# CMPE 110 Lab 2: Second-Order Passive Circuits

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***Abstract*—The purpose of this lab project is to learn about resistance, inductance, capacitance, the time constant, and rise and fall times in RLC circuits with a pulse generator.**

## I. INTRODUCTION

This lab project is based on the implementation of 5 RLC circuits in LTspice, where all circuits have the same capacitance ($C = 100pF$) and inductance—to be determined—but different R values. Each circuit is composed of almost identical RLC series circuits, where the only difference is the resistance's value.

We are asked to:

(a) **Calculate** L such that the oscillation angular frequency, $\omega_0$, is $10^7$rad/sec if C = 100pF is used in the circuit above.

(b) Use the values of C = 100pF and the value of L determined in part (a), construct separate RLC circuits with R = 0Ω, 10Ω, 100Ω, 1KΩ, 10KΩ. In each case, **compute** the real and imaginary parts of s1 and s2. Tabulate your results in an Excel table.

(c) Apply the pulse generator at vin that changes between 0 and 5V to each RLC circuit in part (b) and **measure** the rise and fall times at vout with your oscilloscope's cursors. Make sure to adjust your pulse width **large enough** such that the output voltage settles at a certain value before taking measurements. Tabulate your results in an Excel table.

(d) Apply the pulse generator at vin that changes between 0 and 5V and **measure** the time constant (if applicable) at vout for each RLC circuit in part (b) with your oscilloscope's cursors. Tabulate your results in an Excel table.

(e) Apply the pulse generator at vin that changes between 0 and 5V and measure the free oscillation frequency, $f_0 = \omega_0/2\pi$, (if applicable) at vout for each RLC circuit in part (b) using your oscilloscope's cursors. Tabulate your results in an Excel table.

**Figure 1. Instructions.**

Before assembling the 5 RLC circuits, the inductance value for all circuits is calculated. For this, we use the RL circuits' equation:

- $\omega_0 = \frac{1}{\sqrt{LC}}$

And it's determined that:

- $L = 100\mu H$

After setting up each circuit, $s1$ and $s2$, the imaginary components for each circuit, are computed, and measurements of the rise and fall times, as well as the the time constant and the oscillation frequency—if applicable—for each circuit are made. For these procedures, we use the RLC circuits' equations:

- $s_1, s_2 = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$
- $\alpha = \frac{R}{2L}$
- $f_0 = \frac{\omega_0}{2\pi}$

### A. Parts List

- 0-5V pulse generator. See **Figure 3**.
- $10\Omega, 100\Omega, 1K\Omega$, and $10K\Omega$ resistors
- $1\mu H, 10\mu H, 100\mu H$,and $1mH$ inductors
- Grounding components
- LTspice software

## II. DESCRIPTION OF THE CIRCUITS' SCHEMATICS

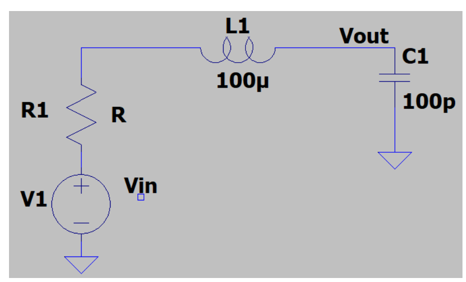


**Figure 2. RLC circuit configuration.**

| | |
|---|---|
| Vinitial[V]: | 0 |
| Von[V]: | 5 |
| Tdelay[s]: | 0 |
| Trise[s]: | 1u |
| Tfall[s]: | 1u |
| Ton[s]: | 1m |
| Tperiod[s]: | 20m |
| Ncycles: | 2 |

**Figure 3. The pulse generator's settings.**

## III. Waveforms and Results

| $R$ (Ω) | $\alpha$ | $s1$ | $s2$ |
|---|---|---|---|
| 0 | 0 | $-10^7 i$ | $10^7 i$ |
| 10 | 50K | $-50K$ $-9.99 * 10^6 i$ | $-50K$ $+9.99 * 10^6 i$ |
| 100 | 500K | $-500K$ $-9.99 * 10^6 i$ | $-500K$ $+9.99 * 10^6 \mathrm{i}$ |
| 1K | 5M | $-5M$ $-8.66 * 10^6 i$ | $-5M$ $+8.66 * 10^6 i$ |
| 10K | 50M | $-9.90 * 10^{-7}$ | $-1.01 * 10^6$ |

**Table 1. $s1$ and $s2$ for all 5 circuits.**

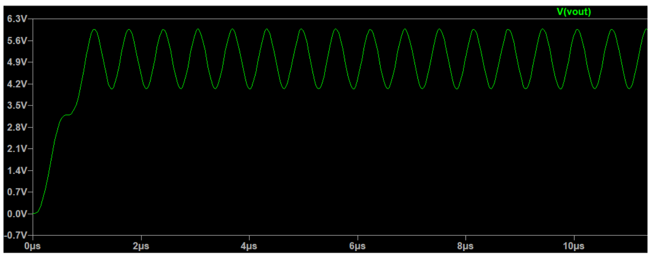


**Figure 4. $R = 0\Omega$ . Raising part.**

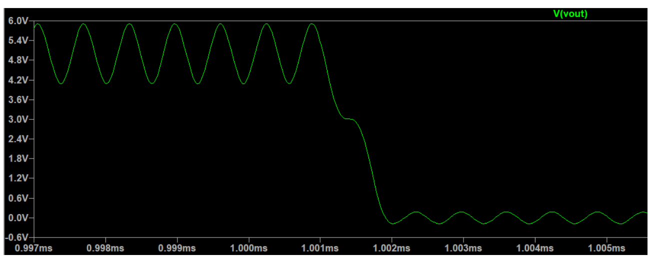


**Figure 5. $R = 0\Omega$ . Falling part.**

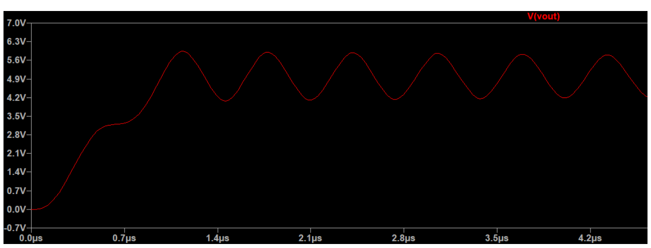


**Figure 6. $R = 10\Omega$ . Raising part.**

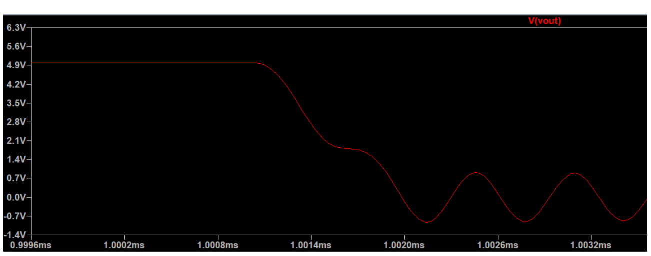


**Figure 7. $R = 10\Omega$ . Falling part.**

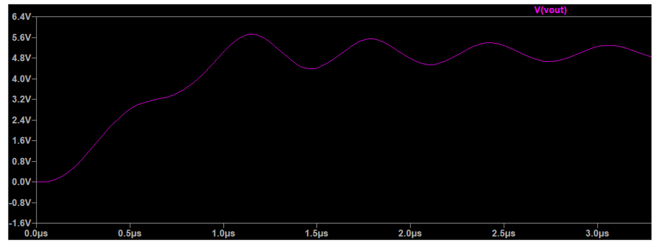


**Figure 8. $R = 100\Omega$ . Raising part.**

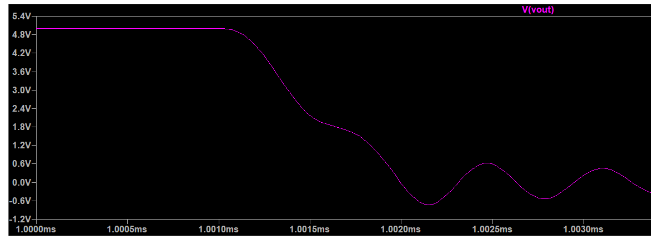


**Figure 9. $R = 100\Omega$ . Falling part.**

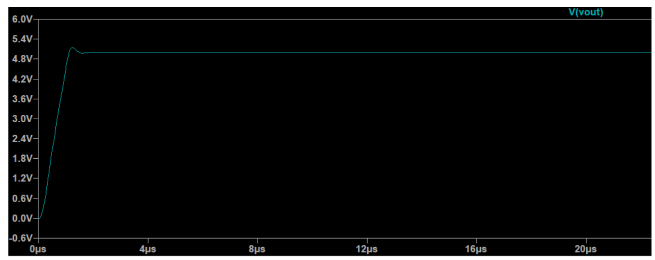


**Figure 10. $R = 1000\Omega$ . Raising part.**

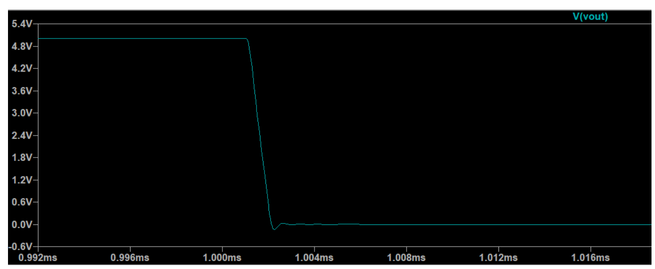


**Figure 11. $R = 1000\Omega$ . Falling part.**

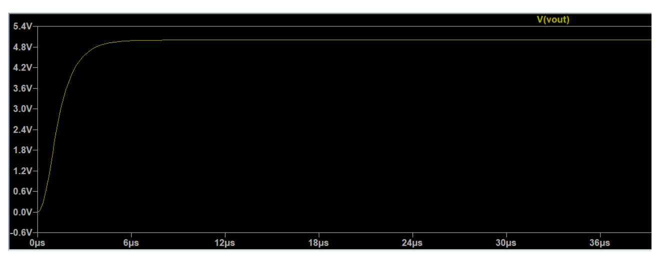


**Figure 12. $R = 10K\Omega$ . Raising part.**

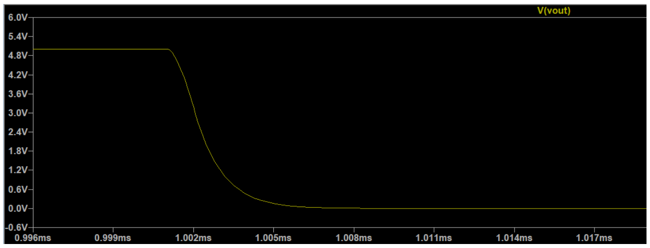


**Figure 13. $R = 10K\Omega$ . Falling part.**

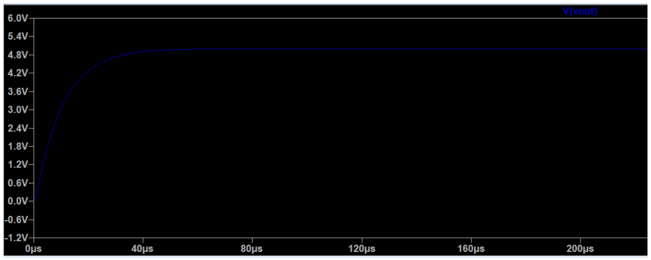


**Figure 12. $R = 100K\Omega$ . Raising part.**

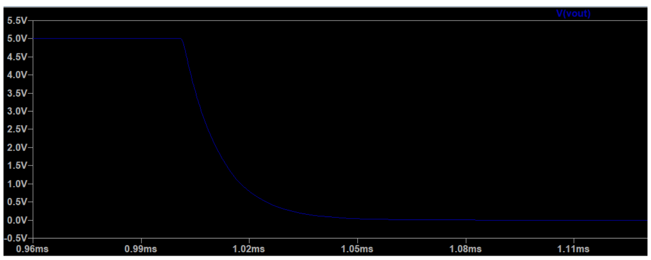


**Figure 13. $R = 100K\Omega$ . Falling part.**

| $R$ (Ω) | Rise $t$ ($ns$) | Fall $t$ ($ns$) | $f_0$(Hz) | $\tau(ns)$ |
|---|---|---|---|---|
| 0 | 615.84 | 616.65 | $1.592 * 10^6$ | - |
| 10 | 607.89 | 613.27 | $1.592 * 10^6$ | - |
| 100 | 607.12 | 603.09 | $1.592 * 10^6$ | - |
| 1K | 578.14 | 564.53 | - | 724.85 |
| 10K | 1470.3 | 1532.9 | - | 1542.6 |

## IV. DISCUSSION

This lab doesn't deal with errors, so it's a complicated task to gauge whether our procedures and calculations were on the right track—numerically—but this lab project was on the conceptual side.

In this lab project, we examined whether an RLC circuit produced a sinusoidal function or not, and if whether or not we could assign that waveform a $\tau$ or a frequency. This was the qualitative takeaway this lab had to offer.

## V. DESCRIPTION OF THE LEARNING EXPERIENCE

This lab project was a challenge that pushed me to learn in-depth details related to RLC circuits. This was an incentive and an opportunity to not only use the existing knowledge I acquired from our lectures and our textbook, but also research, learn, and verify my current knowledge on RLC circuits. To further and to supplement my education on RLC circuits, I visited several higher education institution's websites, which provided me with additional resources on waveforms and how to approach them using different methods, to acquire the different possible variables of interest.

The resources I found the most useful and insightful were the ones on complex numbers and complex analysis. After completing this lab project, I feel more confident about dealing with complex numbers in circuits.

## VI. CONCLUSION

In conclusion, this lab experiment was a fruitful RLC circuits learning experience, where we successfully tried to compute and present the imaginary parts of an RLC circuit, as well as become familiar with the cases in which a time constant might be a possibility for an RLC circuit. Finally, while researching and trying to understand possible error sources, we became more familiar with RLC circuits in the process.