INTRODUCTION TO TIME RESPONSE AND DIFFERENT TYPES OF TEST SIGNALS

LAB EXPERIMENT 8

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***Abstract*—This experiment explores the time-domain behavior of a Linear Time-Invariant (LTI) system when subjected to various standard input signals: step, impulse, and sinusoidal. Using simulation tools, we obtained the system's response characteristics, including rise time, settling time, overshoot, and steady-state values. The analysis revealed an underdamped system with high responsiveness and notable resonance behavior. The outcomes provide valuable insights into system dynamics and form the basis for improving control system performance.**

I. RATIONALE

Time-domain responses are key to understanding the dynamic behavior of systems. Test signals such as step, impulse, and sinusoidal inputs are commonly used to analyze system characteristics.

II. OBJECTIVES

- Compare the time-domain response of an LTI system to different test signals (step, impulse, sinusoidal).
- Quantify the system's performance characteristics such as rise time, settling time, and overshoot for different inputs.
- Determine the system's steady-state value for each input type.

III. MATERIALS AND SOFTWARE

- Software: Python (with matplotlib, scipy)

IV. PROCEDURES

1) Set up the system and determine its transfer function.
2) Apply different test signals (step, impulse, sinusoidal) to the system.
3) Measure and calculate the time-domain response for each test signal, recording rise time, settling time, overshoot, and steady-state value.
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V. OBSERVATION AND DATA COLLECTION

DATA COLLECTION:

https://drive.google.com/drive/folders/1-lTsTDGzJ2KofYhraN7AE4MdgwklzQMw

Click here to open the Drive

VI. DATA ANALYSIS

Based on the simulation results from the graphs, the time-domain responses of the system were analyzed for step, impulse, and sinusoidal inputs. Here's a summary of the key observations:

- **Step Response:**
  - Rise Time: ≈ 0.0038 s
  - Settling Time: ≈ 0.7803 s
  - Overshoot: $\approx 93.38\%$
  - Peak: ≈ 1.9338
  - Steady-State Value: 1.0
- **Impulse Response:**
  - High amplitude peak ($\approx \pm 230$), indicating strong reactivity
  - Oscillations dampen out after approximately 1.2 s
- **Sinusoidal Response (50 Hz):**
  - Output shows phase lag and amplitude gain
  - System resonates or amplifies the input signal

VII. DISCUSSION AND INTERPRETATIONS

This experiment effectively demonstrates how different input signals reveal various characteristics of a system's dynamics.

The **step response** exhibited underdamped oscillations with a significant overshoot, indicating a quick but unstable initial reaction. The system reached the steady state after approximately 0.78 seconds, suggesting it is responsive yet prone to oscillations.

In the **impulse response**, high peak values and quick decaying oscillations were observed. These reflect the system's transient behavior and how it handles sudden shocks, important for systems subjected to rapid changes.

The **sinusoidal input** revealed a phase shift and increased amplitude in the output, showing that the system may amplify inputs at certain frequencies—a behavior that could cause resonance and must be accounted for in real applications.

Overall, the results indicate a second-order underdamped system, one that reacts quickly but may oscillate excessively and amplify certain signals if not properly controlled.

VIII. CONCLUSION

This experiment helped us understand how Linear Time-Invariant (LTI) systems react to common input types—step, impulse, and sinusoidal. We were able to extract meaningful time-domain performance metrics such as rise time, settling time, overshoot, and steady-state value. These insights are critical for assessing system stability and response speed. The results confirmed that while the system is fast and responsive, it is also prone to oscillations and frequency-dependent gain, which must be managed in real-world control applications.