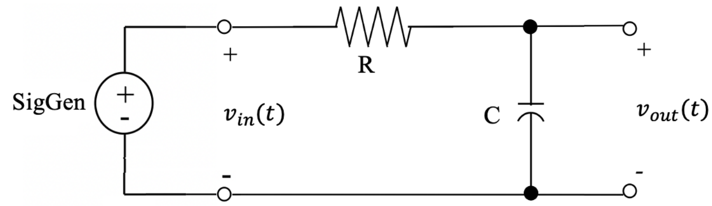
ELE 215 – Lab 5 – Bode Plot of an RC Low Pass Filter

Objectives

- Measure magnitude and phase data for a lowpass filter; generate a Bode plot comparing theory and experimental data.

Notes

- The circuit:



Procedure

1. <u>Setup:</u>

   a) Collect your team's resistor and capacitor from the bins; measure and record their nominal and actual values on the summary sheet. Don't forget units! If the actual values are not within a few percent of the nominal values, reselect components.

   b) Compute the break frequency for your selected components, $f_B = 1/2\pi RC$, to 3 significant figures and record on the summary sheet.

   c) Build the series RC circuit shown above. Connect the signal generator to provide the input, $v_{in}(t)$, and connect the scope to observe $v_{in}(t)$ on channel 1 and $v_{out}(t)$ on channel 2.

   d) Turn on the signal generator and set it for a 1 kHz sinusoid with an amplitude of 4 volts (8 Volts peak-to-peak).

   e) Turn on and configure the scope as follows:
      - Set both channels for AC coupling.
      - Set the measurement menu to show the frequency of channel 1, the amplitudes of both channels, and the phase shift between the two channels (on the scope menu for channel, set this as channel 2 minus channel 1, CH2-CH1).
      - If you've got things connected right, you should see two sinusoids of about the same amplitude almost lined up in phase.

   f) Take a few moments to vary the frequency of the input, observing the changes of the two sinusoids relative to each other; both the changes in their amplitudes and the phase shift between them (press AUTOSET or adjust the time scaling knob on the scope to get a good view of both sinusoids, as needed). At higher frequencies you should see considerable phase shift between the two signals (as much as $-90°$, a quarter of a cycle, but no more!) and $v_{out}(t)$ will be smaller than $v_{in}(t)$ while at lower frequencies the two waveforms should be pretty much aligned in time and equal in amplitude.

g) Set the signal generator for your expected break frequency, f_B, from above. Using the numbers from the measurements menu, verify that the amplitude of v_{out} is 3 dB below the input amplitude (i.e.$4/\sqrt{2} \approx 2.83$ volts) and that the phase shift is 45 degrees; if it is not, make a small adjustment in the frequency to get closer. Record this experimental value on your summary sheet. If the numbers on the scope are jumping around use the "stop" button to freeze the action. Demonstrate your result to the TA.

2. <u>Take data:</u>

   As shown on the summary page I want you to collect data, 7 sets in all including the one above, at frequencies ranging from $1/8^{th}$ to 8 times the break frequency. In all cases, the phase shift should be negative (assuming that you have configured the measurement menu correctly).

3. <u>Reporting:</u>

   Now that you have some data, the goal is to <u>generate</u> a Bode plot for your circuit, comparing the theoretical result to your experimental data.

a) Using a MatLab script similar to mine from Recitation 7, create a Bode plot of the theoretical response using your measured R and C.
b) Compute the amplitude gain of the circuit at each frequency from your experimental data; this is just the ratio of the measured output and input amplitudes. Add this and the phase data to your plot. Employ the following:
   - The theoretical data should appear as a dashed line on each set of axes; use enough frequencies for a smooth plot.
   - Show the experimental measurements as symbols (e.g. circles); do <u>NOT</u> connect them by any line as you already have a line from the theory.
   - Make the symbols large enough, the dashed line thick enough, and the fonts for the words large enough so that this is easily read.
c) Make this plot pretty as I will be carefully looking for nice plots and will penalize missing plot components.
d) Print your plot as a single page and combine it with the lab summary sheet as a two page pdf document; submit this single file in the usual way on Brightspace. If you've taken good data, the experimental data should match the theory quite well. If not, redo your work.

Bode plot check list:

- Two stacked plots, magnitude vs frequency on the top one a phase shift versus frequency on the bottom one
- Frequency variable:

- Unit in Hertz
- Logarithmic axes (i.e. semilogx in MatLab)
- Even powers of 10 for the range (e.g. 100 = 10^2 to 10,000 = 10^4), wde enough to capture data and interesting part of the theoretical curve, but not too wide to waste space
- Same scaling for both sets of axes

- Magnitude variable:
  - Units of decibels, $= 20\ \log_{10}|H(f)|$
  - Wide enough scale to show interesting stuff, but typically no more than a total of 40 dB
- Phase shift variable:
  - Units of degrees
  - Scale ends should be multiples of 90^o
- Theory shown as a dashed line, measurements as symbols large enough to easily see
  - Do not connect measurements with any lines, just use the symbols
- Turn grid on
- Annotate axes with labels and units
- Set fonts large enough to be easily read