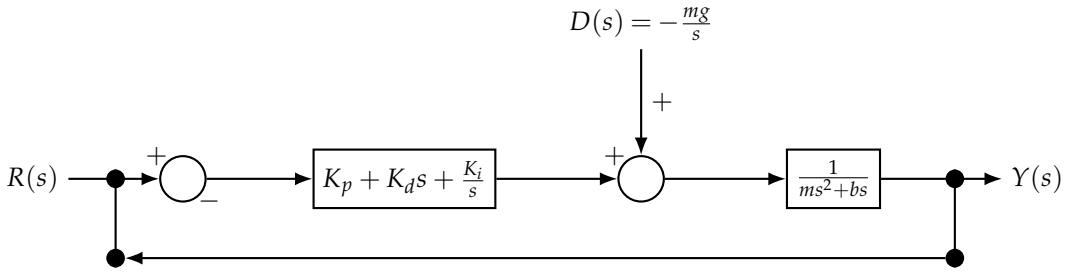
1. Reference Input

Our reference input is modeled as a unit step function scaled by a factor A, $r(t) = Au(t)$, where A corresponds to the desired hover height in meters. A step input is appropriate because our goal is for the drone to reach and maintain a constant altitude. This type of reference represents a sudden change in the altitude and is standard for evaluating performance of height controllers.

2. Performance Specifications

- Rise Time: For the transient responses, we expect the operator to fly between 0-100m. The DJI mavic 3 [1] has a vertical speed of 8 m/s, therefore, our rise time should be around 12.5 s.
- Steady State Error: We would like the steady state error 0 so that the the operators will be able to get the desired angles from the drone.
- Percent Overshoot: We would want the percent overshoot to not be higher than 1 percent this is so that the drone does not hit any ceilings or obstacles when being set to the correct area.

3.Block Diagram



4.Finding best controllers

We have decided that a PID Controller would help our system reach the desired specification of a quicker rise time, lower percent overshoot, and zero steady state error. The PI controller will cause the transfer function to be a type 1 function, and when our system takes a unit step, the steady state error is 0. The PD controller will shorten the rise time and percent overshoot. More details are shown in the block diagram.

5. Controller Transfer Function and Poles

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

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

the closed-loop transfer function is

$$\frac{Y(s)}{R(s)} = \frac{K_d s^2 + K_p s + K_i}{ms^3 + (b + K_d)s^2 + K_p s + K_i}.$$

Using the controller designer and root locus analysis, the tuned gains were $K_p = 6$, $K_i = 2$, and $K_d = 4$. Substituting $m = 0.958$ and $b = 5.56 \times 10^{-5}$ gives the characteristic equation:

$$0.958s^3 + 4.00006s^2 + 6s + 2 = 0.$$

The resulting poles are located at $s = -1.86 \pm 1.05j$ and $s = -0.458$, indicating a stable response. The system is confirmed to be stable since all poles lie on the left-hand side of the imaginary axis. Overall, this configuration meets the required performance criteria for a controlled and well-behaved altitude response.

References:

[1] DJI, "Mavic 3 Pro - Specs." [Online]. Available: https://www.dji.com/mavic-3-pro/specs.