AE 443 Position Control

Colby Davis

Lab Assistant: Christian Hughes

AE 443 – Section 03DB

Department of Aerospace Engineering,
Embry-Riddle Aeronautical University, Daytona Beach, FL, 32114-3990

March 18, 2024

I. Procedure

I.1. Closed-loop & Ramp Response Simulation with PV Controller

To run the simulation:

1. Start setup_srv02_exp02_pos
2. Set the proportional and velocity gains to those found in Pre-lab Question 4
3. Run s_srv02_pos Simulink
   a. For Step Response, in Simulink set the SRV02 Signal Generator:
      i. Signal type = square
      ii. Amplitude = 1
      iii. Frequency = 0.4 Hz
      iv. In the Simulink diagram set Amplitude gain block to $\frac{\pi}{8}$
      v. Set the switch to the UP position in PIV Control Subsystem
   b. For Ramp Response, in Simulink set the SRV02 Signal Generator:
      i. Signal type = triangle
      ii. Amplitude = 1
      iii. Frequency = 0.8 Hz
      iv. In the Simulink diagram set Amplitude gain block to $\frac{\pi}{3}$
      v. Set the switch to the DOWN position in PIV Control Subsystem
4. Open the scopes for both Theta and Vm
5. Run the simulation for 5 seconds

I.2. Closed-loop & Ramp Response Implementation with PV Controller

To setup the implementation:

1. Start setup_srv02_exp02_pos.m
2. Set the proportional and velocity gains to those found in Pre-lab Question 4
3. Run q_srv02_pos Simulink
   a. For Step Response, in Simulink set the SRV02 Signal Generator:
      i. Signal type = square
      ii. Amplitude = 1
      iii. Frequency = 0.4 Hz
      iv. In the Simulink diagram set Amplitude gain block to $\frac{\pi}{8}$
      v. Set the switch to the UP position in PIV Control Subsystem
   b. For Ramp Response, in Simulink set the SRV02 Signal Generator:
      i. Signal type = triangle
      ii. Amplitude = 1
      iii. Frequency = 0.8 Hz
      iv. In the Simulink diagram set Amplitude gain block to $\frac{\pi}{3}$
      v. Set the switch to the DOWN position in PIV Control Subsystem
4. Open the scopes for both Theta and Vm
5. Run the model for 5 seconds

I.3 Hypothesis & Cause-Effect

The hypothesis of this experiment is that by implementing a proportional velocity controller in the environment with appropriate gain parameters, the SRV02 position control system will exhibit a response with minimal steady-state error. Specifically, the proportional velocity control will enable precise adjustment of the system's velocity to track the desired position trajectory over time, resulting in accurate position control without significant deviation from the setpoint.

Introducing a proportional gain helps adjust the control input based on the steady-state error, an integral gain eliminates any residual error, and finally derivative helps in damping and or system stability.

I.4 Independent and Dependent Variables

The independent variable of the system is the gain, which is controlled by the user. The dependent variable is the system response such as system velocity and steady-state error.

I.5 Assumptions

The assumptions for the system should make it ideal, such as no delays on the motor, no friction, and steady-state conditions. By making the system ideal it simplifies the model and allows the focus to be on the control algorithm.

I.6. Ramp Response Implementation & Simulation with PIV Controller

To run the ramp response with PIV:

1. Start
    a. For simulation: s_srv02_pos Simulink
    b. For implementation q_srv02_pos Simulink
2. Run the code setup_srv02_exp02_pos.m
3. Set the proportional and velocity gains to those found in Pre-lab Question 4
4. Set the integral gain found in Pre-Lab Question 7
    a. For Ramp Response, in Simulink set the SRV02 Signal Generator:
        i. Signal type = triangle
        ii. Amplitude = 1
        iii. Frequency = 0.8 Hz
        iv. In the Simulink diagram set Amplitude gain block to $\frac{\pi}{3}$
        v. Set the switch to the DOWN position in PIV Control Subsystem
5. Open the scopes for both Theta and Vm
6. Run the simulation for 5 seconds

II. Results

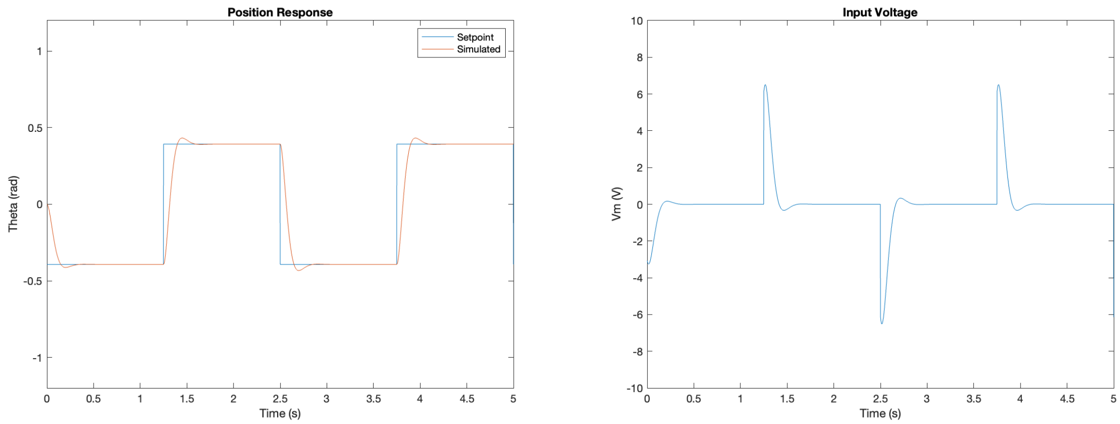

Figure 1: Step Response Simulation Using PV Controller

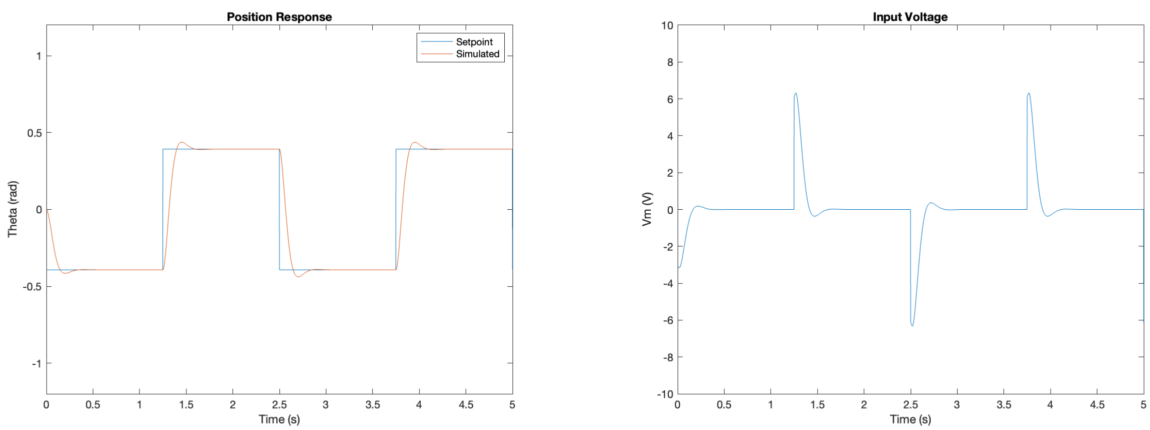

Figure 2: Step Response Simulation Using Low-Pass Filter

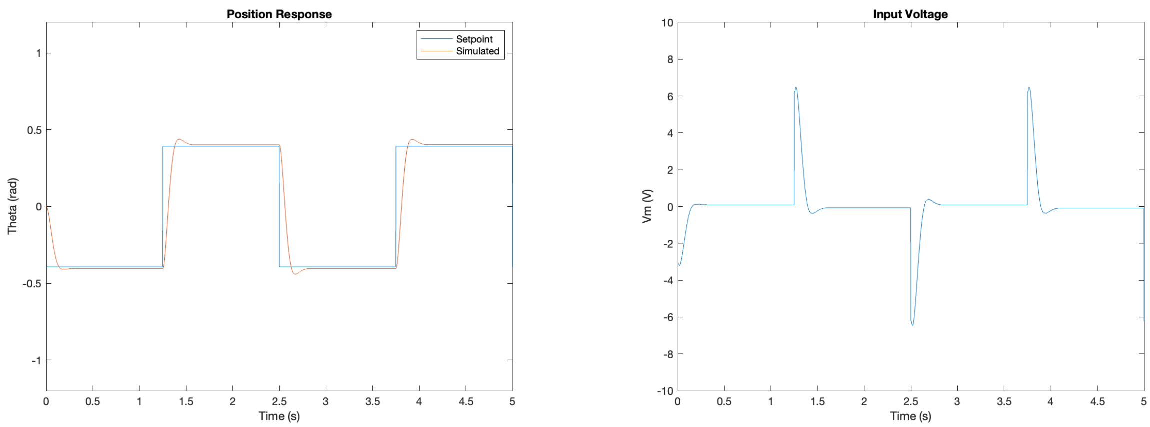

Figure 3: Step Response Implementation using PV Controller

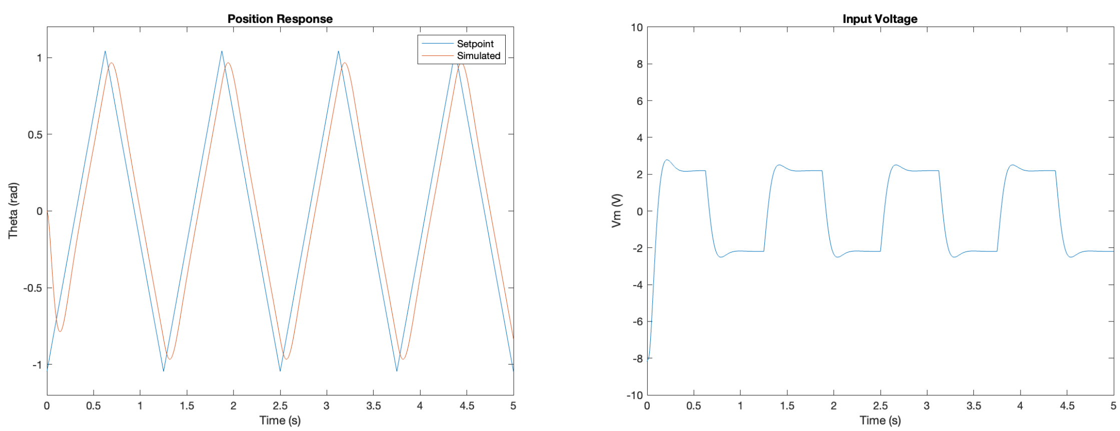

Figure 4: Ramp Response Simulation Using PV Controller

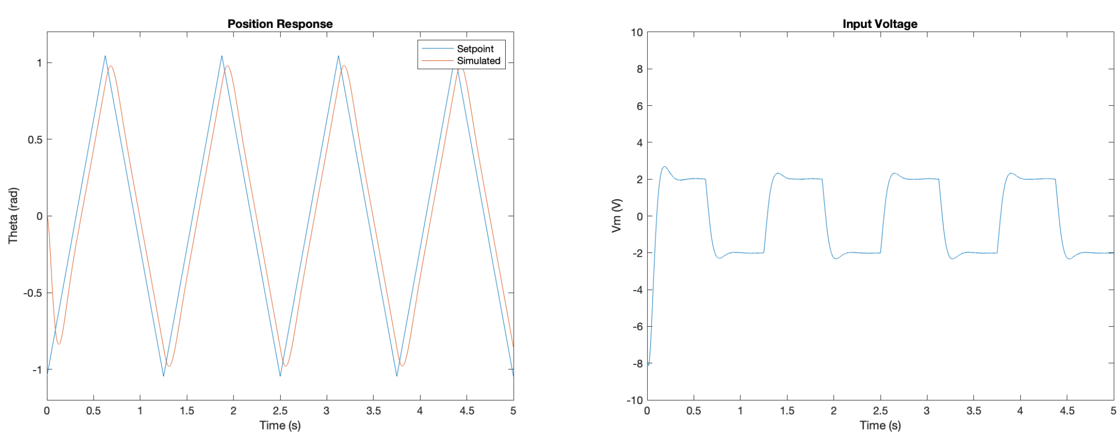

Figure 5: Ramp Response Implementation Using PV Controller

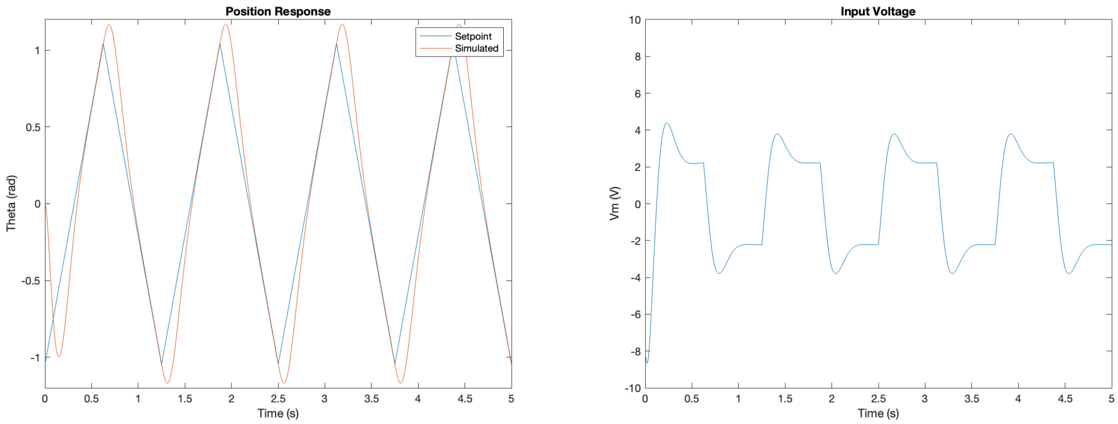

Figure 6: Ramp Response with No Steady-State Error Simulation

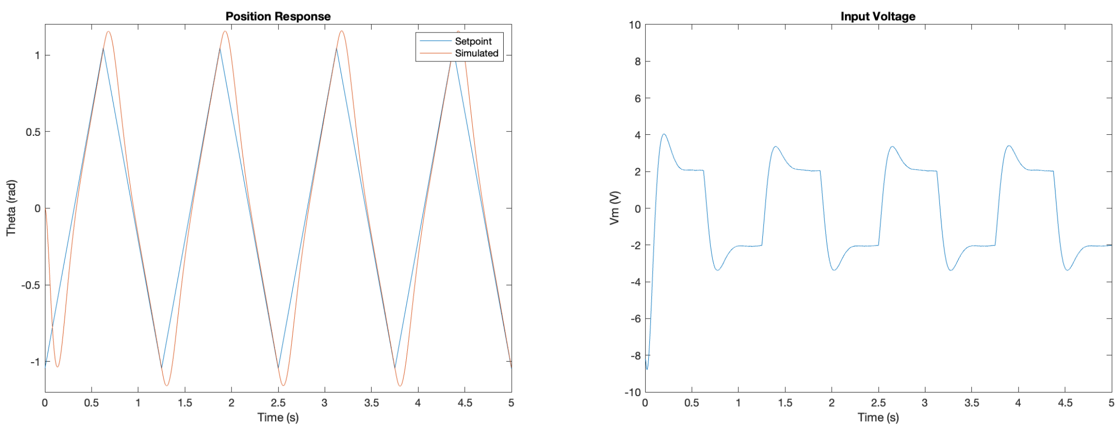

Figure 7: Ramp Response with No Steady-State Error Implementation

Table 1: Results

Section/Question	Description	Symbol	Value	Unit
Question 4	**Pre-Lab: Model Parameters** Open-Loop Steady-State Gain Open-Loop Time Constant	K τ	1.53 0.0254	Rad/(V*s) s
Question 4	**Pre-Lab: PV Gain Design** Proportional Gain Velocity Gain	k_p k_v	7.82 -0.157	V/rad $V*s/rad$
Question 5	**Pre-Lab: Control Gain Limits** Maximum Proportional Gain	$k_{p,max}$	12.7	V/rad
Question 6	**Pre-Lab: Ramp Steady-State Error** Steady-State error using PV	e_{ss}	0.214	rad
Question 7	**Pre-Lab: Integral Gain Design** Integral gain	k_i	38.9	V/rad*s
3.3.1.1	**Step Response Simulation**	t_p	0.39	s

	Peak time Percent overshoot Steady-state error	PO e_{ss}	5 0	% rad
3.3.1.1	**Filtered Response Using PV** Peak time Percent overshoot Steady-state error	t_p PO e_{ss}	0.2 5.76 0	s % rad
3.3.1.2	**Step Response Implementation** Steady-state error	e_{ss}	.0107	rad
3.3.2.1	**Ramp Response Simulation with PV** Steady-state error	e_{ss}	-.213	rad
3.3.2.2	**Ramp Response Implementation with PV** Steady-state error	e_{ss}	0.1897	rad
3.3.3	**Ramp Response Simulation with no steady-state error** Steady-state error	e_{ss}	-0.0069	rad
3.3.3	**Ramp Response Simulation with no steady-state error** Steady-state error	e_{ss}	-0.007	rad

III. Analysis

III.1 Step and Ramp Response

Using the MATLAB function *stepinfo()* was used to find the peak time and percent over shoot of the simulated and implemented for step response. For steady-state error the equation below was used for both step and ramp responses:

$$e_{ss} = \text{data\_theta(end, 2)-data\_theme(end, 3)} \tag{1}$$

This equation uses subtracts the end point of the simulation/implementation response from the ideal setpoint.

IV. Error Analysis

Description	Expected Value	Measured Value	Percent Error
Step Response Simulation Peak time Percent overshoot Steady-state error	0.39 5 0	0.39 5 0	0 % 0 % 0 %
Filtered Response Using PV Peak time Percent overshoot Steady-state error	0.2 5.76 0	0.2 5.76 0	0 % 0 % 0 %

Step Response Implementation Steady-state error	0	.0107	1.05 %
Ramp Response Simulation with PV Steady-state error	0	-.213	17.55 %
Ramp Response Implementation with PV Steady-state error	0	0.1897	15.94 %
Ramp Response Simulation with no steady-state error Steady-state error	0	-0.0069	0.68 %
Ramp Response Simulation with no steady-state error Steady-state error	0	-0.007	0.695 %

V. Conclusions

All the systems whether simulation or the implemented version both in orange closely resembled that of the setpoint (ideal) system with the blue line shown if Figures 1-6. This is also shown with the very low percent error shown in the error analysis.

An improvement to the experiment that could be made is making the experiment start with an unstable system to show with no control system and then implement a controller. The experiment successfully reached its learning outcomes, by showing different controllers and the impacts of its implementation.