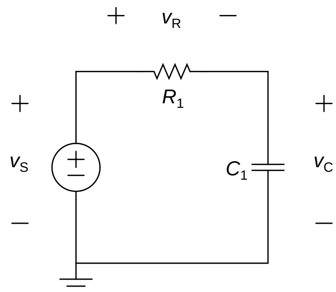
Laboratory 8: RC ACSS Analysis

8.1 Introduction

For this lab, you will be looking at the AC Steady State response of an RC circuit in the time domain and in the frequency domain. You will be comparing a time-domain-based analysis with a frequency domain analysis of the steady state behavior. The circuit you will be looking at is as follows:



and you will be tracking the source voltage $v_s(t)$, the capacitor voltage $v_C(t)$, and the resistor voltage $v_R(t)$.

You will be looking at responses to a series of single frequency sinusoids and then you will construct a Bode plot based on simulated data and compare it to the analytical Bode plot for the circuit.

8.2 Resources

The additional resources required for this assignment include:

- Books: None
- Pratt Pundit Pages: `EGR 224/RC ACSS Analysis`

8.3 Tinkercad

You will be using Tinkercad to look at the response to a rectangular wave and a couple sinusoidal waves. Follow the instructions on the Pundit page. You will end up with a screen shot of the simulation for the square wave, a sinusoid with $f = \frac{1}{8\tau}$, and a sinusoid with $f = \frac{10}{8\tau}$. Each screen shot should show the three oscilloscopes.

8.4 Multisim

You will be using Multisim to look at the responses to several single-frequency sinusoids and to perform an AC Sweep analysis. Follow the instructions on the Pundit page. You will end up with 9 data files (single frequency transient data for ω=1, 2, 5, 12, 25, 60, 130, and 300 rad/s as well as the AC Sweep data), one schematic image, and one grapher image from the AC Sweep. Later, you will be using the first eight data files to create approximations to the Bode magnitude and phase plots by examining the values and relative locations of the peak values once the system is in steady state. You will be comparing those to the Bode magnitude and phase values obtained through the AC Sweep. This process is described in the next section.

8.5 "Experimental" Bode Plots

Now that you have eight data sets for the transient analysis of eight different sinusoids, you can generate experimental Bode plots. You need to write a program that will run a for loop that goes through each of the frequencies used in the transient analysis. Within the loop, your program should:

- Load the appropriate data set and generate individual variables to keep track of the time, total voltage, capacitor voltage, and resistor voltage.
- Determine the value and time for the last peaks of the total, capacitor, and resistor voltages.
- Determine the amplitude ratios and phase differences given that information. Store those values in arrays or Dataframes called "magnitude" and "phase." Note that the phase should be in degrees.

Once the loop is done, print out the information so that you can fill out the following table:

ω	$v_{\text{s,peak}}$	$t_{\text{s,peak}}$	$v_{\text{C,peak}}$	$t_{\text{C,peak}}$	$\lvert\mathbb{H}\rvert = \left\lvert\frac{v_{\text{C,peak}}}{v_{\text{s,peak}}}\right\rvert$	$\angle\mathbb{H} = \frac{180}{\pi}\omega(t_{\text{s,peak}} - t_{\text{C,peak}})$
1						
2						
5						
12						
25						
60						
130						
300						

You are going to create two figures: one for the magnitude information and one for the phases. In the first figure, create a `semilogx` plot of the values of $20\log_{10}(H)$ you got from the transient analysis versus the forcing function frequencies - since you only have eight data points, plot them as black circles. Does this graph make any sense given that you are plotting the magnitude ratio of the capacitor voltage as a function of frequency? If not - figure out why not. If the plot seems to make sense so far, however, you may proceed to the next step.

Next, have your code load the information from the AC Sweep. Add a plot of the values of $20\log_{10}(H)$ you got from the AC Sweep versus the forcing function frequencies to the one you just created. You have many of these data points, so you can plot them as a solid line in whatever color you like best. Your eight dots should be pretty close to the line.

For the second figure, follow a very similar procedure for plotting the transient-based and AC Sweep-based phases (in degrees!) on the same graph. Remember that the original data sets will be in radians. In the lab report, you will include these two graphs as well as the code used to create them. You should also comment on how well or poorly the transient data matches the AC Sweep and any reasons you can think of for any discrepancies.

8.6 Summary of Lab Report

For the lab report, you will need to include:

- What values you used for R and C and what your τ, ω_{co}, and f_{co} for your particular filter would be.
- A discussion of how the Tinkercad simulation values changed for the sinusoidal input when you increased the frequency.
- A data table of the $\mathbb{H}(j\omega)$ you found from the individual transient responses.
- A Bode magnitude plot for the capacitor voltage with the values you found using the one-frequency-at-a-time transient analysis as dots and the values found by the AC Sweep as lines.
- A Bode phase plot for the capacitor voltage with the values you found from the one-frequency-at-a-time transient analysis as dots and the values found by the AC Sweep as lines.
- A discussion of the similarities / differences between the values obtained through transient analysis and those obtained through the AC Sweep.
- A discussion of which parts of this lab were clearest and which were not; which parts felt like you were learning the most and which seemed like busy-work.
- A list of recommendations for how you might change / expand / improve / clarify this lab going forward in order to make sure the goal of comparing simulated, analytical, and numerical results is achieved.

You will also be uploading your three Tinkercad screen shots, the Schematic Image and Grapher Image from Multisim, the nine data files, your code for analyzing the data files, your Bode magnitude plot, and your Bode phase plot. You can include the images in your lab report or have them as separate files - in the latter case, in your lab report provide a description of what is contained within each file name.