

Project Part 3.5: Verification and Iteration

We are designing a controller for a drone to achieve stable altitude regulation by minimizing rise time, percent overshoot, and steady-state error in the height response.

Our plant is modeled as the transfer function

$$G(s) = \frac{1}{ms^2 + bs},$$

where $R(s)$ is the desired height, $Y(s)$ is the output height, $E(s) = R(s) - Y(s)$ is the error, $C(s)$ generates the control force $F_r(s)$, $D(s) = -\frac{mg}{s}$ represents gravity, and $G(s) = \frac{1}{ms^2 + bs}$ maps the net force to the mass position. Our closed-loop system is modeled in Simulink as shown in Figure 1, where $R(s)$ is the reference input, $Y(s)$ is the output height, $E(s)$ is the error signal at the first summing junction, $F_r(s)$ is the controller-generated force, and $D(s)$ represents the gravity disturbance added at the second summing junction.

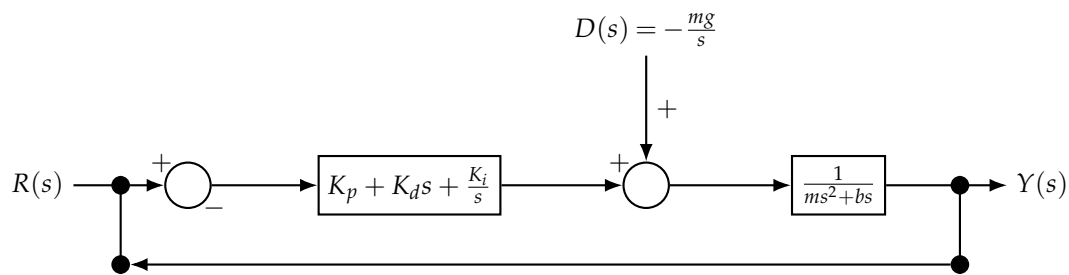


Figure 1: Block diagram of the PID-controlled mass-damper system with gravity disturbance input $D(s) = -\frac{mg}{s}$.

Our controller $C(s)$ is

$$C(s) = K_p + \frac{K_i}{s} + K_d s$$

where K_p is the proportional gain, K_i is the integral gain, and K_d is the derivative gain. The final values for all 3 of these constants were 6, 2, and 4 respectively. This controller was developed by using MATLAB's Control System Designer by examining the open-loop transfer function, rise-time, and percent-overshoot targets on the root-locus plot, then adjusting pole and zero locations until the closed-loop step response met the required performance.

The results from our controller design are shown in Figure 2 - 4.

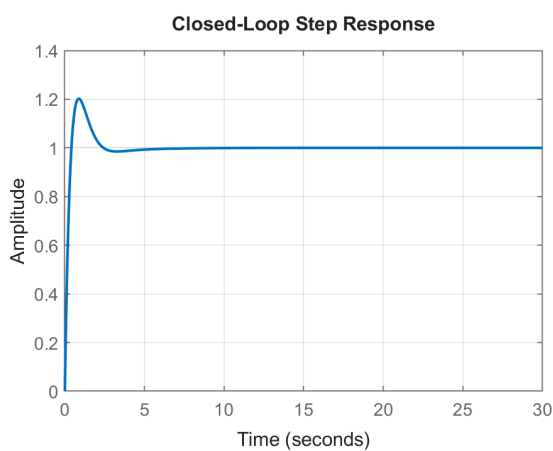


Figure 2: Closed-loop step response of the system.

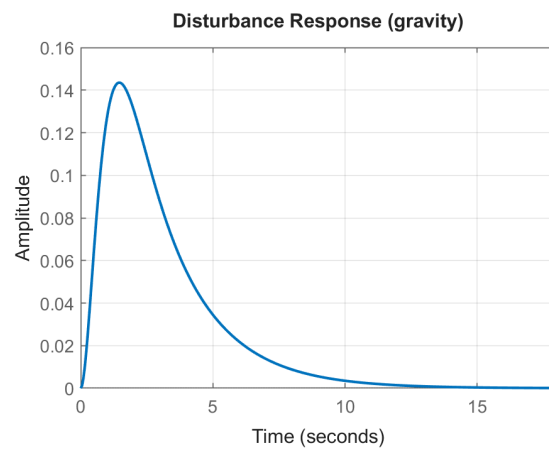


Figure 3: Response of the system to a gravity disturbance input.

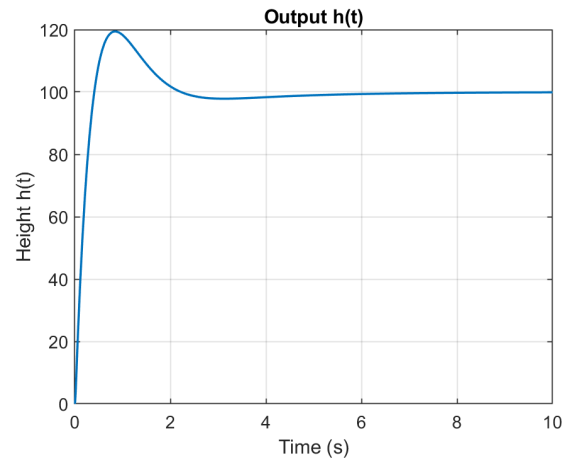


Figure 4: Output height $h(t)$ showing tracking of the reference signal.

The primary results are shown in Figures 2–4, which include the closed-loop step response, the disturbance rejection response, and the output height trajectory.

Figure 2 shows that the closed-loop step response meets the rise-time and overshoot specifications, settling quickly with minimal oscillation, indicating that the controller provides adequate damping and stability.

Figure 3 shows that the system effectively rejects the gravity disturbance, with the output force decaying smoothly to zero, demonstrating strong disturbance attenuation and proper integral action.

Figure 4 shows that the output height $h(t)$ tracks the reference without steady-state error and with well-behaved transient dynamics, confirming that the controller maintains accurate position control under the modeled conditions.

The closed-loop system is BIBO stable with poles at $s = -1.86 \pm 1.05j$ and $s = -0.458$.