Lab Exercise 04 RLC Frequency Response

In this lab exercise, we will be measuring the steady-state response of a capacitor voltage in the RLC circuit shown in Figure 04.1 with an AC input. We will record the data by hand, enter it into a data file in MATLAB, plot the data, derive an analytic model, and compare the analytic model to the data.

The objectives of this lab exercise are for students:

1. to explore steady state circuit frequency response,
2. to deepen their understanding of RLC circuits,
3. to learn to better measure AC voltage with an oscilloscope,
4. to model real circuits and compare the theory and experiment, and
5. to get a sense of resonance in a circuit.

Lab 04.1 Materials

The following materials are required for each lab station:

- ☐ 1. a function generator,
- ☐ 2. an oscilloscope,
- ☐ 3. a multimeter,
- ☐ 4. a breadboard,
- ☐ 5. four male-male jumper wires,
- ☐ 6. a 78 Ω resistor,
- ☐ 7. a 100 nF capacitor (label: `104`),
- ☐ 8. a 10 mH inductor,
- ☐ 9. one BNC Y- or T-connector,
- ☐ 10. one BNC cable, and
- ☐ 11. two BNC-to-alligator cables.

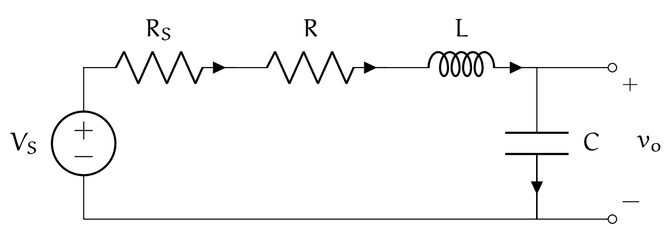

Figure 04.1: a model of an RLC circuit with a source model including the source output impedance R_S. Since the function generator is not a regulated source, we must consider its output impedance.

Lab 04.2 Build the circuit

The following steps describe how to build the RLC circuit of Figure 04.1 on the breadboard. Note that the output resistance R_S of the source is internal to the function generator.

- ☐ 1. Measure and record the actual resistance R of the resistor and capacitance C of the capacitor with a multimeter.
- ☐ 2. Build the passive portion of the circuit on a breadboard.
- ☐ 3. Use the function generator as the voltage source V_S. Its output resistance is $R_S = 50\ \Omega$. Use a BNC T- or Y-connector to split the output of the output such that one cable connects directly to the oscilloscope's Channel 1 and the other connects (via alligator clips and jumpers) across the circuit.
- ☐ 4. Into Channel 2 of the oscilloscope, connect another cable that has alligator clip probes connected to jumpers probing $v_o(t)$.

Lab 04.3 Measure the steady state response at different frequencies

In steady state, this linear circuit with a sinusoidal input will have a sinusoidal output. The only difference between the input and output signals will be in amplitude and phase. It is these two quantities we will measure in each signal.

- ☐ 1. Set the function generator to a sinusoidal output around 100 Hz and record the actual frequency. (Take care that the output channel above the connector is pressed to turn it on!) Make sure you can see the input and output sinusoids, simultaneously. Measure and record the peak-to-peak amplitudes of the *input* ($\widetilde{V}_S - \tilde{v}_{R_S}$) and the *output* ($\tilde{v}_o$). Also measure and record the *time lag* between input and output. (That's four recorded measurements, folks.)
- ☐ 2. Repeat these measurements and record the results in Table 04.1 for inputs near the input frequencies listed in the table (you don't need to be that close, just record the actual frequencies).
- ☐ 3. By fiddling with the input frequency, find a frequency that yields the highest output amplitude and make a final set of measurements at that frequency. Don't forget to include this in your data (it will be obvious in your report plots).

Box 04.1 Tip for those using the BK Precision 2120B oscilloscope

If you're using the BK Precision 2120B oscilloscope, don't use the fine-tuning knobs on the vertical scale knobs of the oscilloscope. Instead, rotate them all the way clockwise until they "click" for calibrated voltage operation.

Box 04.2 Tip for those using the BK Precision 4003 function gen.

If you're using the BK Precision 4003 function generator, your frequency control isn't very precise, but don't worry: you can measure it easily by taking the reciprocal of the period on the oscilloscope!

Lab 04.4 Report requirements

Write a detailed report of your experimental results, as outlined in the report template. Pay special attention to the following.

- ☐ 1. A *thorough* description of the theoretical analysis of the circuit using impedances. Make sure you derive the *amplitude ratio* $r(\omega)$ of output over input as a function of source frequency ω. Also (along the way) derive the theoretical phase shift $\phi(\omega)$ between input and output.
- ☐ 2. A figure with the *theoretical* r plotted versus logarithmic frequency (use the measured R and C values) overlayed with the measured amplitude ratio $\tilde{r}$ data.
- ☐ 3. A figure with the *phase shift* ϕ plotted versus logarithmic frequency overlayed with the measured phase shift $\tilde{\phi}$ data.
- ☐ 4. The other parameters measured in the lab (e.g. R and C).

$f(\mathrm{Hz})$	$\tilde{f}$ (Hz)	$\widetilde{V}_S - \tilde{v}_{R_S}$ (V_{pp})	$\tilde{v}_o$ (V_{pp})	$\tilde{\Delta}$ (ms)
100				
127				
162				
206				
263				
335				
428				
545				
695				
885				
1128				
1438				
1832				
2335				
2976				
3792				
4832				
6158				
7847				
10000				
peak				

Table 04.1: table of RLC circuit measurements: frequency $\tilde{f}$, input amplitude $\widetilde{V}_S - \tilde{v}_{R_S}$, output amplitude $\tilde{v}_l$, and time delay $\tilde{\Delta}$.