Problem Set #5: 1 DOF Linear Control

In this problem set, we will again consider a single DOF robot, namely the Quanser SRV-02, which has been turned on its side with a pendulum attached to the output shaft, as shown in Figure 1.

Figure 1. Single DOF Robot

We will assume that the robot is controlled by a current amplifier such that the linearized dynamics are given by:

$$(Nk_t)\, i(t) = (I_1 + N^2 J_m)\, \ddot{\theta} + N^2 b\dot{\theta} + m_1 g\, r_{01}\theta$$

where θ is the angle of the output shaft and $i(t)$ is the motor current.

Use the same parameter values from PS#4:

Motor torque constant: k_t	0.0077 N·m/A
Armature resistance: R_a	2.6 Ω
Gear ratio: N	70
Moment of inertia of link: I_1	0.83×10^{-3} kg·m^2
Motor inertia: J_m	0.65×10^{-6} kg·m^2
Mechanical damping: b	3.1×10^{-6} N·m·s/rad
Gravitational torque constant: $m_1 g\, r_{01}$	0.067 m/rad

Problem Set #5: 1 DOF Linear Control

Suppose we have a feedback system as shown below, where G_P is the open loop transfer function of the SRV-02 using the current amp, and G_C is a controller.

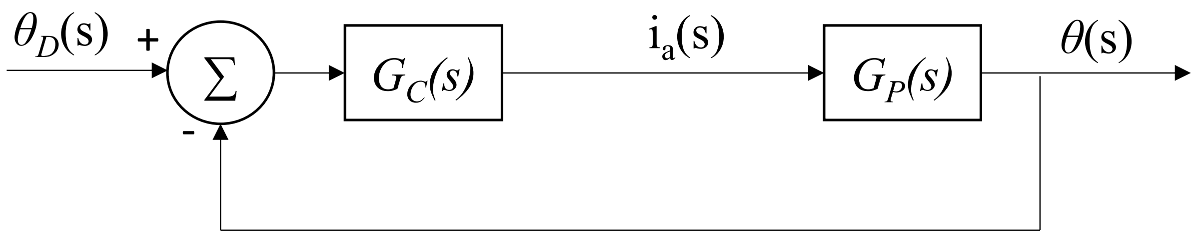

Figure 2. Block Diagram of the Closed-Loop Controller.

1. Use root locus techniques to design a closed-loop PD controller: $G_c(s) = K_P + K_D s$. Design for 20% overshoot and settling time of 0.2 sec.

2. Use root locus techniques to design a closed-loop PID controller: $G_c(s) = K_P + K_D s + \frac{K_I}{s}$. Design for 20% overshoot, settling time of 0.2 sec, and no steady-state error.

3. Simulate the closed-loop step responses of your systems from problems 1 and 2 using Simulink. Send data to the workspace and use MATLAB plotting commands to plot the step response. Label your plots/axes in MATLAB and indicate the % overshoot, settling time, and steady-state error. Also include a picture of your Simulink model(s). Comment on whether the performance matches your design specifications.

4. Now change your PD and PID controllers to PV and PIV controllers, respectively. As shown in Figures 3 and 4, remove the derivative term from G_C and implement a separate velocity feedback, using the same values for K_V as you used for K_D. Show that this results in the same closed-loop pole locations as in problems 1 and 2, but now there is one less closed-loop zero. How does the presence/absence of the closed-loop zero influence the step response? Simulate and use plots to compare the responses. Also include a picture of your Simulink model(s).

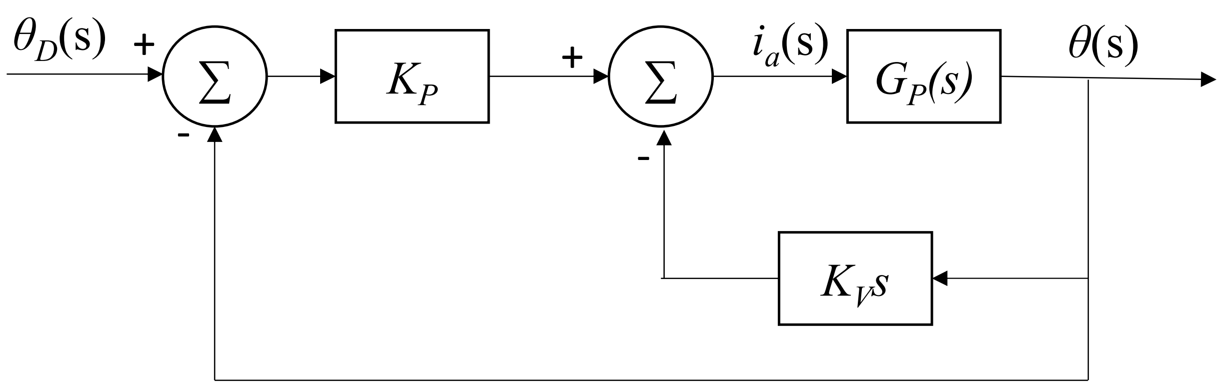

Figure 3. Block diagram of PV Control

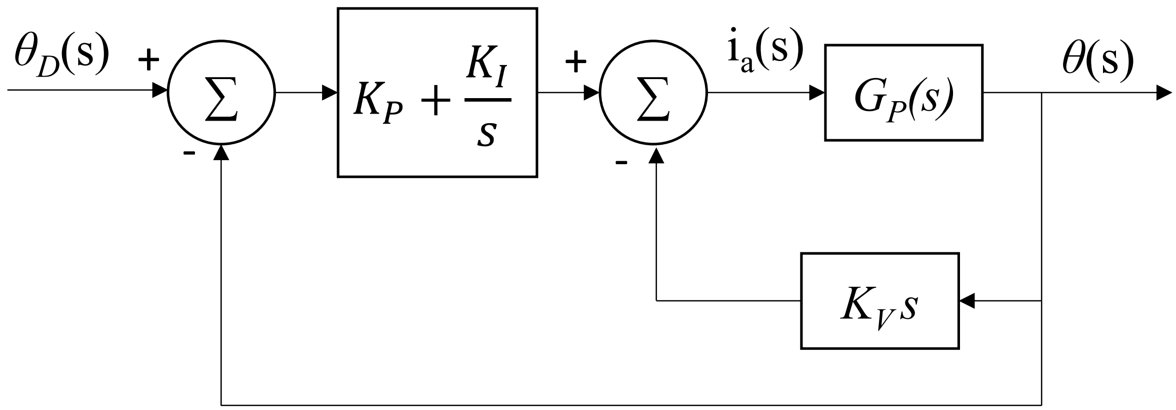

Figure 4: Block diagram of PIV Control

5. Now add a constant disturbance *d(s)* right before the plant. Use a large enough disturbance to induce a noticeable steady-state error in your PD or PV controlled system. Simulate and use plots to compare the performance of your PD/PV vs. your PID/PIV controllers in the presence of this disturbance.