

Project 1 Report - ME155C/ECE147C

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Abstract

1 Introduction

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 applies a force F 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.

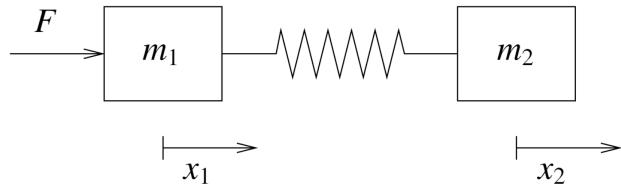


Figure 1: Two cart system

2.2 Non-Parametric Identification

2.3 Parametric Identification

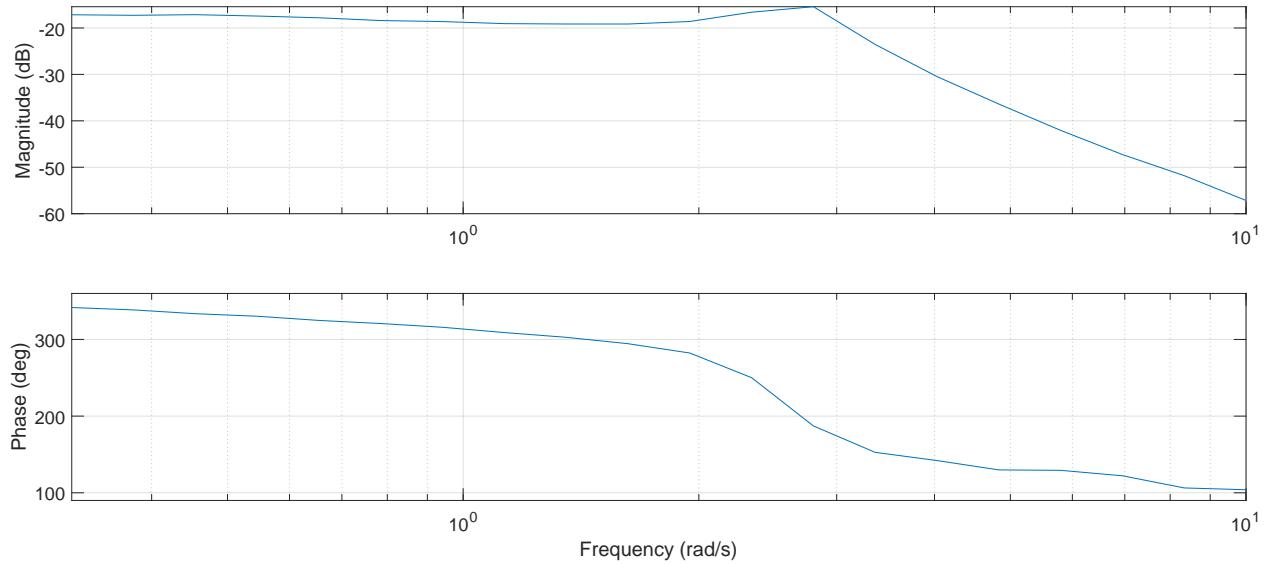


Figure 2: Bode plot of the identified system using non-parametric identification

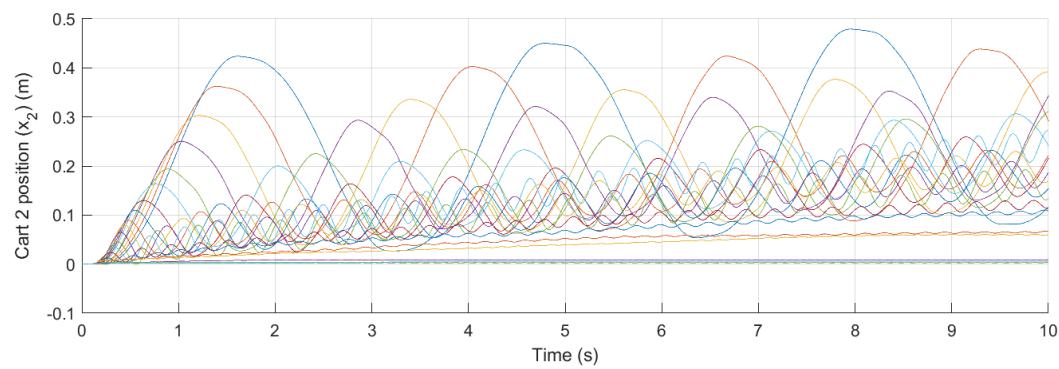


Figure 3: Output signals of all experiments for parametric identification

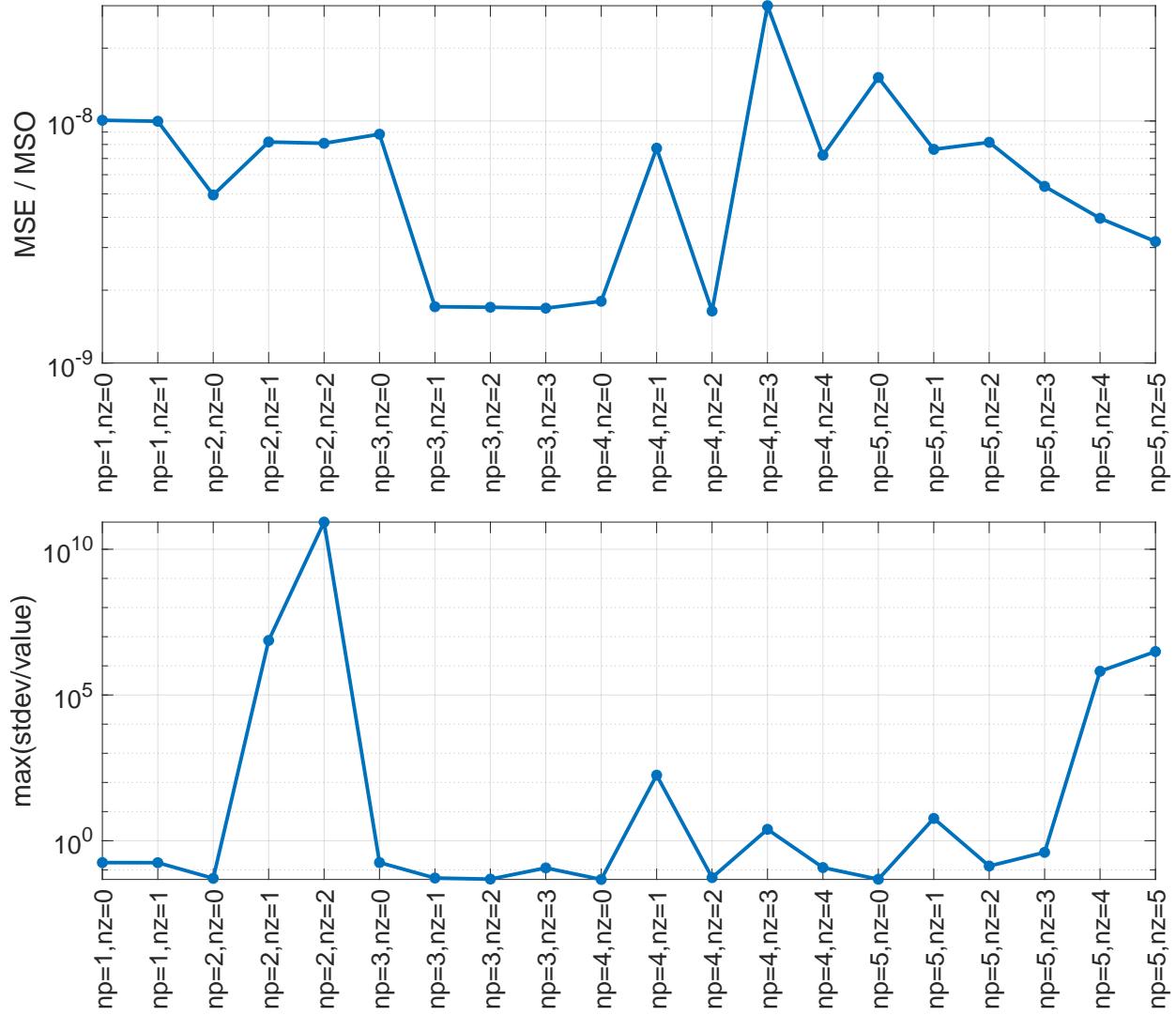


Figure 4: Normalized MSE and worst parameter standard deviation for different model orders

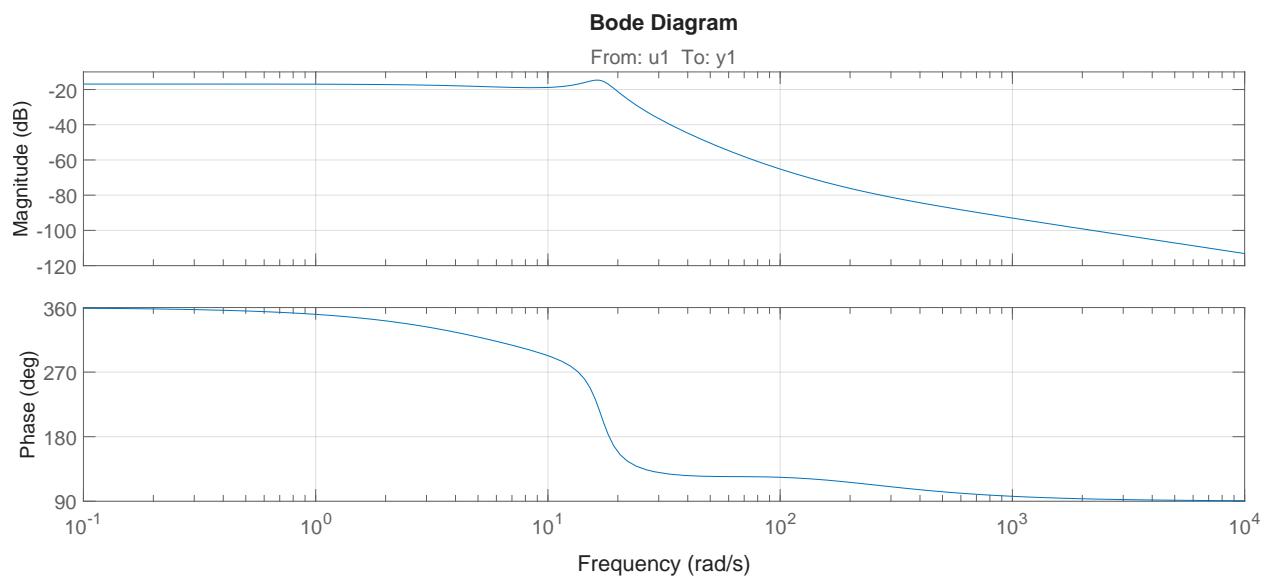


Figure 5: Bode plot of the identified system using parametric identification

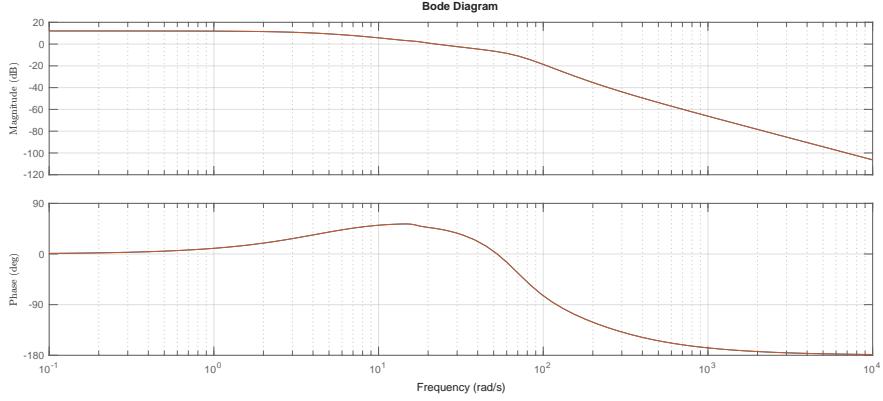


Figure 6: Closed-loop frequency response (simulated)

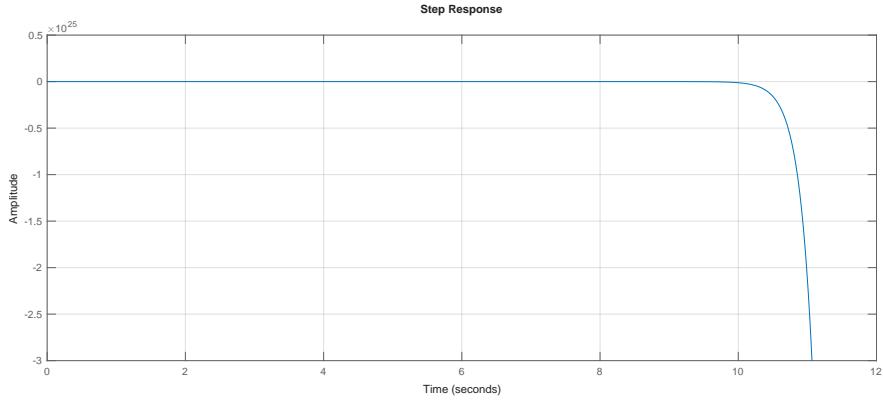


Figure 7: Closed-loop step response (simulated)

3 Controller Design

3.1 Design Methodology

Next, we were tasked to design a controller for the system. We shot for an overshoot of less than 15% and a settling time of less than 2 seconds. To achieve this, we chose to use an LQR/LQG design. Using our identified model, we used Matlab to calculate the optimal LQR gains and Kalman filter.

However, even with the optimal linear controller, the unmodelled dead zone of the motor still caused there to be a large steady state error. To fix this, we added an integrator to the controller, which successfully eliminated the steady state error. The final controller is an LQR/LQG controller in parallel with an integrator, which led to a closed loop system with an adequate performance.

3.2 Simulation Results

We simulated the closed-loop system in Simulink using the identified model. The frequency response can be seen in Figure 6. The simulated step response is unstable, as seen in Figure 7.

4 Closed-loop Testing

4.1 Step Response Experiments

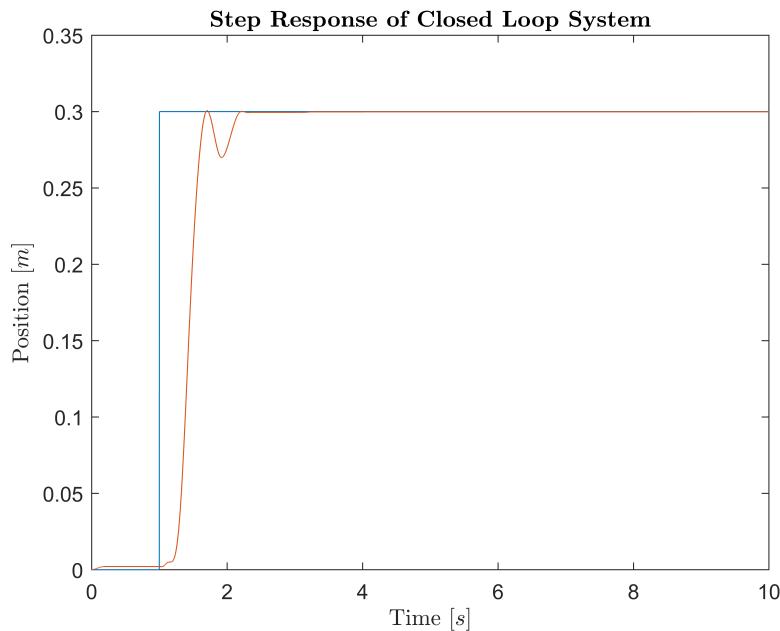


Figure 8: Closed-loop step response

4.2 Closed-loop Frequency Response

5 Conclusions and Future Work

References

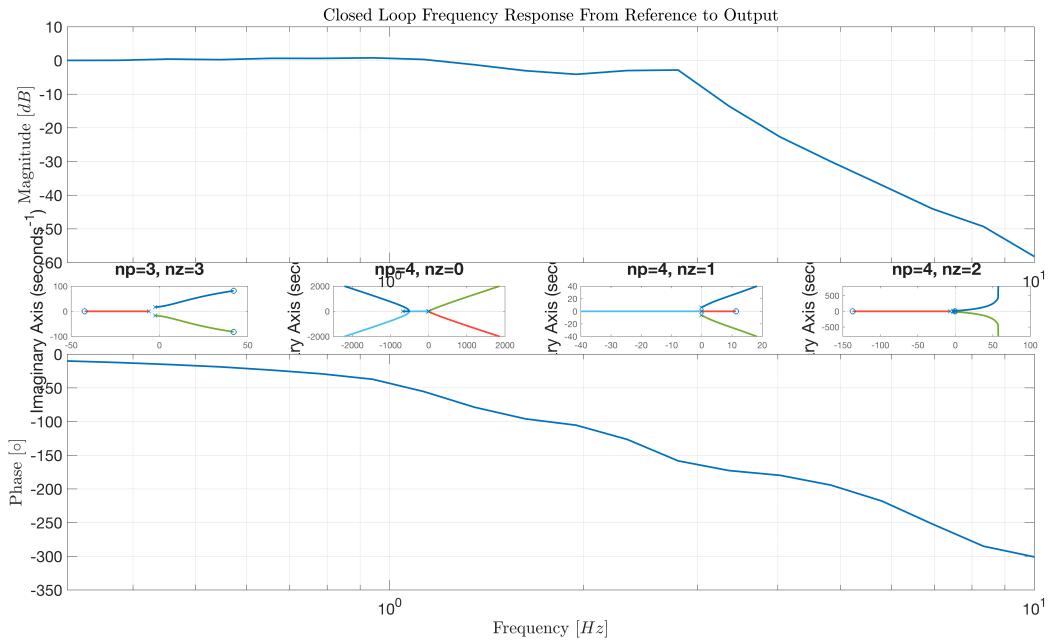


Figure 9: Closed-loop frequency response of the transfer function from reference to output

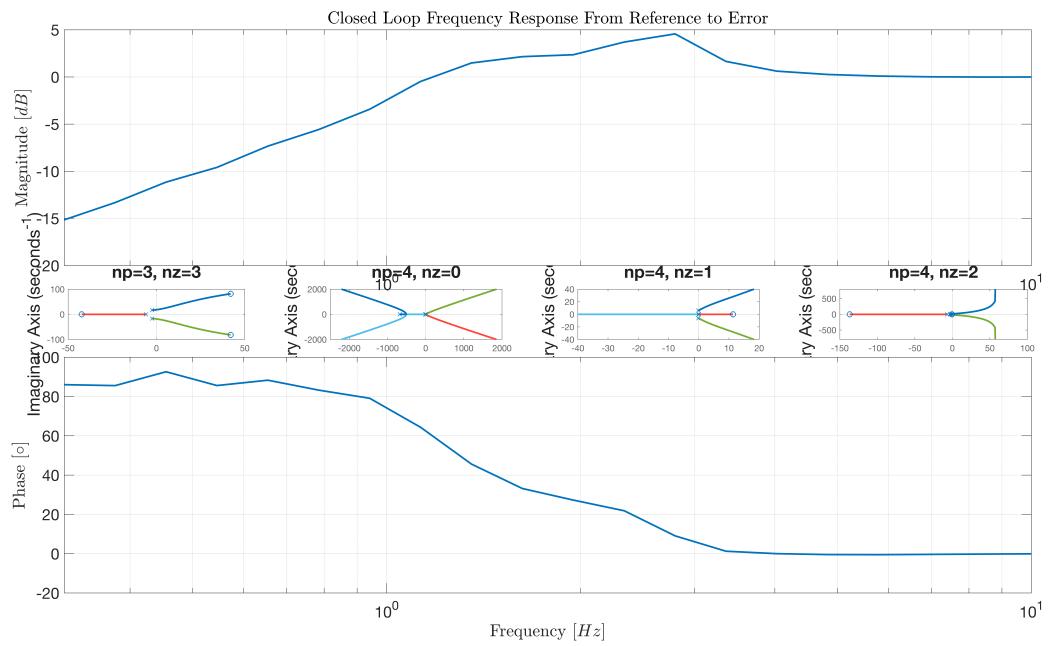


Figure 10: Closed-loop frequency response of the transfer function from reference to error