A Design Study Approach to Classical Control

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Homework C.16

For the inner loop of the satellite attitude control, use the Matlab `bode` command to create a graph that simultaneously displays the Bode plots for (1) the plant, and (2) the plant under PD control, using the control gains calculated in Homework C.10.

(a) To what percent error can the closed loop system under PD control track a step in $\theta_r(t)$ of 20 degrees?

(b) If the input disturbance has frequency content below $\omega_{d_{in}} = 0.1$ radians per second, what percentage of the input disturbance appears in the output.

For the outer loop of the satellite attitude control, use the Matlab `bode` command to create a graph that simultaneously displays the Bode plots for (1) the plant, (2) the plant under PID control using the control gains calculated in Homework C.10.

(c) If all of the frequency content of the noise $n(t)$ is greater than $\omega_{no} = 10$ radians per second, what percentage of the noise shows up in the output signal ϕ, using PID control?

Solution

(a) The Bode plot of the plant $P(s)$, and the loop gain with PD control $P(s)C_{PD}(s)$ are shown in Figure 1.

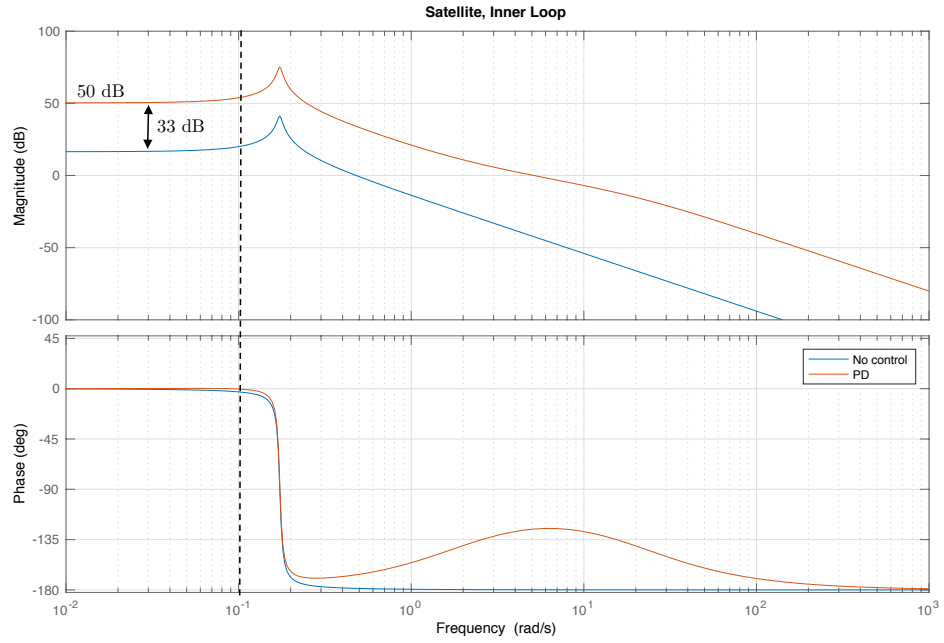

Figure 1: Bode plot for inner loop of the satellite attitude control, plant only, and under PD control.

From Figure 1 it can be seen that under PD control the inner loop is type 0 and that the loop gain as $\omega \to 0$ is $B_0 = 50$ dB. Therefore from Equation (16.10) the steady state error to a step of $\theta_d = 20$ degrees is

$$\lim_{t\to\infty} |e(t)| \leq \frac{1}{1+M_p} A = \frac{20}{1+10^{50/20}} = 0.0630 \text{ degrees.}$$

(b) If the input disturbance is below $\omega_{d_{in}} = 0.1$ rad/s, then the difference between the loop gain and the plant is $B_{d_{in}} = 33$ dB, therefore, from Equation (16.9) we see that

$$\gamma_{d_{in}} = 10^{-33/20} = 0.0224,$$

implying that 2.2% of the input disturbance will show up in the output.

(c) The Bode plot of outer loop $P_{out}(s)$, and the loop gain with PI control $P_{out}(s)C_{PI}(s)$ are shown in Figure 2.

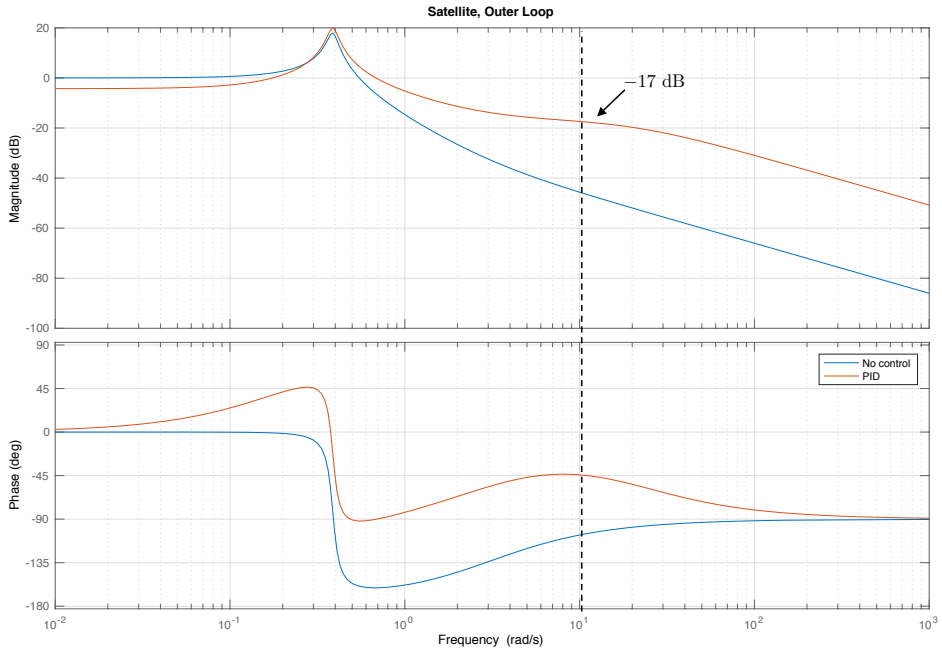

Figure 2: Bode plot for outer loop of the satellite attitude control, plant only, P control, and PI control.

For noise greater than $\omega_{no} = 1$ rad/sec, we see from Figure 2 that $B_n = 17$ dB. Therefore, $\gamma_n = 10^{-17/20} = 0.1413$ which implies that 14% of the noise will show up in the output signal.