Project 1 Report - ME155C/ECE147C

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May 11, 2025

Abstract

In this project, we design a controller for a two mass - one spring, cart system. The goal is to optimize the performance of the second cart's response to a step input to the reference through control of the first cart's behavior, with respect to several key control metrics. We look at optimizing for a very short settling time along with minimizing the amount of overshoot. The 'undershoot' is treated as an acceptable behavior since the cart will pass through this region, so we give ourselves the difficulty of treating the overshoot as a highly undesirable set. We achieve our goals with a settling time under three seconds along with less than one percent overshoot.

1 Introduction

We begin our control journey with the search of an optimal controller. The first idea here is LQR, but it is clear that we have noise in our system and uncertainty in our data, so we consider going to LQG. We try to decrease our uncertainty by doing a sinusoidal sweep of 20 frequencies.

2 System Identification

2.1 Process to be controlled

The process we are controlling is a two cart system connected by a spring. The system is driven by a motor that's given a voltage V [Volt], which produces a force F [N] applied to the first cart with mass m_1 [kg], and the second cart with mass m_2 [kg] is connected to the first cart via a spring with spring constant k [N/m]. In this system, x_1 [m] is the position of the first cart, and x_2 [m] is the position of the second cart. The control input is the voltage $u := V$ [Volt] applied to the motor, and the measured output is the position $y := x_2$ [m] of the second cart.

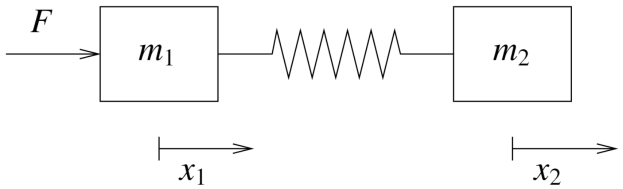

Figure 1: Two cart system

2.2 Non-Parametric Identification

The non-parametric identification method used was sine-wave testing in conjunction with the correleation method. This strategy consists of applying sinusoidal inputs at distinct frequencies to calculate the magnitude and phase of the frequency response at that frequency from the output of the system.

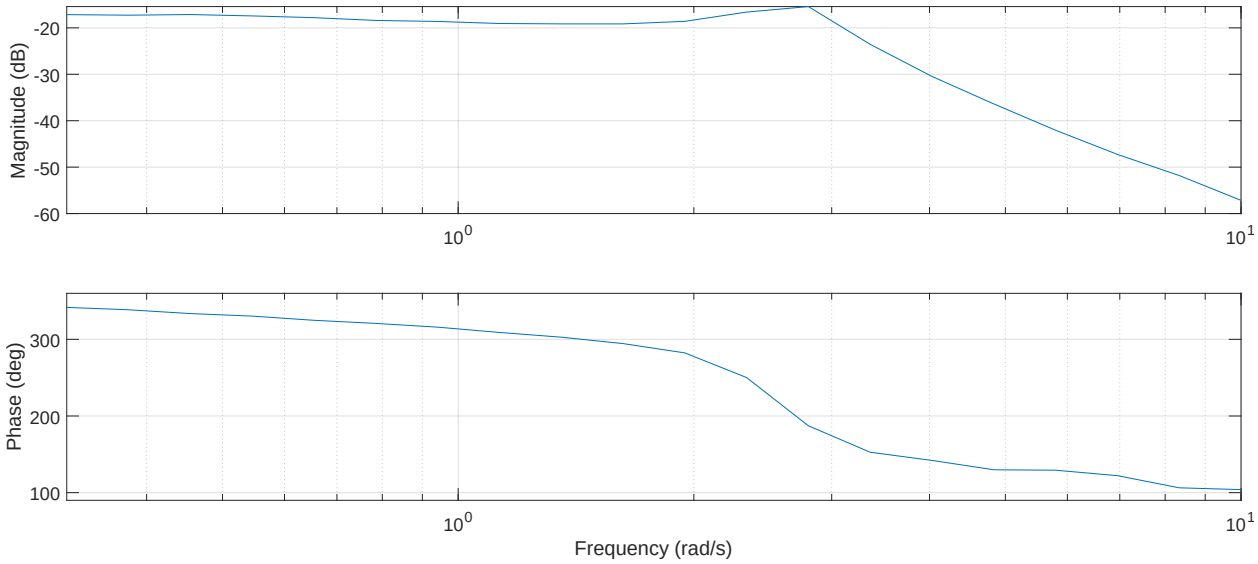

Figure 2: Bode plot of the identified system using non-parametric identification

2.3 Parametric Identification

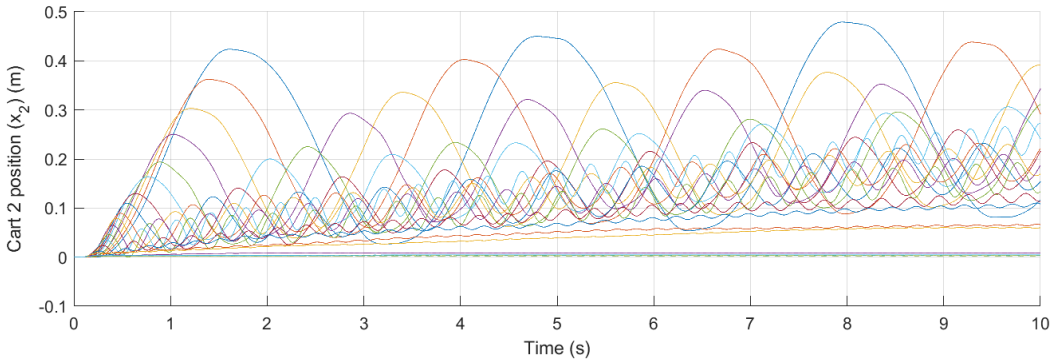

Figure 3: Output signals of all experiments for parametric identification

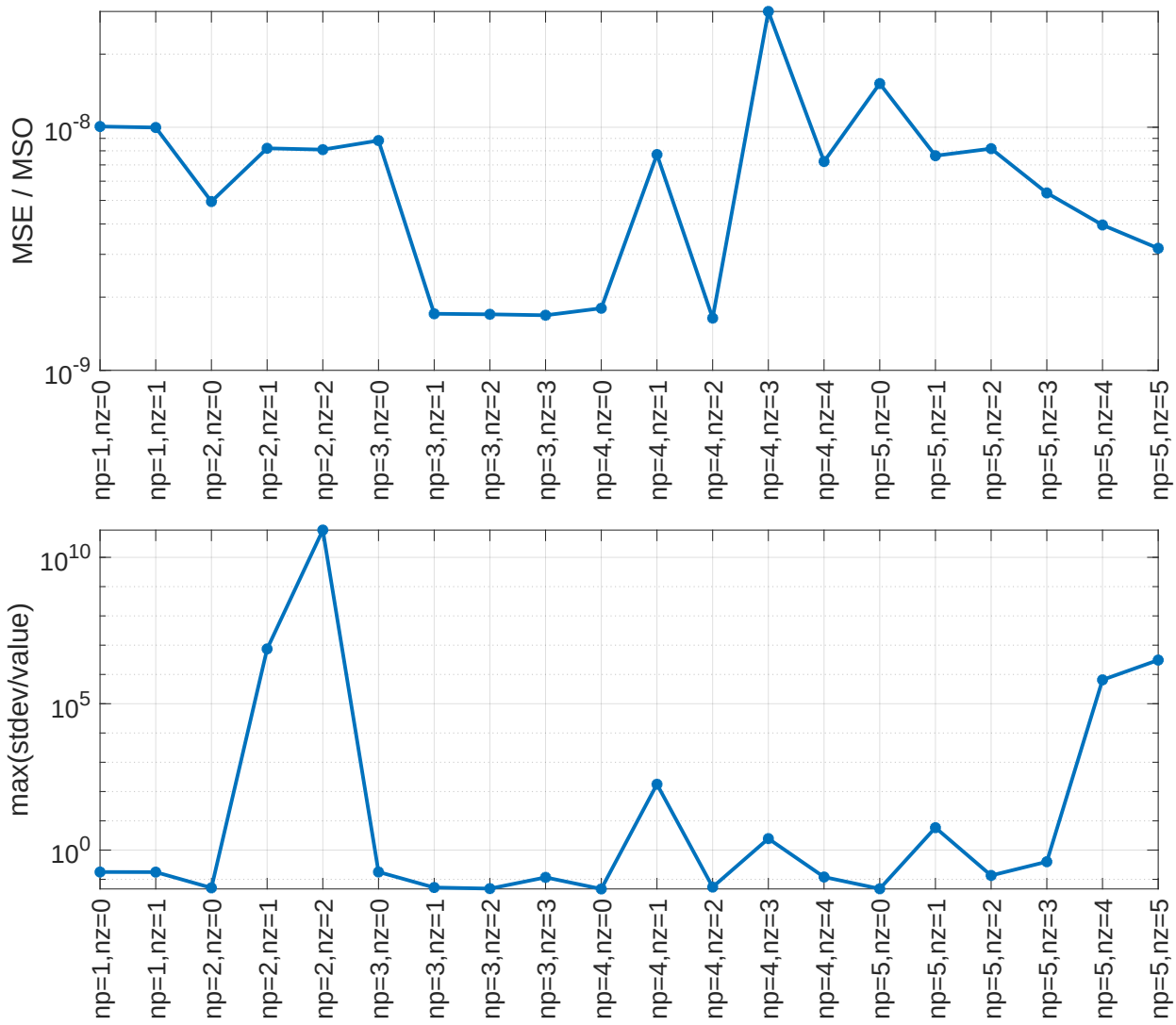

Figure 4: Normalized MSE and worst parameter standard deviation for different model orders

3 Controller Design

3.1 Design Methodology

3.2 Simulation Results

4 Closed-loop Testing

4.1 Step Response Experiments

4.2 Closed-loop Frequency Response

5 Conclusions and Future Work

References

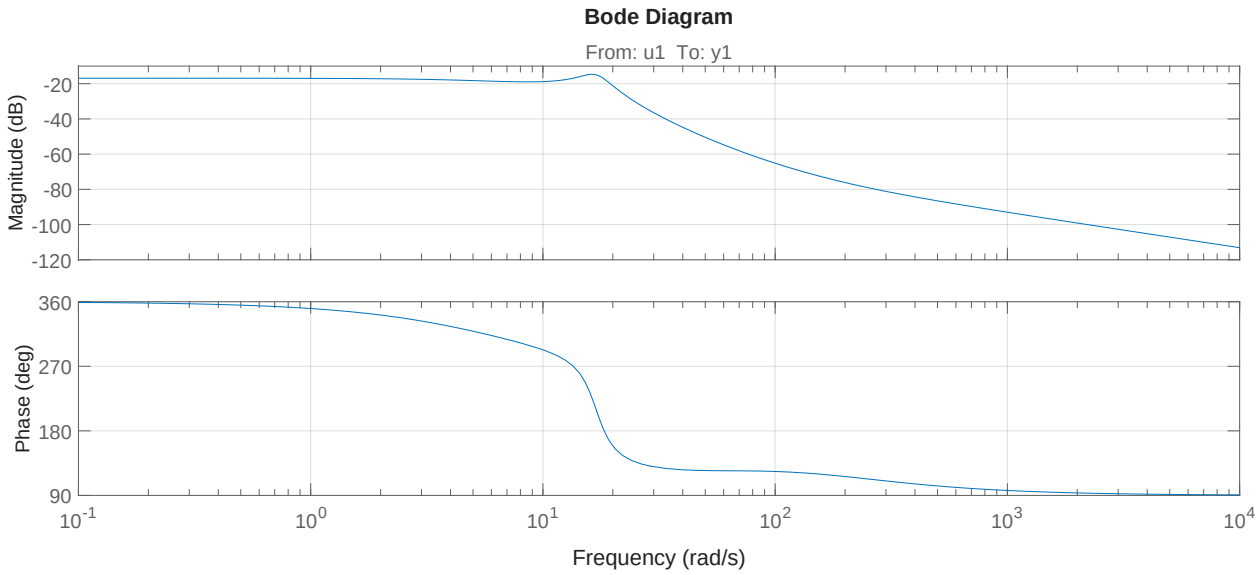

Figure 5: Bode plot of the identified system using parametric identification

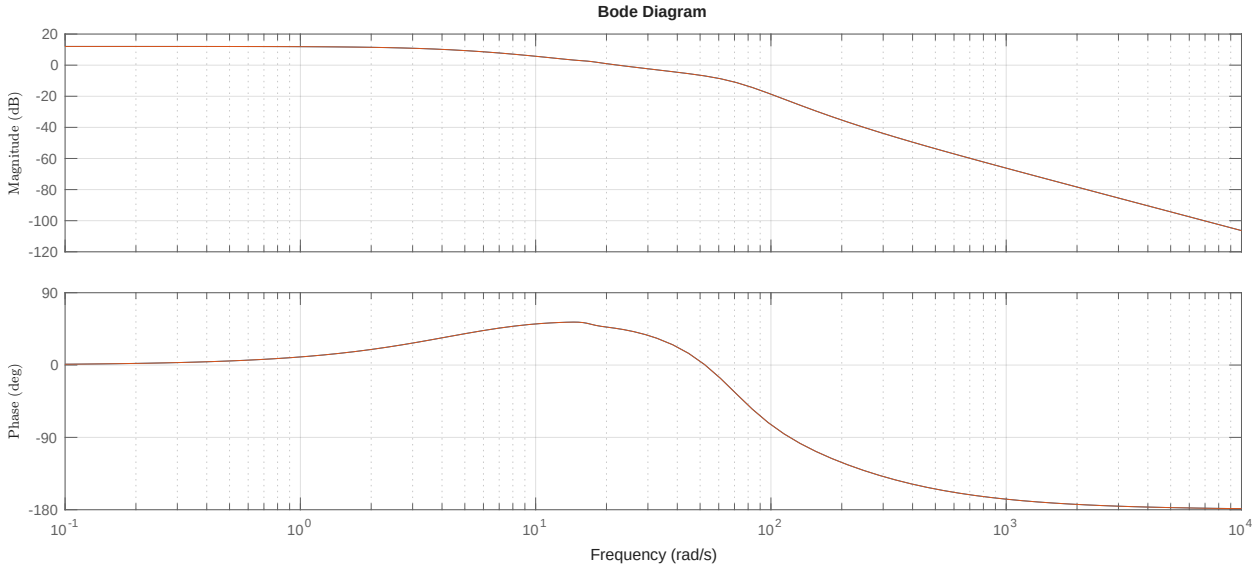

Figure 6: Bode plot of complementary sensitivity function of simulated controller

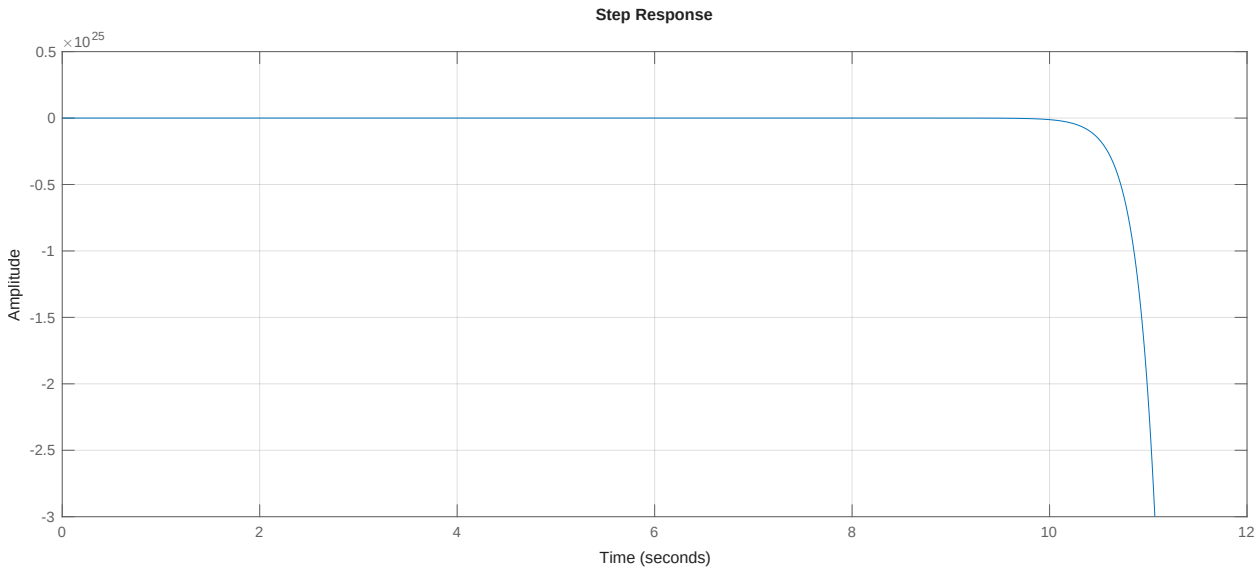

Figure 7: Simulated closed-loop step response

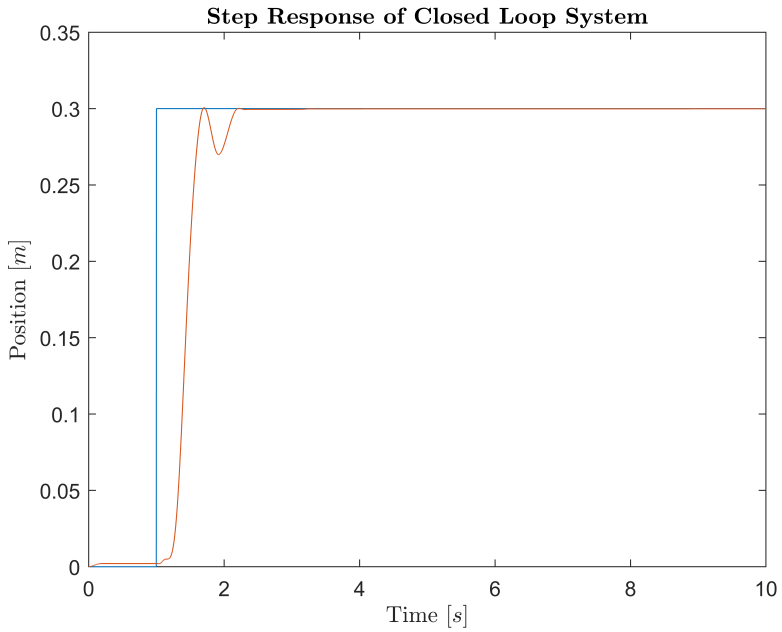

Figure 8: Closed-loop step response

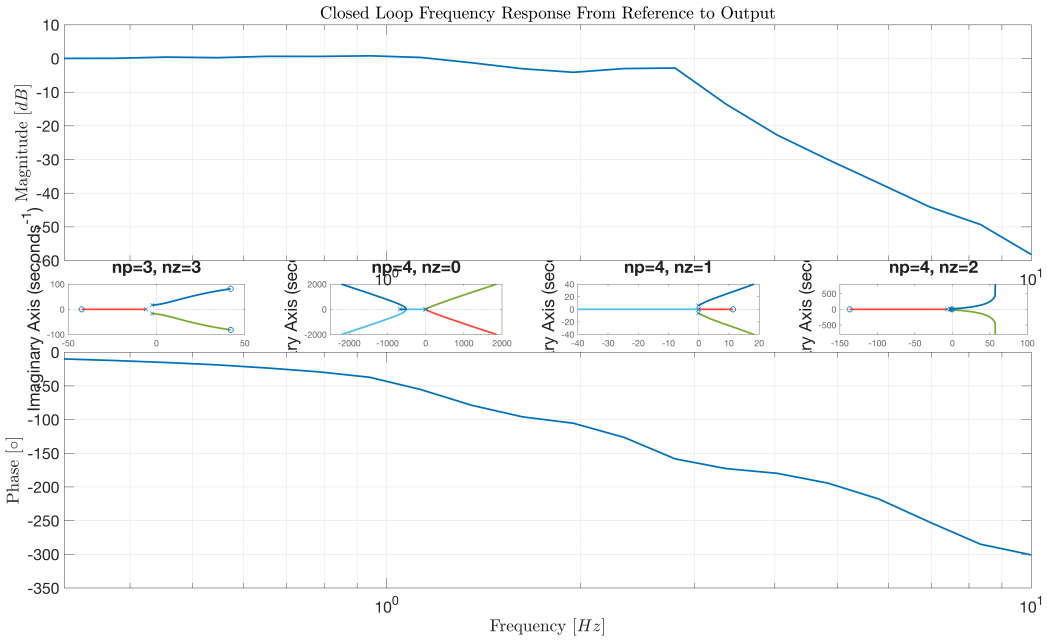

Figure 9: Closed-loop frequency response of the transfer function from reference to output

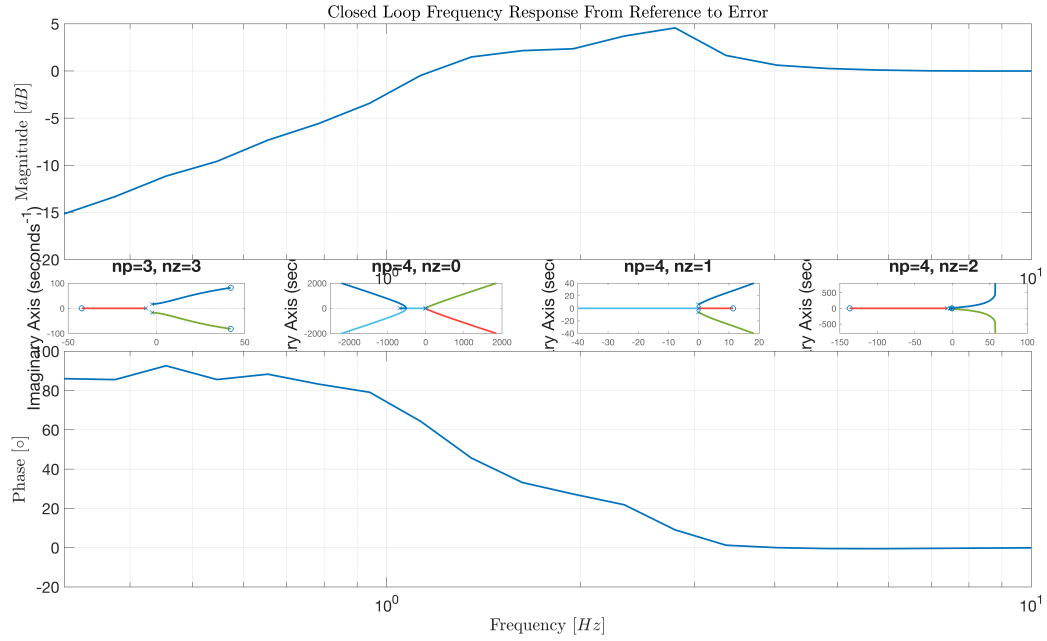

Figure 10: Closed-loop frequency response of the transfer function from reference to error