ELEX 3120/3321: Electric Circuits 2

LAB 7 – First Order

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Table of Contents

Table of Figures

Table of Tables

1 Introduction

In this lab, we explore the behavior of first-order electrical circuits through both theoretical and practical approaches. The primary objectives include determining the transfer function for the circuit, analyzing its step and frequency responses, and comparing predicted results with experimental measurements. By incorporating tools such as LTSpice for simulation and an oscilloscope for real-time measurements, this lab aims to provide insights into the transient and frequency domain characteristics of the circuit, thereby bridging theoretical understanding with practical application.

2 Experiments

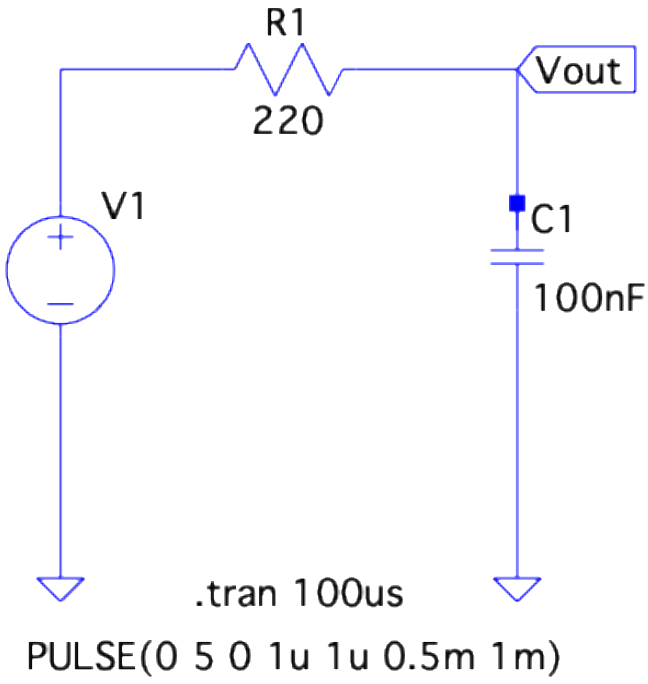

Figure 1 - RC circuit LTSpice Schematic

2.1 Component Measurement

	Predicted	Measured
R[Ω]	220	218
C[nF]	100	102.6
L[mH]	10	9.912
L[Ω]	20	21

Table 1 - Predicted and Measured Value of Component

2.2 Step Response

$$\tau = (R + Rg)C = (218 + 50) \cdot 102.6 \cdot 10^{-9} = 27.5$$

$$t_{rise} = 2.2 \cdot \tau$$

$$\mathbf{V_{out} = 5\,[1 - e^{\left(\frac{-t}{\tau}\right)}]}$$

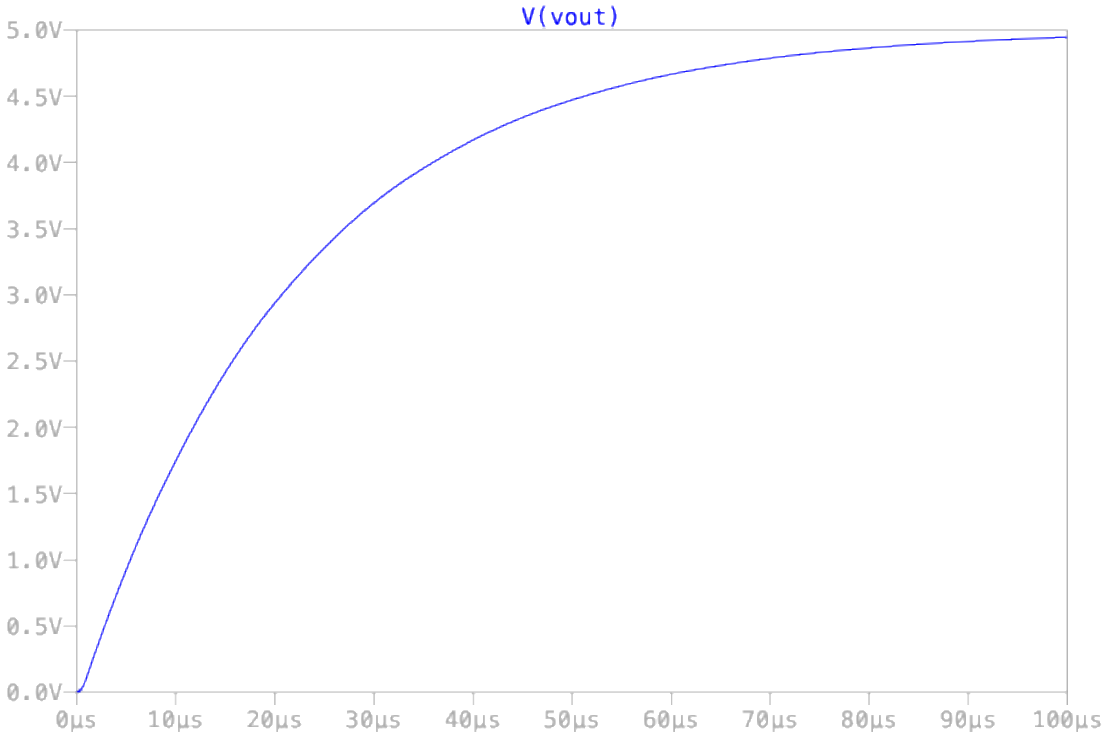

Figure 2 - LTSpice Simulation of Step Response

	Predicted	Measured
Time constant	27.5	30.4
Rise time	60.5	52.1

Table 2 - Predicted and Measured Value of Time Constant and Rise Time

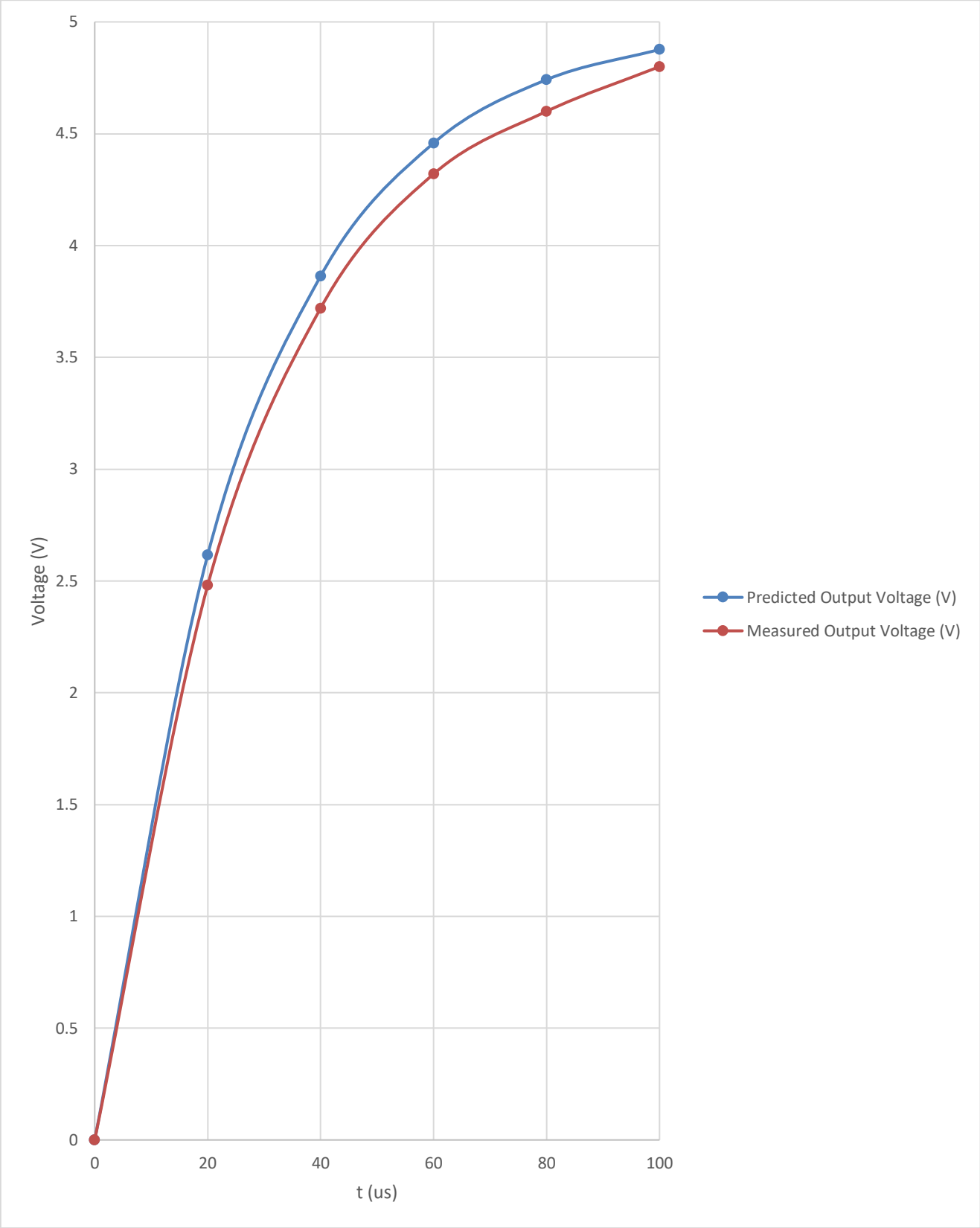

Figure 3 - Predicted and Measured Step Response Plot

-Measured value is smaller than the predicted, maybe caused by resistance of function generator and other internal resistance.

2.3 Frequency Response

$$H\,(jw) = \frac{1}{1+(w\tau)^2} - \frac{w\tau}{1+(w\tau)^2}\,j$$

$$|H\,(jw)| = \frac{1}{\sqrt{1+(w\tau)^2}} \quad , \quad |H\,(f)| = \frac{1}{\sqrt{1+(2\pi f\tau)^2}}$$

$$\angle H\,(jw) = -\tan^{-1}(w\tau) \quad , \quad \angle H\,(f) = -\tan^{-1}(2\pi f\tau)$$

$$f = \frac{\sqrt{\frac{1}{(10^{(-\frac{3}{20})})^2} - 1}}{2\pi\tau}$$

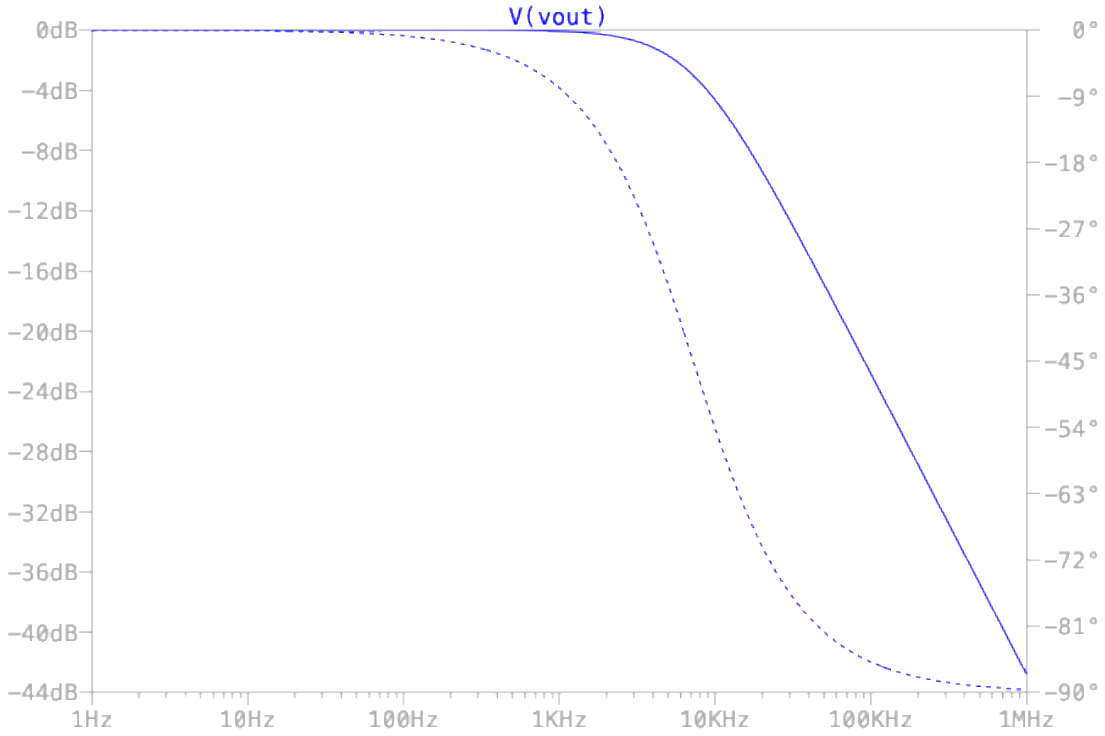

Figure 4 - LTSpice Simulation of Frequency Response

-3 dB Point	Mag [dB]	Phase [^{o}]
Predicted f = 7.21 kHz	-3.00	-44.93
Measured f = 4.7 kHz	-3.04	-36.25

Table 3 - Predicted and Measured Value of Magnitude and Phase of -3dB Point

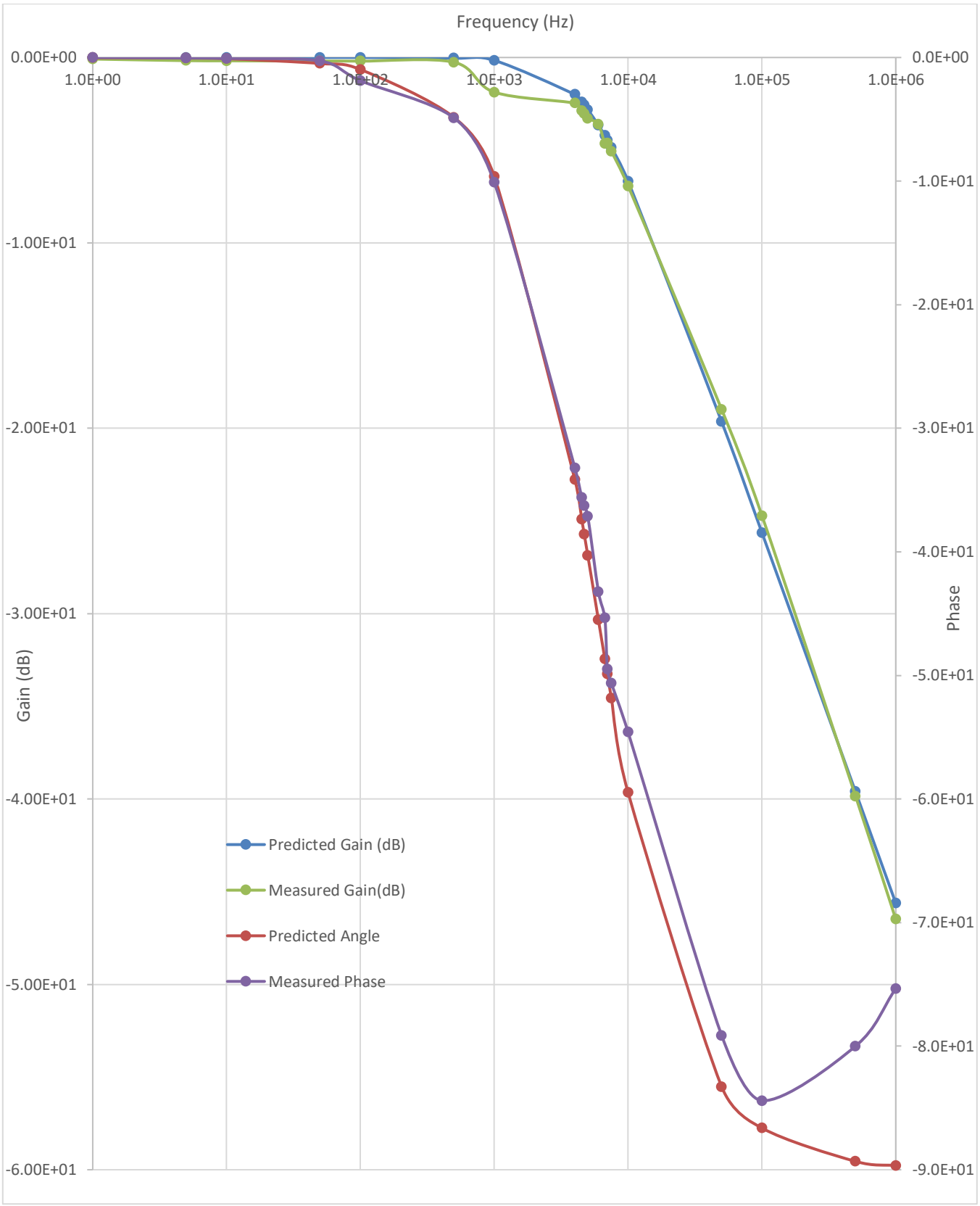

Figure 5 - Measured and Predicted Frequency Response Plot

Frequency (Hz)	Measured Gain(dB)	Measured Phase
1.0E+00	-2.63E+01	0
5.0E+00	-1.23E+01	-0.042
1.0E+01	-6.28E+00	-0.076
5.0E+01	7.70E+00	-0.279
1.0E+02	1.37E+01	-1.88
5.0E+02	2.77E+01	-4.89
1.0E+03	3.37E+01	-10.11
4.0E+03	4.58E+01	-33.2
4.5E+03	4.68E+01	-35.62
4.7E+03	4.72E+01	-36.25
5.0E+03	4.77E+01	-37.11
6.0E+03	4.93E+01	-43.23
6.7E+03	5.02E+01	-45.35
7.0E+03	5.06E+01	-49.5
7.5E+03	5.12E+01	-50.64
1.0E+04	5.37E+01	-54.59
5.0E+04	6.77E+01	-79.13
1.0E+05	7.37E+01	-84.41
5.0E+05	8.77E+01	-80
1.0E+06	9.37E+01	-75.34

Table 4 - Measured Frequency Response Data

3 Conclusions

The lab successfully demonstrated the principles underlying the step and frequency responses of first-order circuits. The measured time constant and rise time aligned closely with the predicted values, highlighting the accuracy of the theoretical models when actual component parameters are used. Discrepancies in frequency response, particularly at higher frequencies, underscored the importance of considering real-world factors such as parasitic elements and measurement limitations. Overall, the experiment reinforced foundational concepts in circuit analysis and provided a deeper appreciation for the interplay between theory and practice.