POLES AND ZEROS OF TRANSFER FUNCTIONS, THE POLE-ZERO MAP

LAB EXPERIMENT 7

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***Abstract*—This experiment investigates the relationship between a system's poles and zeros and its time-domain behavior using an RLC circuit. Through simulation, the pole-zero map and step response were generated to evaluate the circuit's stability and transient response. The results confirmed that the location of poles in the complex plane directly influences damping, oscillation, and system stability. The experiment demonstrates that pole-zero analysis provides valuable insight into system behavior before time-domain simulation is even performed.**

I. RATIONALE

Poles and zeros determine the behavior of a system in terms of stability and transient response. This experiment introduces the pole-zero map and shows how it can be used to analyze system dynamics.

II. OBJECTIVES

- Plot the pole-zero map of a transfer function and identify the poles and zeros.
- • Analyze the relationship between the pole-zero map and the system's stability, response time, and damping. the system's time-domain response using the pole-zero map.

III. MATERIALS AND SOFTWARE

- Materials:RLC circuit, Power supply, Oscilloscope (Simulated using Falstad.com/circuit/)
- Software: Python (with control library)

IV. PROCEDURES

1) Set up the system and determine its transfer function (e.g. using a DC motor or RLC circuit).
2) Compute the poles and zeros of the transfer function.
3) Plot the pole-zero map using Python or Matlab.
4) Analyze the effect of the poles and zeros on the system's stability and transient response (e.g., damping, rise time).
5) Simulate the system and compare the time-domain response with predictions based on the pole-zero map.

V. OBSERVATION AND DATA COLLECTION

DATA COLLECTION:

https://drive.google.com/drive/folders/1qYdJLs6BDxg8PYQ6UA17jEv_iPPPnICa

Click here to open the Drive

VI. DATA ANALYSIS

The simulated step response and pole-zero map of the RLC circuit reveal a pair of complex conjugate poles located at:

$$-5.0000 \pm 258.1505j$$

No zeros were present in the system, as confirmed by the plot.
The damping ratio (ζ) and natural frequency (ω_n) were calculated from the pole positions:

$$\zeta = \frac{-\text{Re(pole)}}{\sqrt{\text{Re(pole)}^2 + \text{Im(pole)}^2}} = 0.0194$$

$$\omega_n = \sqrt{\text{Re(pole)}^2 + \text{Im(pole)}^2} = 258.20 \text{ rad/s}$$

The step response plot shows a lightly damped oscillation that gradually settles over time, characteristic of an underdamped second-order system.

VII. DISCUSSION AND INTERPRETATIONS

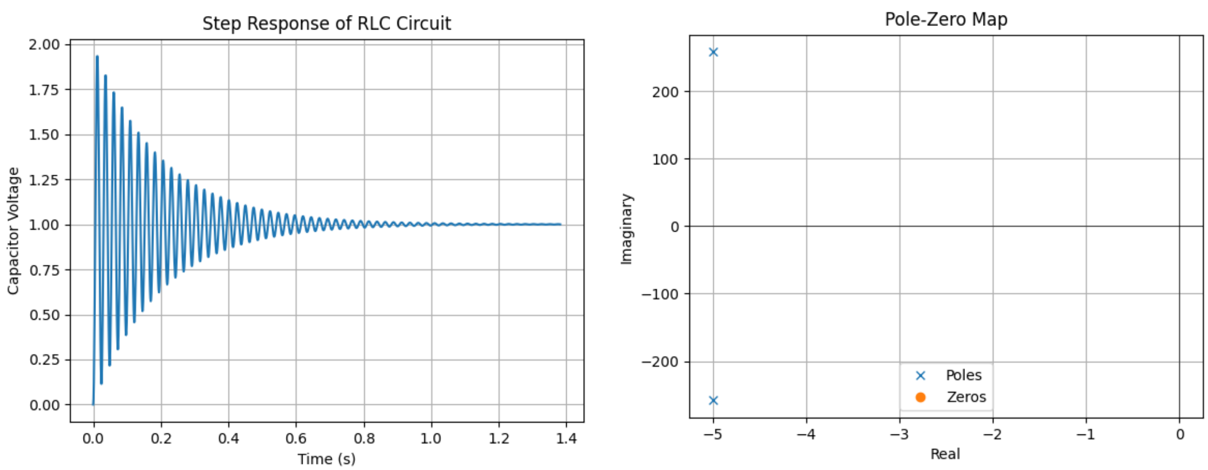
From the pole-zero map, we observe that both poles lie in the left half of the complex plane, indicating that the system is stable. The proximity of the poles to the imaginary axis suggests a low damping ratio, which matches the oscillatory behavior seen in the time-domain step response.
The small real part of the poles (-5) relative to the imaginary part (± 258) results in sustained oscillations with slow exponential decay. This explains the sharp peaks and gradual decline observed in the capacitor voltage over time.

Because no zeros are present, the system has no additional frequency shaping, meaning the behavior is governed entirely by the poles. The absence of zeros results in a clean, predictable oscillatory response, reinforcing that the poles dominate the transient dynamics.

These findings confirm that pole location directly informs expected time-domain performance. High imaginary values correlate with high-frequency oscillation, and low damping ratios yield extended ringing—both clearly observed here.

VIII. CONCLUSION

This experiment successfully demonstrated the connection between the pole-zero map and a system's dynamic behavior. The RLC circuit's transfer function yielded complex conjugate poles, which explained the underdamped response and oscillatory behavior observed. The simulation validated the theoretical prediction, reinforcing the importance of pole-zero analysis in control systems design. Understanding pole locations enables accurate forecasting of system stability, oscillation, and settling characteristics without needing to run full time-domain simulations.

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Poles: [-5.+258.15047292j -5.-258.15047292j]
Zeros: []
Pole 1: -5.0000+258.1505j, Damping: 0.0194, Natural Frequency: 258.20 rad/s
Pole 2: -5.0000-258.1505j, Damping: 0.0194, Natural Frequency: 258.20 rad/s
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Fig. 1. Step Response and Pole-Zero Mao