Physics 4L Lab 5 (2026)

5.1 LCR circuit - driven response to a sinusoidal input

(Re)build the circuit (Figure 5.1) with **L** = 15 mH (accompanied by $\mathbf{r_L} \approx 30\ \Omega$) **C** =33 nF, and $\mathbf{r_{Thevenin}}$ as determined below.

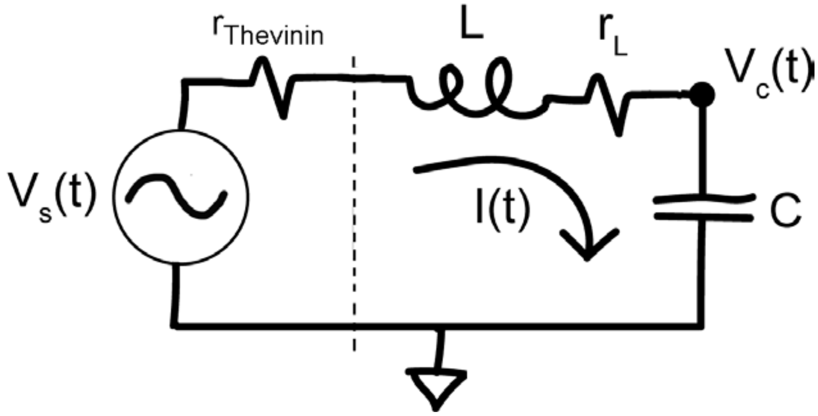


Figure 5.1 The serial RLC circuit for resonance experiments.

Choose $V_S(t)$ to be a sine wave of about 5V amplitude from the waveform generator. Choose the offset to be zero. Carefully sweep through the region of the resonance. Measure $V_C(t)$ and $V_S(t)$ with your oscilloscope.

Q1. Determine the resonant frequency as the maximum peak-to-peak value of the voltage across the capacitor. Take a SCREENSHOT of $V_C(t)$ and $V_S(t)$ and explain.

Let's now again estimate the Thevenin resistance, denoted $\mathbf{r_{Thevenin}}$, of the waveform generator, which will contribute to the resistance in the LCR resonant circuit. As we will calculate for HW, the series LC has zero "impedance" at resonance. The drop in the amplitude of $V_s(t)$ can be used in a voltage divider equation with the known value of $\mathbf{r_L}$ to find the unknown value of $\mathbf{r_{Thevenin}}$.

Q2. Estimate the Thevenin resistance of the waveform generator.

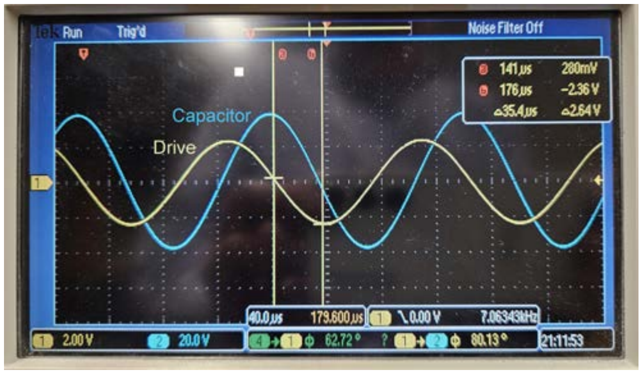
Q3. Estimate the expected the resonant frequency using $r_{total} = r_L + r_{Thevenin}$?

Remember that there are differences between the free induction resonant frequency (class notes) and the driven frequency (HW). In terms of radian frequency:

$$\omega_{Free\ induction} = \sqrt{\omega_o^2 - (1/2\tau_L)^2}$$

$$\omega_{\text{Driven resonance}} = \sqrt{\omega_o^2 - 2(1/2\tau_L)^2}$$

Q4. Determine the resonant frequency as the location of the rapid ($\pi/2$) phase shift between $V_C(t)$ and $V_S(t)$. Take a SCREENSHOT and explain. Is your answer the same for the phase versus the amplitude method?



Q.5 Choose values of frequency in the vicinity of the resonant frequency, say 10-times higher and ten-times lower, and construct a Bode plot, i.e., the ratio of amplitudes and the phase. Be sure to sample enough logarithmically evenly spaced frequencies to see the shape of the curve.

5.2 Rapid measurement of the magnitude of the transfer function

The waveform generator has a sweep feature that lets you vary the frequency across a range of initial (start) and final (stop) frequencies, at a user defined rate. Further, the sweep can be logarithmic in time or linear in time.

The oscilloscope, under **Math**, has a **Fast Fourier Transform (FFT)** feature that will indicate the response at each frequency. The FFT is a means to quicly take a Fourier transform when the number of points is a power of 2, e.g., $2^{10} = 1024$. The oscilloscope, under **Acquire**, has a **Persistence** feature, so that the sweep in frequency can be turned into overlapping FFTs and thus generate the magnitude of the spectral repones of the circuit. Recall that the bandwidth is just the inverse of the time spent at each frequency, so the spectral estimates with increase in accuracy as you sweep more slowly.

Q.6 Perform a control run. Use the oscilloscope to take the FFT of the input "Continuous" sine wave from the waveform generator and manually vary the frequency of the sine wave to see the peak position move. Take a SCREENSHOT and explain why the width of the peak is not infinitely narrow.

Q.7 Now switch to a "Sweep" sine wave. Try this method to get the magnitude of the spectral response of your serial RLC circuit. Take a SCREENSHOT and explain its features, i.e., low frequency limit, high frequency limit, peak frequency, and width of the peak.

Q.8 Since the waveform generator is already non-ideal in terms of being a voltage source, speculate on how this affects the estimate of the peak frequency of the resonance. Do the same for the magnitude of the resonance.

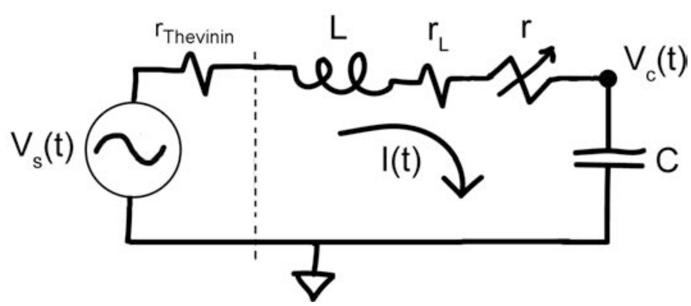


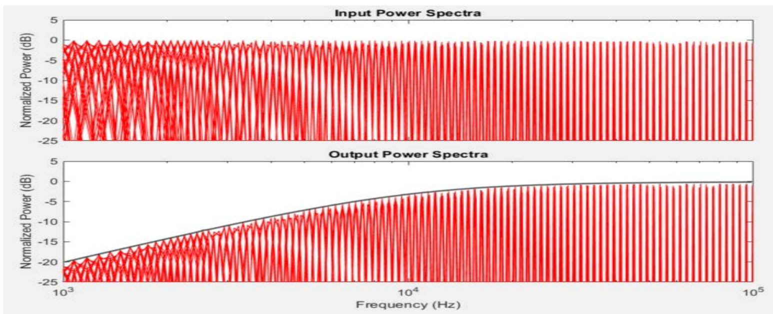
Figure 5.2.

Q.9 Add a 300 Ω resistor, r, in series with the inductor and remeasure the spectral response of your serial RLC circuit (Figure 5.2). Take a SCREENSHOT and explain what has changed, what has not changed, and why.

5.3 Data acquisition

The next set of exercises will use the waveform generator and the oscilloscope to "rough out" a circuit, followed by use of the waveform generator and analog to digital conversion with the National Interface DAQ module, controlled by Matlab, for more complete and precise measurements.

- Record both the waveform output, $V_s(t)$, and and the circuit output, $V_{out}(t)$.
- The DAQ inputs are <u>not</u> compatible with oscilloscope probes.
- The analysis code is on the lab website. The desired outup is power, i.e., the square of the FFT or Power ~ V(ω)V(ω)*
- For these exercises, the acquisition rate is preset to 200 kHz.
- Test your set-up and the accompanying analysis code to compute the power spectrum, the square of the FFT.



5.4 Filter Circuit designs.

Use available components in the laboratory to build circuits

- C = 2000 pF, 0.01 μF, 0.033 μF, and 0.1 μF
- L = 1 mH (r_L ~ 30 Ω), 10 mH (r_L ~ 300 Ω), and 15 mH (r_L ~ 30 Ω), ; remember to measure the internal resistance of the inductor.
- Keeping the load resistance on the waveform generator large, R > 2 kΩ.

Use this procedure to design the circuits below

- Attempt to hit the desired "break frequency" at 5 % (and no worse than 10 %).
- Acquire data first as roughed out with the oscilloscope to achieve the design parameter(s).
- Measure carefully using a slow, logarithmic sweep, i.e., 2 or more sweeps of 30 s of increasing frequency and 30s of decreasing.
- Apply a "short FFT" coded in Matlab. This analysis calculates the local frequency content within a short duration of a longer signal.

Q.10 An RC high pass with f_{3dB} = 1.0 kHz (Figure 5.3). Include a SCREENSHOT of the rough performance and the full Bode plot of the magnitude only to demonstrate that your measurements confirm that you hit the desired "break frequency.

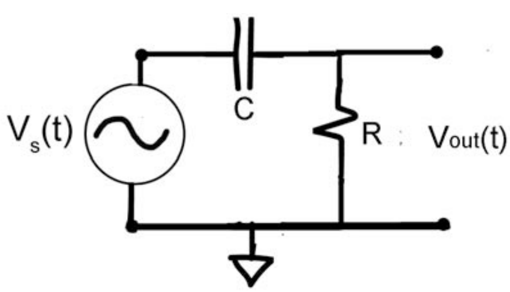


Figure 5.3.