ELEX 3120/3321: Electric Circuits 2

LAB 8 – Second Order

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1 Introduction

This lab is to investigate the behavior of second-order circuits, focusing on their frequency response, step response, and conditions for achieving critical damping. By determining the transfer function of the circuit, we predicted its performance analytically and validated these predictions through experimental measurements and simulations in LTSpice. The study aimed to deepen our understanding of second-order system dynamics and their practical implications in electronics.

2 Experiments

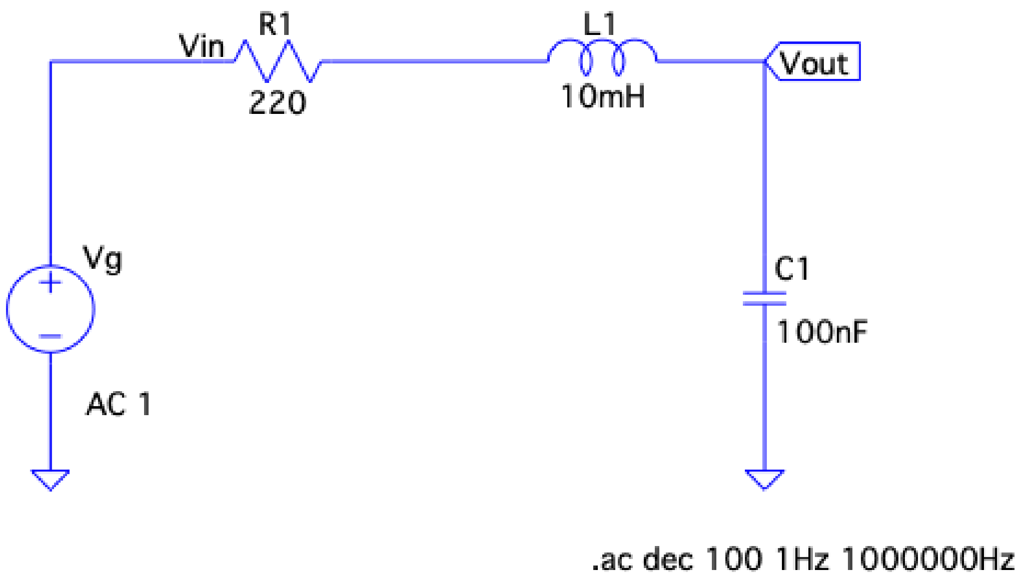

Figure 1 - RLC circuit LTSpice Schematic

2.1 Frequency Response

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{{w_n}^2}{s^2 + 2\delta w_n s + {w_n}^2}$$

$$w_n = \sqrt{\frac{1}{LC}}\ , \qquad \delta = \sqrt{\frac{R^2 C}{4L}}$$

$$H(jw) = \frac{{w_n}^2}{(jw)^2 + 2\delta w_n (jw) + {w_n}^2}$$

$$= \frac{{w_n}^2}{({w_n}^2 - w^2) + 2\delta w_n wj}$$

$$|H(jw)| = \frac{{w_n}^2}{\sqrt{({w_n}^2 - w^2)^2 + (2\delta w_n w)^2}}$$

$$\angle H(jw) = -\tan^{-1}\left(\frac{2\delta w_n w}{{w_n}^2 - w^2}\right), \angle H(jw) = -pi - \tan^{-1}\left(\frac{2\delta w_n w}{{w_n}^2 - w^2}\right)$$

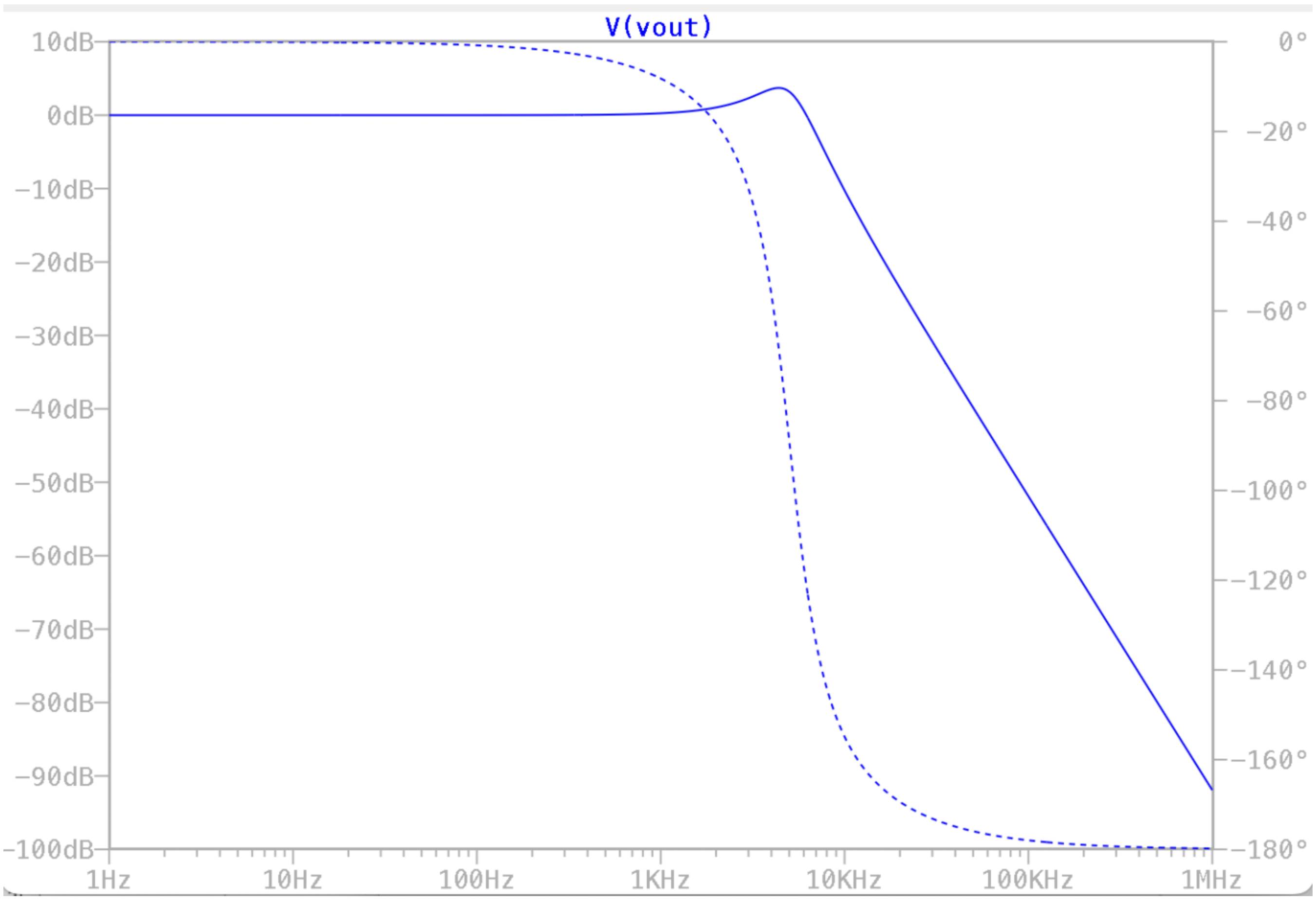

Figure 2 - LTSpice Simulation of Frequency Response

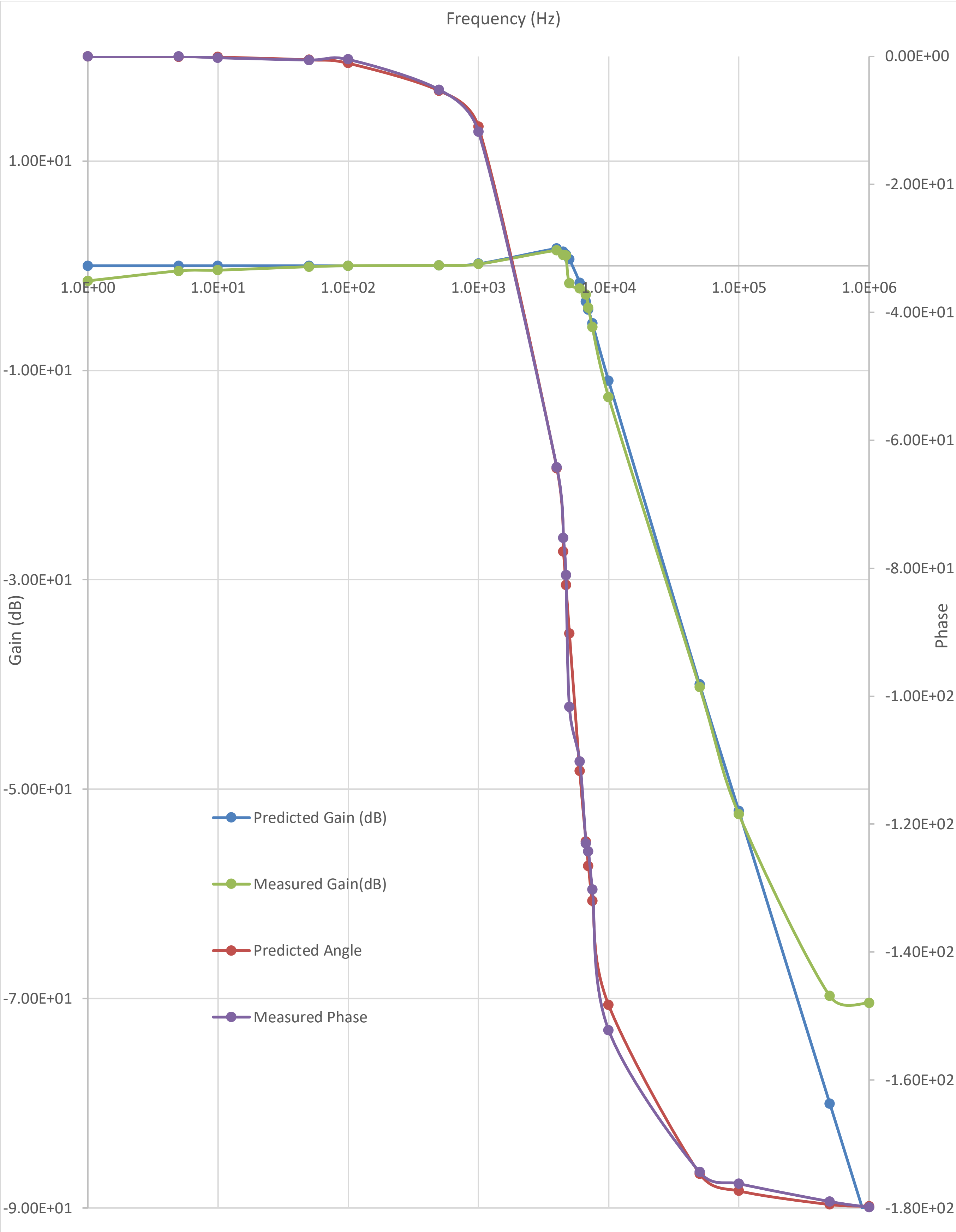

Figure 3 - Measured and Predicted Gain and Phase Plot

Frequency (Hz)	Measured Gain(dB)	Measured Phase
1.0E+00	-2.64E+01	-0.107
5.0E+00	-1.25E+01	-0.118
1.0E+01	-6.44E+00	-0.203
5.0E+01	7.54E+00	-0.557
1.0E+02	1.36E+01	-0.4715
5.0E+02	2.75E+01	-5.203
1.0E+03	3.36E+01	-11.75
4.0E+03	4.56E+01	-64.2
4.5E+03	4.66E+01	-75.3
4.7E+03	4.70E+01	-81.1
5.0E+03	4.75E+01	-101.7
6.0E+03	4.91E+01	-110.2
6.7E+03	5.01E+01	-123
7.0E+03	5.05E+01	-124.3
7.5E+03	5.11E+01	-130.2
1.0E+04	5.36E+01	-152.2
5.0E+04	6.75E+01	-174.4
1.0E+05	7.36E+01	-176.2
5.0E+05	8.75E+01	-179
1.0E+06	9.36E+01	-179.9

Table 1 - Measured Frequency Response Data

2.2 Step Response

$$w_n = \sqrt{\frac{1}{LC}} = \sqrt{\frac{1}{9.912 * 10^{-3} * 102.6 * 10^{-9}}} = 31358$$

$$\delta = \sqrt{\frac{R^2C}{4L}} = \sqrt{\frac{289^2 * 102.6 * 10^{-9}}{4 * 9.912 * 10^{-3}}} = 0.46$$

Underdamped

$$T_p = \frac{pi}{w_n\sqrt{1-\delta^2}} = 133\,us$$

$$\%OS = e^{\frac{-\delta * pi}{\sqrt{1-\delta^2}}} * 100 = e^{\frac{-0.46 * pi}{\sqrt{1-0.46^2}}} * 100 = 19\%$$

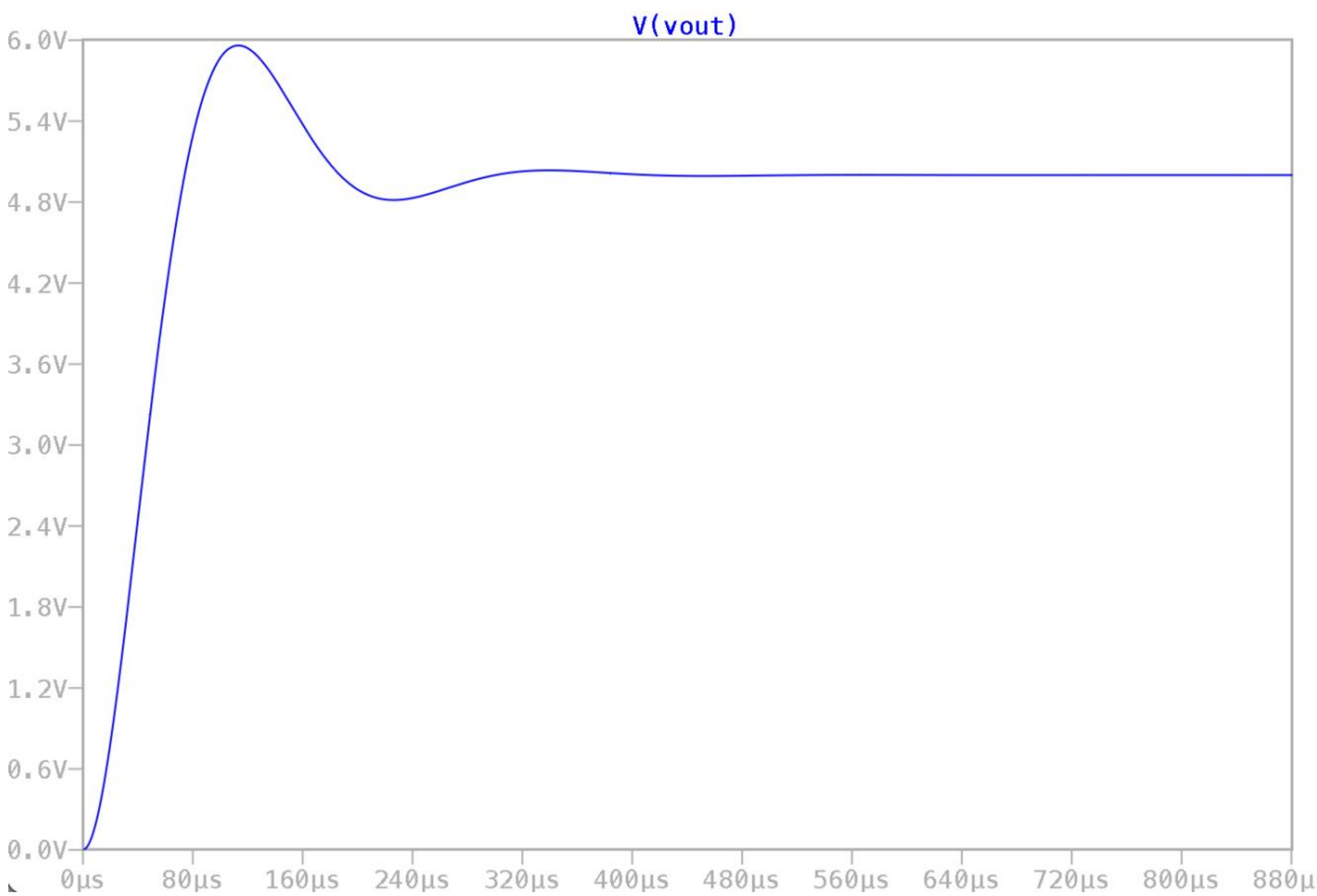

Figure 4 - LTSpice Simulation of Step Response

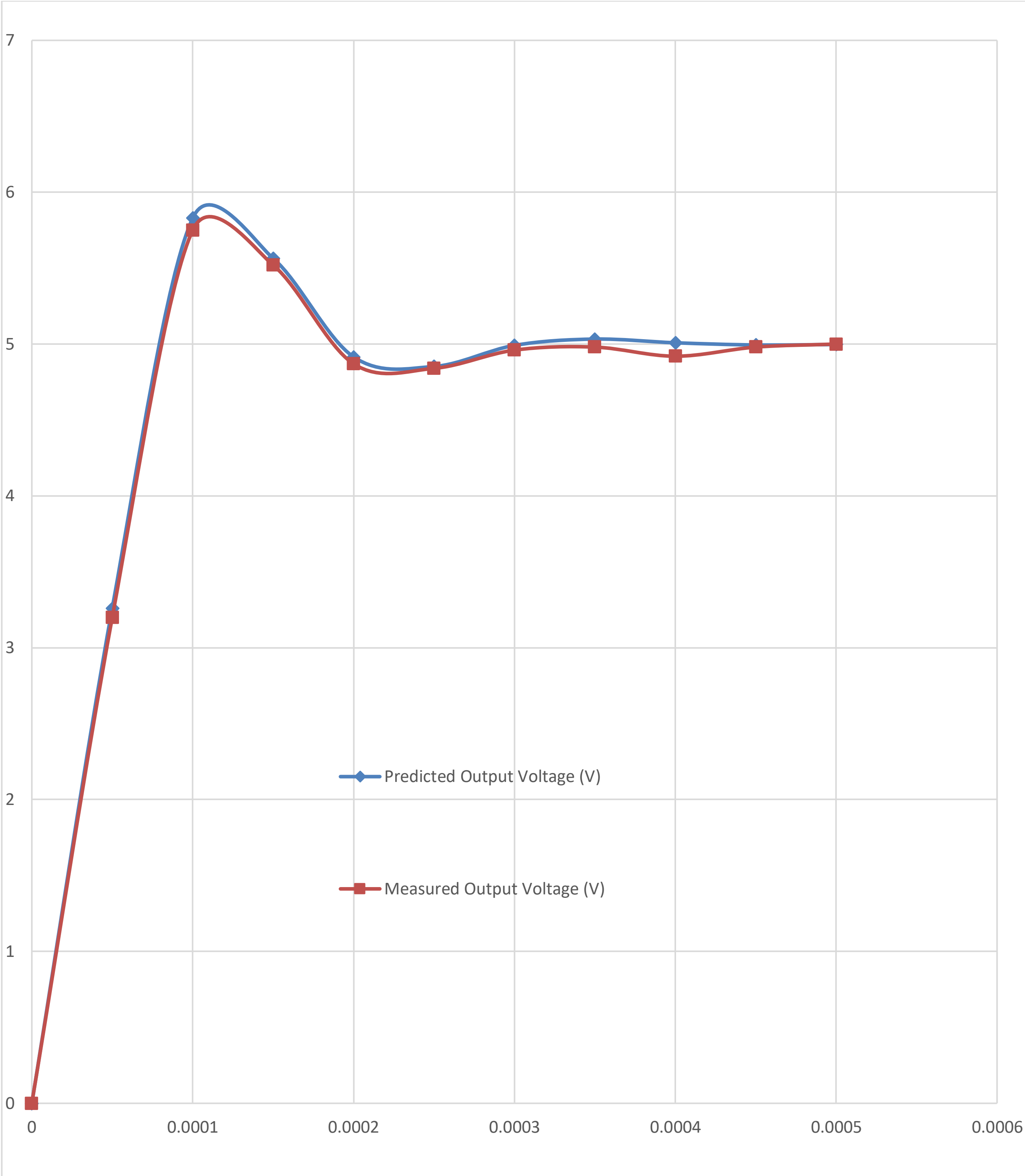

Figure 5 - Predicted and Measured Step Response Plot

2.3 Critical Damping

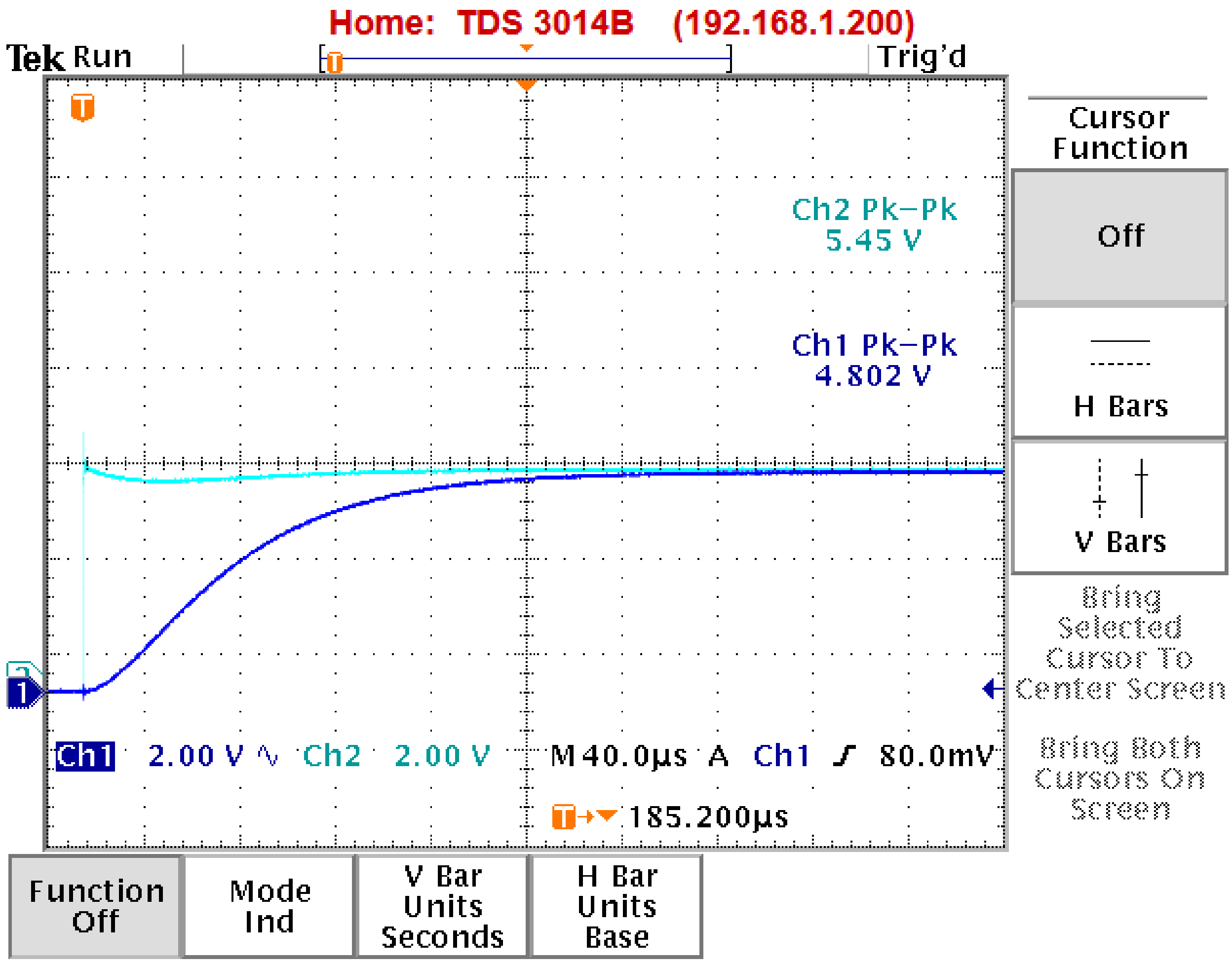

Figure 6 – Critical Damping

	Predicted	Measured
$R_{critical}$	622	547

Table 2 - Predicted and Measured Critical Damping Resistance

3 Conclusions

In this lab, we successfully demonstrated the behavior of second-order circuits under various conditions, including frequency and step inputs. The experimentally measured responses closely aligned with the predicted values, confirming the accuracy of the theoretical models and simulations. Additionally, achieving critical damping showcased the practical tuning required to eliminate overshoot in system responses. These findings highlight the importance of precise parameter adjustments in optimizing circuit performance.