A Design Study Approach to Classical Control

Randal W. Beard Timothy W. McLain
Brigham Young University

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Homework C.17

For this problem, use the gains found in HW C.10.

(a) For the inner loop of the satellite attitude controller, use the Matlab `bode` and `margin` commands to find the phase and gain margin for the inner loop system under PD control. On the same graph, plot the open loop Bode plot and the closed loop Bode plot. What is the bandwidth of the closed loop system, and how does this relate to the crossover frequency?

(b) For the outer loop of the satellite attitude controller, use the Matlab `bode` and `margin` commands to find the phase and gain margin for the outer loop system under PI control. Plot the open and closed loop Bode plots for the outer loop on the same plot as the open and closed loop for the inner loop. What is the bandwidth of the closed loop system, and how does this relate to the crossover frequency?

(c) What is the bandwidth separation between the inner (fast) loop, and the outer (slow) loop. For this design, is successive loop closure justified?

Solution

The Matlab code used to generate the plots is shown below.

```
1  % transfer functions
2  P_in = tf([1/P.Js],[1,P.b/P.Js,P.k/P.Js]);
3  P_out = tf([P.b/P.Jp, P.k/P.Jp],[1,P.b/P.Jp,P.k/P.Jp]);
4
5  C_in = tf([(P.kd_th+P.sigma*P.kp_th), P.kp_th], [P.sigma, 1]);
6  C_out = tf([(P.kd_phi+P.kp_phi*P.sigma),...
7              (P.kp_phi+P.ki_phi*P.sigma),P.ki_phi],...
8             [P.sigma,1,0]);
9
10 % margin and bode plots
11 figure(1), clf, margin(P_in*C_in), grid on, hold on
12 bode(P_in*C_in/(1+P_in*C_in))
13 margin(P_out*C_out)
14 bode(P_out*C_out/(1+P_out*C_out))
15 legend('Open Loop-Inner', 'Closed Loop-Inner',...
16        'Open Loop-Outer', 'Closed Loop-Outer')
```

The transfer functions for the inner and outer loop plants and controller are defined in Lines 2–3. For this problem we plot both the inner and outer loop frequency response on the same Bode plot, as implemented in Lines 10–16. The results of this code are shown in Figure 1.

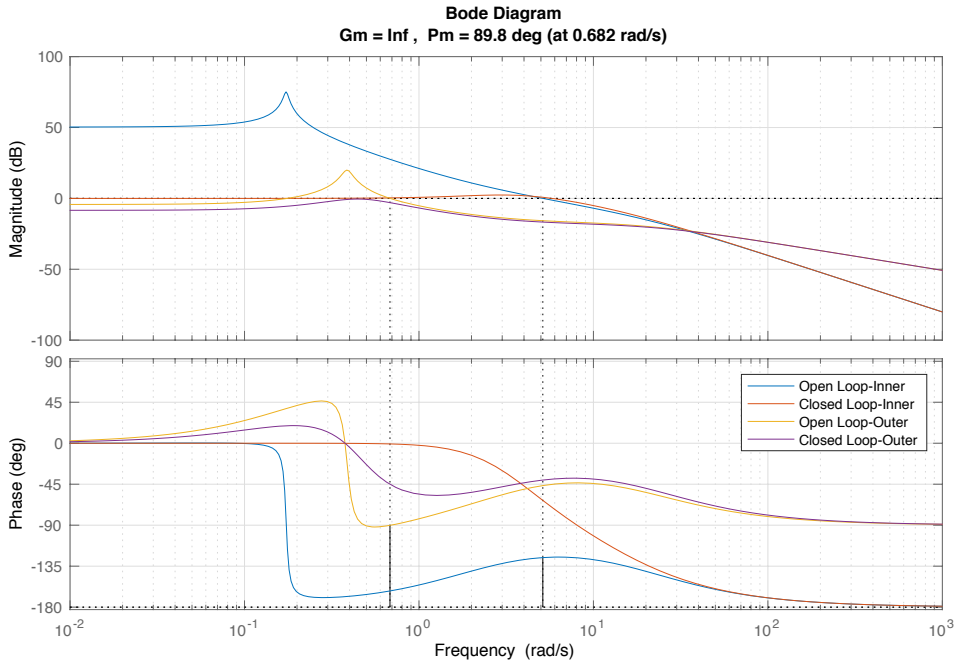

Figure 1: The `margin` and `bode` plots for the the open and closed loop systems of both the inner and outer loops of the satellite attitude control system.

As seen from Figure 1 the bandwidth of the inner loop is approximately 7.8 rad/sec, which is slightly larger then the cross over frequency of 5.2 rad/sec, with a phase margin of $PM = 55$ degrees. Similarly, Figure 1 indicates that the bandwidth of the outer loop is approximately the cross over frequency of 0.68 rad/sec. The bandwidth separation between the inner and outer loop is close to a decade and successive loop closure is approximately one far beyond the cross over frequency of the outer loop.