

A Unified Approach for Continuous-Time Compensator Design via a Graphical User Interface (GUI)

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Abstract. In the field of control theory, compensators are used when a control design does not meet the intended design specifications. Some examples of these design specifications could be percent overshoot (P.O.), settling time (T_s), steady-state error (e_{ss}) for a specified system type, gain margin (G.M.), and phase margin (P.M.). This paper will deal with continuous-time compensators. This paper will discuss a compensator graphical user interface (GUI) implemented using Matlab. This GUI enables the user to design a compensator using two different methods. The first method is through the use of the root locus. The second method is through the use of a Bode plot. The root locus method is used in the time domain while the Bode plot is used in the frequency domain. By making both the root locus and Bode plot available on the GUI, the user can take advantage of the features of each design method in order to meet the desired design specifications.

1. Introduction

The Graphical User Interface (GUI) in this paper was created in Matlab 7.0. The GUI shows two possible approaches to compensator designs; utilizing the root locus or Bode plots. The user has the ability to choose which of the two methods to use. The GUI can be used as a quick educational tool when discussing different compensator designs in the continuous-time domain

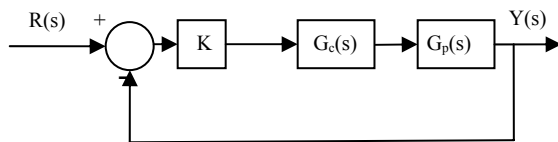


Fig. 1 Block Diagram of Unity Feedback System

2. Experiment, Results, Discussion, and Significance

The purpose of the GUI was to create a useful and user-friendly way of designing compensators in the continuous-time domain. The GUI is based on the integrated design

procedure described in [1,2]. The procedure, using time or frequency domain plant data, generalizes the angle criterion in root locus design. The standard closed-loop system is represented by the block diagram in Fig. 1. K is the control gain, $G_c(s)$ is the compensator, and $G_p(s)$ is the plant dynamics. From [1,2], the generalized magnitude constraints takes the form

$$K|G_c(s_0) G_p(s_0)| = 1$$

where the design point is given by

$$s_0 = \begin{cases} -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2} & , \text{root locus} \\ j\omega_{gc} & , \text{Bode} \end{cases}$$

ζ is the damping factor, ω_n is the natural frequency, and ω_{gc} is the gain crossover frequency. The generalized angle constraint takes the form

$$\angle G_c(s_0) + \angle G_p(s_0) = \phi$$

where the desired angle is given by

$$\phi = \begin{cases} \pm 180^\circ & , \text{root locus} \\ \pm 180^\circ + PM & , \text{Bode} \end{cases}$$

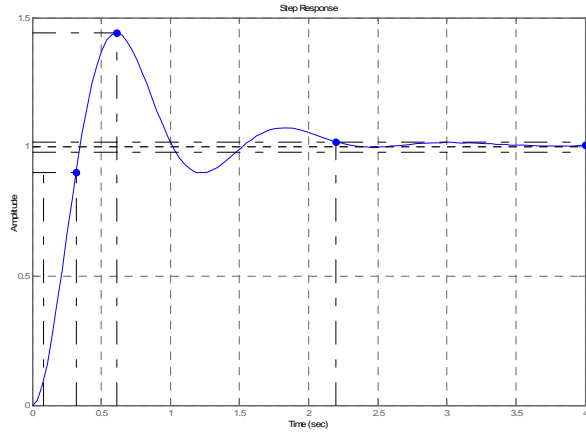
This paper will not concentrate solely on the methods of determining the compensators, but also the application. In order to make the discussion of the GUI simpler, the GUI can be thought of as 3 separate portions. The left hand portion of the GUI displays the uncompensated and compensated root loci. The right hand portion displays the magnitude and phase Bode plots. The central portion of the GUI is where the user enters the system specifications. The user can select the compensator type, system plant, design points, phase margin (PM), and compensator zeros (if applicable based on the compensator chosen). Once the system specifications are entered, the Update button is pressed to execute the GUI. The GUI then plots the root locus and Bode plots in their respective areas. The rise time (T_r), settling

time (T_s), peak time (T_p), and percent overshoot (P.O.) are a few possible design specifications.

In order to demonstrate the GUI, we will represent laser eye surgery with the plant, $G_p(s)$. The overall system is represented in Fig. 1. The GUI is shown in Fig. 2. The design specifications that we are designing for will be $T_s < 3$ sec, P.O. $< 30\%$, and $e_{ss}=0$ for a step input. We will define the system plant to be:

$$G_p(s) = \frac{2}{s(s+1)(s+4)}$$

The compensator used will be a proportional-integral derivative (PID) compensator. The PID compensator was chosen because it improves the transient response of the system. The desired design points will be chosen as $s_0 = -1 + j5$. Once this is complete, pressing the Update button automatically plots the root locus and Bode plots, as well as displays the compensator. The step response can be viewed in order to compare the step response with that of the design specifications. According to step response of the closed-loop system in Fig. 3, the design specifications are not met. The current design resulted in $T_s=2.2$ sec and P.O.=44.1%. The design specification for T_s was met but not for the P.O. Because the design specifications were not met, the user has the opportunity to re-evaluate the system parameters and re-design the compensator. The user can also iteratively modify the system parameters in order to observe how the step response reacts to different system parameters.



3. Step Response

3. Conclusions

The GUI can be a very effective teaching tool. It is easy to demonstrate whether a particular compensator is needed. It can also be used to verify whether the design specifications are met. In the future, the GUI can be modified to include discrete time compensator designs.

References

- [1] R. H. O'Brien, Jr. and J.M. Watkins, "A Streamlined Approach for Teaching Root Locus Compensator Design," Proceedings of Conference on Decision and Control, Orlando, FL, Dec 2001.
- [2] R. H. O'Brien, Jr. and J.M. Watkins, "A Unified Approach for Teaching Root Locus and Bode Compensator Design," Proceedings of the American Control Conference, Denver, CO, Jun 2003.

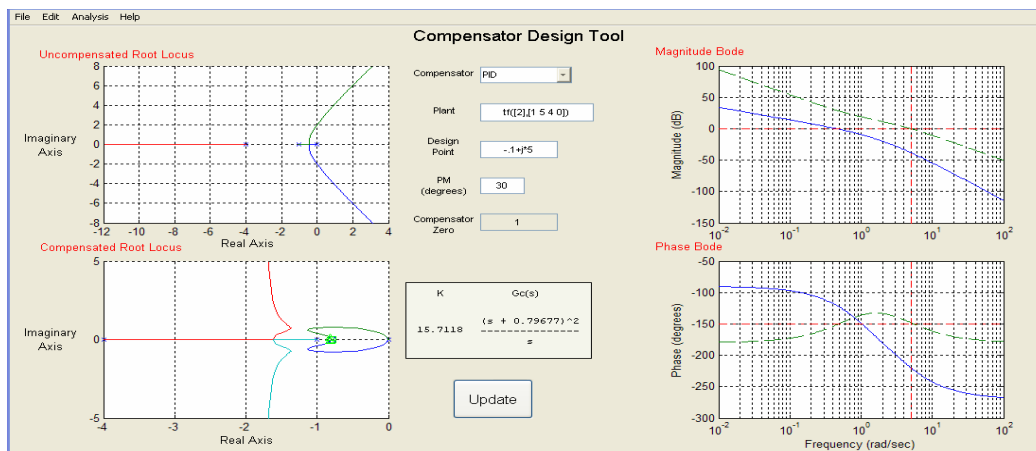


Fig. 2 Graphical User Interface (GUI) in Matlab