23W-EC ENGR-11L-LEC-1 Module 4: Transient Response of the 2nd -Order Circuits

SANJIT SARDA

TOTAL POINTS

65 / 65

QUESTION 1

Series RLC Circuit Analysis 20 pts

1.1 Waveforms Image **6 / 6**

✓ **+ 6 pts** *Correct*

+ 3 pts Click here to replace this description.

+ 0 pts Missing

1.2 Inductor Resistance **3 / 3**

✓ **+ 3 pts** *Correct*

+ 2 pts Slightly Incorrect

+ 0 pts Missing

1.3 Derivation of Output Voltage **8 / 8**

✓ **+ 8 pts** *Correct*

+ 7 pts Slightly Incorrect

+ 6 pts Slightly incorrect

+ 4 pts Incorrect

+ 2 pts Incorrect

+ 0 pts Missing

1.4 Discussion 1 **3 / 3**

✓ **+ 3 pts** *Correct*

+ 2 pts Incomplete

+ 1 pts Incomplete

+ 0 pts Missing

QUESTION 2

Underdamped RLC Circuit Design 26 pts

2.1 Waveforms Image **6 / 6**

✓ **- 0 pts** *Correct*

- 1 pts Slightly higher Overshoot

- 3 pts Lower Overshoot

- 1 pts Slightly lower Overshoot

- 3 pts Higher Overshoot

- 6 pts Incorrect

2.2 Overshoot measurement **3 / 3**

✓ **- 0 pts** *Correct*

- 2 pts Too high Overshoot

- 3 pts Incorrect

- 1 pts Higher Overshoot

- 1 pts Lower Overshoot

- 3 pts Too Low Overshoot

2.3 Damped Frequency measurement **3 / 3**

✓ **- 0 pts** *Correct*

- 3 pts Incorrect

- 2 pts Slightly incorrect

- 2 pts Partially incorrect

2.4 Derivation of Output Voltage 8 / 8

✓ **- 0 pts** *Correct*

- 4 pts Mistake

- 2 pts Small mistake

- 4 pts Partial

- 8 pts Missing

- 4 pts Derivation Missing

2.5 Discussion 1 3 / 3

✓ **- 0 pts** *Correct*

- 3 pts Incorrect

- 1 pts Partially correct

2.6 Discussion 2 3 / 3

✓ **- 0 pts** *Correct*

- 3 pts Incorrect

- 1 pts Partial explanation

QUESTION 3

Critically Damped RLC Circuit 19 pts

3.1 Waveforms Image 6 / 6

✓ **+ 6 pts** *Correct*

+ 5 pts Slightly Incorrect.

+ 4 pts Slightly Incorrect

+ 3 pts Incorrect

+ 0 pts Missing

3.2 Potentiometer resistance 3 / 3

✓ **+ 3 pts** *Correct*

+ 1 pts Incorrect

+ 0 pts Missing

+ 2 pts Slightly incorrect

3.3 Derivation of Critical Damping Resistance 4 / 4

✓ **+ 4 pts** *Correct*

+ 3 pts Slightly Incorrect

+ 2 pts Incorrect

+ 0 pts Missing

3.4 Discussion 1 3 / 3

✓ **+ 3 pts** *Correct*

+ 2 pts Slightly incorrect

+ 0 pts Missing

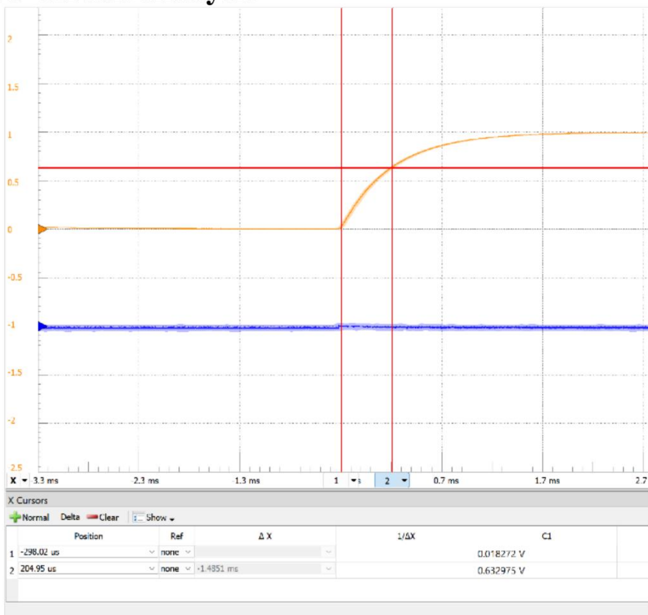
3.5 Discussion 2 3 / 3

✓ **+ 3 pts** *Correct*

+ 2 pts Slightly Incorrect/Incomplete.

+ 0 pts Missing

1. Series RLC Circuit Analysis



cross the capacitor.>

ansient response.>

- What is the inductor resistance?

R $_{\text{inductor}}$ = 165 Ω

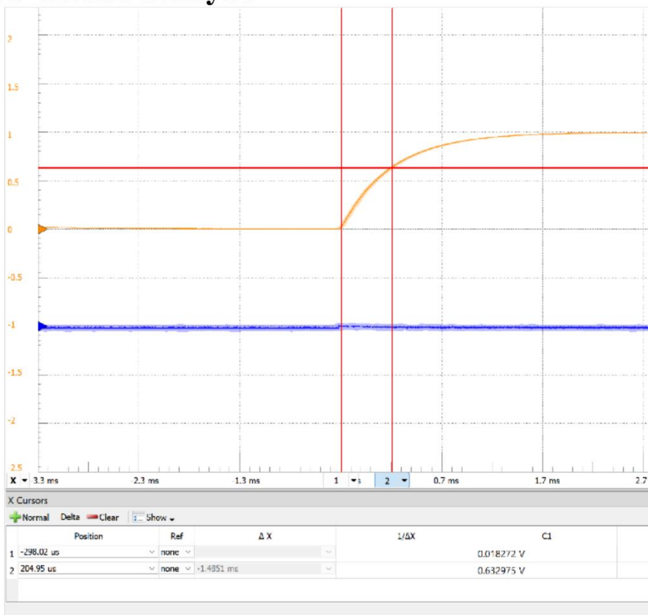
1.1 Waveforms Image **6 / 6**

✓ **+ 6 pts** *Correct*

+ 3 pts Click here to replace this description.

+ 0 pts Missing

1. Series RLC Circuit Analysis



cross the capacitor.>

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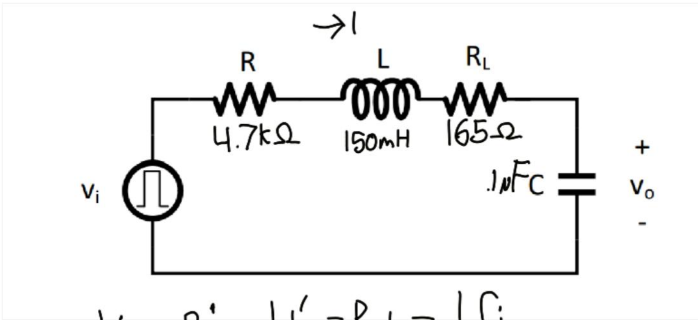
- What is the inductor resistance?

R $_{\text{inductor}}$ = 165 Ω

1.2 Inductor Resistance **3 / 3**

- ✓ **+ 3 pts** *Correct*
- **+ 2 pts** Slightly Incorrect
- **+ 0 pts** Missing

- Derive theoretical equation for output voltage $v_o(t)$ (including R_L) across capacitor for your design.



$V_0 = \frac{1}{C}\int i$

$I = CV_0'$

$V_1 - Ri - LI' - R_L I = \frac{1}{C}\int i$

$\therefore V_1 - RCV_0' - LCV_0'' - R_L CV_0' = V_0$

$LCV_0'' + (R+R_L)CV_0' + V_0 = V_1$

$\therefore V_0'' + \frac{R+R_L}{L} V_0' + \frac{V_0}{LC} = V_1$

$\therefore V_0'' + \frac{4865}{0.15} V_0' + \frac{V_0}{1.5E\text{-}8} = V_1$

$\therefore V_0'' + 32433 V_0' + (6.667E7) V_0 = V_1$

Solution to characteristic:

$V_0 = C_1 e^{-2205t} + C_2 e^{-30229t} + C_3$

When V_1: falling edge

$V_0(0^+) = V_0(0^-) = 1$ $\quad V_0(\infty) = 1$

$V_0'(0^+) = \frac{I(0^+)}{C} = \frac{I(0^-)}{C} = 0$

$\therefore$ Solving for $V_1 = 0$ @ falling edge

$C_3 = V_0(\infty) = 1$

$V_0(0) = 1 = C_1 + C_2$

$V_0'(0) = 0 = -2205C_1 - 30229C_2$

$\therefore C_1 = 1.079$

$C_2 = -0.079$

$\therefore V_0(t) = 1.079e^{-2205t}$

Discussion

- What kind of damping is observed? Verify that this matches with the theoretical expectation.

Over damped. $\zeta = \frac{\alpha}{\omega_0} = \frac{R}{2L} \cdot \frac{1}{\frac{1}{\sqrt{LC}}} = \frac{R\sqrt{LC}}{2L} = \frac{R\sqrt{LC}}{2L^2} = \frac{R}{2}\sqrt{\frac{C}{L}} =$

$\frac{4865\Omega}{2}\sqrt{\frac{0.1\mu F}{150mH}} = 1.97 \therefore \zeta > 1 \therefore$ Overdamped.

We can see on the graph that the waveform is overdamped.

1.3 Derivation of Output Voltage **8 / 8**

✓ **+ 8 pts** *Correct*

- **+ 7 pts** Slightly Incorrect
- **+ 6 pts** Slightly incorrect
- **+ 4 pts** Incorrect
- **+ 2 pts** Incorrect
- **+ 0 pts** Missing

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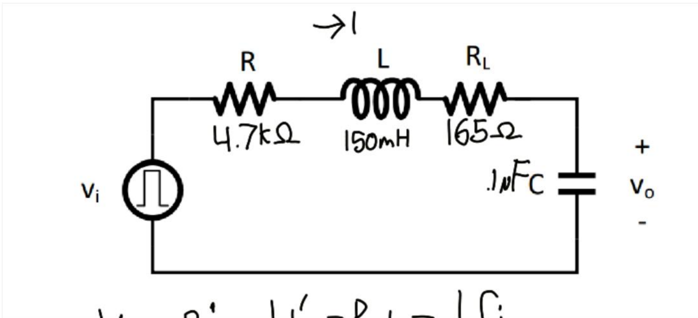

$V_o = \frac{1}{C}\int i$

$I = C V_o'$

$V_1 - Ri - LI' - R_L I = \frac{1}{C}\int i$

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$LCV_o'' + (R+R_L)CV_o' + V_o = V_1$

$\therefore V_o'' + \frac{R+R_L}{L} V_o' + \frac{V_o}{LC} = V_1$

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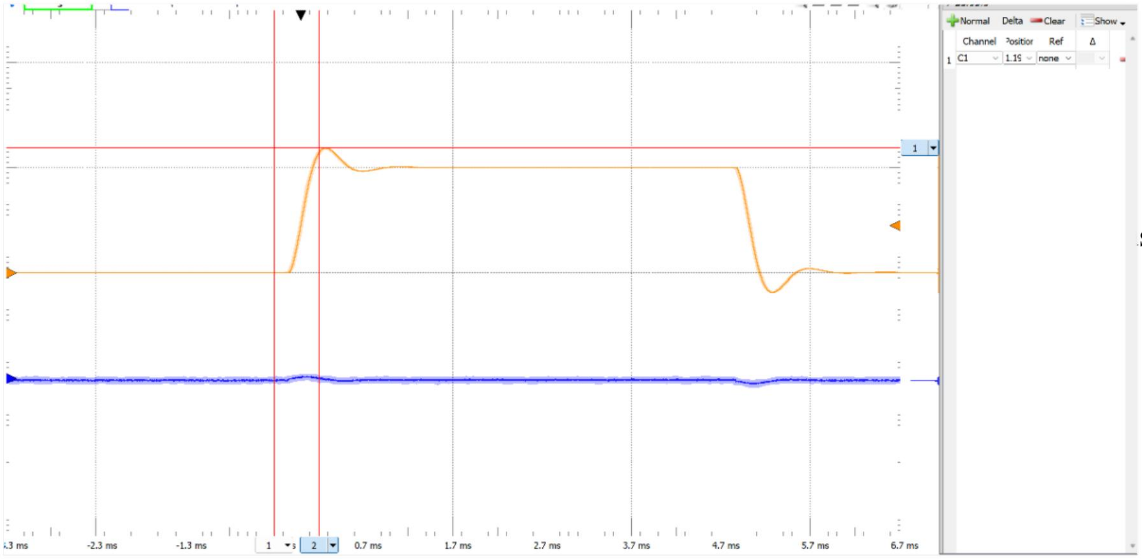
1.4 Discussion 1 **3 / 3**

- ✓ **+ 3 pts** *Correct*
- **+ 2 pts** Incomplete
- **+ 1 pts** Incomplete
- **+ 0 pts** Missing

2. Underdamped RLC Circuit Design



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Overshoot Measurement:

Experimental Value of Resistor used (Ω)	Overshoot measured (%)
1000	.19%

Damped Frequency Measurement:

Experimental Damped Frequency (Hz)	Theoretical Damped Frequency (Hz)
1/2(669 μS − 225 μS) = 1205 Hz	1145 Hz

2.1 Waveforms Image **6 / 6**

✓ **- 0 pts** *Correct*

- 1 pts Slightly higher Overshoot

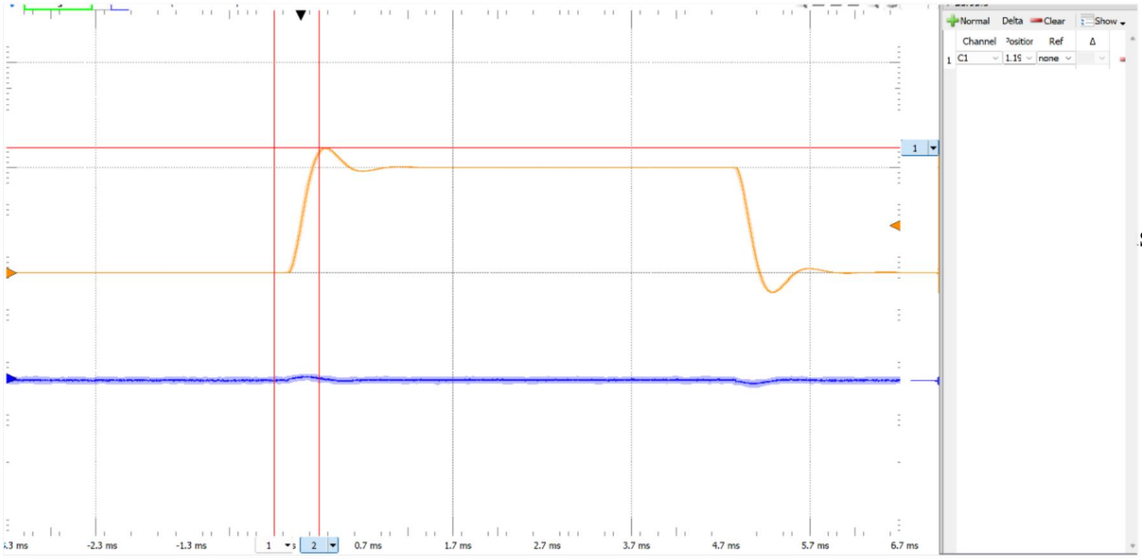
- 3 pts Lower Overshoot

- 1 pts Slightly lower Overshoot

- 3 pts Higher Overshoot

- 6 pts Incorrect

2. Underdamped RLC Circuit Design



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Damped Frequency Measurement:

Experimental Damped Frequency (Hz)	Theoretical Damped Frequency (Hz)
1/2(669 µS−225 µS) = 1205 Hz	1145 Hz

2.2 Overshoot measurement **3 / 3**

✓ **- 0 pts** *Correct*

- 2 pts Too high Overshoot

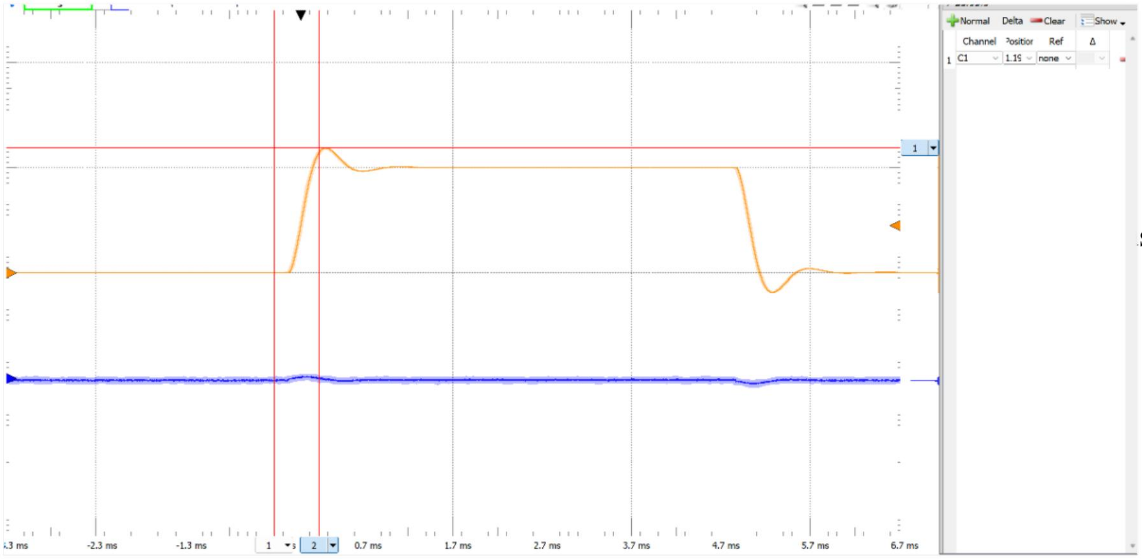
- 3 pts Incorrect

- 1 pts Higher Overshoot

- 1 pts Lower Overshoot

- 3 pts Too Low Overshoot

2. Underdamped RLC Circuit Design



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2.3 Damped Frequency measurement **3 / 3**

✓ **- 0 pts** *Correct*

- 3 pts Incorrect

- 2 pts Slightly incorrect

- 2 pts Partially incorrect

- Derive theoretical equation for output voltage $v_o(t)$ (including R_L) across capacitor for new design.

$$V_0'' + 7766 V_0' + (6.667E7) V_0 = 0$$

$$\therefore V_0 = C_1 e^{-3883t} \cos(7182t) + C_2 e^{-3883t} \sin(7182t) + 1$$

$$V_0(0+) = V_0(0-) = 0$$

$$V_0'(0+) = V_0'(0-) = \frac{i(0-)}{C} = 0$$

$$C_1 = -1$$

$$C_2 = -.5377$$

$$V_0 = -e^{-3883t} \cos(7182t) - .5377 e^{-3883t} \sin(7182t) + 1$$

Discussion

- How did the experimental damped frequency compare with the theoretical values?

The experimental damped frequency is within 5% of the theoretical, ∴ It matches the theoretical value correctly.

<Answer in 2-3 lines. >

- What happens if you try to make the overshoot smaller?

To do this we would need to increase the resistance.

<Answer in 1-2 lines.>

If we keep doing this, it will become critically damped

2.4 Derivation of Output Voltage **8 / 8**

- ✓ **- 0 pts** *Correct*
- **- 4 pts** Mistake
- **- 2 pts** Small mistake
- **- 4 pts** Partial
- **- 8 pts** Missing
- **- 4 pts** Derivation Missing

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<Answer in 1-2 lines.>

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2.5 Discussion 1 **3 / 3**

- ✓ **- 0 pts** *Correct*
- **- 3 pts** Incorrect
- **- 1 pts** Partially correct

- Derive theoretical equation for output voltage $v_o(t)$ (including R_L) across capacitor for new design.

$$V_0'' + 7766 V_0' + (6.667E7) V_0 = 0$$

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<Answer in 1-2 lines.>

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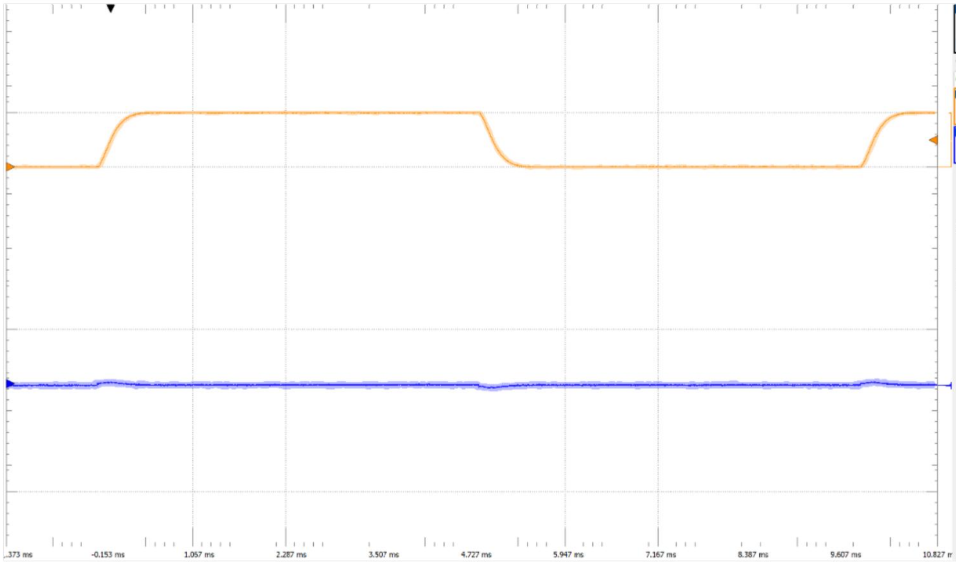
2.6 Discussion 2 **3 / 3**

- ✓ **- 0 pts** *Correct*
- **- 3 pts** Incorrect
- **- 1 pts** Partial explanation

3. Critically Damped RLC Circuit



apacitor.>

ritical damping

- What is the potentiometer resistance for critical damping?

$$R_{\text{potentiometer}} = 2.246\,k\Omega$$

- Derive theoretical resistance needed for critical damping. (Include the effect of R_L)

$$\zeta = 1 = \frac{R+R_L}{2}\sqrt{\frac{C}{L}}$$

$$\therefore\ R = 2\sqrt{\frac{L}{C}} - R_L = 2279\,\Omega$$

3.1 Waveforms Image **6 / 6**

✓ **+ 6 pts** *Correct*

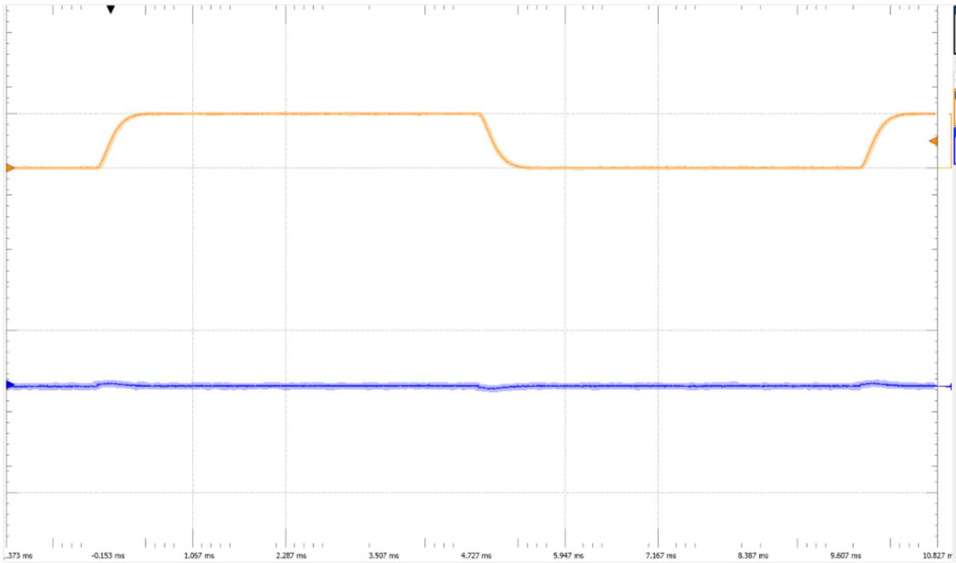
+ 5 pts Slightly Incorrect.

+ 4 pts Slightly Incorrect

+ 3 pts Incorrect

+ 0 pts Missing

3. Critically Damped RLC Circuit



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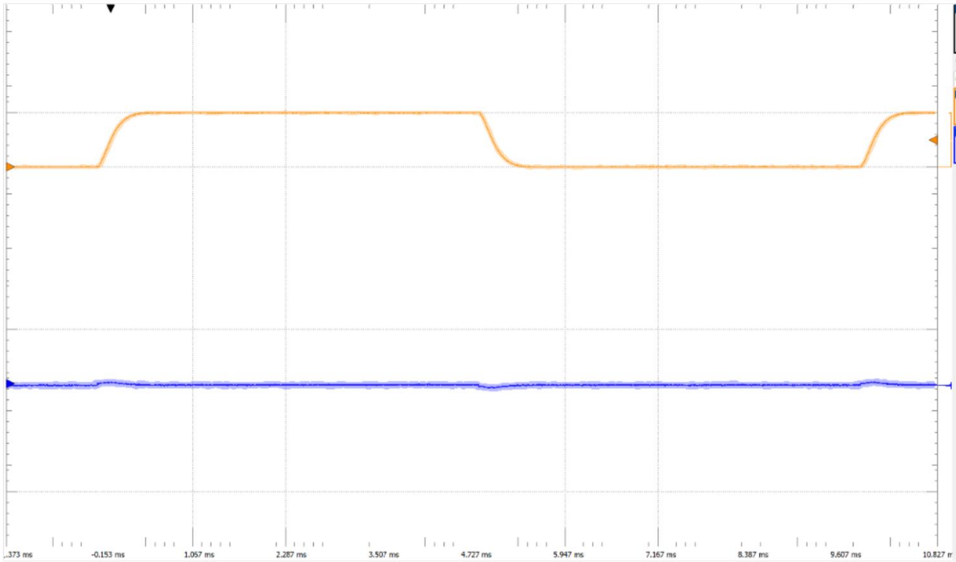
3.2 Potentiometer resistance **3 / 3**

- ✓ **+ 3 pts** *Correct*
- **+ 1 pts** Incorrect
- **+ 0 pts** Missing
- **+ 2 pts** Slightly incorrect

3. Critically Damped RLC Circuit



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3.3 Derivation of Critical Damping Resistance 4 / 4

✓ **+ 4 pts** *Correct*

+ 3 pts Slightly Incorrect

+ 2 pts Incorrect

+ 0 pts Missing

Discussion

- How close was the value of resistance you ended up with when using the potentiometer to obtain a critically damped response, to the theoretical value you have derived? Consider the effects of inductor resistance as well.

It was within 5% of the theoretically derived valve.

<Answer in 1-3 lines. >

The error may be a result of tuning the pot.

- What did you observe in the output waveform as resistance varied?

<Answer in 1-2 lines. >

The Resistance controls the behavior of dampening of the circuit

Under damped	Low R
Critically Damped	Mid R
Overdamped	High R.

3.4 Discussion 1 **3 / 3**

✓ **+ 3 pts** *Correct*

+ 2 pts Slightly incorrect

+ 0 pts Missing

Discussion

- How close was the value of resistance you ended up with when using the potentiometer to obtain a critically damped response, to the theoretical value you have derived? Consider the effects of inductor resistance as well.

It was within 5% of the theoretically derived valve.

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The Resistance controls the behavior of dampening of the circuit

Under damped	Low R
Critically Damped	Mid R
Overdamped	High R.

3.5 Discussion 2 **3 / 3**

- ✓ **+ 3 pts** *Correct*
- **+ 2 pts** Slightly Incorrect/Incomplete.
- **+ 0 pts** Missing

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Department of Electrical and Computer Engineering

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Experiment 4: Transient Response of the 2^{nd}-Order Circuits

ECE11L Lab

Instructor: Sudhakar Pamarti