

Experiment 10

Lab Activity

Pre-Lab Activity

Read the Pre-reading materials, the laboratory activity and the post-lab before coming to the Laboratory. Solve the following problems and submit your solution to your instructor.

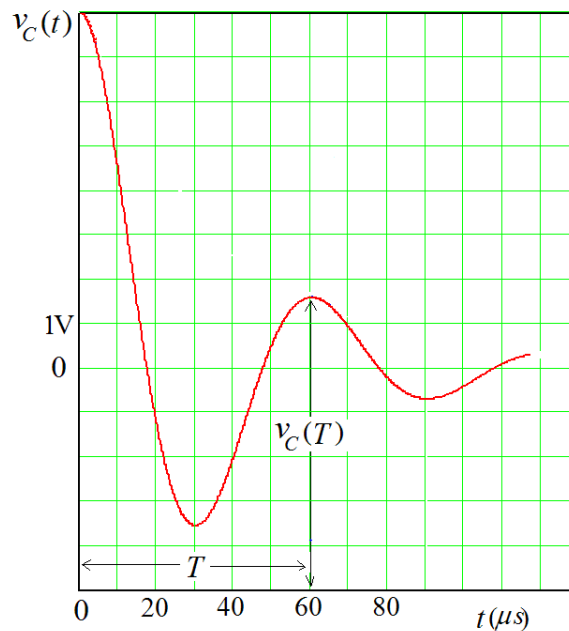
Problems

1. Determine the oscillation (radian) frequency, ω_o , for an ideal LC circuit with $L = 1\text{mH}$ and $C = 0.1\mu\text{F}$.
2. Consider an LC circuit with $L = 1\text{mH}$. What should the capacitance be so that $f_o = \omega_o/2\pi = 500\text{Hz}$.
3. Determine the *damping factor* (α) and the *damped frequency* (ω_d) for a series RLC circuit with $R = 100\Omega$, $L = 1\text{mH}$ and $C = 0.1\mu\text{F}$.
4. Plot the capacitor discharge voltage [Equation (8)] for the circuit of Problem 3. Assume $V_o = 5\text{V}$.
5. Plot the capacitor charging voltage [Equation (11)] for the circuit in Problem 3. Assume $V_o = 5\text{V}$.
6. Show that $v_c(0) = V_o$ for the voltage signal in Equation (8). Hint:
$$\cos(\tan^{-1} x) = \frac{1}{\sqrt{1+x^2}}.$$
7. Show that the expression for the under-damped inductor current for the circuit in Figure 4, starting with Equation (8), is given by:

$$i_L(t) = \frac{V_o}{L\omega_d} e^{-\alpha t} \sin(\omega_d t)$$

8. Consider a series RLC circuit with $R_T = 400\Omega$, $L = 1\text{mH}$, $C = 0.1\mu\text{F}$ and $V_o = 8\text{V}$. Show that the circuit response is over-damped. Plot the circuit current $i(t)$.
9. Determine the value of R_T that leads to critical damping in a series RLC circuit with $L = 1\text{mH}$ and $C = 0.1\mu\text{F}$. Write the expression for the circuit current $i(t)$. Plot $i(t)$. Assume that $V_o = 8\text{V}$.
10. Write down (in simplified form) the expressions for the capacitor voltage and inductor voltage for the circuit in Problem 8. Plot these expressions using a common system of axis.

11. Repeat Problem 10 using Multisim. Use the virtual scope to display the voltage signals.
12. Consider the following response for an under-damped RLC circuit with $R_T = 62\Omega$. Use the graph to estimate the values of L and C .



Laboratory Activity

Required components:

One 470Ω resistor ($\pm 5\%$, $\frac{1}{2}$ W)

One 500Ω potentiometer ($\pm 10\%$, $\frac{1}{2}$ W)

One 1mH ferrite-cored inductor ($\pm 10\%$, 70mA)

One $0.1\mu F$ multilayer ceramic capacitor ($\pm 10\%$)

1. Use the multimeter to measure and record the actual capacitance of the $0.1\mu F$ capacitor, the actual resistance of the 470Ω resistor and the resistance R_o of the 1mH inductor.

2. Build the circuit in Figure 6a using the 1mH inductor and the 0.1 μ F capacitor. Set the function generator so that it outputs the signal in Figure 6b with $V_S = 8\text{V}$ and $f = R/20L$. Here, $R = R_o + 50$.
3. Use the scope to display a complete charge/discharge capacitor voltage waveform. The display should look similar to that in Figure 7. Save the display in an image file.
4. Adjust the horizontal and vertical gain of the scope so that it displays the largest possible discharge waveform (employ signal averaging). Use the cursor system to measure T and $v_C(T)$. Refer to Figure 8 for details.
5. Adjust the knob of the 500 Ω potentiometer (operating as a variable resistor) so that one of its ports is set to few Ω 's. Add this variable resistor to your circuit as shown in Figure 13. As you monitor the capacitor voltage on the scope, slowly increase the resistor value. Record your observations and draw sketches of the displayed waveforms. You should be able to see the transition from under-damped operation to over-damped operation.
6. Adjust the resistor value so that the scope displays the critically-damped response. Save the display into an image file. Remove the potentiometer from the circuit (do not touch the knob) and measure the resistance, R_{pot} , of the port you have used as a variable resistor.
7. Build the series RLC circuit in Figure 12 using the 470 Ω resistor. Adjust the function generator output so it generates the negative square signal shown in Figure 10. Let $V_o = 8\text{V}$ and set the frequency to $f = \alpha_1/10 = (\alpha - \sqrt{\alpha^2 - \omega_o^2})/10$ (note: $\alpha = R_T/2L$, $\omega_o = 1/\sqrt{LC}$ and $R_T \cong 470 + R_o + 50\ \Omega$).
8. Connect the scope to measure the resistor voltage, $v_R(t)$. Adjust the scope so as to display a complete charge/discharge voltage cycle. Save the display. Make sure you record the horizontal and vertical gain settings of the scope, and make a note of the zero reference of the displayed signal.
9. Repeat Step 8 for the function generator output signal (i.e., v_{ab} in Figure 9).
10. Swap the capacitor and the resistor. The capacitor should now have one of its terminals connected to the ground node. Repeat Step 8 for the capacitor voltage, $v_C(t)$.

11. Swap the capacitor and the inductor. The inductor should now have one of its terminals connected to the ground node. Repeat Step 8 for the inductor voltage, $v_L(t)$.
12. Sort all components and give them back to your instructor.

Post-Lab Activity

Write a [technical report](#) that discusses your observations and includes analysis and justifications of all steps in this activity. Tabulate and/or plot experimental data whenever possible. More specifically, your report should address the following points:

- Compute the value of the damping factor α and the damping frequency ω_d using the measurements you made in Step 4. Employ Equation (9) with $R = 50 + R_o$ to find the experimental value of L and compare it to its 1mH nominal value.
- Compute ω_o using Equation (3) and using the measured values of C and L . This is the frequency at which the circuit will oscillate if $R = 0$. How does ω_o compare to the measured damped frequency ω_d ?
- What is the effect of increasing the resistance value on the capacitor voltage in Step 5? Give a qualitative explanation justifying the transition from damped oscillatory response (under-damped response) to pure exponential decay (over-damped response) in a series RLC circuit.
- The total resistance that led to critical damping is given by $R_T = 50 + R_o + R_{pot}$, where R_{pot} is the variable resistor value that you obtained in Step 6. Compare R_T to its theoretical value (i.e., $2\sqrt{L/C}$).
- Compare the capacitor voltage and the inductor voltage waveforms you obtained in Steps 10 and 11 to those obtained via simulation using Multisim (i.e., simulate the circuit).