PID Controller Design and Simulation for a Mass-Spring-Damper System

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Abstract

This project presents the modeling and PID control design for a mass-spring-damper system using MATLAB and Simulink. The objective is to study the system's dynamic behavior and improve performance via classical control techniques.

System Description

The system is modeled by the second-order differential equation:

m * x'' + b * x' + k * x = F(t)

Where:

m = 1 kg (mass)

b = 10 Ns/m (damping coefficient)

k = 20 N/m (spring constant)

Transfer Function in s-domain:

$G(s) = 1 / (m \cdot s^2 + b \cdot s + k) = 1 / (s^2 + 10s + 20)$

PID Controller

The control design uses a PID controller in the form:

$C(s) = Kp + Ki/s + Kd \cdot s$

Selected gain values:

Kp = 350

Ki = 300

Kd = 50

MATLAB Simulation

The system was simulated using MATLAB with the tf, pid, and feedback functions. Step response plots were generated for both open-loop and closed-loop systems.

Simulink Implementation

The Simulink model includes the following blocks:

Step input

Sum block for error calculation

PID Controller block

Transfer Function block (representing the plant)

Scope to display the response

A negative feedback loop connects the plant output back to the input summation point.

Results

Figure 1: Open-loop Step Response (from MATLAB)

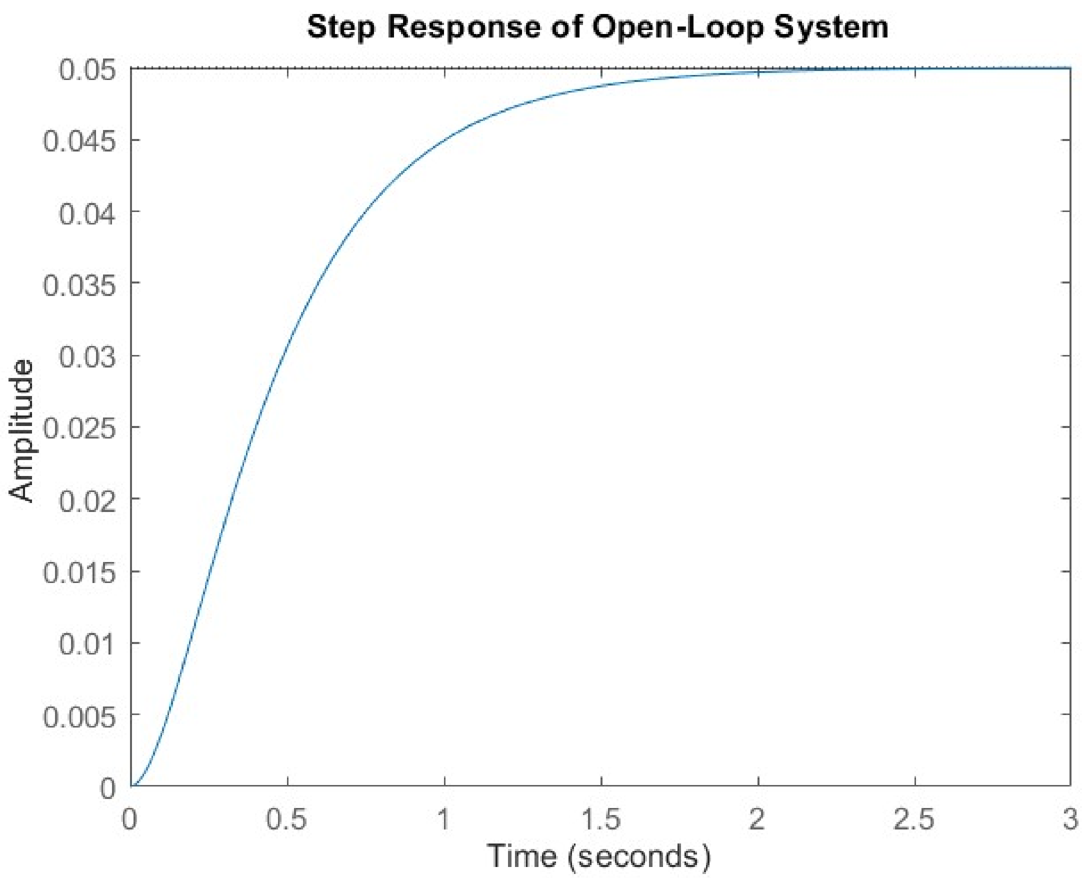


Figure 2: Closed-loop Step Response with PID Controller (from MATLAB)

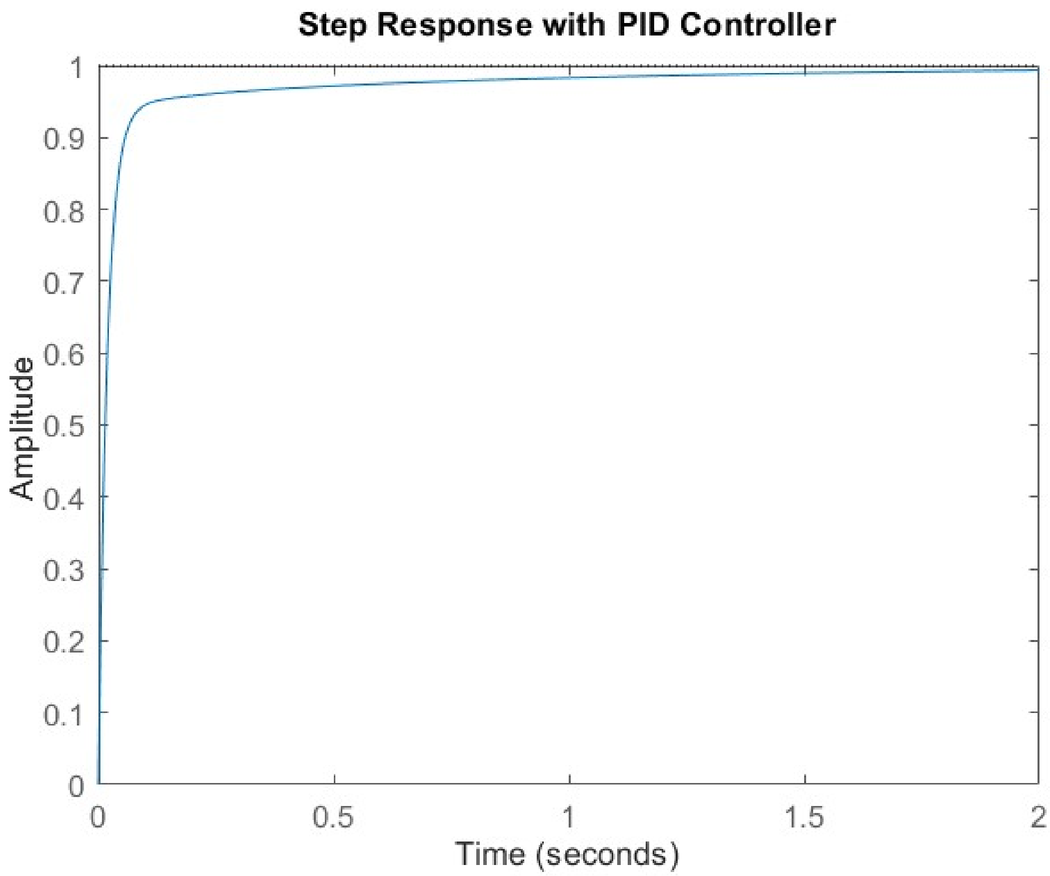
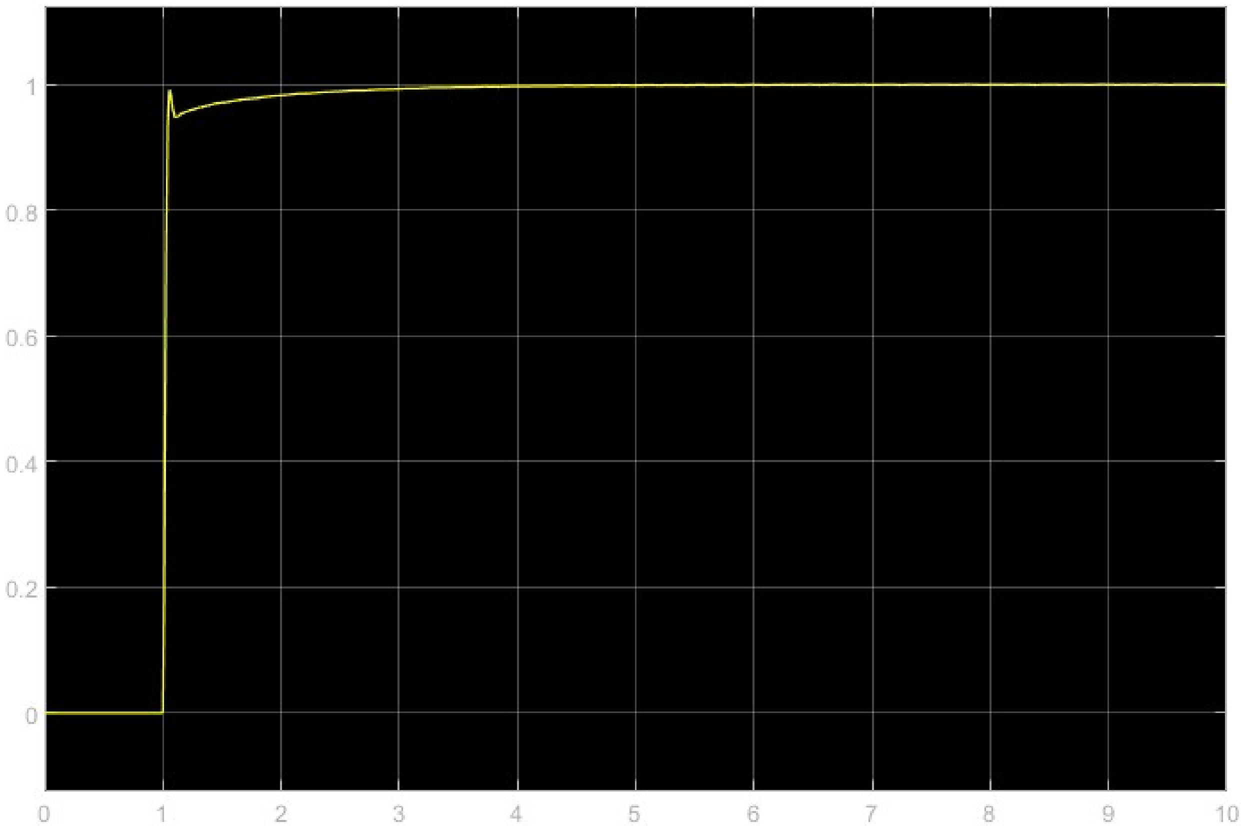


Figure 3: System Response in Simulink (from Scope)



Conclusion

The designed PID controller significantly enhanced the dynamic behavior of the system. The closed-loop system demonstrated faster rise time, minimal overshoot, and stable steady-state performance. This simple project serves as a foundation for more advanced control applications.

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