UNIVERSITY OF LOUISIANA AT LAFAYETTE

CONTROL SYSTEMS

MCHE 474

Lab 5

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G = Plant Function
G_c = PID Controller
s = Laplace Domain Variable
PID = Proportional-Integral-Derivative Controller
K = Gain
K_P = Proportional Gain
K_I = Integral Gain
K_D = Derivative Gain

Introduction

This lab was conducted using MATLAB to analyze a control system. The system's plant is given in Equation 1. The system root-locus is plotted and used for analysis. A PID controller is then implemented into the system in order to improve the system's performance. The gains for the PID controller are chosen based on the zeros found in the root-locus analysis.

$$G = \frac{1}{(s+2)(s+3)} \tag{1}$$

$$G_c = \frac{K_d(s+Z_1)(s+Z_2)}{s} \tag{2}$$

Theory

The root-locus plot of a system can reveal much about the behavior of the system. The root-locus is a plot showing the location of zeros and poles of the system. Zeros of a system are the values of s that cause the numerator of the transfer function to equal zero. Poles are the values of s that cause the denominator of the transfer function to equal zero. The zeros and poles of a system are often times complex numbers. For this reason, the root-locus plot of a system is plotted on the real-imaginary plane. The root-locus plot shows how the poles and zeros change as an applied gain K goes from 0 to ∞.

A PID is a feedback controller which accounts for not just one state of error, but three, in order to modify the input to the system to achieve the desired state. The equation for a PID controller is shown in Equation 3, and is rewritten in Equation 4.

$$PID = K_P + \frac{K_I}{s} + K_D s \tag{3}$$

$$PID = \frac{K_D s^2 + K_P s + K_I}{S} \tag{4}$$

The effect of the proportional, integral, and derivative components of the controller are weighted by their gains KP, KI, and KD respectively. Adjusting these gains allows for the PID con- troller to be tailored to fit the system and the desired performance. Adjusting the proportional gain changes how intensely the controller reacts to error. Adjusting the integral gain changes how quickly accumulated error is accounted for by increasing the controller output. Adjusting the derivative gain changes how quickly the controller reacts to a change in the rate of error change, which is useful for situations where the error changes signs frequently (like an autonomous vehicle which needs to stick to a straight course).

Procedure & Analysis

The root-locus of the system without the compensation of PID control is shown in Figure 1. The step response of the system is plotted in Figure 2 and the system performance criteria are shown in Figure 3. The uncompensated system can be thought of as having a gain $K = 1$.

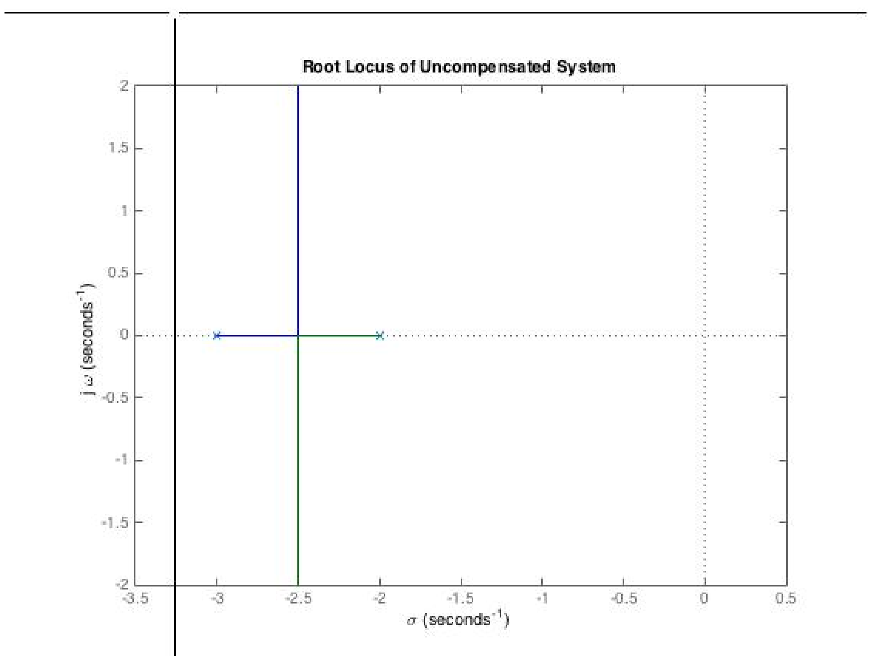

Figure 1: Uncompensated System Root-Locus

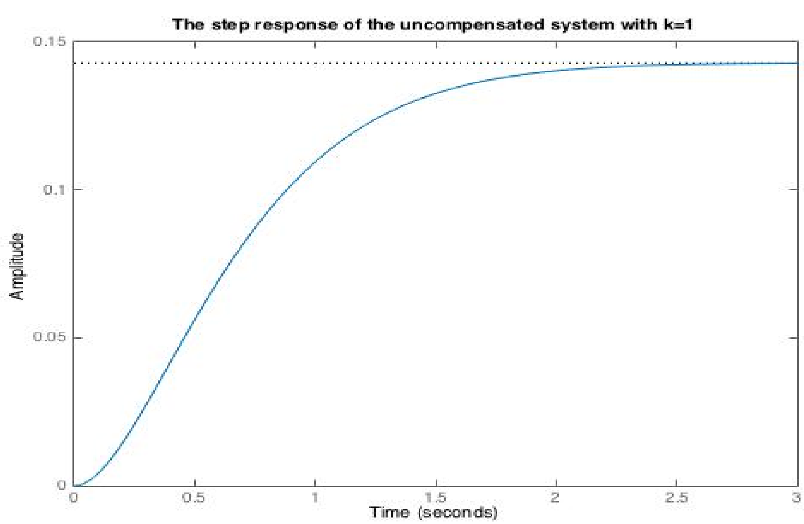

Figure 2: Uncompensated System Step Response ($K = 1$)

```
     RiseTime: 1.1683
 SettlingTime: 1.9666
  SettlingMin: 0.1291
  SettlingMax: 0.1429
    Overshoot: 0.0038
   Undershoot: 0
         Peak: 0.1429
     PeakTime: 3.2973
```

Figure 3: Uncompensated System Step Response Performance ($K = 1$)

The PID controller was then introduced to the system, where $Z_{1,2} = -3 \pm j$. The root-locus of the compensated system is shown in Figure 4. The highest point on the root-locus plot was then chosen to define a value of K_d and the system step response was plotted for this gain in Figure 5. The performance criteria for the system with this K_d is shown in Figure 6.

The gain K_d was then chosen so that the system has even less damping. The system step response with this gain is plotted in Figure 7 and the performance criteria are shown in Figure 8. The performance criteria of all three step system configurations is tabulated in Table 1.

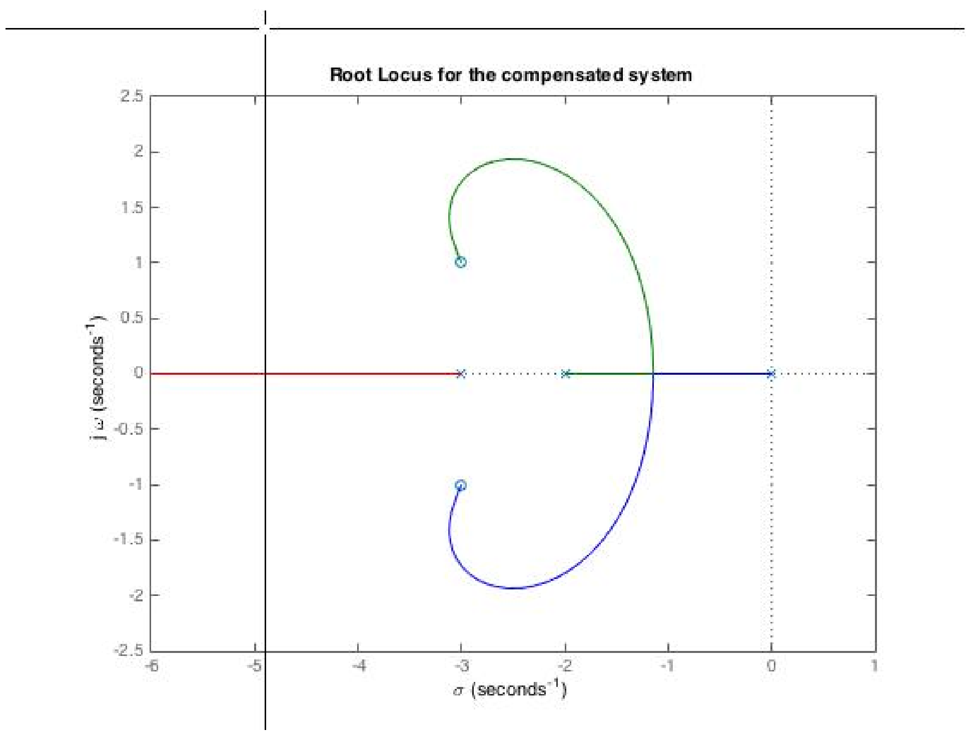

Figure 4: Compensated System Root-Locus

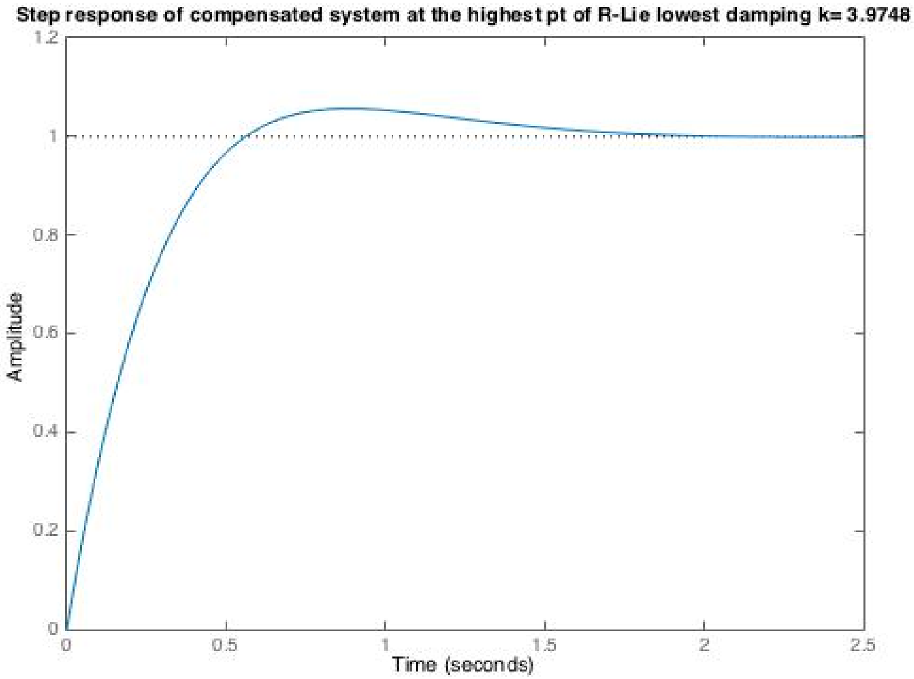

Figure 5: Compensated System Step Response ($K = 3.9748$)

```
    RiseTime: 0.3862
SettlingTime: 1.4596
 SettlingMin: 0.9115
 SettlingMax: 1.0567
   Overshoot: 5.6670
  Undershoot: 0
        Peak: 1.0567
    PeakTime: 0.8872
```

Figure 6: Compensated System Step Response Performance ($K = 3.9748$)

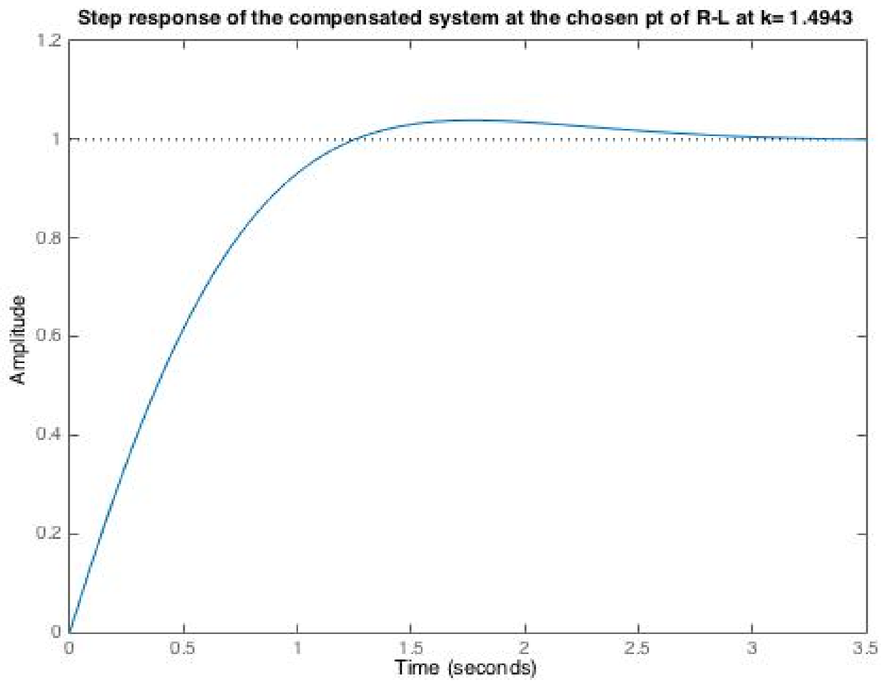

Figure 7: Compensated System Step Response ($K = 1.4943$)

```
    RiseTime: 0.8545
SettlingTime: 2.4441
 SettlingMin: 0.9031
 SettlingMax: 1.0388
   Overshoot: 3.8800
  Undershoot: 0
        Peak: 1.0388
    PeakTime: 1.7774
```

Figure 8: Compensated System Step Response Performance ($K = 1.4943$)

Table 1: Comparison of Performance Criteria

Performance Criteria	Uncompensated System	Compensated System (K=3.9748)	Compensated System (K=1.4943)
Rise Time (s)	1.1683	0.3862	0.8545
Settling Time (s)	1.9666	1.4596	2.4441
Overshoot (Amplitude)	0.0038	5.6670	3.8800

Conclusion

The exercises conducted in this lab reinforce the theory learned in the classroom. It is shown that the root-locus plot of a system can show much information about the system. It is also shown that the performance of a system can be improved using a PID controller, which is a tunable feedback controller that accounts for present, past, and future error states of the system. Choosing the zeros of the PID controller to be similar to the zeros of the system plant results in performance improvement for the system. These system characteristics are important for control systems with feedback loops which utilize PID control. With the information obtained from the root-locus, the zeros and gains of the PID controller can be wisely chosen.