

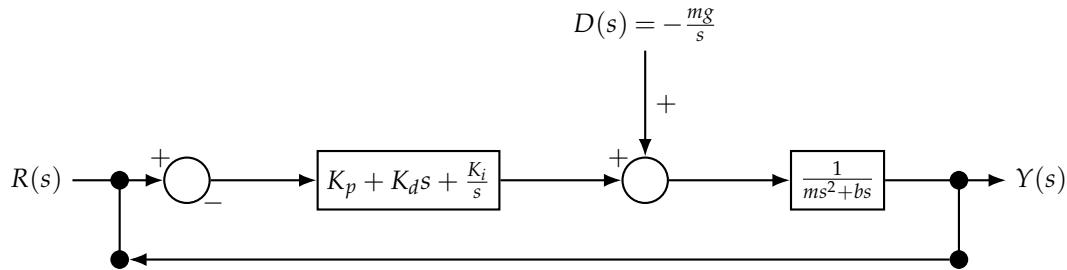
### Project Part 3.5: Verification and Iteration

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.



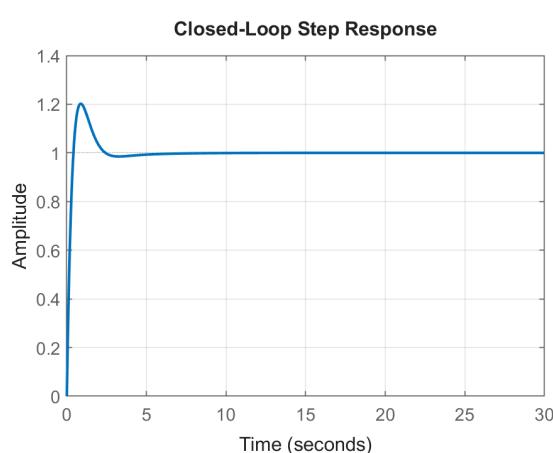
**Figure 1:** Block diagram of the PID-controlled mass-damper system with gravity disturbance input  $D(s) = -\frac{mg}{s}$ .

Our controller  $C(s)$  is

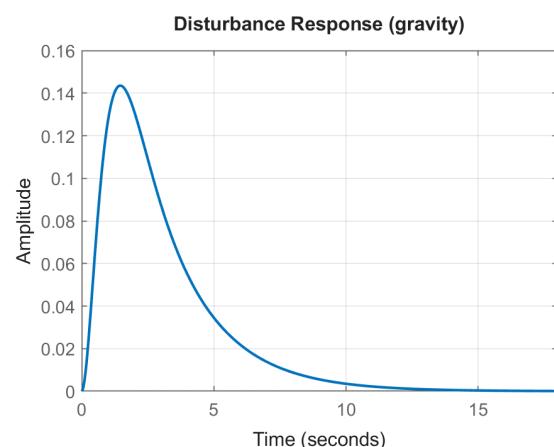
$$C(s) = K_p + \frac{K_i}{s} + K_d s$$

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.

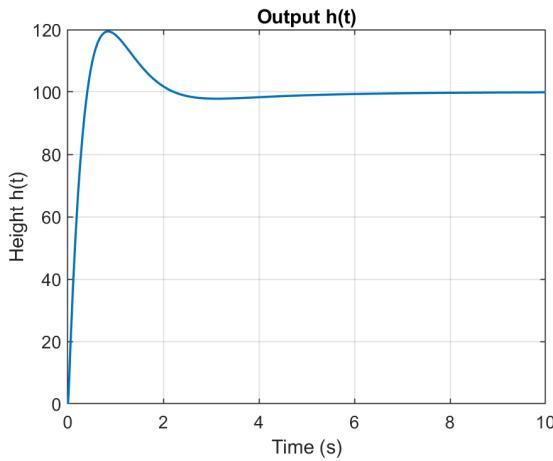
The results from our controller design are shown in Figure 2 - 4.



**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  $s = -0.458$ .