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
10. Calculate the amplitudes of the $x(t)$'s and $y(t)$'s in Problem (3) in dBV. Put your results in a Table

LAB

1. Given the following RC circuit from the prelab with $R = 1K$ and $C = 0.1\mu f$



- a. Measure $|G(jf)| = B/A$ for at least ten frequencies f . Put your results in a Table
- b. Then plot your data points on the graph of Prelab Problem (4). How well do the data points match up with your curve
- c. Save screen captures of $x(t)$ and $y(t)$ on the same graph for $x(t) = 5\cos(2 \times 1000t)$ and then $x(t) = 5\cos(2 \times 3000t)$
2. The objective of this exercise is to learn how to use the HP scope as a spectrum analyzer to obtain the spectral plot of a signal. Note that the scope does this by calculating the FFT of $x(t)$
 - a. First display $x(t) = \cos(2 \times 1000t)$ from the signal generator on the scope. Measure its peak-to-peak amplitude, peak amplitude and frequency
 - b. Then use the FFT function on the scope to measure the one-sided spectrum of the sinusoid as follows. Save a screen capture of $x(t)$ and its spectral plot for your report
 - (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 Frequency Span
- (8) Since $x(t)$ is a single sinusoid at $f = 1$ KHz turn the dial to set the frequency span to 12.21 KHz. Each horizontal division represents $12.21/10 = 1.221$ KHz/Div
- (9) Select the *Hanning window function to measure the frequency* of the sinusoid
- (10) Press Previous Menu
- (11) Since the amplitude of $x(t)$ is -3 dBV set the reference level (at the top of the screen) to 0dBV by selecting ref level and then turning the dial
- (12) Set the units at 5 dBV/div
- (13) Press cursor
- (14) Set the Source to F2
- (15) Remove the sinusoid so that only its spectrum on the screen
- (16) Select f1 for Active Cursor
- (17) Move the cursor f1 to find the frequency where the spectral line peaks
- (18) Press the \pm key between Channel 1 and Channel 2 to get back to the FFT menu
- (19) Go back to FFT and select the *Flattop window to measure the amplitude* of the sinusoid in dBV
- (20) Use voltage cursors to measure the amplitude of the sinusoid in dBV

3. Repeat Problem (2) for $x(t) = 3\cos(2 \ 1000t)$
4. Use the HP scope to obtain spectral plots of $x(t)$ and $y(t)$ for your RC circuit in Problem (1) for each of the following sinusoids. Save screen captures for your report
 - a. $x(t) = 5\cos(2 \ 1000t)$
 - b. $x(t) = 5\cos(2 \ 3000t)$
5. Use Simulink to simulate the response of your RC circuit in Problem (1) 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