Transactions on Engineering Sciences vol 3, © 1993 WIT Press, www.witpress.com, ISSN 1743-3533

A computer simulation for control systems design

A.M. Eydgahi
Telecommunication Company of Iran, and Department of Electrical and Computer Engineering, University of Tehran, Tehran, Iran

ABSTRACT

A menu-driven graphics-based simulation package called DESIGN has been developed. It enables the users to add/delete poles or zeros and vary design requirements such as the value of the gain, damping factor, overshoot, delay time, rise time, bandwidth, resonance frequency, etc., to see the effects on system response. The package is designed around the root locus plot of a unity feedback control system in a window environment. It is a useful tool for both the teachers and the students in a basic control system theory course with a special emphasis on design.

INTRODUCTION

In recent years, the use of various software for analysis and design of control systems has been a routine practice both in industrial and educational environments [1]-[2]. A number of commercially available packages such as MATLAB, MATRIXx, CTRL-C, and program CC have received a great deal of interest and have been widely used for research and teaching purposes. Many universities and technical institutions have developed special-purpose simulation programs for analysis and design to fulfill their needs and, to some extent, the needs of control community [3]-[6].

Most of the available computer aided control systems design packages vary drastically in their user-interface and their application areas. Many of them are command-driven and it is hard for the infrequent users to remember the various commands. Therefore, the experience of the users is one of the main

factor in successfully using any of these command-driven programs. In some cases, the user has to answer too many questions even when he needs to enter a few data. It is very hard to see and change the data that have already been entered. This is because the data are entered in sequence. Also, they mostly suffer from lack of having any command for directly providing the user with the relationship between the time-domain and the frequency-domain parameters of the system. These information are very important factors in design of a control system when a designer is changing one parameter and wants to know the effect of that change on the other parameters of the system.

To overcome these difficulties, a computer program called DESIGN has been developed. It is menu-driven and is developed in a window environment. It uses a mouse and pop-up menus to select a command and therefore there is no need of remembering any function or instruction. For data entry, it uses dialog boxes which allows the user to easily change the data in any sequence with the click of the mouse. The program gives the relationship between the time and the frequency parameters by utilizing the root locus representation of the system. It allows the user to change gain or any time or frequency parameters of the system and see how the system will respond to that change. The user can also delete or add any poles or zeros to the open-loop transfer function of the system, to see how the closed-loop system and its time and frequency parameters will be effected.

DESCRIPTION OF THE PACKAGE

DESIGN provides a user-friendly widow-based environment which allows the users to vary system parameters and design requirements such as the value of the gain, damping factor, overshoot, delay time, rise time, bandwidth, resonance frequency, etc., to see the effects on system behavior. The package is designed around the root locus plot of a unity feedback control system. It uses a second order approximation technique to calculate and plot the unit step response of the system for any value of gain, and gives all the time and frequency parameters of the system.

The software makes use of pull-down menus, windows , and push-buttons. It consists of Analysis, Design, Show, and Zoom modules. Each module has a menu which offers a number of choices. A sample screen capture of the package is shown in figure 1.

Transactions on Engineering Sciences vol 3, © 1993 WIT Press, www.witpress.com, ISSN 1743-3533

<Analysis module>:

The choices in *Analysis* module allow the user to enter the transfer function of the system, delete and/or add poles and zeros to the system under consideration, plot the unit step response of the system for any point selected on the root locus, and turn on/off the grid. The system should be represented by the transfer function in the following form:

$$\frac{Y(s)}{U(s)} = \frac{a_m s^m + a_{m-1} s^{m-1} + \ldots + a_1 s + a_0 s}{b_n s^n + b_{n-1} s^{n-1} + \ldots + b_1 s + b_0 s}$$

<Design module>:

The options in *Design* module let the user to select any desired value for the gain and the time and frequency parameters of the system to see how the closed-loop poles will be effected.

The time-domain design parameters that can be changed are rise time, delay time, time constant, settling time, maximum overshoot, peak time, damping factor, natural undamped frequency, and damped frequency. The frequency-domain design parameters that are included in the program and can be changed are bandwidth, resonance peak, and resonance frequency.

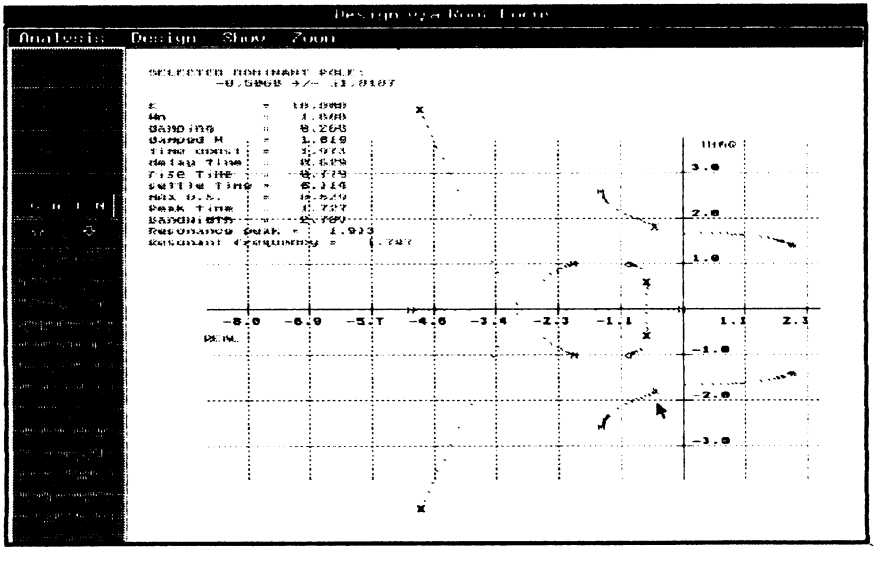


Figure 1: A Sample Screen Capture of The Package

<Show module>:

The *Show* module gives the open-loop poles and zeros of the system. Since the system under consideration may be changed by adding/deleting poles or zeros at any time during the use of the program, its menu has also a choice to allow the user to see the latest transfer function of the system.

<Zoom module>:

The choices in *Zoom* module provide the facility for zooming in and/or out the X and Y axes of the root locus plot. Its menu has seven different zooming options.

The top of the screen is used to display the modules. Two push-buttons are displayed at the left side of the screen for varying the gain factor K. One is used for incrementing the gain and the other is for decrementing it. Figure 2 shows the structure of the package.

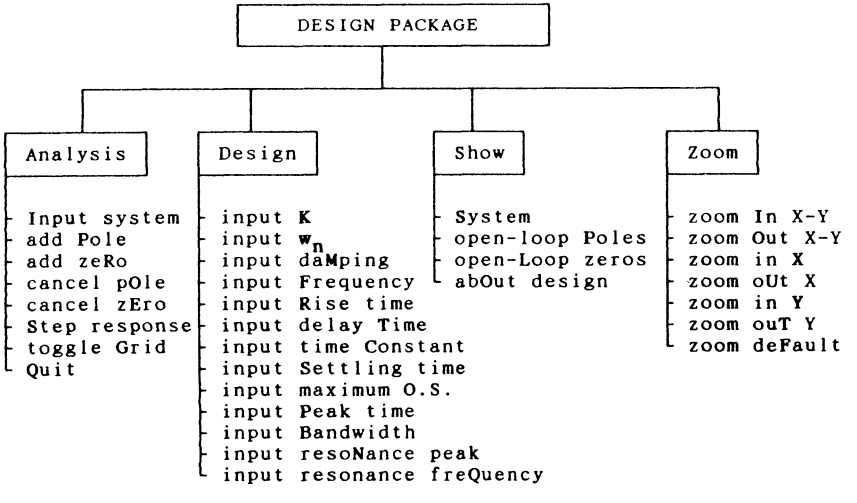


Figure 2: DESIGN's Menu Structure

To use the DESIGN program, the user should give the open-loop transfer function of the system. The program will automatically compute and display the root locus of the system. Then, the user can delete or add any zeros or poles to the system by using the *Analysis* module. At any time the user can click on any portion of the root locus plot to obtain the corresponding time and frequency parameters and the closed-loop poles of the system for the selected point. These data will be displayed at the left top portion of the graphing area. The dominant-poles of the system will be displayed in green color. The yellow color is used to display other stable closed-loop poles of the system. The unstable poles will be shown in red color. The unit-step response of the system at the selected point may also be displayed at a separate window by making a choice from *Analysis* module. This feature is shown in figure 3.

The push-buttons can be used to change the gain factor of the system and see how the corresponding closed-loop poles will move around the s-plane. At any time the *Design* module may be used to select any desired value for any of the time and the frequency parameters of the system to see how the system will be effected by that choice.

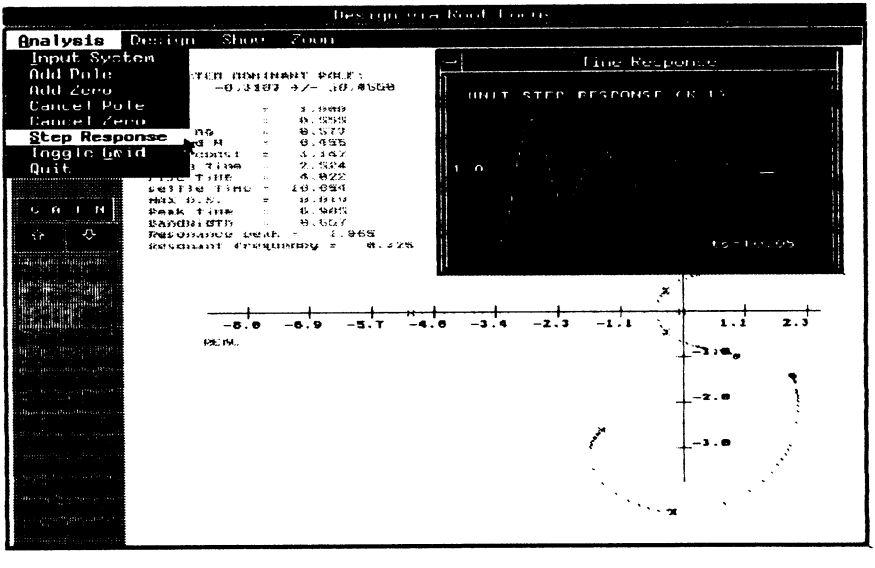


Figure 3: A Sample Example of a Step Response

CONCLUSIONS

A computer simulation program based on the root locus plot of a system has been presented. The program is called DESIGN and enables the user to change parameters of the system or even modify the system by adding/deleting any desired poles and zeros, to see how the system response will be effected.

The program offers an interactive graphical user interface environment written in TURBO C++. It can be used on the IBM or compatible personal computers and as a complement to a design-oriented course in control systems.

The development of DESIGN was mainly based on the idea of providing the control community with a tool which would directly give the relationship between the time-domain parameters and the frequency-domain parameters of a control system with the hope that such a tool would increase the users understanding of the design subjects.

ACKNOWLEDGEMENT

The author would like to acknowledge two of his students S. Wahid and D.P. Prendergast for contributing to this project.

REFERENCES

1. Jamshidi, M. and Herget,C.J. (Eds), Computer-Aided Control Systems Engineering, North-Holland, Amsterdam, 1985.

2. Jamshidi, M., Tarokh, M. and Shafai,B., Computer-Aided Analysis and Design of Linear Control Systems, Prentice Hall, New Jersey, 1992.

3. Wahid, M.S. and Eydgahi, A.M., 'A Character-Based CAD Software For Control Systems Modeling,' Proceedings of First International Conference on Computer Applications in Science, Technology, and Medicine in Iran, Isfahan, pp. 68-71, Dec. 1991.

4. Bingulac, S., 'CAD Package L-A-S: A Resource and Educational Tool in Systems and Control,' Proceedings of 12th Southern Symposium on System Theory, Charlotte, NC, March 1988.

5. Wahid, M.S. and Eydgahi, A.M. 'Computer Simulation

Transactions on Engineering Sciences vol 3, © 1993 WIT Press, www.witpress.com, ISSN 1743-3533

for Teaching System Stability Concepts,' International Journal of Applied Engineering Education, Vol. 7, No. 5, pp. 392-397, 1991.

6. Mason, J.M., Neuman, C.P. and Krogh, B.H. 'CACHE: An Interactive Control System Analysis and Design Packages,' IEEE Transactions on Education, Vol. E-28, No. 3, pp. 143-149, 1985.