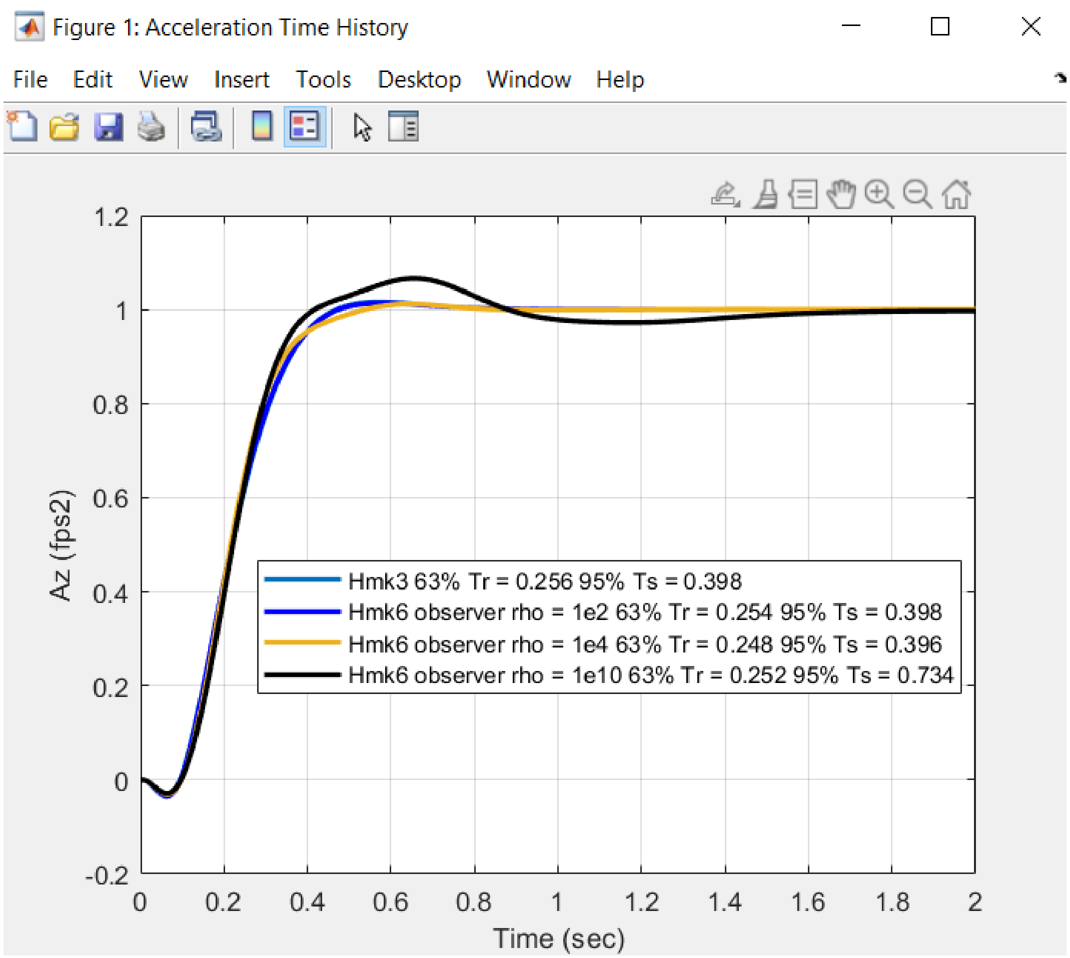
HW6 | amithr3

The observer is: $\dot{\hat{x}} = \left(\tilde{A} - \tilde{B}K_{lqr} - L_\rho C\right)\hat{x} + L_\rho y_{meas} + Fr$, where $r = A_{z_{cmd}}$ and $y_{meas} = [e_I \quad q]^T$.

This requires us to form the integral error $e_I = \int\left(y_{reg} - r\right) = \int\left(A_z - A_{z_{cmd}}\right)$ and make it available to the observer as a measurement. This method adds an additional integrator into the overall control architecture, and is shown in the following block diagram:

Simulate using a constant unit step command. Compare these LQG/LTR designs with the RSLQR state feedback controller. (Include the RSLQR and all three designs on each plot). Turn in plots of the accel command and response, pitch rate, and elevon deflection and rate. Analyze each controller in the frequency domain using a plant model that contains the actuator.

Plot Nyquist and Bode for L_u, $\underline{\sigma}\left(I + L_u\right)$, $\underline{\sigma}\left(I + L_u^{-1}\right)$, $e_{A_z}/r = S$, $A_z/r = T$, and compute singular value margins at the plant input for each. Plot the noise-to-control and noise-to-control rate frequency responses.



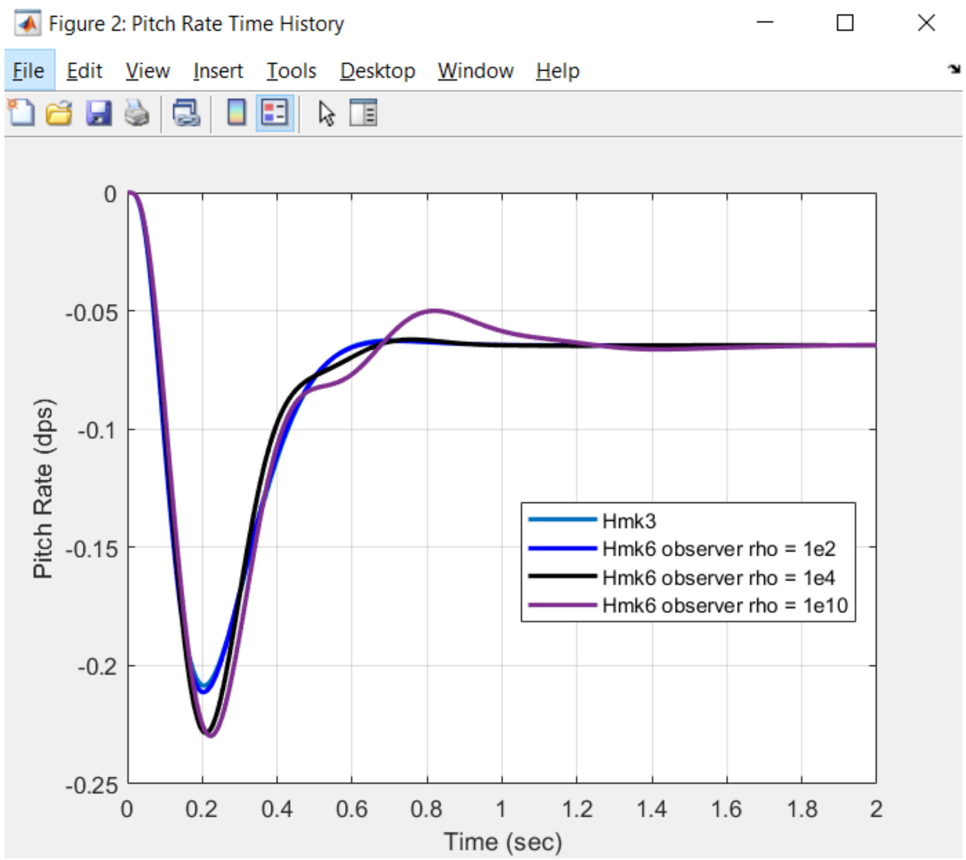


Figure 2: Pitch Rate Time History
File Edit View Insert Tools Desktop Window Help
Pitch Rate (dps)
Time (sec)
0
-0.05
-0.1
-0.15
-0.2
-0.25
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
Hmk3
Hmk6 observer rho = 1e2
Hmk6 observer rho = 1e4
Hmk6 observer rho = 1e10

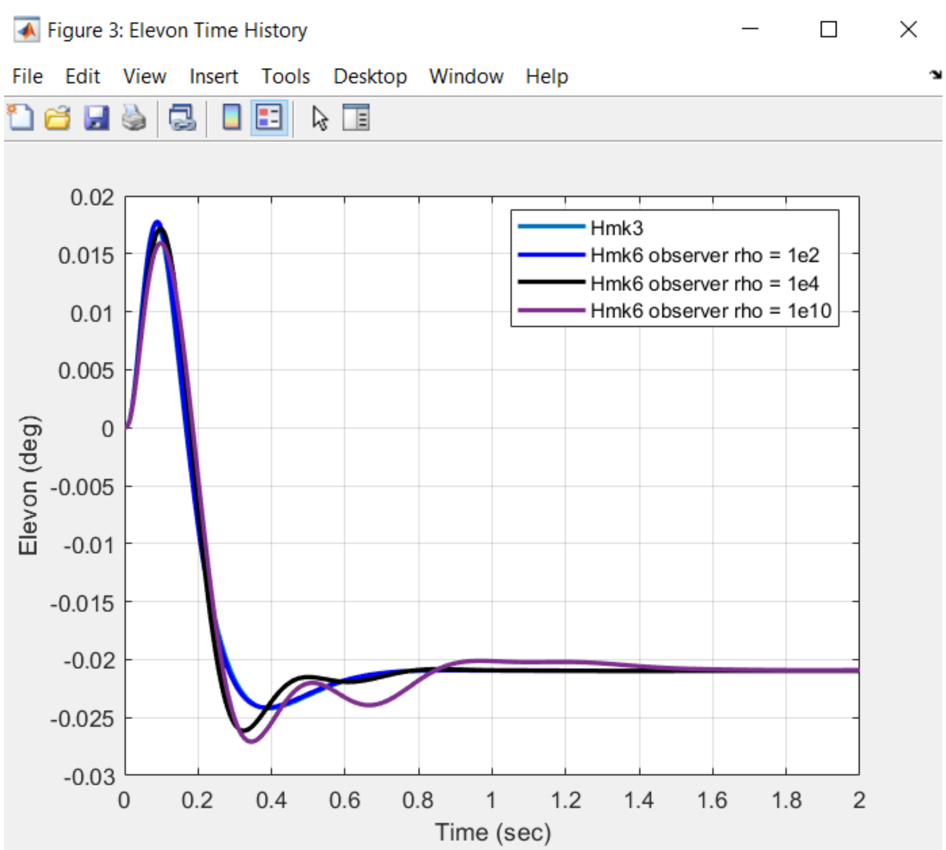


Figure 3: Elevon Time History
File Edit View Insert Tools Desktop Window Help
Elevon (deg)
Time (sec)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
Hmk3
Hmk6 observer rho = 1e2
Hmk6 observer rho = 1e4
Hmk6 observer rho = 1e10

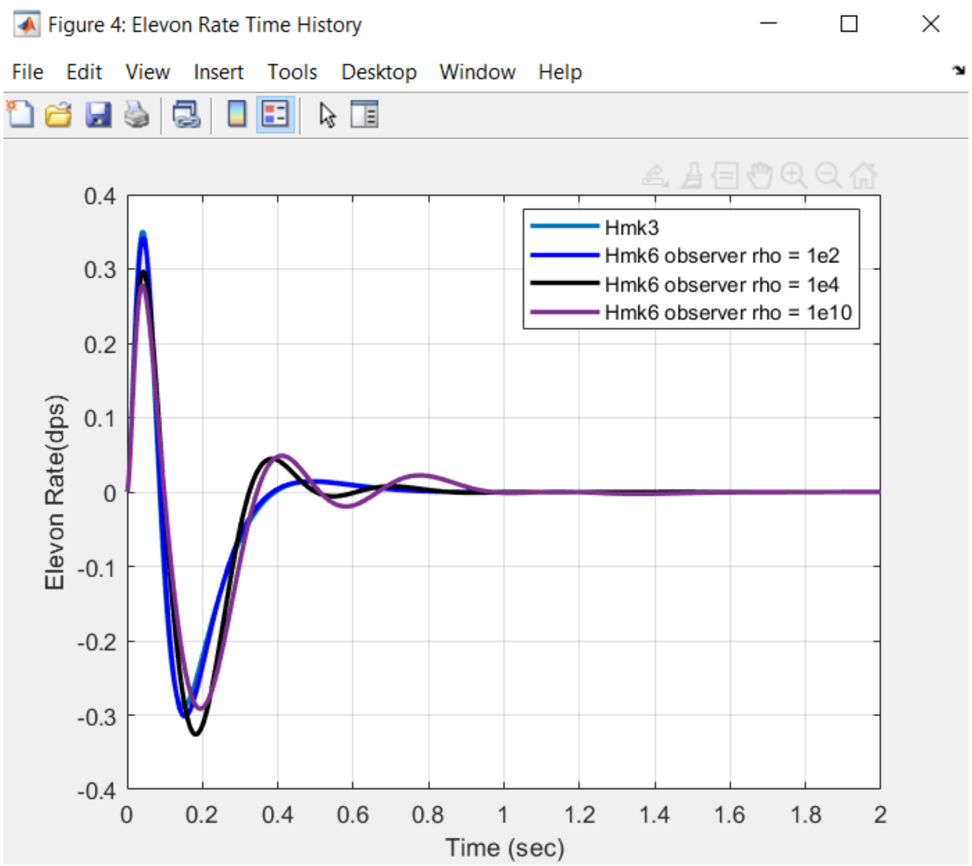


Figure 4: Elevon Rate Time History
File Edit View Insert Tools Desktop Window Help
Hmk3
Hmk6 observer rho = 1e2
Hmk6 observer rho = 1e4
Hmk6 observer rho = 1e10
Elevon Rate(dps)
Time (sec)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

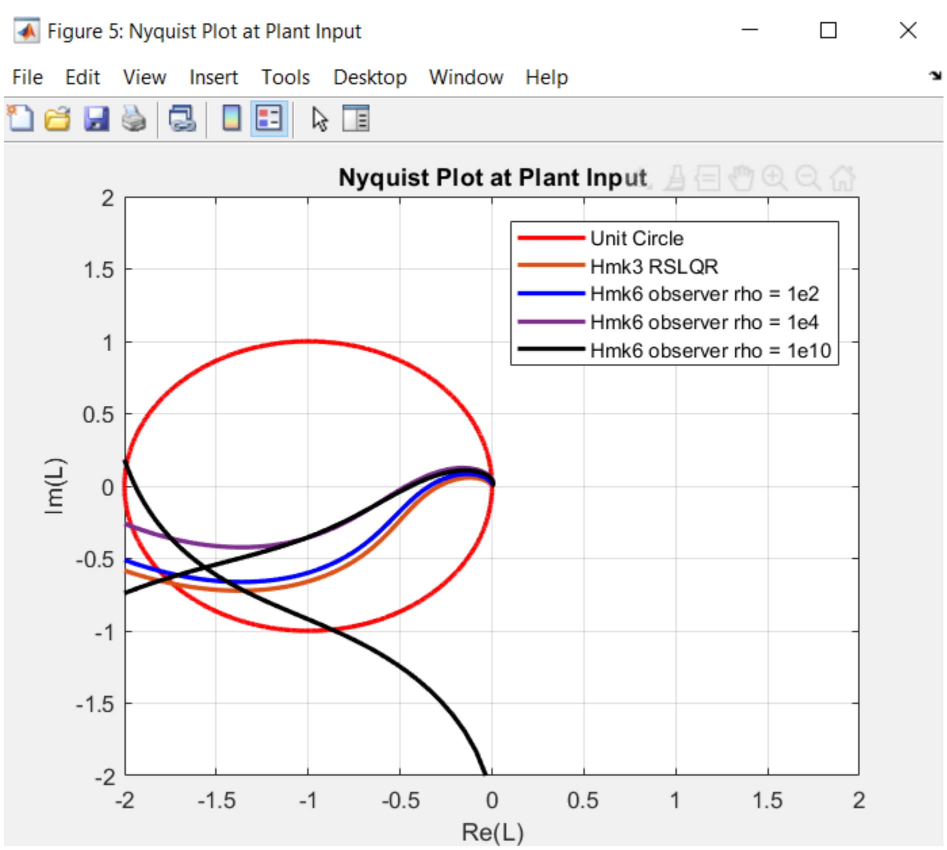


Figure 5: Nyquist Plot at Plant Input
File Edit View Insert Tools Desktop Window Help
Nyquist Plot at Plant Input
Unit Circle
Hmk3 RSLQR
Hmk6 observer rho = 1e2
Hmk6 observer rho = 1e4
Hmk6 observer rho = 1e10
Im(L)
Re(L)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2

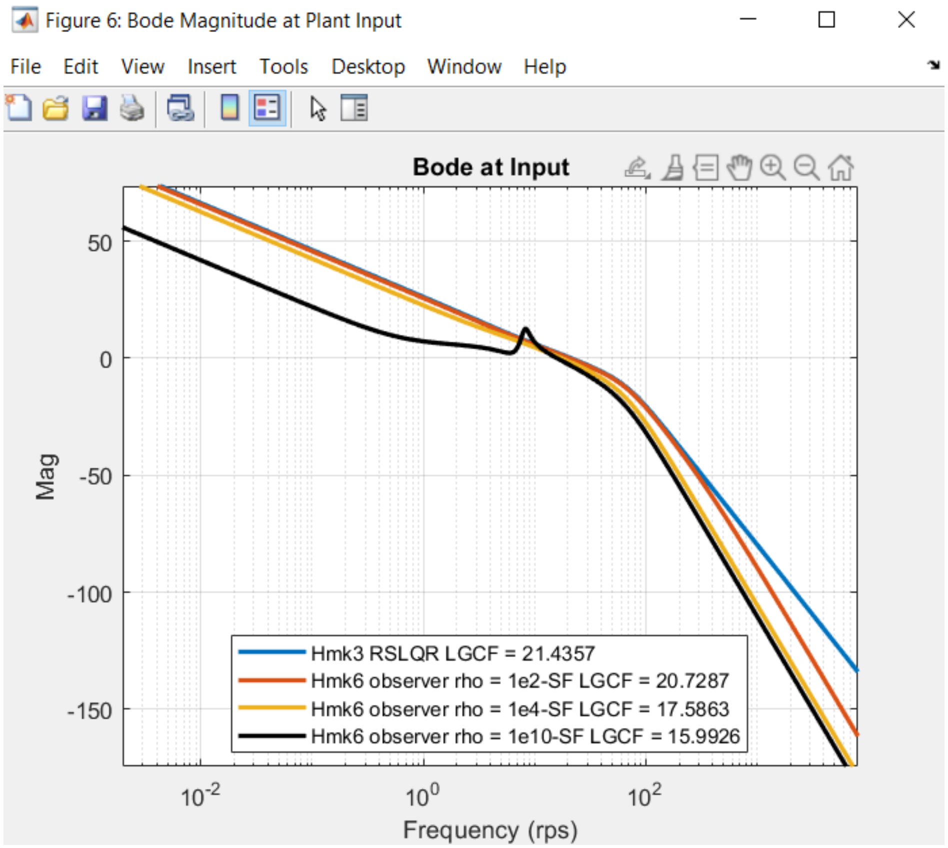


Figure 6: Bode Magnitude at Plant Input
File Edit View Insert Tools Desktop Window Help
Bode at Input
Mag
50
0
-50
-100
-150
Hmk3 RSLQR LGCF = 21.4357
Hmk6 observer rho = 1e2-SF LGCF = 20.7287
Hmk6 observer rho = 1e4-SF LGCF = 17.5863
Hmk6 observer rho = 1e10-SF LGCF = 15.9926
10^-2
10^0
10^2
Frequency (rps)

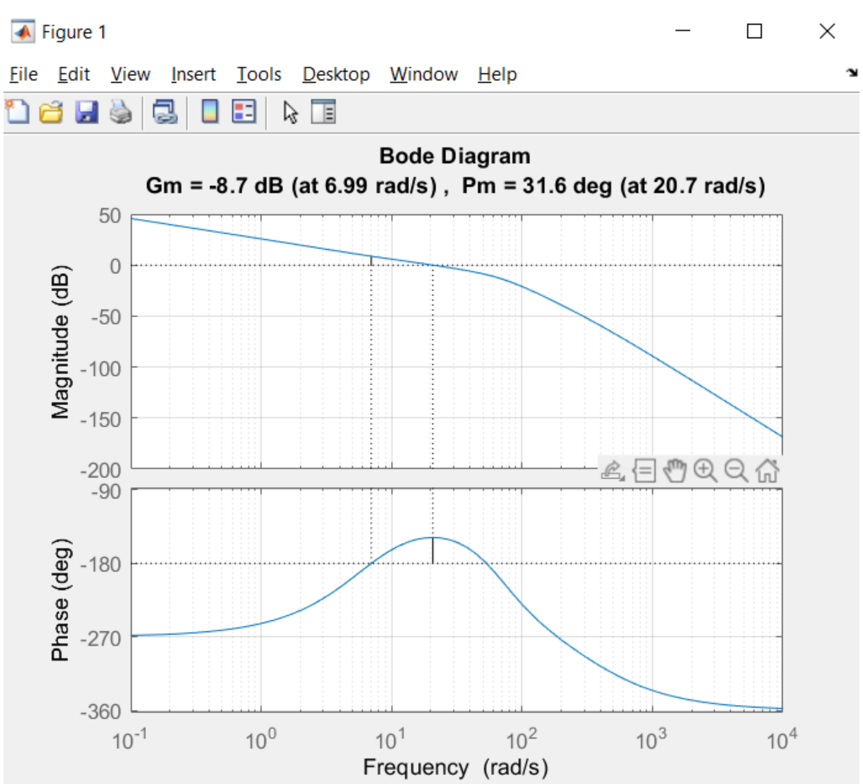
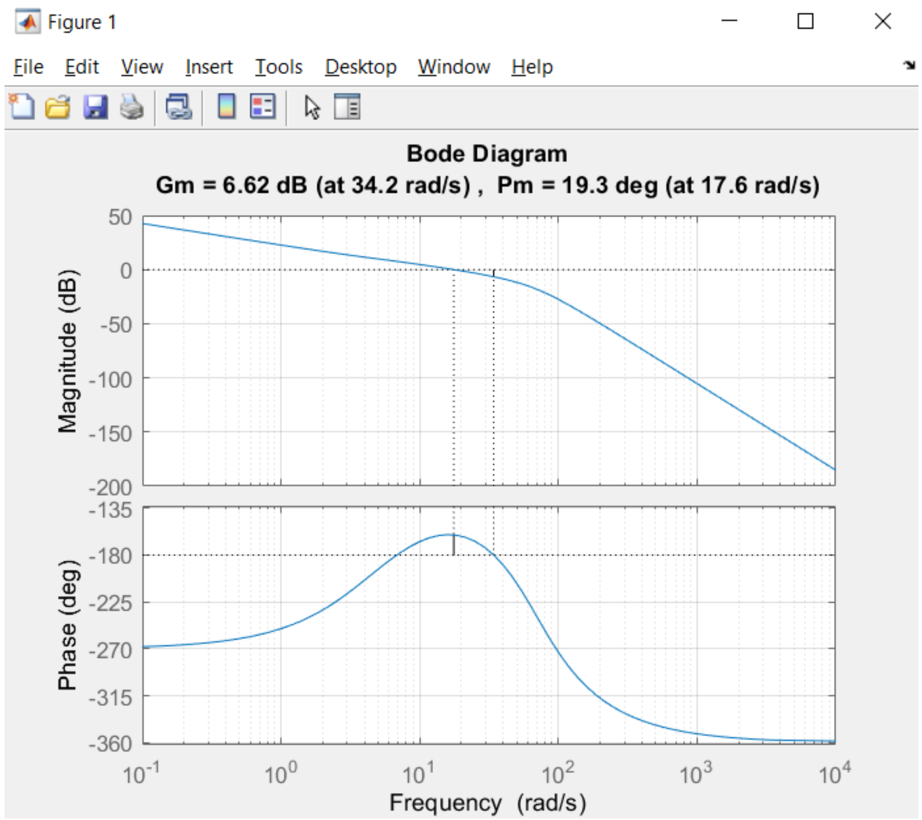
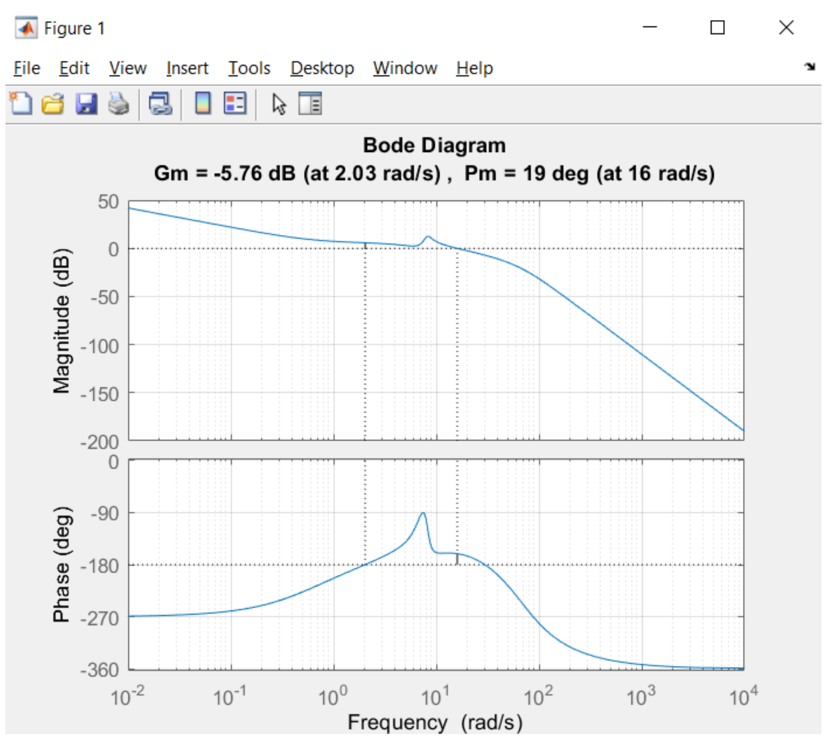


Figure 1
File Edit View Insert Tools Desktop Window Help
Bode Diagram
Gm = -8.7 dB (at 6.99 rad/s) , Pm = 31.6 deg (at 20.7 rad/s)
Magnitude (dB)
50
0
-50
-100
-150
-200
Phase (deg)
-90
-180
-270
-360
10^-1
10^0
10^1
10^2
10^3
10^4
Frequency (rad/s)

Rho = 10^2



Rho = 10^4



Rho = 10^{10}

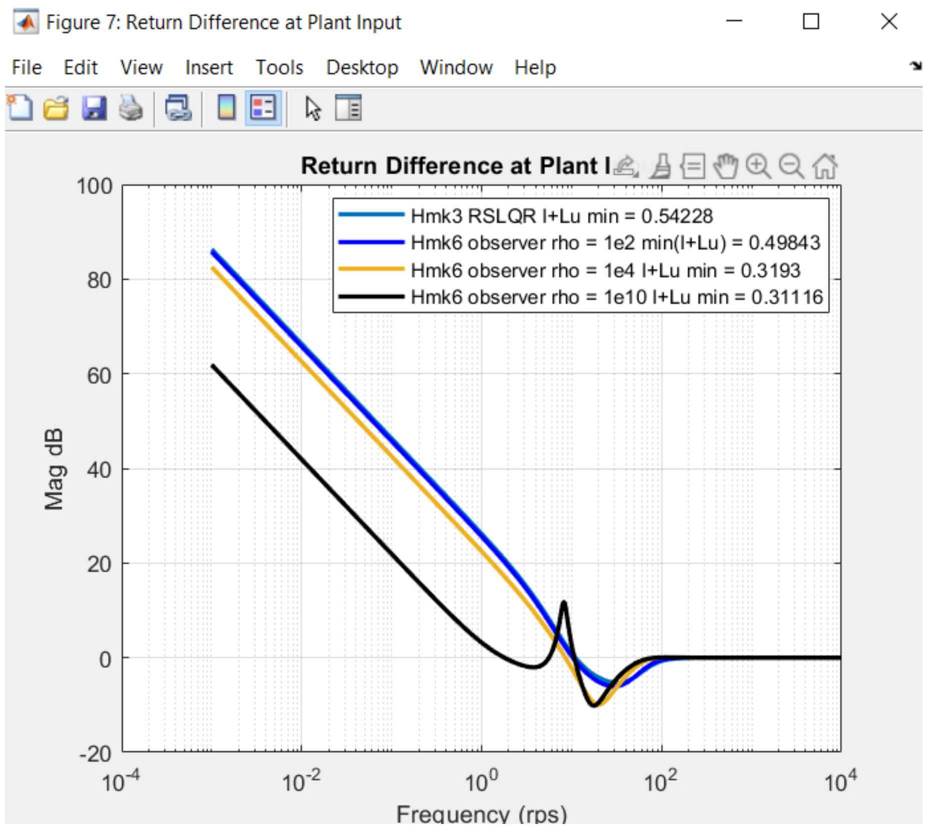


Figure 7: Return Difference at Plant Input
File Edit View Insert Tools Desktop Window Help
Return Difference at Plant I
Hmk3 RSLQR I+Lu min = 0.54228
Hmk6 observer rho = 1e2 min(I+Lu) = 0.49843
Hmk6 observer rho = 1e4 I+Lu min = 0.3193
Hmk6 observer rho = 1e10 I+Lu min = 0.31116
Mag dB
100
80
60
40
20
0
-20
10^{-4}
10^{-2}
10^{0}
10^{2}
10^{4}
Frequency (rps)

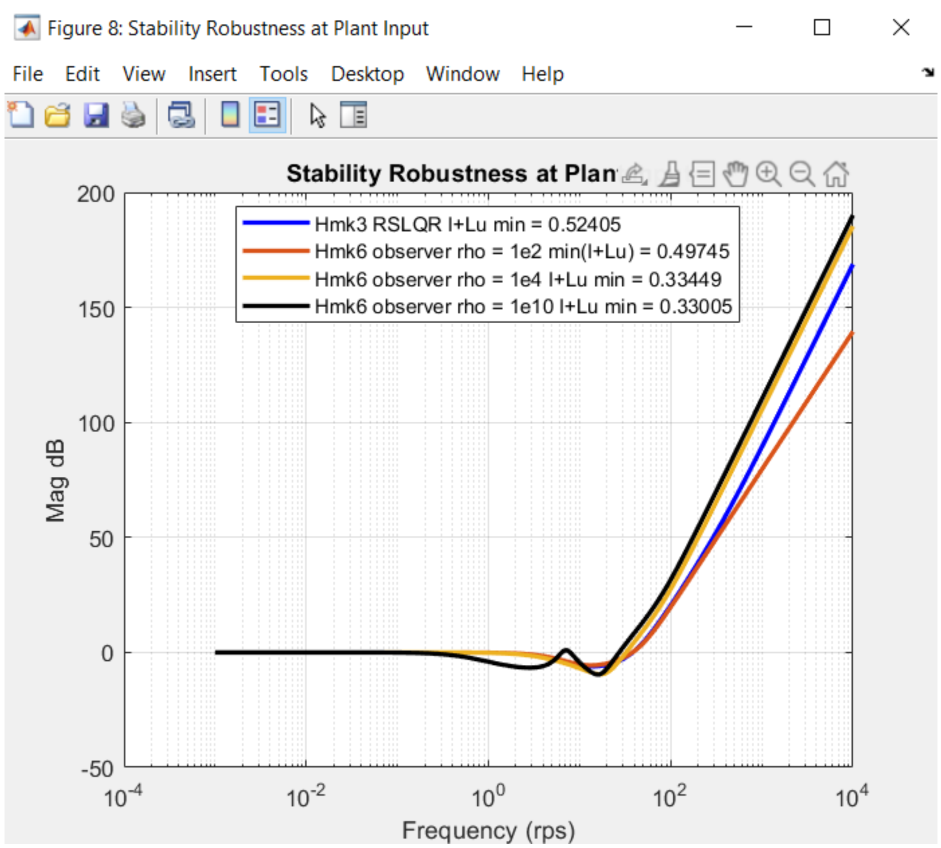


Figure 8: Stability Robustness at Plant Input
File Edit View Insert Tools Desktop Window Help
Stability Robustness at Plan
Hmk3 RSLQR I+Lu min = 0.52405
Hmk6 observer rho = 1e2 min(I+Lu) = 0.49745
Hmk6 observer rho = 1e4 I+Lu min = 0.33449
Hmk6 observer rho = 1e10 I+Lu min = 0.33005
Mag dB
200
150
100
50
0
-50
10^{-4}
10^{-2}
10^{0}
10^{2}
10^{4}
Frequency (rps)

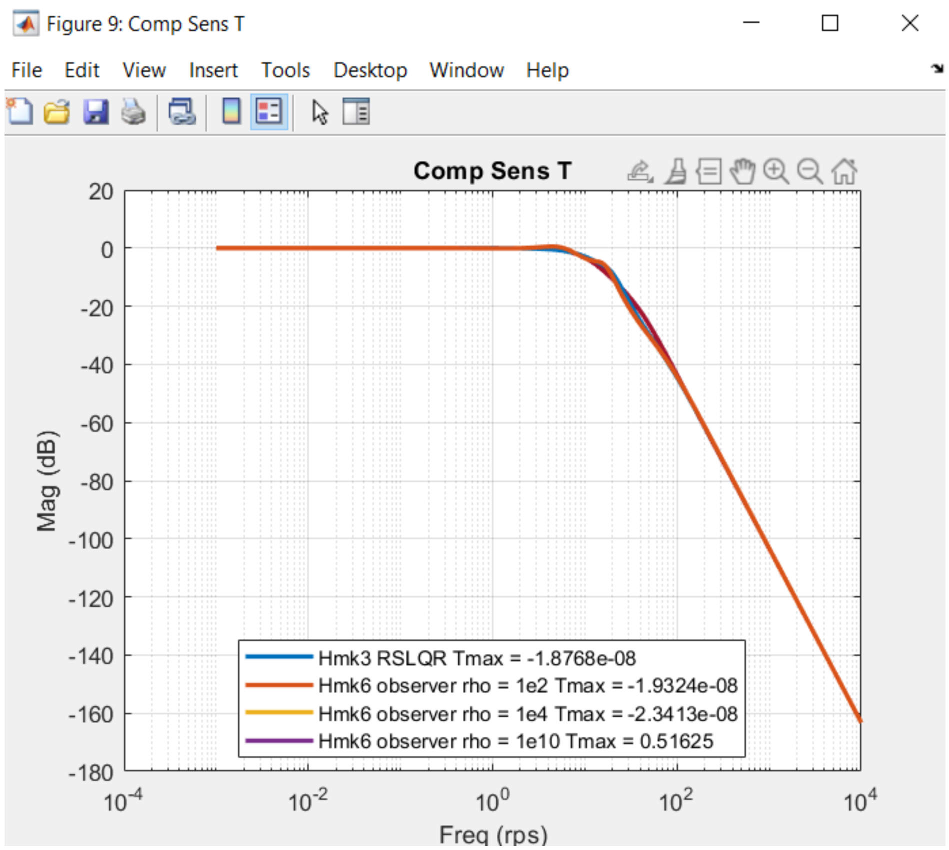


Figure 9: Comp Sens T
File Edit View Insert Tools Desktop Window Help
Comp Sens T
Mag (dB)
Freq (rps)
Hmk3 RSLQR Tmax = -1.8768e-08
Hmk6 observer rho = 1e2 Tmax = -1.9324e-08
Hmk6 observer rho = 1e4 Tmax = -2.3413e-08
Hmk6 observer rho = 1e10 Tmax = 0.51625

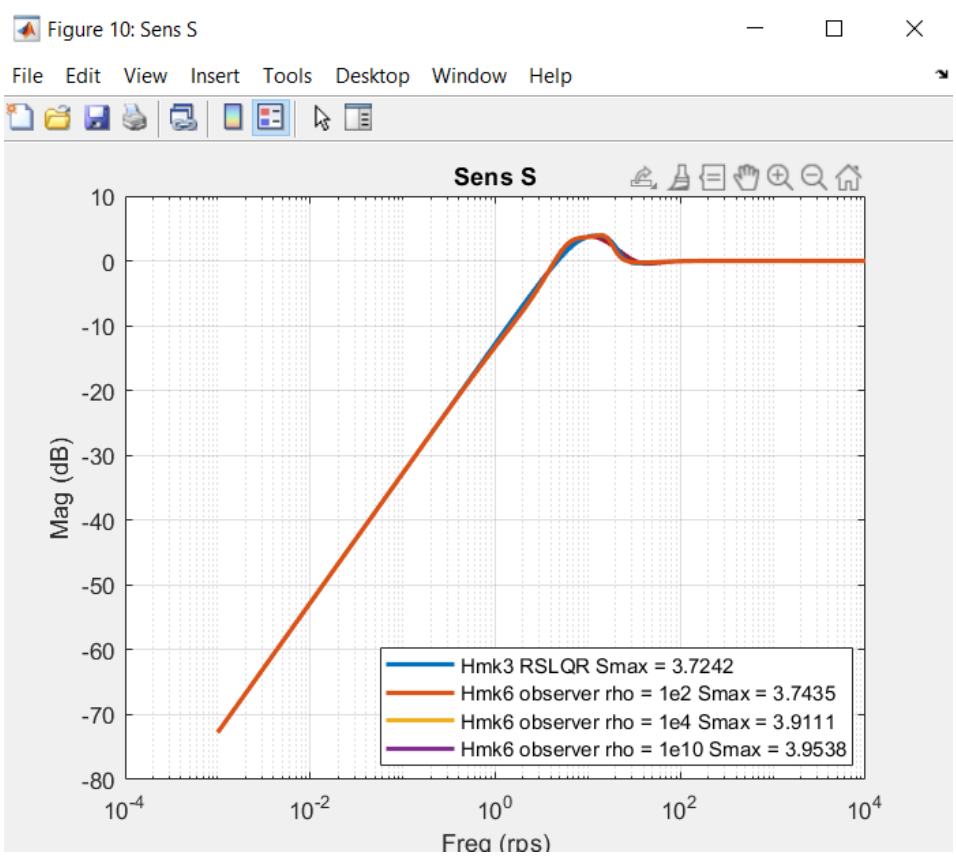


Figure 10: Sens S
File Edit View Insert Tools Desktop Window Help
Sens S
Mag (dB)
Freq (rps)
Hmk3 RSLQR Smax = 3.7242
Hmk6 observer rho = 1e2 Smax = 3.7435
Hmk6 observer rho = 1e4 Smax = 3.9111
Hmk6 observer rho = 1e10 Smax = 3.9538

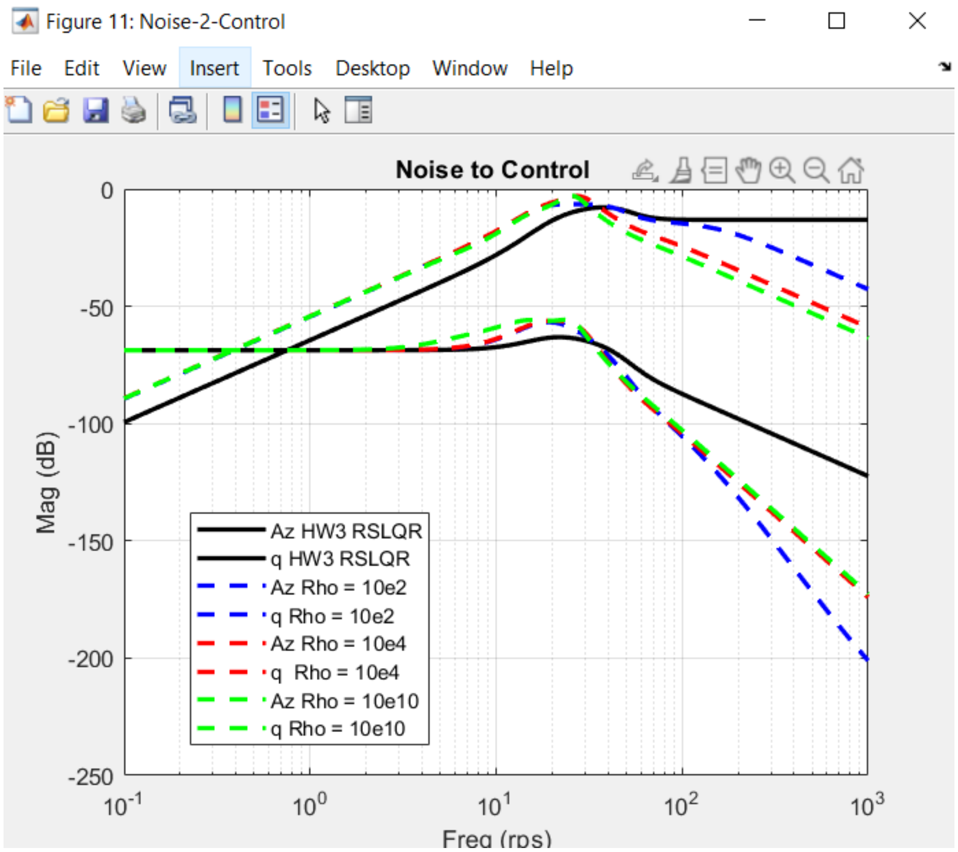


Figure 11: Noise-2-Control
File Edit View Insert Tools Desktop Window Help
Noise to Control
Mag (dB)
Freq (rps)
Az HW3 RSLQR
q HW3 RSLQR
Az Rho = 10e2
q Rho = 10e2
Az Rho = 10e4
q Rho = 10e4
Az Rho = 10e10
q Rho = 10e10

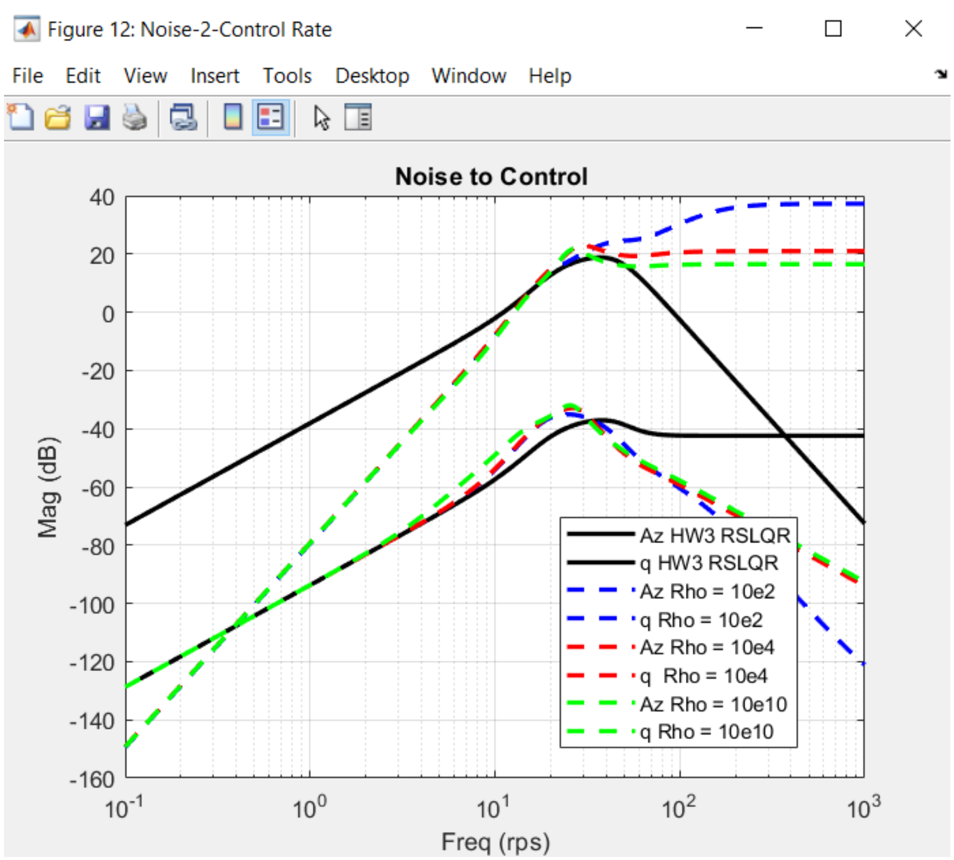


Figure 12: Noise-2-Control Rate
File Edit View Insert Tools Desktop Window Help
Noise to Control
Mag (dB)
Freq (rps)
Az HW3 RSLQR
q HW3 RSLQR
Az Rho = 10e2
q Rho = 10e2
Az Rho = 10e4
q Rho = 10e4
Az Rho = 10e10
q Rho = 10e10

Singular Value Margins

```
Homework 3 RSLQR
Singular value margins
Min Singular value I+Lu =    0.54228
Min Singular value I+invLu = 0.52405
Singular value gain margins = [-6.4488 dB,6.7879 dB ]
Singular value phase margins = [ +/-31.4639 deg ]

Hmk6_observer_rho1 = e2
Singular value margins
Min Singular value I+Lu =    0.49843
Min Singular value I+invLu = 0.49745
Singular value gain margins = [-5.9765 dB,5.9935 dB ]
Singular value phase margins = [ +/-28.8624 deg ]

Hmk6_observer_rho1 = e4
Singular value margins
Min Singular value I+Lu =    0.3193
Min Singular value I+invLu = 0.33449
Singular value gain margins = [-3.5369 dB,3.3409 dB ]
Singular value phase margins = [ +/-19.2552 deg ]

Hmk6_observer_rho1 = e10
Singular value margins
Min Singular value I+Lu =    0.31116
Min Singular value I+invLu = 0.33005
Singular value gain margins = [-3.4791 dB,3.2376 dB ]
Singular value phase margins = [ +/-18.9973 deg ]
```

For $\rho = 10^2$, List out your observer design matrices $\left(\tilde{A}, C, Q, R, L_\rho\right)$. List the controller matrices $\left(A_c, B_{c_1}, B_{c_2}, C_c, D_{c_1}, D_{c_2}\right)$ implementing the controller.

```
Aw =

         0   -1.1569e+03             0
         0   -1.3046e+00    1.0000e+00
         0    4.7711e+01             0

C =

     1     0     0
     0     0     1

Q =

   3.6080e+02   4.0687e-01   1.9912e+02
   4.0687e-01   1.8588e-03   2.2455e-01
   1.9912e+02   2.2455e-01   1.0990e+02

R =

   6.2500e-01            0
            0   1.0000e-03

L =

   1.2979e+01   5.6878e+02
  -4.7012e-02   1.7985e+00
   9.1005e-01   3.3099e+02
```

Common Controller

```
Ac =

              0              0              0              0
     1.2979e+01    -1.1542e+01    -1.5956e+03    -6.1073e+02
    -4.7012e-02     4.8633e-02    -1.7994e+00    -8.4582e-01
     9.1005e-01    -1.1704e-01    -1.9443e+02    -3.5414e+02

Bc1 =

   1.0000e+00              0              0              0              0
            0              0     5.6878e+02              0              0
            0              0     1.7985e+00              0              0
            0              0     3.3099e+02              0              0

Bc2 =

    -1
    -1
     0
     0

Cc =

     0   -7.5646e-03    2.3099e+00    2.2086e-01

Dc1 =

     0     0     0     0     0

Dc2 =

     0
```