Furkan Şahbaz, 60124 **15.12.2018**

ELEC 301 Homework 3 Report

Question 1

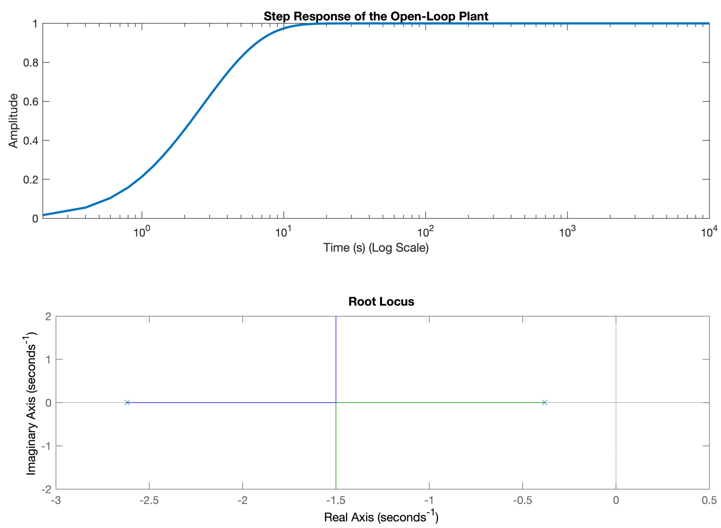

Figure 1: The Step Response and the Root-Locus Representation of the Open-Loop Plant System

The open-loop plant system is stable. This can be observed both from the step response plot and the root-locus plot of the system. The step response of the system shows that the system saturates to 1 at nearly 10.6 seconds (i.e. the system's response doesn't oscillate infinitely or it doesn't go to infinity). The root-locus plot shows that both of the poles are on the left half plane of the s-plane, therefore indicating that the system is, again, stable.

Question 2

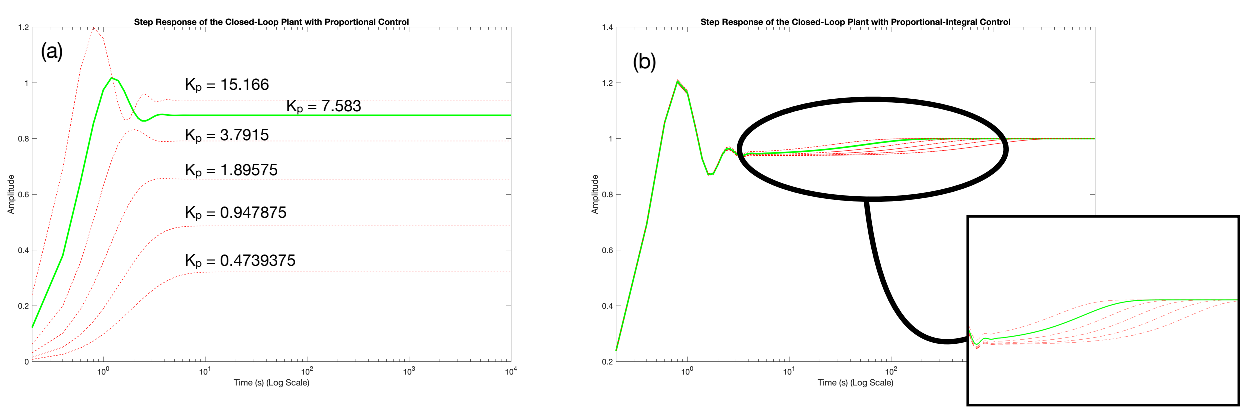

Figure 2: The Step Responses of: (a) Closed-Loop Plant with P Controller, (b) Closed-Loop Plant with PI Controller

I have designed an analog controller with the constants K_p = 7.583 and K_i = 0.2906. I have used the heuristic method where we initially define a small constant (i.e. 0.4739375 for K_p and 0.0181625 for K_i). Then I have doubled these values at each iteration until I have started observing considerable oscillations. Then, I have fixed K_p to the half of that value. The similar process went on for K_i too, though this time the deviations were too small so I could not state the values on the plot, but I have zoomed in on the plot so that the deviations can be observed and to show that the value I have chosen is the most stable option.

Question 3

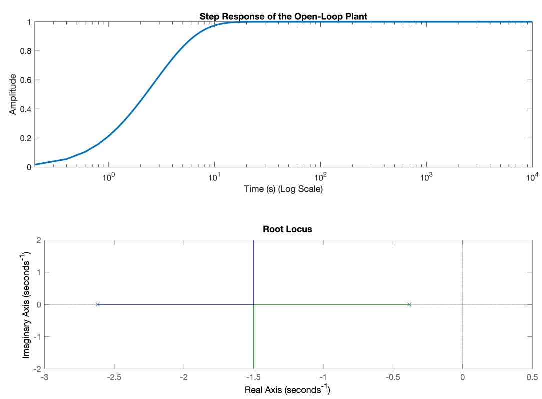

Figure 3: The Step Response and the Root-Locus Representation of the Open-Loop Plant System

Rise Time	5.8584
Settling Time	10.6547
Overshoot	0
Peak Response	0.9999
Steady-State Error	9.9920E-16

Table 1: The Rise Time, Settling Time, Overshoot, Peak Response, and the Steady-State Error of the Given System

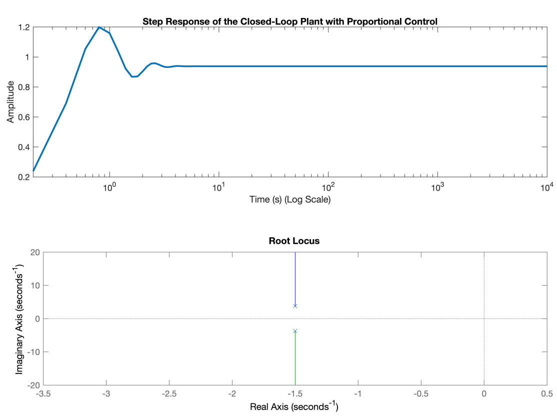

Figure 4: The Step Response and the Root-Locus Representation of the Closed-Loop Plant with P Controller

Rise Time	0.5675
Settling Time	2.7091
Overshoot	15.3659
Peak Response	1.0192
Steady-State Error	0.1165

Table 2: The Rise Time, Settling Time, Overshoot, Peak Response, and the Steady-State Error of the Given System

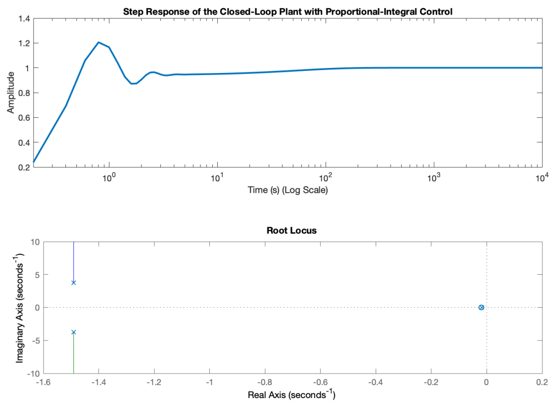

Figure 5: The Step Response and the Root-Locus Representation of the Closed-Loop Plant with PI Controller

Rise Time	0.6695
Settling Time	49.0001
Overshoot	3.6372
Peak Response	1.0364
Steady-State Error	1.2212E-15

Table 3: The Rise Time, Settling Time, Overshoot, Peak Response, and the Steady-State Error of the Given System

By observing the above tables and plots, it is possible to see that all systems are stable. The open-loop system has a distinctively higher rise and settling times, compared to the others. This would be an undesired result in controller designs, since one of the main aspects is reducing these time parameters. The PI controller system has relatively lower rise and settling times than the P controller, but there is not a big difference between them, since it doesn't allow future predictions (i.e. it lacks the differentiator component). In terms of overshoot, it can be observed that introducing controller constants K_p and K_i increase the overshoot parameter immensely. This is the side-effect of applying P or PI controllers to the systems. Though, it can be observed that there isn't too much of a steady-state errors in the resulting systems. The open-loop system has a steady-state error of 9.992E-14%, which is actually a negligible percentage, the closed-loop system with P controller has a steady-state error of 11.65%, and the closed-loop system with PI controller has a steady-state error of 1.2212E-13%, which is also a negligible percentage. The PI controller apparently causes less error than the P controller, however, all of these percentages need to be lower in order for the system to work perfectly. The peak responses of the systems actually demonstrate how great the initial oscillations of the systems were, before they saturated to their final values. The open-loop system's peek value is 0.9999, showing that no oscillations occurred during that process. The P and PI controllers have a relatively higher and close values of peak responses. This shows that there was an initially exceeding response, but after seeing their steady state errors and observing their plots, it can be said that these systems saturate (nearly) to the desired output values, after partially oscillating. Also, the fact that I have generated the P and PI controlled systems with a unity feedback supports the fact that those systems are stable, since unity feedback is one crucial aspect of creating stable systems. The settling time for the P controller is suitable, but MATLAB calculated the settling time of the PI controller to be ~49 seconds, though, actually the system's response is at an acceptable level even before then.

Question 4

In order to convert my analog converter to a digital one, I have used the Tustin (Bilinear Approximation) method, since it preserved my systems properties such as frequency and dynamics; I also causes no shift in the root-locus representations. Also, I have used the Zero-order Hold method in order to map my discrete system to an analog system. Though, this method is not the most desirable method, I needed to use it in order to demonstrate passing my analog signal from an A/D converter first, and then a D/A converter. Since these converter cause certain delays in real life, which are not always constant, I have introduced an artificial (constant) delay of 0.01 seconds (my sampling period). This helps me realize the digital system and avoid variable delays. However, the results are satisfactory in terms of rise time, overshoot, and steady-state error.

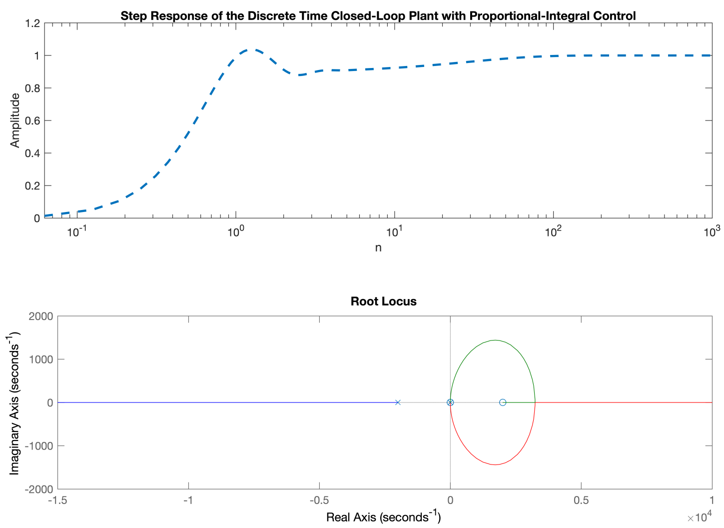

Figure 6: The Step Response and the Root-Locus Representation of the Digital Closed-Loop Plant with PI Controller System

Rise Time	10.7304
Settling Time	787.8837
Overshoot	3.7326
Peak Response	1.0373
Steady-State Error	5.2403E-14

Table 4: The Rise Time, Settling Time, Overshoot, Peak Response, and the Steady-State Error of the Given System

It can be observed from both the step response plot and the root-locus representation of the system that it is indeed stable. It can be observed that every pole of this discrete time system is within the unit circle, and it saturates to ~1 with a steady state error of 5.2403E-12%, thus supporting the fact that this system is stable. This system has close rise time values to its analog counterpart, but it has a far greater settling time. It has a higher steady state error and rise time, though these values are still desirable. Overall, these systems show us that in order to improve some aspect of the controller designed controllers, one must sacrifice others.