ELECENG 2CI4 AD3 Homework 3

Resistor-Inductor-Capacitor (RLC) Circuits (with PSpice and Hardware)

Department of Electrical and Computer Engineering, McMaster University, Fall 2025

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Required Equipment

- Analog Discovery 3 kit.
- Custom breadboard with jumper cables.
- Computer with OrCAD PSpice software.

Required Components

- $1 \times 100\ \Omega$ resistor (0.25 W)
- $3 \times 1\ \mathrm{k}\Omega$ resistors (0.25 W)
- Various other resistors in the 2CI4 components kit (as required)
- 1×1.5 mH inductor (Part Number: 434-01-152J)
- 1×10 nF capacitor (Code: 103)

Timeline:

- Release Date: Monday, November 10, 2025.
- Submission Deadline: **Friday, November 28, 2025, 11:59 pm.**

Required Deliverable:

- Each student should make a **group of two** with another student. To keep things simple, you should continue with your AD3 Homework 1/2 partner.
- Within a group, each student must first work on AD3 Homework 3 individually.
- After each student is done with their homework, the two students in the group should get together and evaluate each other's work (i.e., peer evaluation). We expect that you will critically analyze each other's work so that you can learn from each other and rectify any mistakes before submitting your work.
- Finally, each group of two students must write and submit a formal report, i.e., **one report per group of two students** (not two reports).
- In your report you should provide part wise answers to all questions in order. You should provide well structured answers that clearly state your observations and are supplemented by tables, calculations, photographs, and screenshots of the measurements, as applicable.
- Work that needs to be provided in the report has been **mentioned in bold**.

Your report can be prepared in MS Word or in LaTeX if you prefer. **Make sure that you submit it only as a single PDF format document.** **Furthermore, you must follow the following two points for providing identification information:**

1. The report must have a title page. Both group members should clearly state their full name, student numbers, and class section(s) on the title page of the report.
2. The report file should be named as: EE2CI4_AD3_HW3_Student1_Student2.pdf, where Student1 is the student number of the first student and Student2 is the student number of the second student.

Submission Procedure:

- Only one student in each group should submit the report to the **Avenue Dropbox** for AD3 Homework 3, while the other should confirm that the report has been submitted (no double submissions please).
- If you follow the above-mentioned file naming convention and also mention both students' names on the title page of the report, we will be able to allocate marks (and provide feedback) to both group partners without issue.
- The Dropbox will accept submissions until 11:59 pm (Eastern Standard Time) on Friday, November 28, 2025. The Dropbox will cease accepting new submissions after this time and late submissions will not be accepted separately (zero marks will be awarded).

Penalties:

- If three or more students submit one report together, then all students mentioned on the report will receive a mark of zero on the homework.
- Students are expected to provide a **formal and properly formatted report** for this homework with a title page that provides their identification information as mentioned above. If students do not abide by this requirement, e.g., provide a handwritten report, do not provide a title page, and so on, then a 10 mark penalty will be applied to their AD3 Homework 3 marks.

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1 Objectives

- To become familiar with overdamped, critically damped, and underdamped second-order transient circuits by working with a simple series RLC circuit.
- To simulate and analyze a simple RLC circuit in PSpice.
- To build a simple RLC circuit in hardware and analyze it by using the Analog Discovery 3.

2 AD3 Homework 3 Tasks

Work that needs to be provided in the report has been mentioned in bold.

2.1 Part 1

Consider the simple series RLC circuit given in Fig. 1. This circuit is a second-order transient circuit. It is second-order because of the presence of two energy storage elements (an inductor and a capacitor). It is transient because of the nature of the voltage source (square wave that is similar to repeated switch action). Do the following:

a. **Write the loop equation for this circuit. Show your work in the report.** This should be a second-order differential equation in terms of $i(t)$, forcing function $v_S(t)$, R, L, and C.

b. **Now write the homogeneous version of the equation that you obtained above.** Remember, the general form of the homogeneous equation for second-order circuits is:

$$\frac{d^2x_c(t)}{dt^2} + 2\zeta\omega_0\frac{dx_c(t)}{dt} + \omega_0^2 x_c(t) = 0 \quad (1)$$

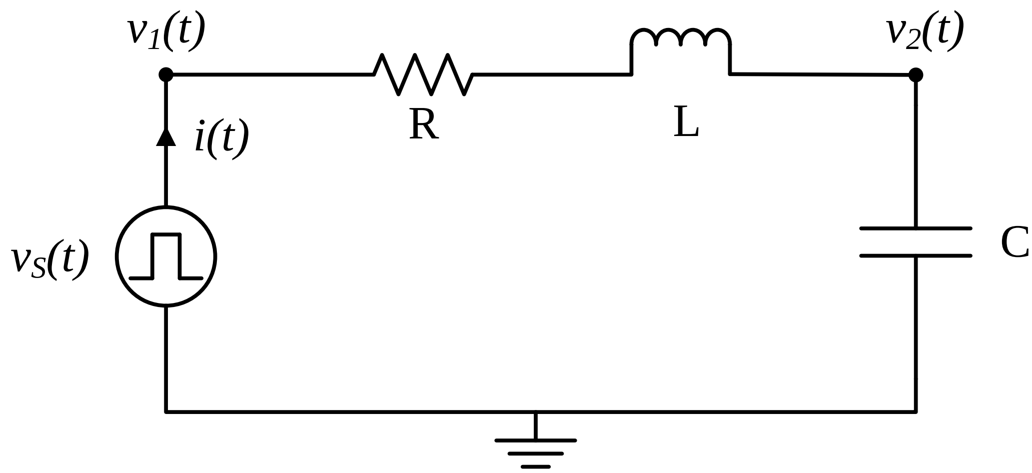

Figure 1: Circuit for AD3 Homework 3.

c. **Find an expression for the *undamped natural frequency* ω_0 in terms of R, L, and/or C. Show your work in the report.** [Hint: This can be done by comparing the second-order homogeneous equation that you obtained for the circuit of Fig. 1 in Part 1(b) with the general form of such equations given in Eq. 1.]

d. **Similarly, find an expression for the *exponential damping ratio* ζ in terms of R, L, and/or C. Show your work in the report.**

2.2 Part 2

Use the following values in this part:

- $R = 3\ \text{k}\Omega$
- $L = 1.5$ mH
- $C = 10$ nF

Do the following:

a. **Plug in the values of R, L, and/or C into the expression for the *exponential damping ratio* ζ that you obtained in Part 1(d) and find the value of ζ for this case. Is this circuit overdamped, critically damped, or underdamped?**

b. **PSpice:** Simulate the circuit of Fig. 1 with the given values of R, L, and C in PSpice.

- As a source, use a Square wave that goes from 0 V to 5 V and has a frequency of 2.5 kHz. To simulate such a square wave use a *pulse voltage source* and set its time Period to 0.4 msec (PER = 0.4m), set Pulse Width to half the period, i.e., 0.2 msec (PW = 0.2m), Rise Time to 0.1 nsec (TR = 0.1n), Fall Time to 0.1 nsec (TF = 0.1n), Delay Time to zero (TD = 0), Lower Voltage to zero (V1 = 0), and Upper Voltage to 5 V (V2 = 5).
- Place voltage probes at the points where node voltages $v_1(t)$ and $v_2(t)$ have been marked in Fig. 1 to view the input voltage and the voltage at the point between the inductor and capacitor, respectively (all with respect to ground). Observe that node voltage $v_1(t)$ is also the voltage across the source ($v_S(t)$) and node voltage $v_2(t)$ is the voltage across the capacitor. **Run the PSpice simulation such that two complete cycles are visible. Provide a screenshot of the resulting PSpice simulation plot in your report.**
- Visually inspect the plot of the node voltage $v_2(t)$ and **comment in your report whether the waveform confirms the finding in Part 2(a).**

c. **AD3:** For the given values of R, L, and C, build the circuit of Fig. 1 onto the breadboard by using components from your 2CI4 components kit. You do not have a 3 kΩ resistor in your kit but you can certainly construct one by combining various resistors that are available in the kit.

- Drive the circuit with a square waveform having a frequency of 2.5 kHz going from 0 V to 5 V. This waveform can be generated by using the AD3 waveform generator (Pin W1). Connect the AD3 oscilloscope Channel 1 (Pin 1+) to Node 1 ($v_1(t)$) and Channel 2 (Pin 2+) to Node 2 ($v_2(t)$). Connect the oscilloscope Pins 1− and 2− to Ground.
- Display Channel 1 and Channel 2 together on the AD3 oscilloscope to view the $v_1(t)$ and $v_2(t)$ waveforms. To view around two cycles, set the vertical scale to 1 V/division for both Channels 1 and 2, and the horizontal time scale to 100 μsec/division. You can drag the waveforms down a bit to view them in their entirety, however, ensure that the same vertical offset is added to both channels. **Provide a screenshot of the resulting AD3 oscilloscope plot in your report.**
- Visually inspect the plot of node voltage $v_2(t)$ on the AD3 oscilloscope and **comment in your report whether the waveform is comparable to the one obtained in the PSpice simulation in Part 2(b) and whether it confirms the finding in Part 2(a).**

2.3 Part 3

Use the following values in this part:

- $R = 100\ \Omega$
- $L = 1.5$ mH
- $C = 10$ nF

Do the following:

a. **Plug in the values of R, L, and/or C into the expression for the *exponential damping ratio* ζ that you obtained in Part 1(d) and find the value of ζ for this case. Is this circuit overdamped, critically damped, or underdamped?**

b. **PSpice:** Simulate the circuit of Fig. 1 with the given values of R, L, and C in PSpice.

- Use the same source as constructed in Part 2(b).
- Place voltage probes as in Part 2(b) and plot the waveforms for $v_1(t)$ and $v_2(t)$. **Provide a screenshot of the resulting PSpice simulation plot in your report.**
- Visually inspect the plot of the node voltage $v_2(t)$ and **comment in your report whether the waveform confirms the finding in Part 3(a).**

c. **AD3:** For the given values of R, L, and C, build the circuit of Fig. 1 onto the breadboard by using components from your 2CI4 components kit.

- Drive the circuit by using the same source as in Part 2(c). Make the pin connections also as in Part 2(c).
- View the $v_1(t)$ and $v_2(t)$ waveforms as was done in Part 2(c). Set the horizontal and vertical scales as discussed in Part 2(c). **Provide a screenshot of the resulting AD3 oscilloscope plot in your report.**
- Visually inspect the plot of the node voltage $v_2(t)$ on the AD3 oscilloscope and **comment in your report whether the waveform is comparable to the one obtained in the PSpice simulation in Part 3(b) and whether it confirms the finding in Part 3(a).**

d. In your **PSpice Simulation** for this part, replace the 100 Ω resistor with a 10 Ω resistor and plot the waveforms for $v_1(t)$ and $v_2(t)$ again. **Provide a screenshot of the resulting PSpice simulation plot in your report. Compare the plot of waveform $v_2(t)$ obtained in this part with the one obtained in Part 3(b) and explain the difference(s) that you observe.** [Hint: To develop this explanation, you should refer to the general form of the natural response (i.e., general form of the complementary solution) for the case under consideration (i.e., overdamped or critically damped or underdamped).] *Note: You do not have to do Part 3(d) on the AD3.*

2.4 Part 4

Use the following values in this part:

- $L = 1.5$ mH
- $C = 10$ nF

Do the following:

a. **Find the value of R that will make the circuit of Fig. 1 *Critically damped.***

b. **PSpice:** Simulate the circuit of Fig. 1 in PSpice with the given values of L and C, and the value of R that you determined in Part 4(a).

- Use the same source as constructed in Part 2(b).
- Place voltage probes as in Part 2(b) and plot the waveforms for $v_1(t)$ and $v_2(t)$. **Provide a screenshot of the resulting PSpice simulation plot in your report.**
- Visually inspect the plot of the node voltage $v_2(t)$ and **comment in your report whether the waveform appears to be critically damped.**

c. **AD3:** For the given values of L and C, and the value of R that you determined in Part 4(a), build the circuit of Fig. 1 onto the breadboard by using components from your 2CI4 components kit. You can construct the required resistor R by using series and/or parallel combinations of resistors that are present in your 2CI4 components kit.

- **Provide an updated circuit diagram that clearly shows the resistor configuration that achieves the value of R found in Part 4(a).**
- **Provide a photograph of your breadboard circuit in the report.**
- Drive the circuit by using the same source as in Part 2(c). Make the pin connections also as in Part 2(c).
- View the $v_1(t)$ and $v_2(t)$ waveforms as was done in Part 2(c). Set the horizontal and vertical scales as discussed in Part 2(c). **Provide a screenshot of the resulting AD3 oscilloscope plot in your report.**
- Visually inspect the plot of the node voltage $v_2(t)$ on the AD3 oscilloscope and **comment in your report whether the waveform is comparable to the one obtained in the PSpice simulation in Part 4(b) and whether it appears to be critically damped.**