Assignment 3

ME46085 Mechatronic System Design

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1. Section 1: Error

1.1 Question 1: Design a tamed-PID controller (no additional terms) for a bandwidth of 100 Hz, using the rules of thumb

The plant from Assignment 1 was used (Figure 1)

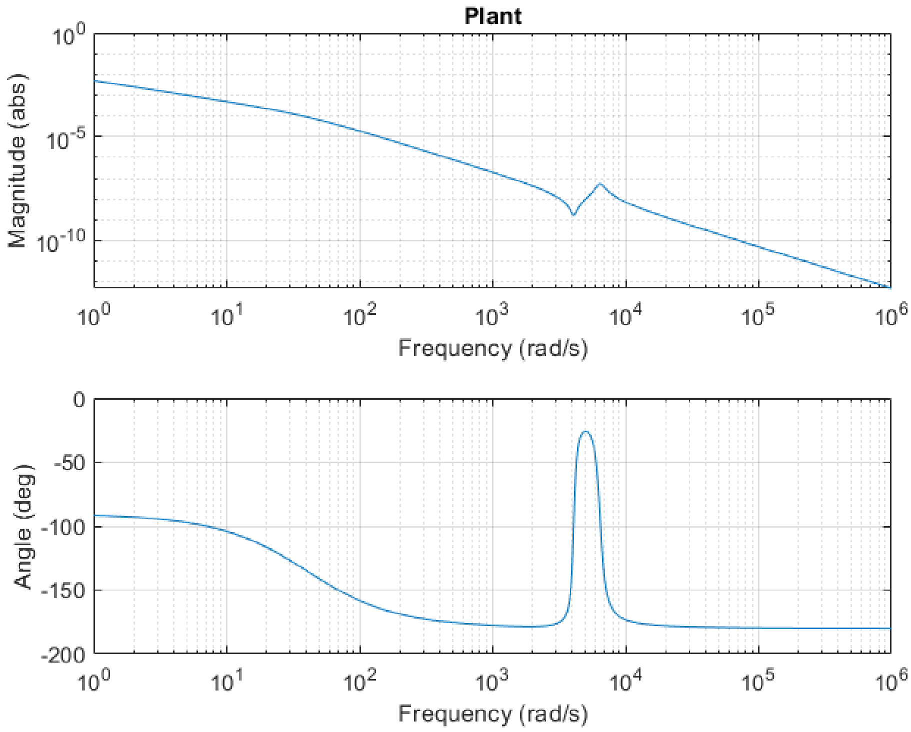

Figure 1: Bode Plot of Plant

A tamed PID controller of the form (Equation 1) was used, applying the rules of thumb (Equation 2) in table 1.

$$G_c = k_p(1 + \frac{\omega_i}{s})\frac{(\frac{s}{\omega_d} + 1)}{(\frac{s}{\omega_t} + 1)}; \tag{1}$$

$$\omega_i = \frac{\omega_a}{10}, \quad \omega_d = \frac{\omega_a}{a}, \quad \omega_t = a\omega_a, \quad k_p = \frac{1}{a}\frac{1}{|G_d(j\omega)|} \tag{2}$$

Table 1: Controller Parameters

Proportional Gain $[k_p]$	2.4e+6
Integrator Frequency (Rad/s) $[\omega_i]$	117
Differentiator Frequency (Rad/s) $[\omega_d]$	390
Tamed Frequency (Rad/s) $[\omega_t]$	3510
Bandwidth (Rad/s) $[\omega_a]$	1170

These results were calculated from the bandwidth, which was the highest value of ω_a without causing a double cross-over of the loop (Figure 3)

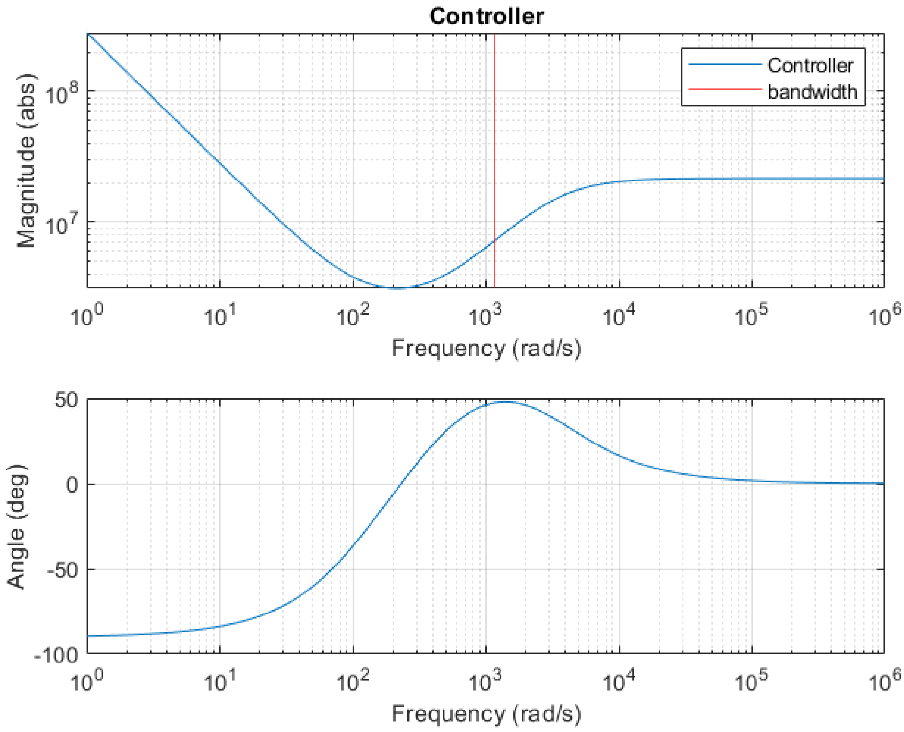

Figure 2: Bode Plot of Controller

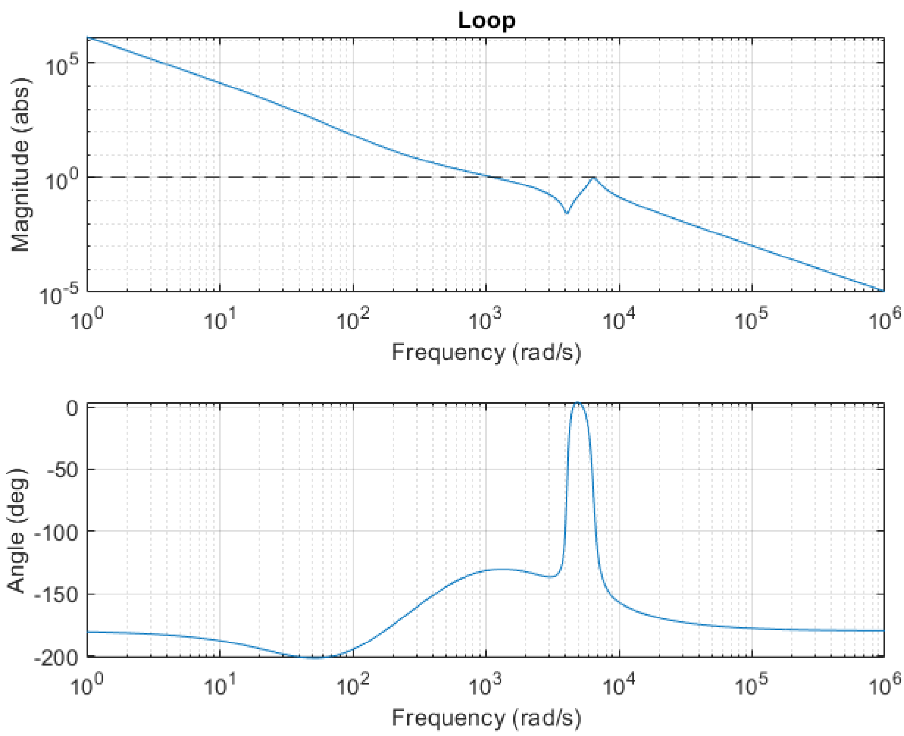

Figure 3: Bode Plot of Loop

1.2 Question 2: Compute the total error of the system at 10 Hz

Firstly, the sensitivity, process sensitivity and complementary sensitivity (Equation 3) were calculated, and this is shown in Figure 4.

$$S(s) = \frac{1}{1+GC}, \quad GS(s) = \frac{G}{1+GC}, \quad T(s) = \frac{GC}{1+GC} \tag{3}$$

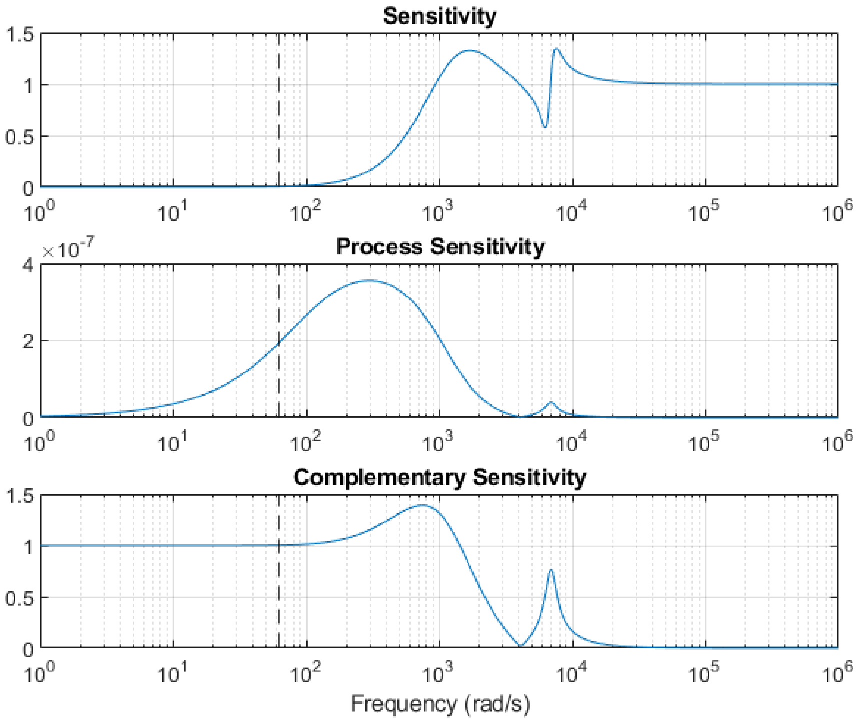

Figure 4: Sensitivities

The real error (Equation 4) of the system was calculated to be **1.004 mm**, which was predominantly driven by the noise.

$$e = \sqrt{(S(s)r)^2 + (GS(s)d)^2 + T(s)n)^2} \tag{4}$$

1.3 Question 3: Suggest at least two methods to reduce the total error of the system obtained in Q2

One method of reducing the error is to place a notch or anti-notch filter on the frequency which the three causes of error driven by. Since the main error is caused by noise, to optimise the controller, the complementary sensitivity must be reduced. This involves attenuating the controller at the noise frequency, which in this case is 10Hz.

Alternatively, a low pass filter can be implemented, however since the noise frequency is below the resonance peak, this is not applicable in this situation. Also, an extra integrator could be added, as this will boost the loop gain at low frequencies, however this only reduces the impact of disturbances which are not causing much of the error in this scenario.

1.4 Question 4: Modify the controller from Case 1 (by adding additional elements) to reduce the total error of the system at 10 Hz by 1/10th the magnitude obtained in Q2.

By adding a notch at 10Hz, the error could be reduced by up to 16%, however it could not be reduced further without casuing the system to become unstable. The value of Q2 was 1000 times smaller than Q1.

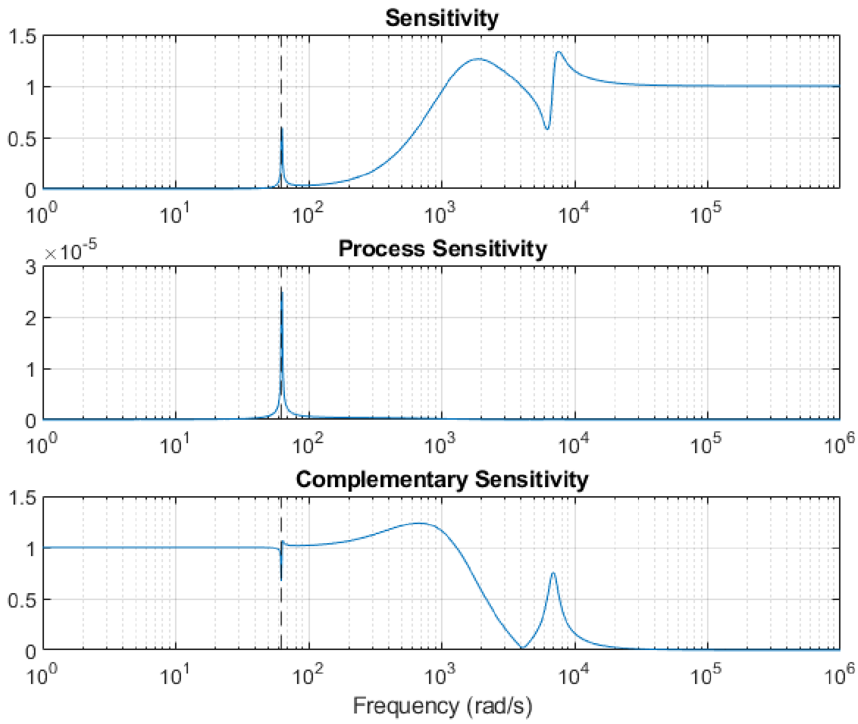

Figure 5: Sensitivity with Notch

1.5 Question 5: Examine and comment on the pros and cons of the solution implemented in Q4.

Adding a notch can help to reduce the error, but it is only applicable for a limited range of frequencies and also decreases the phase margin and therefore the bandwidth.

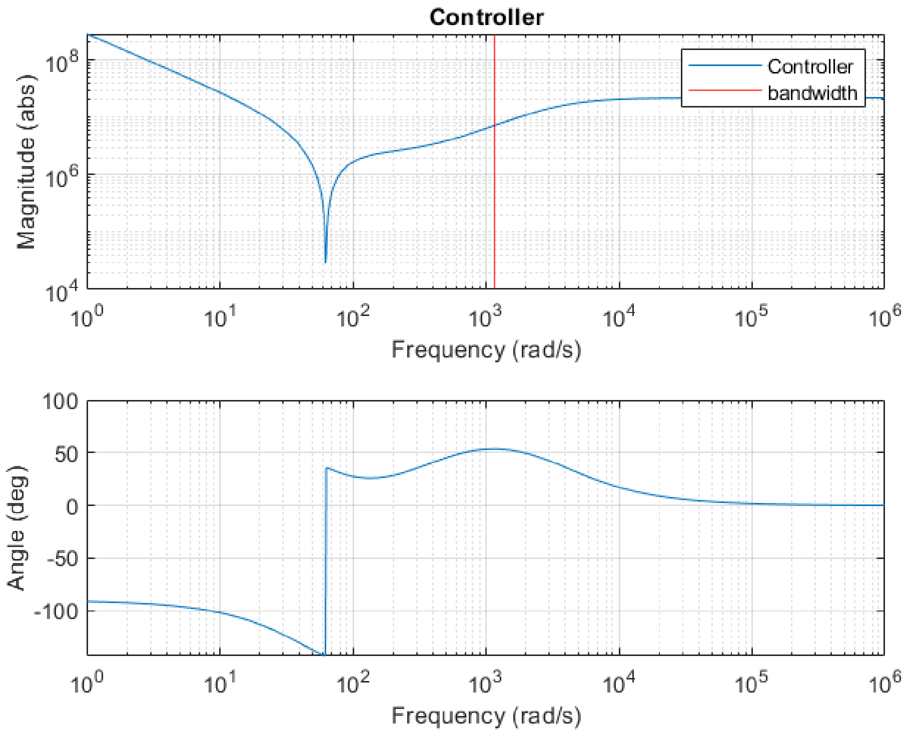

Figure 6: Controller with Notch

Appendices

References