ELECENG 3CL4 Lab 5 Report

Aaron Pinto	Raeed Hassan
pintoa9	hassam41
L02	L02

April 12, 2021

1 Design of a Lead-Lag Compensator for the Quanser Servomotor

The design of the lead-lag compensator uses the lead compensator that was designed in Lab 4, and modifies it to reach a steady-state error target without affecting the transient response significantly. This is achieved by introducing a lag compensator with the addition of an additional pole and zero. The zero was placed at 0.2, a point close to the origin. As the design objective of the lag compensator is to reduce the steady state error due a step disturbance by a factor of 10, the pole is placed at $z/10 = 0.02$. The angle between the zero and pole relative to the closed-loop pole was found to be 0.52 degrees, below the 1 degree design guideline. This lag compensator is simply added in series to the existing lead compensator. The addition of the lag compensator in MATLAB can be seen in Listing 1.

Listing 1: Lag compensator

```
G = tf(A/tau_m,[1,1/tau_m,0]);
Gc_lead=tf(kc*[1,z],[1,p]);

zlag = 0.2;
plag = zlag/10;

%Construct the transfer function model of the lead-lag compensator
lag_system=tf([1,zlag],[1,plag]);
Gc_leadlag=series(lag_system,Gc_lead);

%Construct the open loop transfer functions
L_lead=series(Gc_lead,G);
L_leadlag=series(Gc_leadlag,G);
```

The addition of the lag compensator does not have a significant effect on the transient performance of the system, as seen in the root locus in Figure 1, the step response in Figure 2, and the ramp response in Figure 3.

The addition of the lag compensator significantly reduces the steady state error of the system, as seen in the response to a step disturbance in Figure 4. The steady state error in the system with the lead-lag compensator is about 10% of the error in the system with just a lead compensator. The steady state error design objective of the lead-lag compensator is achieved, while also keeping the transient response that is designed with the lead compensator largely unchanged.

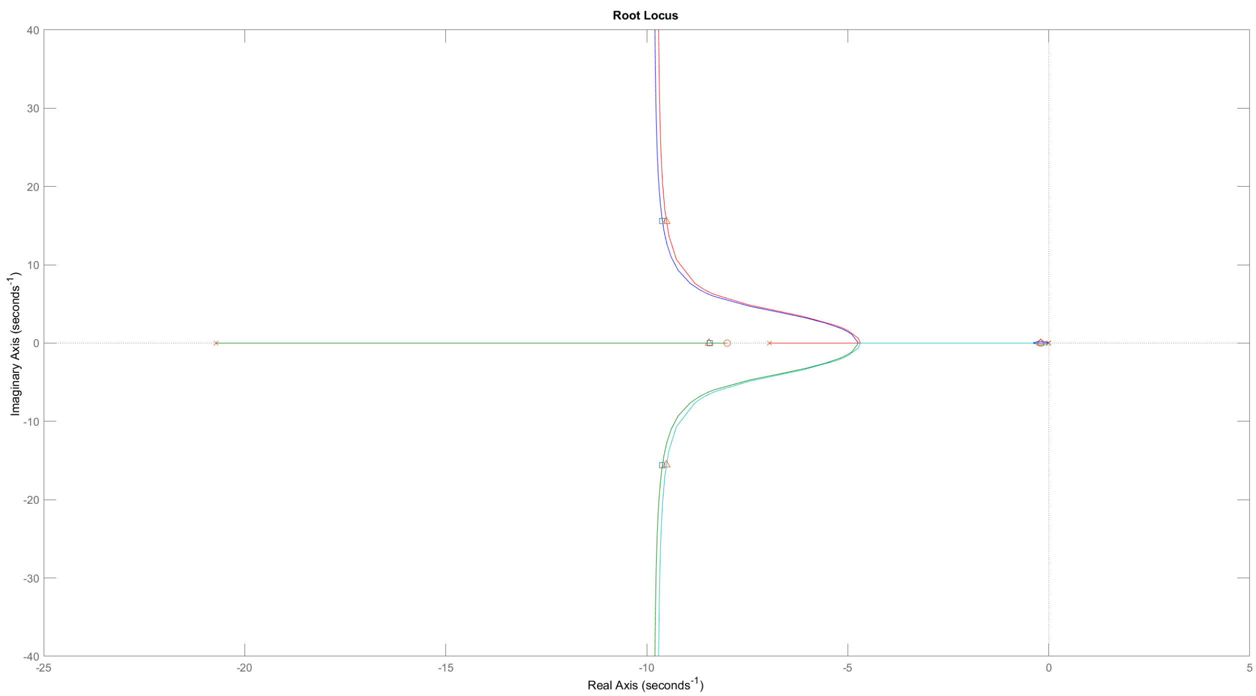

Figure 1: Root Locus

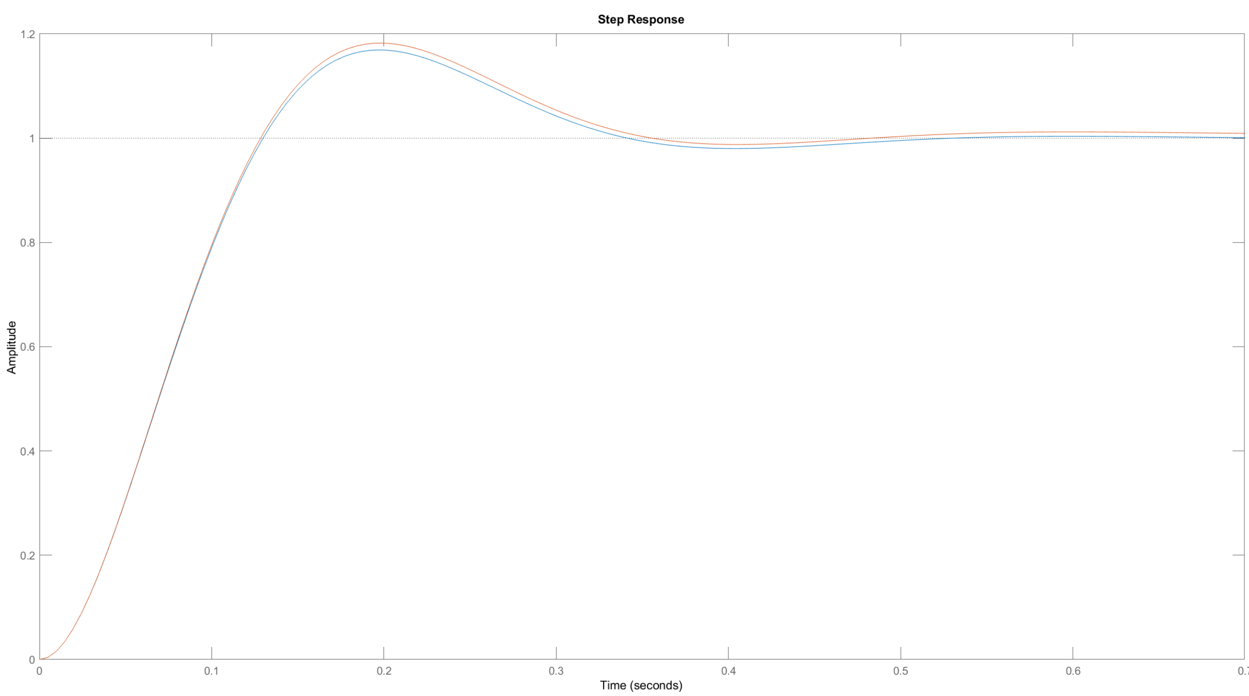

Figure 2: Step Response

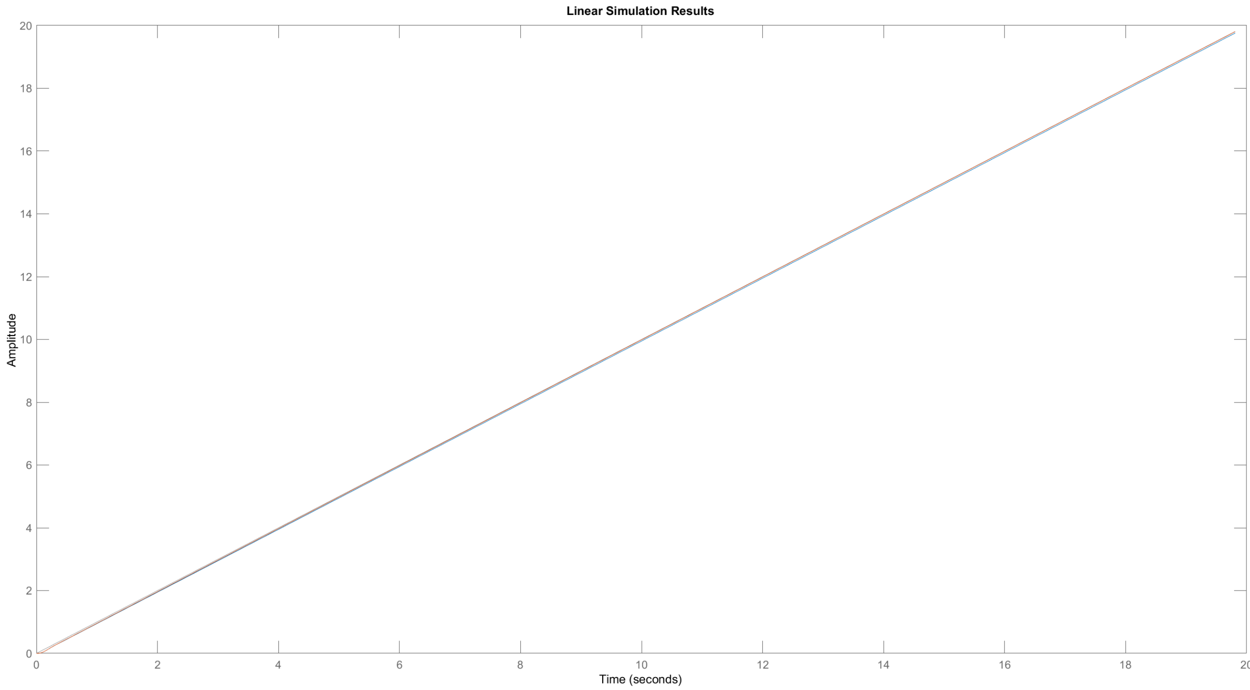

Figure 3: Ramp Response

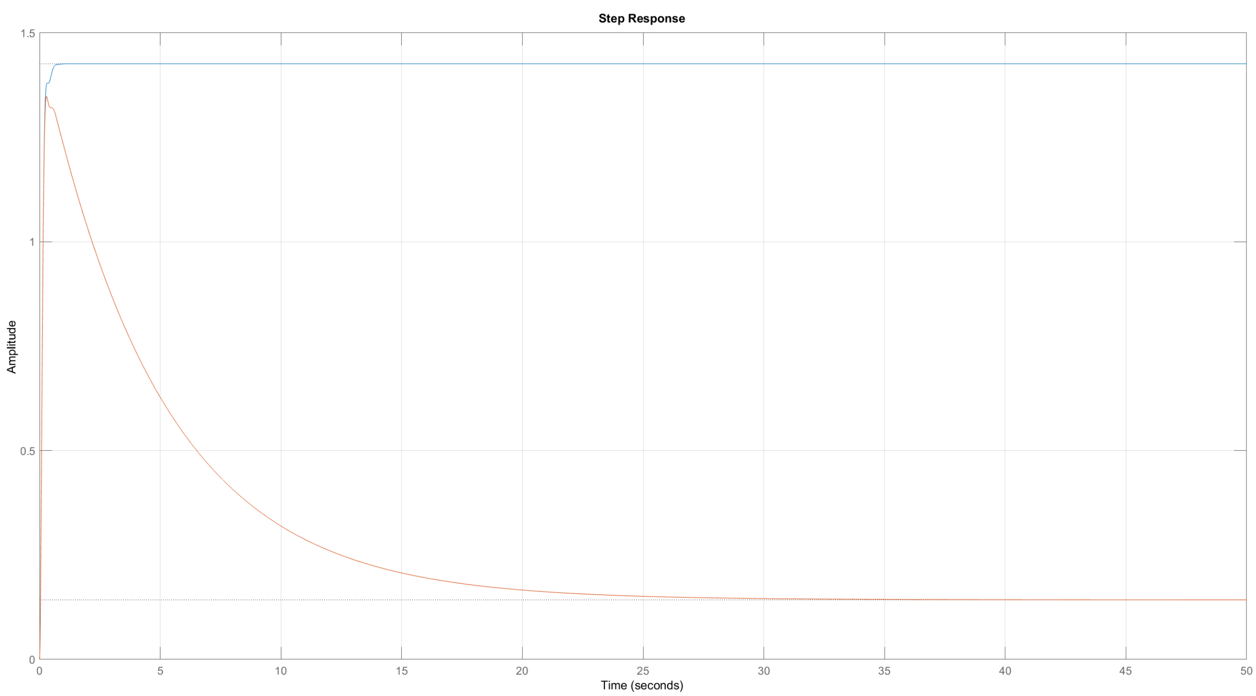

Figure 4: Step Disturbance

2 Experiment: Implementation of Your Lead-Lag Compensator

The step response of the system with the lead compensator is shown in Figure 5, and the step response of the system with the lead-lag compensator is shown in Figure 6. The transient response does not change significantly, with the percent overshoot decreasing slightly (increases from about 4.7% to 6.2%) and the settling time remaining similar.

The response to a step disturbance with the lead compensator is shown in Figure 7, and the response a step disturbance with the lead-lag compensator is shown in Figure 8. The steady state error is significantly reduced, with the system with the lead compensator system having an error of 14.24 degrees, and the lead-lag compensator system having an error of 1.58 degrees, almost a reduction by a factor of 10.

The unit ramp response of the system with the lead compensator is shown in Figure 9, and the unit ramp response of the system with the lead-lag compensator is shown in Figure 10. For a unit ramp response, the steady state error is simply $1/k_v$, and when there if a scaling factor applied to the ramp response so that the slope increases or decreases the steady state error is equivalent to slope$/k_v$. Because it's just a constant scaling factor, the ramp response of the system still converges to the steady state error. From the bode plot shown in Figure 11, we can see that the magnitude increase at lower frequencies of the lead-lag compensator corresponds to its slightly lower ramp response steady state error, compared to the lead compensator.

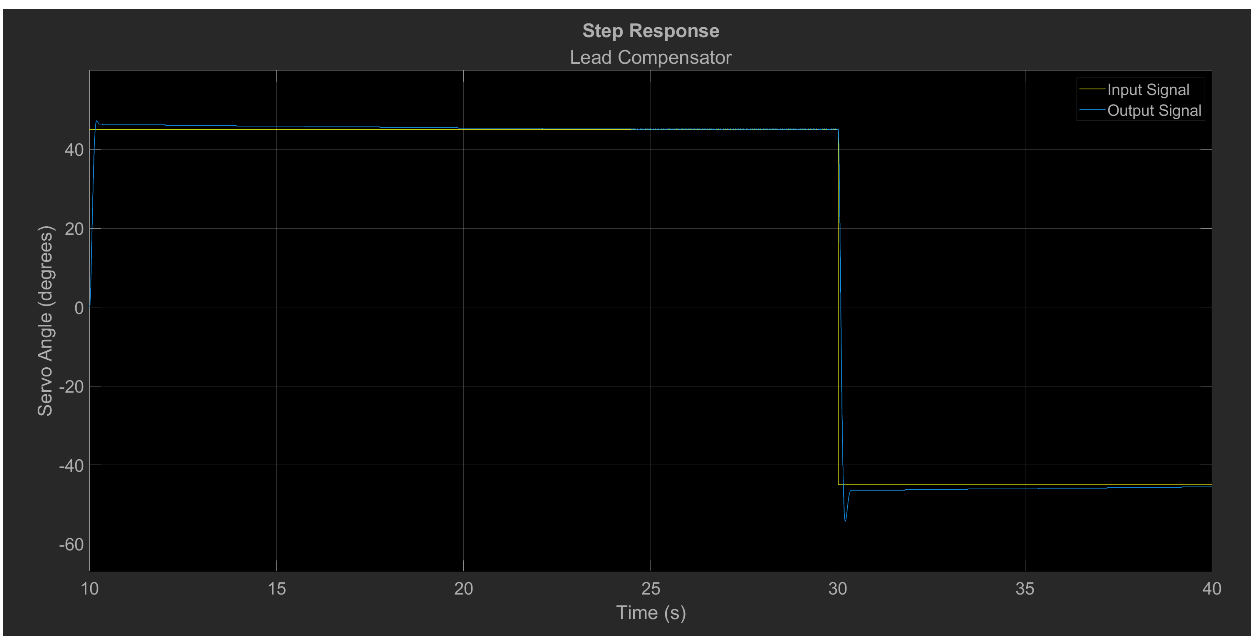

Figure 5: Lead Compensator: Step Response

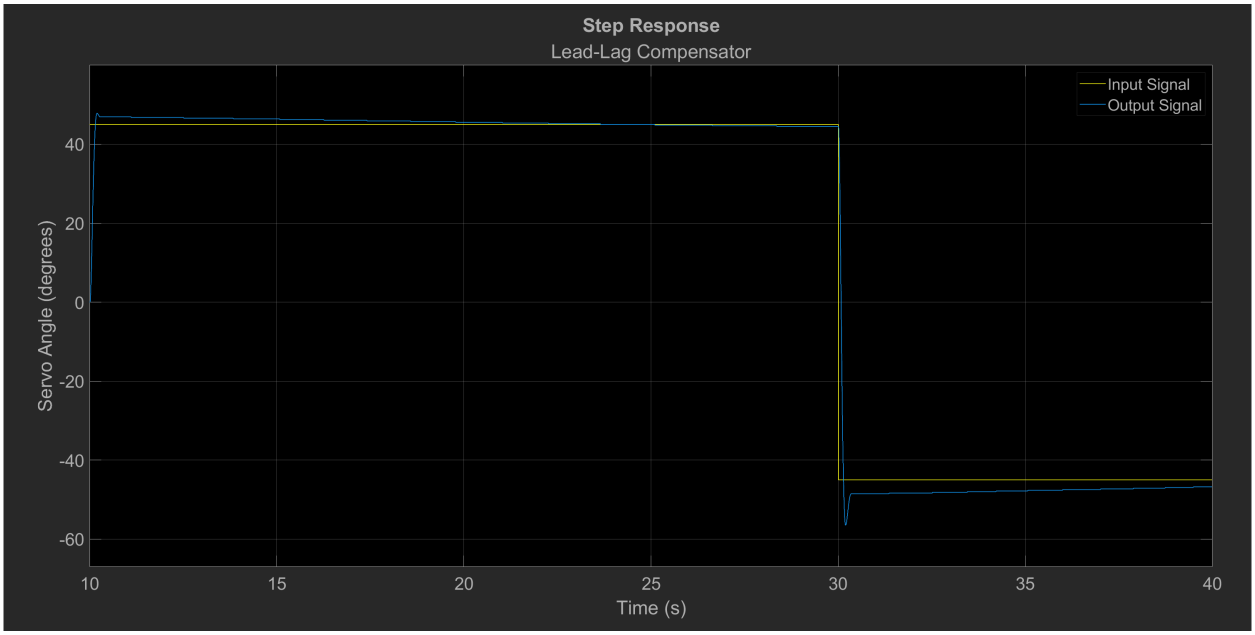

Figure 6: Lead-Lag Compensator: Step Response

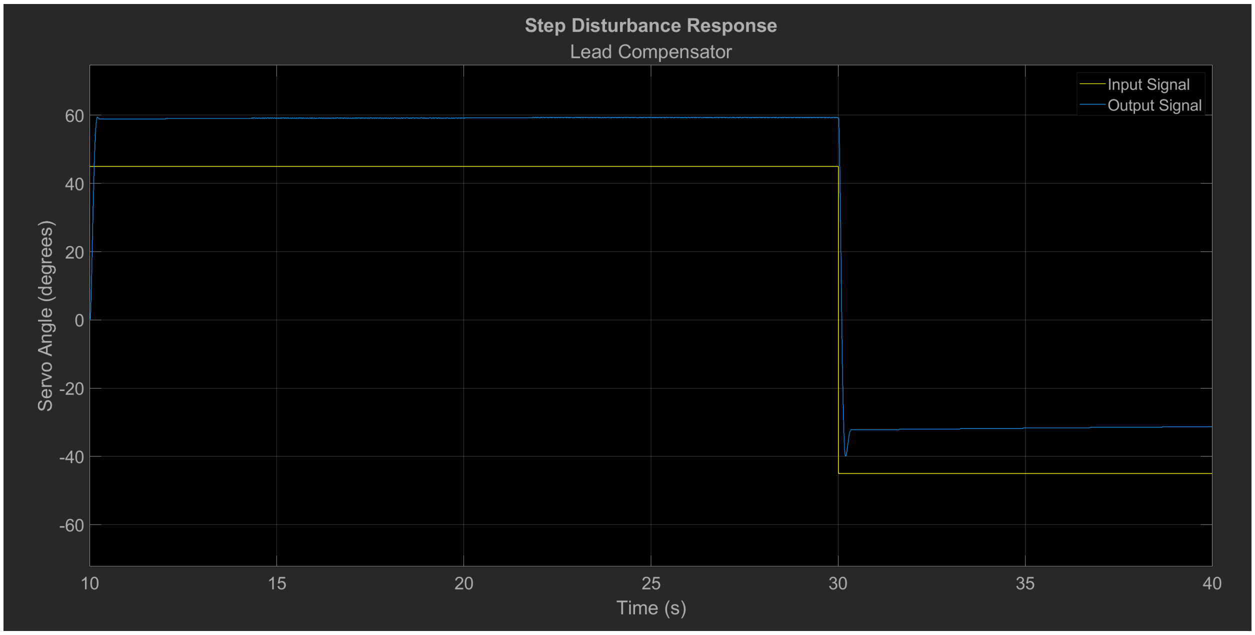

Figure 7: Lead Compensator: Step Disturbance Response

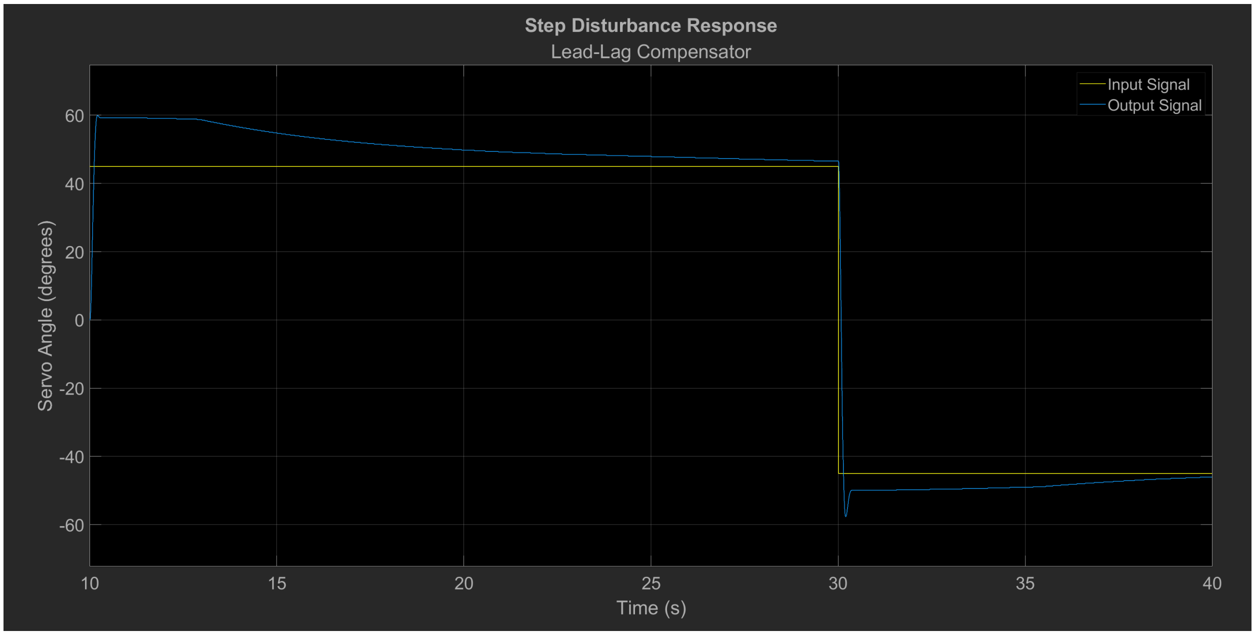

Figure 8: Lead-Lag Compensator: Step Disturbance Response

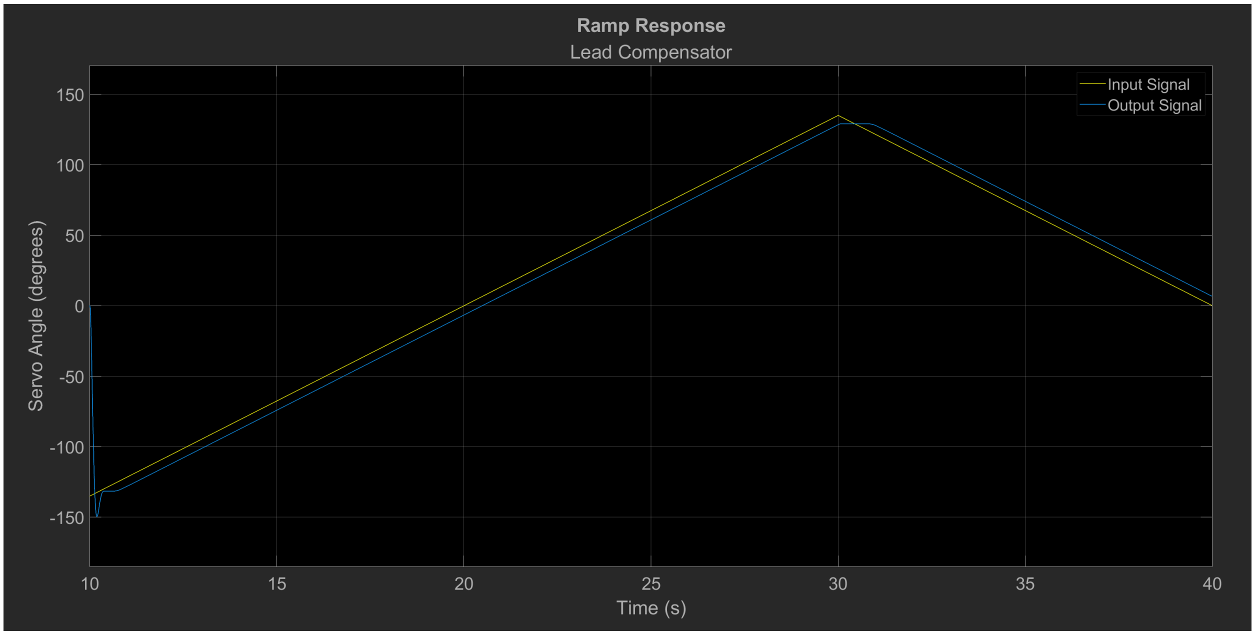

Figure 9: Lead Compensator: Ramp Response

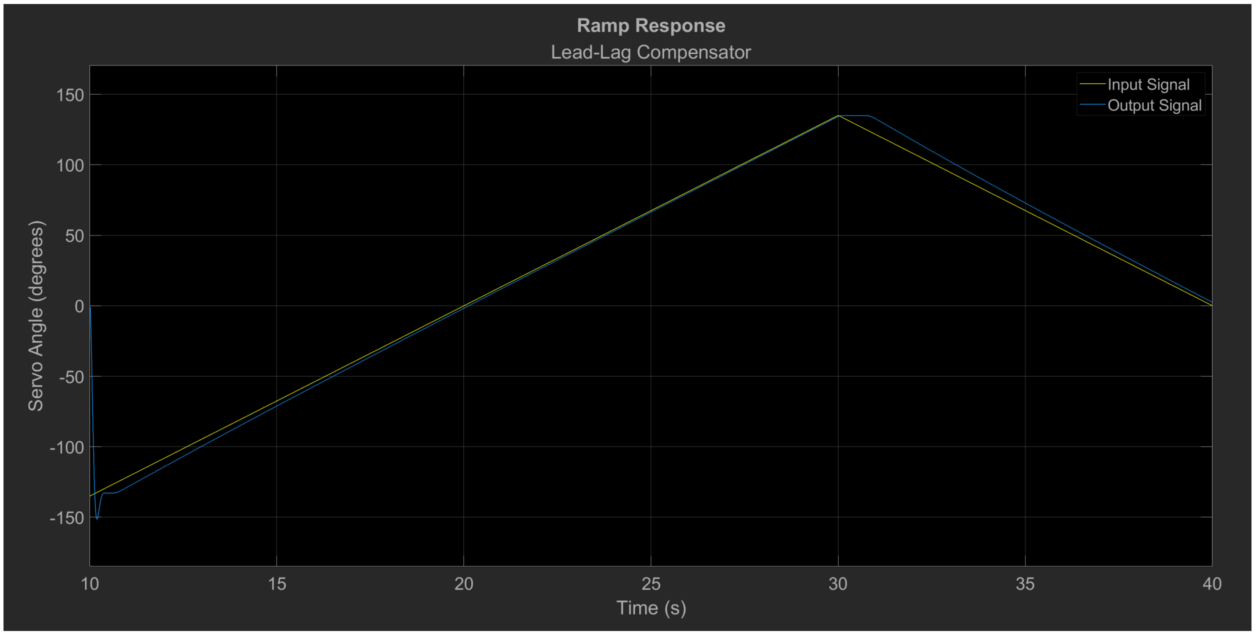

Figure 10: Lead-Lag Compensator: Ramp Response

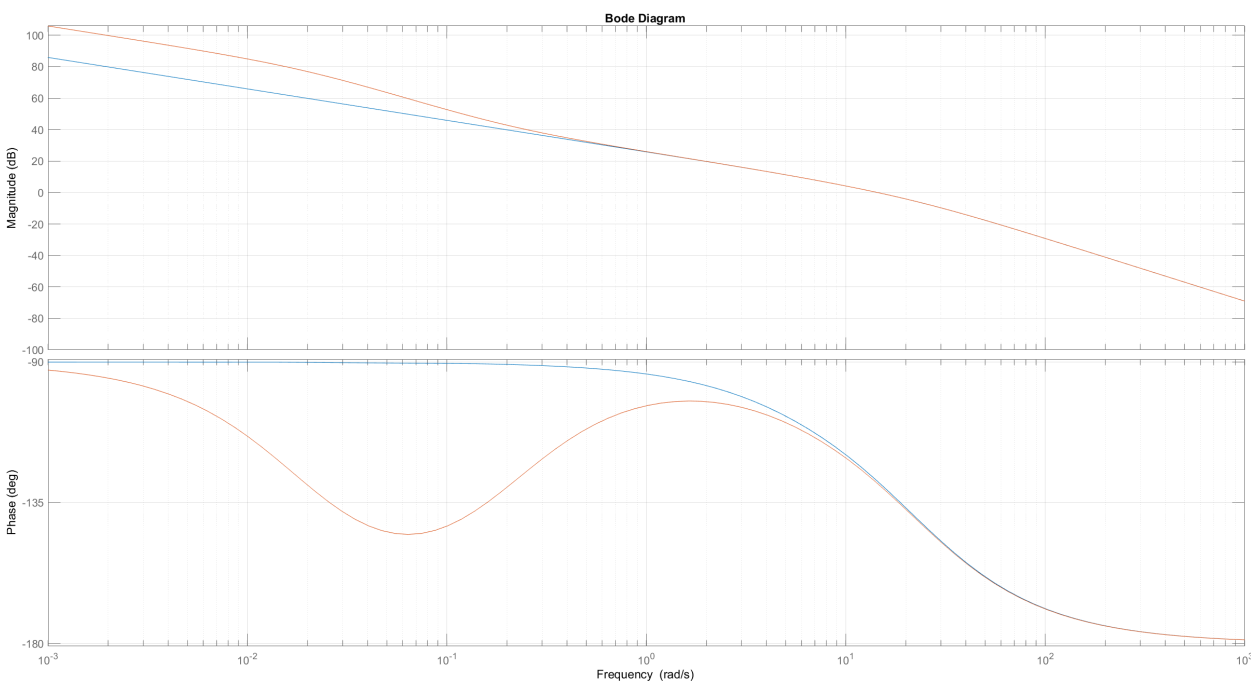

Figure 11: Bode Plot