SOEN 385 (Section S):Control Systems and Applications

Term Project

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April 15, 2023

Part 1

Open Loop Transfer Function

The values chosen for K_t and K_e are the same, thus

$K_t = K_e = K$

Eq. 1

$\ddot{\theta} = \frac{1}{J}(Ki - b\dot{\theta})$ **(1)**

Take the Laplacian

$\mathscr{L}[\ddot{\theta} = \frac{1}{J}(Ki - b\dot{\theta})]$:

$Js^2\theta(s) + bs\theta(s) = KI(s)$

Isolate for $I(s)$

$I(s) = \frac{s(Js + b)\theta(s)}{K}$

Eq. 2

$\frac{di}{dt} = \frac{1}{L}(-Ri + v - K\dot{\theta})$ **(2)**

Take the Laplacian

$\mathscr{L}[\frac{di}{dt} = \frac{1}{L}(-Ri + v - K\dot{\theta})]$:

$sI(s) = \frac{1}{L}(-RI(s) + V(s) - K\theta(s))$

Isolate for $I(s)$

$$I(s) = \frac{V(s) - Ks\theta(s)}{Ls - R}$$

subtract (1) from (2):

$$0 = \frac{s(Js + b)\theta(s)}{K} - \frac{1}{L}(-RI(s) + V(s) - K\theta(s))$$

Isolate $\frac{\theta(s)}{V(s)}$:

$$\frac{\theta(s)}{V(s)} = \frac{K}{sK^2 + s(Ls + R)(Js + b)}$$

finally, replacing constants with the selected values

$J = 1.25$

$K = 1.75$

$L = 0.001882$

$b = 1.75$

$R = 0.06727$

$$\frac{\theta(s)}{V(s)} = \frac{1.75}{s(1.75)^2 + s((0.001882)s + (0.06727))((1.25)s + 1.75)}$$

Open-loop Transfer Function

$$\frac{\theta(s)}{V(s)} = \frac{1.75}{0.0023525s^3 + 0.087381s^2 + 3.18022s}$$

System Response Analysis

Step Response

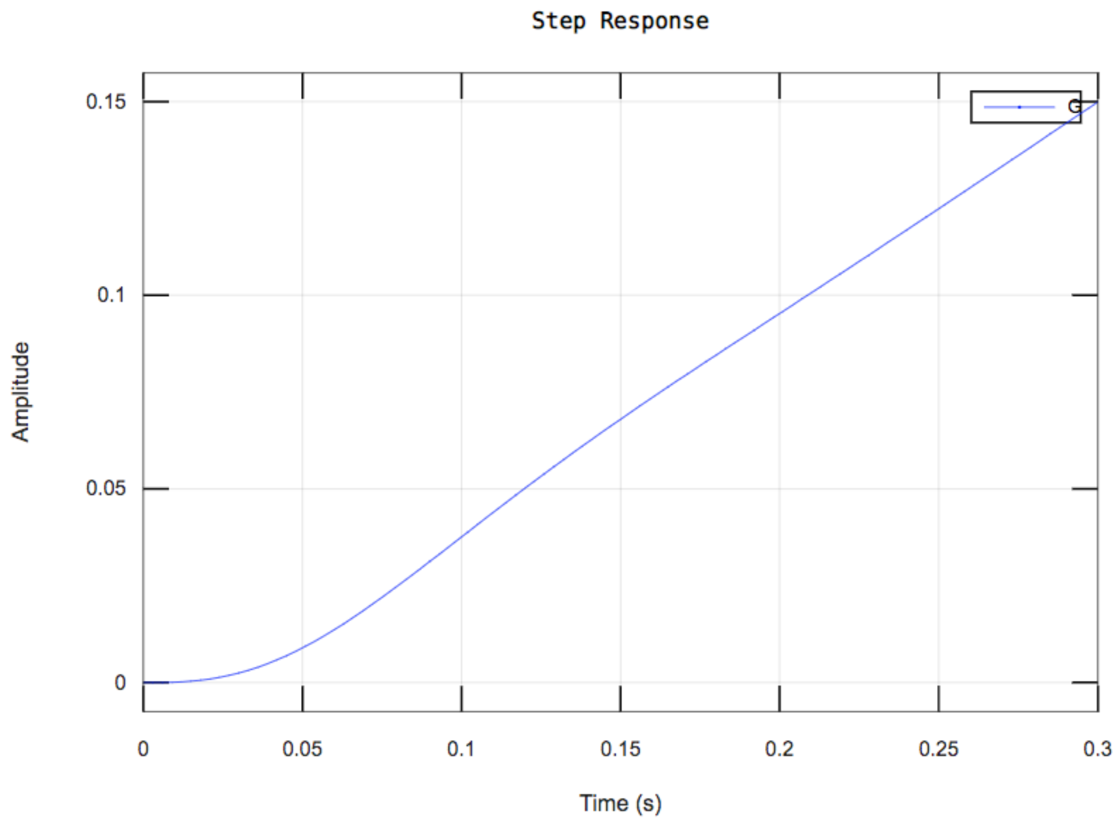


Figure 1: Open-loop step response

Ramp Response

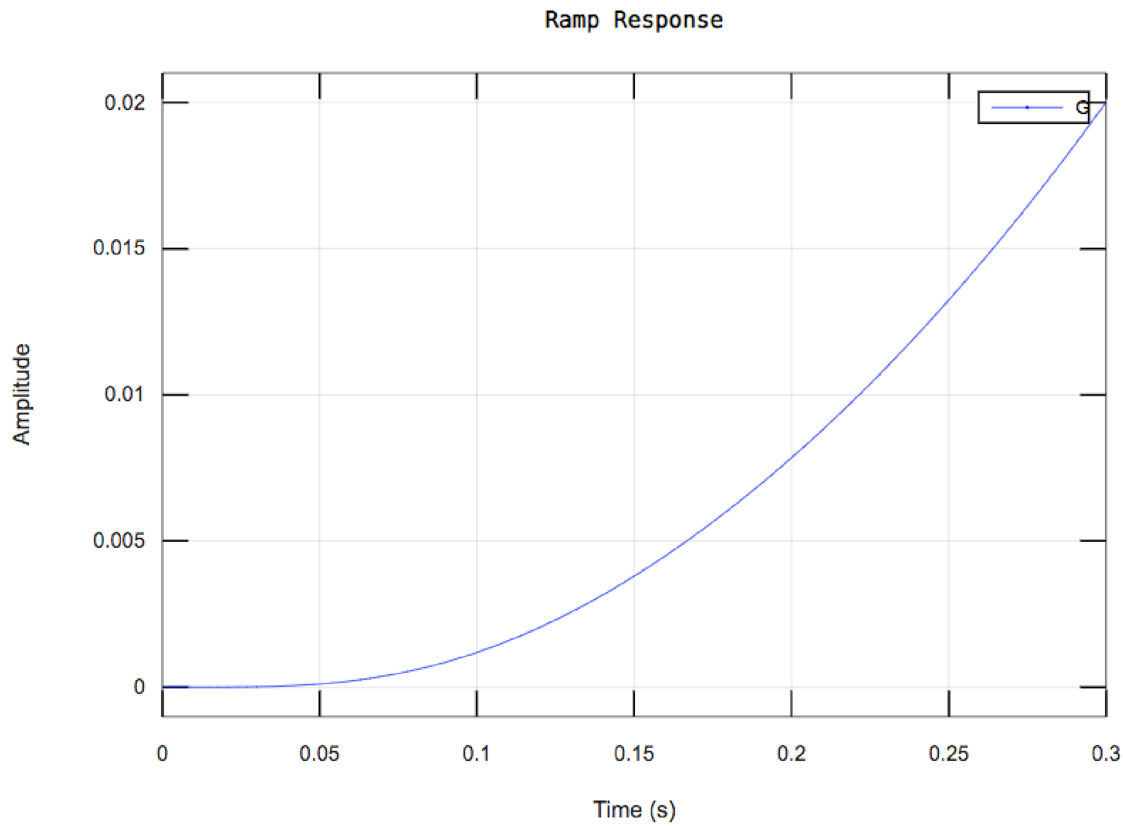


Figure 2: Open-loop ramp response

PID Control

In terms of an armature circuit (and machines that use such a circuit), we considered the most desirable properties to be the settling time and overshoot. Optimizing the settling time and overshoot in an armature circuit for a motor vehicle (like a Tesla Model S) can result in smoother and more responsive acceleration and deceleration, improving the driving experience for the user. It can also lead to more efficient operation of the vehicle, resulting in improved fuel economy and reduced emissions. Minimizing overshoot can help to prevent instability or loss of control during rapid acceleration or deceleration.

Initially, we used the values

$Kp = 0.1$

$Ki = 0.001$

$Kd = 0.001$

After lots of trial and error, including the use of an optimizer that made use of weights corresponding to the properties (i.e. settling time, overshoot, sensitivity), to guide the optimization process to zero in on the appropriate PID values, we arrived at the following after further manual adjustments:

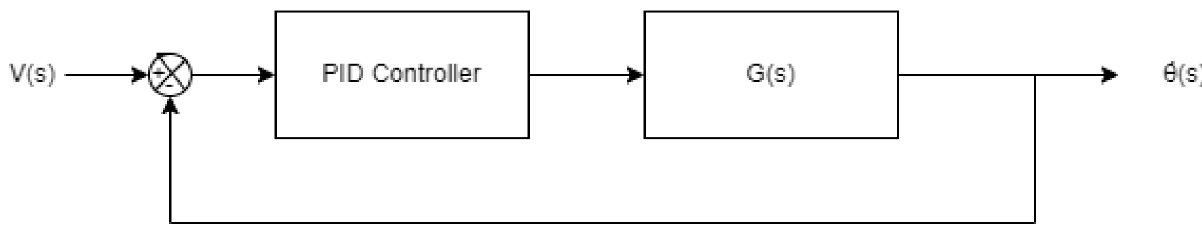
$Kp = 30.04$

$Ki = 13.823$

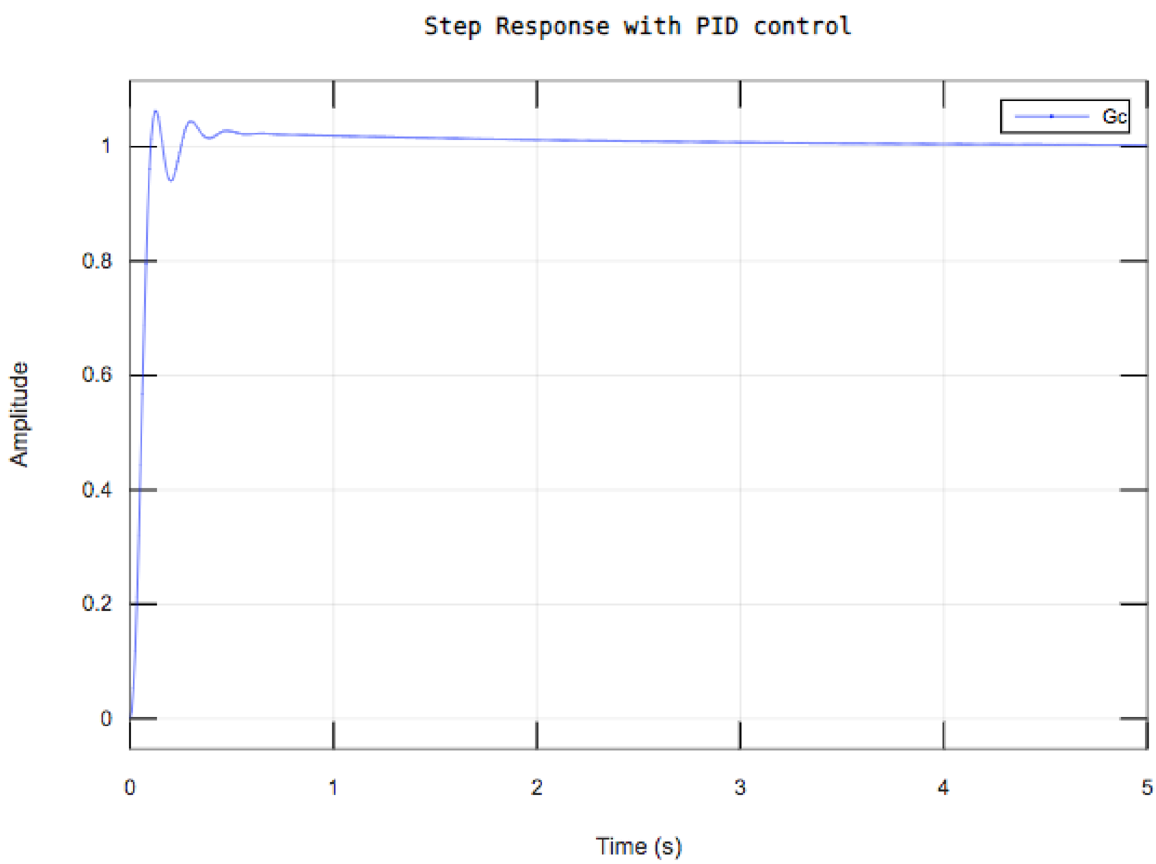
$Kd = 0.4056$

Open-loop Transfer Function Diagram

Closed-loop Transfer Function with PID Control



Step Response with PID Control



The optimizer gave us parameters that performed better than the open-loop plant, however there was still room for improvement. Firstly, response time was not satisfactory so we increased the proportional gain which yielded better results. Secondly, we noticed we had a significant steady state response error so we adjusted the integral gain to compensate for this. Finally, once satisfied with the response and error rate of our system, we reduced the stability of the system by doubling the derivative gain to dampen the system.

To conclude, it was difficult to arrive at PID parameters that satisfied the proposed design criteria, however the trial-and-error process we employed taught us a lot about the utility of PID controllers when designing control systems.