

Project Specification: Interactive RLC Circuit Simulator (Version 2.0)

1. Project Overview

1.1. Project Title:

Interactive RLC Circuit Simulator

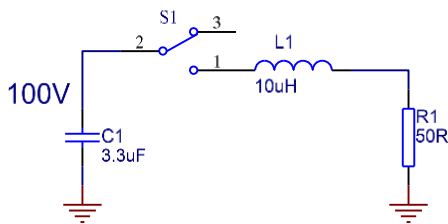
See <https://aistudio.google.com/prompts/1jcAe2EaO7la875p8ndSBUHjwvAYRmsxq>

1.2. Elevator Pitch:

A web-based application that simulates and visualizes the current response of a series RLC (Resistor-Inductor-Capacitor) circuit. Users can configure the circuit's parameters and initial conditions to instantly see the resulting current waveform, making it an ideal educational tool for students, hobbyists, and engineers.

1.3. Core Objective:

To create a user-friendly program that accurately simulates the discharge current in a series RLC circuit. The user must be able to define the initial voltage, resistance, inductance, and capacitance, and in response, view a graph of current over time and see the calculated peak current.



2. Core Functionality & Physics

2.1. Circuit Model

The simulation is based on a series RLC circuit. The initial state (at time $t=0$) is:

- A capacitor (C) is charged to an initial voltage (V_0).
- There is no initial current flowing through the inductor ($I(0) = 0$).
- At $t=0$, a switch closes, connecting the charged capacitor to the inductor (L) and resistor (R), allowing the capacitor to discharge through the circuit.

2.2. Governing Equations

The primary behavior is governed by the RLC differential equation:

$$L * d^2I(t)/dt^2 + R * dI(t)/dt + (1/C) * I(t) = 0$$

However, the application must also handle simplified cases where L or R are zero.

2.3. Damping Cases (for $L > 0$)

When $L > 0$, the application must correctly calculate and plot the waveform for the three possible RLC cases:

1. **Underdamped:** $(R/2L)^2 < 1/LC$
2. **Critically Damped:** $(R/2L)^2 = 1/LC$

3. Overdamped: $(R/2L)^2 > 1/LC$

2.4. Peak Current Calculation

The application must calculate the maximum absolute value of the current, $|I(t)|_{\max}$, over the simulation period and display it. For the RC case, the peak current occurs at $t=0$.

3. User Interface (UI) and User Experience (UX)

3.1. Layout

A clean, two-panel layout is recommended:

- **Left Panel (Controls):** Contains all user input fields and action buttons.
- **Right Panel (Visualization):** Contains the output graph and key metrics.

3.2. Input Controls Panel

Provide four clearly labeled input fields.

Parameter	Label	Unit	Default Value	Input Validation
Initial Voltage	Initial Voltage (V_0)	Volts	100	Numeric, can be positive or negative.
Capacitance	Capacitance (C)	μF (microfarads)	3.3	Numeric, must be greater than 0.
Inductance	Inductance (L)	μH (microhenries)	10	Numeric, must be greater than or equal to 0.
Resistance	Resistance (R)	Ω (Ohms)	50	Numeric, must be greater than or equal to 0.

3.3. Action Controls

- A single button labeled "**Run Simulation**".
- Upon clicking, it triggers the calculations and updates the visualization panel.
- After the first run, the button could be relabeled "**Re-run Simulation**" or remain the same.

3.4. Visualization Panel

- **Graph:**
 - **Title:** "RLC Circuit Current Response"
 - **Y-Axis (Vertical):** Labeled "Current (A)".
 - **X-Axis (Horizontal):** Labeled "Time (μs)".
- **Metrics Display:**
 - **Peak Current:** Displayed clearly, e.g., Peak Current: 1.57 A.

- **Circuit Status:** Display the calculated circuit condition, e.g., Status: Underdamped.
-

4. Detailed Behavior and Edge Cases

4.1. Initial State

On page load, the application should display the default values in the input fields and show a blank or placeholder graph.

4.2. Simulation Flow

1. User adjusts the input values.
2. User clicks "Run Simulation".
3. The application validates all inputs.
4. The application calculates the circuit case (RLC, RC, LC, or error).
5. It generates an array of time and current data points based on the correct formula.
6. It determines the peak current from the generated data.
7. The application renders the graph and displays the metrics.

4.3. Special Case: $R = 0$ (Ideal LC Circuit)

If $R = 0$ (and $L > 0$), the circuit becomes an ideal LC circuit.

- **Behavior:** The current oscillates indefinitely (undamped).
- **UI Display:** The status should read Status: Undamped (Ideal LC Circuit).

4.4. Special Case: $L = 0$ (RC Circuit)

If $L = 0$ (and $R > 0$), the circuit simplifies to a series RC circuit.

- **Behavior:** The current begins at its peak and exhibits a simple exponential decay.
- **UI Display:** The status should read Status: RC Circuit (Exponential Decay).

4.5. Special Case: $L = 0$ AND $R = 0$ (Short Circuit)

If both $L = 0$ and $R = 0$, this represents a direct short circuit.

- **Action:** The simulation **must not** run. Instead, it should display a clear error message, such as: "Error: A circuit with $R=0$ and $L=0$ represents a short circuit. Please provide a non-zero Resistance or Inductance."

5. Technical Recommendations (Optional)

- **Platform:** Web application (HTML, CSS, JavaScript).
 - **Charting Library:** Use a robust charting library like **Chart.js**, **Plotly.js**, or **D3.js**.
 - **Code Structure:** Separate UI logic from physics calculation logic.
-

6. Acceptance Criteria (Checklist for Completion)

1. The UI has four input fields for V_0 , C, L, and R with correct units and default values.
2. A "Run Simulation" button is present.
3. Input validation prevents simulation with non-positive C, or non-numeric values.
4. Clicking the button generates a current vs. time graph with proper labels (A vs. μ s).
5. The graph correctly displays an oscillating, decaying curve for an **underdamped** RLC case.
6. The graph correctly displays a non-oscillating curve for **overdamped** and **critically damped** RLC cases.
7. The simulation correctly handles the **R=0** case (ideal LC circuit).
8. The simulation correctly handles the **L=0** case (RC circuit).
9. The application prevents simulation and shows an error message for the **L=0 and R=0** (short circuit) case.
10. The calculated peak current is displayed and is accurate for all valid cases.
11. The calculated circuit status is displayed.
12. The graph axes auto-scale appropriately to the generated waveform.
13. The application is responsive and provides a smooth user experience.