ME581 Lab 2 Report

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Abstract

The report details a simulation of direct z-plane controller design utilizing the root locus technique. Initially, we determine the combination of control gains including feedback (kff), proportion (kp), integral (ki), and derivative (kd) that result in a signal response satisfying both the performance and stability margin objectives that are specified. Next, we validate the determine combination of control gains by applying them to the bread-boarded plant in Figure 1. The output result satisfy all the objectives, proof how PID controller is helpful to design a system for specific tasks.

1 Discussion

The goal of this lab is to design a PID controller that satisfy the Performance Objectives (PO) as listing:

1. Peak overshoot of the y response to a unit step r input $\leq 2\%$.
2. Time for the y response to a unit step r input to settle to within 2% of its steady-state value ≤ 1 sec.
3. Zero steady-state tracking error (i.e., $y = r$ in the steady state) in the response to a unit step r input.
4. Zero steady-state tracking error (i.e., $y = r$ in the steady state) in the response to a unit step d input.
5. Time for the y response to a unit step d input to settle to within 0.1 volts ≤ 30 sec.
6. Peak magnitude of the control signal u in response to a unit step r input as small as possible.

The first step in this lab was to test the setup function by setting all the control gains except for k_{ff} to zero, and the results are shown in Figure 2. To meet PO 1, the value of the derivative control was tuned, as it reduces overshoot. The response showed overshoot less than 2% at $k_d = 0.2631$, which also met PO 2, 3, and 4, as seen in Figure 3. The next step was to tune the integral control to settle the disturbance response by setting $k_i = 0.125$, which is shown in Figure 4. However, it was noticed that the response had a slight overshoot, so an additional proportional gain of $k_p = 0.55$ was added to satisfy all the performance objectives, as demonstrated in Figure 5.

This combination of control gain also satisfied the following Margin Objectives (SMO):

1. Positive gain margin $\geq 10dB$.
2. Negative gain margin $= \infty dB$.
3. Phase margin $\geq$ 50 degrees.

In Figure 8, it can be seen that all the SMOs have been satisfied with a positive gain of 11.11 dB and a phase margin of 50.33 degrees. It should be noted that SMO 2 automatically satisfies if SMO 1 is met. Additionally, the poles and zeros locations of the system have been plotted. It is interesting to observe that the pzmap is identical for both the input r and d to output y. This is because the transfer function is the same for both inputs, and the only reason for the differences in the responses is the location where the input is applied. Finally, I test the designed control gain with hardware setup. As shown in Figure 6, the tested result (bottom) has same response as the simulated one (above). Same for disturbance input in Figure 7, the distance converge to zero with PID controller (bottom) which is expected as the simulation shown (above).

2 Summary

Overall, this report demonstrates that the tuned control gains effectively meet all performance and stability margin objectives. Furthermore, the system has been validated through hardware testing.

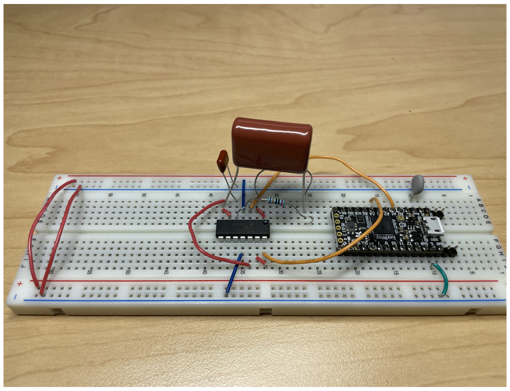

Figure 1: Breadboard setup

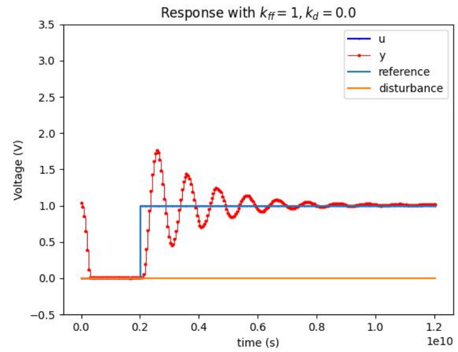

Figure 2: Step response with $k_{ff} = 1, k_d = 0$

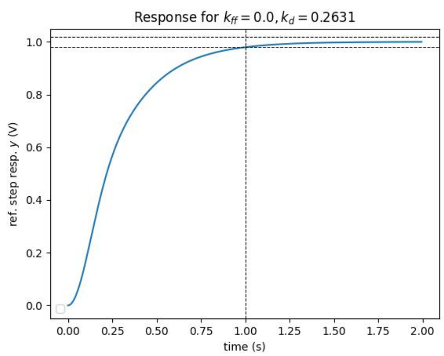

Figure 3: Step response with $k_{ff} = 1, k_d = 0.2631$

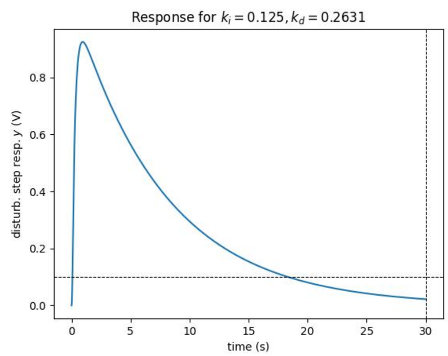

Figure 4: Step response with $k_i = 0.125, k_d = 0.2631$

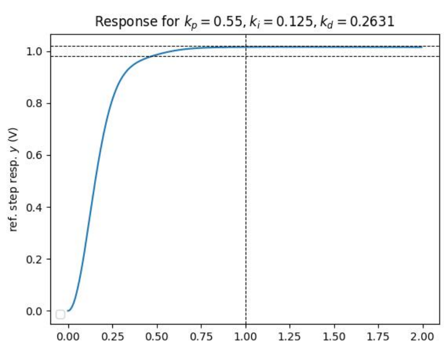

Figure 5: Step response with $k_p = 0.55, k_i = 0.125, k_d = 0.2631$

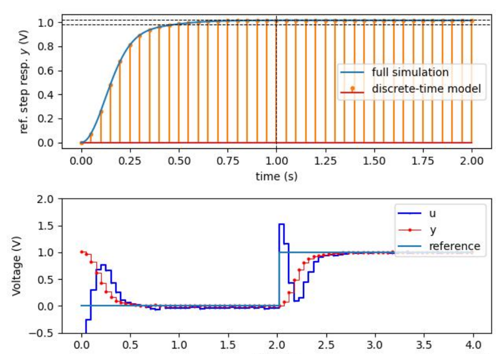

Figure 6: Comparison between simulation and hardware for y

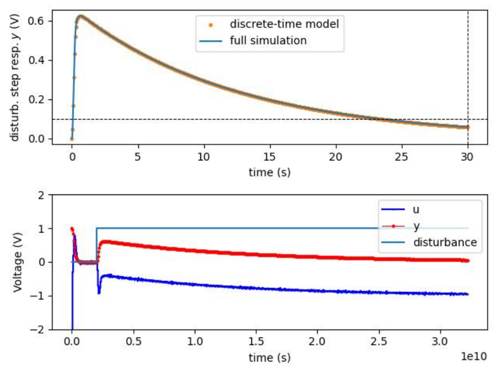

Figure 7: Comparison between simulation and hardware for d

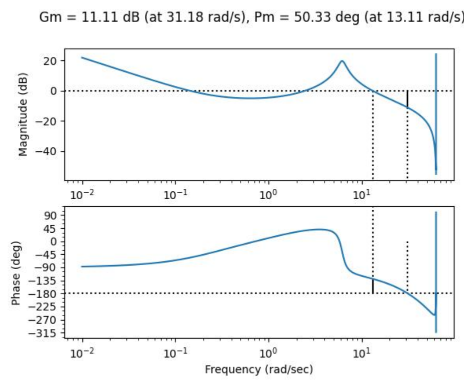

Figure 8: Bode plot

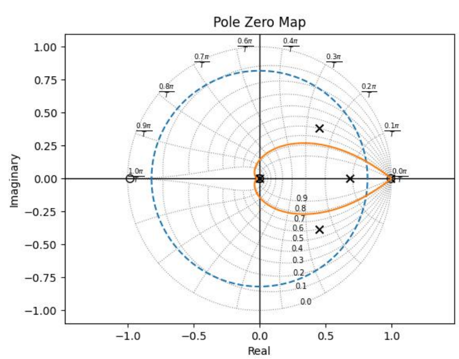

Figure 9: Bode plot