

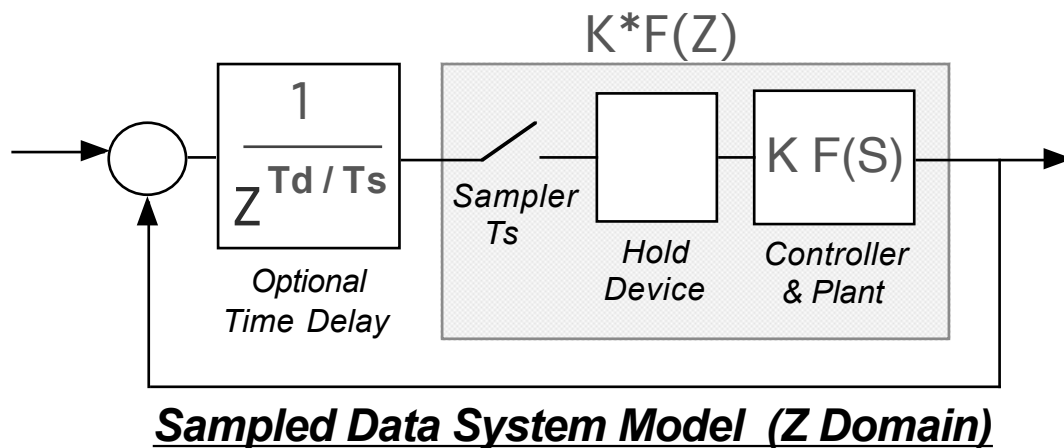
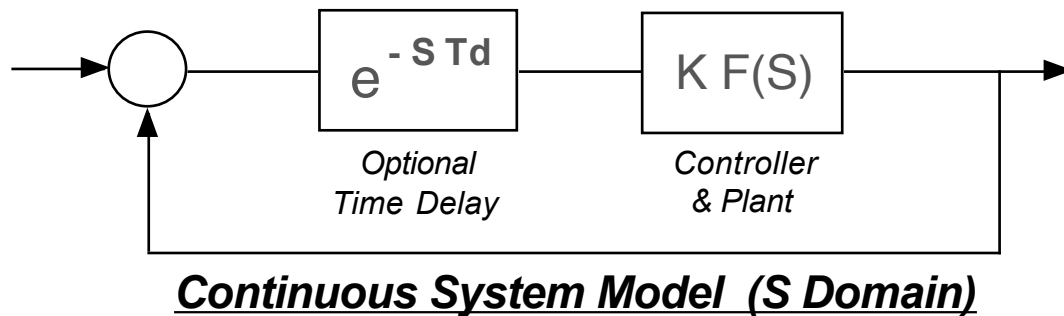
# ROOTLOCS

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## **1. Program Description**

ROOTLOCS is a program for plotting Root Locus diagrams of 'Single Input Single Output' (SISO) feedback loops as illustrated by the following generic models :



Given a system's open loop poles and zeros in the complex plane, and optionally a time delay element in the loop, ROOTLOCS plots the loci of the system's closed loop poles as the loop gain parameter  $K$  is increased indefinitely, starting from  $K=0$ .

ROOTLOCS can handle systems with up to 20 poles and 20 zeros and the systems can have either negative or positive feedback.

An outstanding feature of the program is its speed : on a reasonably fast machine the root locus diagram of a system with the full complement of 20 poles and 20 zeros is generated in less than a second. Other noteworthy features include:

- tools for finding the root locus gain, damping, transient response and frequency response of the system at any point on the locus
- easy addition, deletion and repositioning of poles & zeros with the mouse

In order to use the program effectively, new users should familiarise themselves with at least the basic principles of the root locus method. Any good book on classical control should suffice for this purpose.

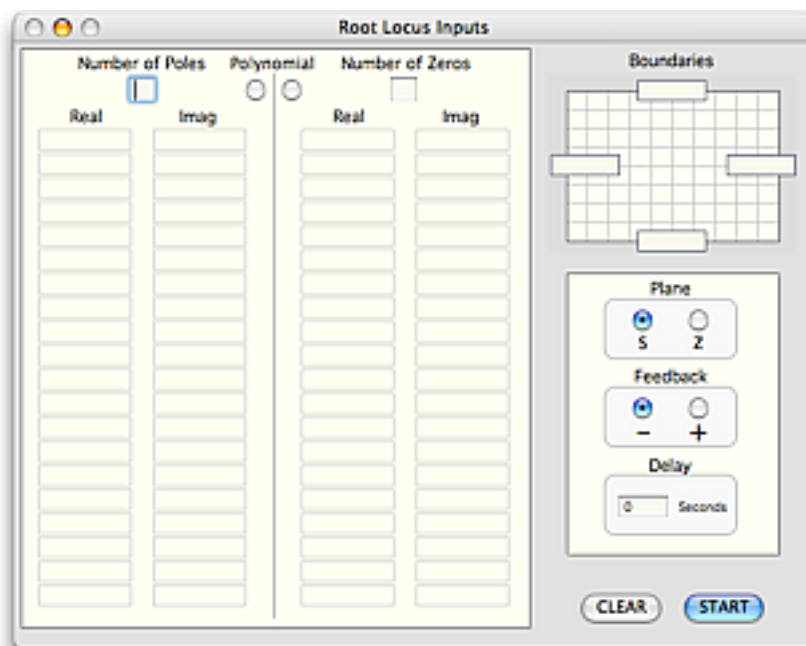
## 2. Versions & System Requirements

RootLocs is available in three versions :

- Macintosh Classic version for machines running Mac OS 8.6 to Mac OS 9.2. with CarbonLib 1.0.4 or later installed
- Macintosh Carbon version for machines running Mac OS X 10.0 or later.
- PC version for machines running Windows 95 or later, including XP.

## 3. Input Window

On launching the program a window called "Root Locus Inputs" appears :

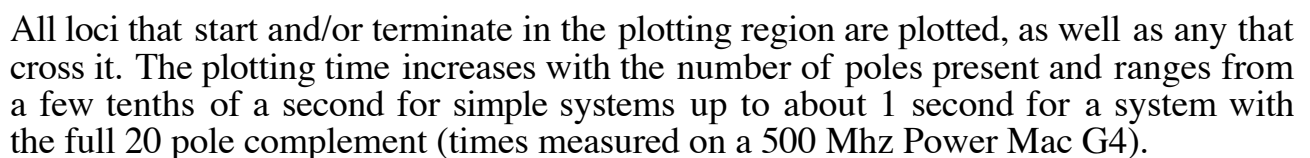


This window allows the user to specify :

- the number of poles and zeros in the system
- the open loop pole and zero positions (real and imaginary parts)
- the boundaries of a region in the complex plane where the loci are to be plotted
- the complex plane of interest, S or Z
- the sign of the feedback (+ or -)
- the optional time delay parameter Td (see block diagrams above)

When all the inputs have been entered, locus plotting is started by clicking the START button (or pressing the Carriage Return key).

On clicking the START button (or pressing the Return key), the Input window is replaced by an Output window and plotting of the locus commences:



## 5. Menus

This menu contains the following items, only some of which are accessible at any time

- **Save Inputs** - saves all the data in the Input window to a text file.
- **Load Inputs** - enables a previously saved set of inputs to be loaded from a file.
- **Random Inputs** - loads a random set of conjugate poles and zeros. This feature was originally included only as a program development tool. It has no engineering value as such but has been left in place as a means of quickly demonstrating the program's capabilities.
- **Save Plot** - saves a copy of the currently displayed plot (i.e. the locus plot, transient response plot or frequency response plot) to disc. This feature is useful for saving plots for subsequent inclusion in a report.
- **Print Plot** - prints the currently displayed plot, together with a list of all the input parameters from which it was derived.
- **Quit** - closes the program.

## 5.2. The Tools Menu

When the root locus diagram is showing, a number of things can be superimposed on it, or obtained from it, with the aid of the tools in this menu :

- **Gain Points** - this tool allows the user to place up to 10 numbered points on the plot by simply clicking on the loci with the mouse. The **root locus gain** for each point is reported in a list on the right of the plot. The root locus gain is defined as the coefficient K in the system's open loop transfer function when the latter is expressed as below :

$$F(S) = K * \frac{(S+Z_1)(S+Z_2)(S+Z_3).....(S+Z_m)}{(S+P_1)(S+P_2)(S+P_3).....(S+P_n)}$$

Caution: The root locus gain K should not be confused with D.C. gain G, which is related to K as follows :

$$G = K * \frac{Z_1 * Z_2 * Z_3 * .....Z_m}{P_1 * P_2 * P_3 * .....P_n}$$

- **Gain Flag** - this tool places a flag (i.e. a marker) at a user defined value of K on all the locus branches.
- **Damping Lines** - this tool superimposes lines of constant damping ratio on the locus plot. In the Z-Plane, lines of undamped natural frequency are shown as well.
- **Transient Response** - this tool shows the system's response to unit-step and unit-impulse excitation signals applied at its input. Up to four time response traces can be displayed on the same plot. Caution: The transient plot is valid for unity feedback systems only.
- **Frequency Response** - this tool shows the system's response to a unit amplitude swept sinusoidal signal applied at its input. Up to four frequency response traces can be displayed on the same plot. Caution: The frequency plot is valid for unity feedback systems only.
- **Wipe Tools** - erases all the tools from the locus plot and dismisses the transient and frequency response plots if they are showing.

## 5.3. The DrawPZ Menu

This items in this menu allow the poles and zeros to be modified graphically using only the mouse. The loci are automatically re-plotted whenever a change is made.

- **Add PZ** - allows poles and zeros to be added to the plot.
- **Delete PZ** - allows poles and zeros to be deleted from the plot.
- **Move PZ** - allows poles and zeros to be repositioned on the plot.
- **Original PZ** - restores the poles and zeros that were listed in the Input window when the START button was last pressed.

## 5.4 The Help Menu

This menu may contain several items but only the following one is relevant to RootLocs :

- **RootLocs Help** - opens a Help window that provides detailed instructions for using the program.

## 6. Other Features of the Program

### **Input Window**

The round buttons marked 'Polynomial' can be used to find the poles and/or zeros of a transfer function when its denominator and/or numerator is given as a polynomial expression. On clicking one of these buttons a slide-out drawer (or new window) appears which allows the coefficients of the polynomial to be specified. On clicking the round button in this coefficients window, the roots of the polynomial are computed and are automatically transferred to the main window as poles or zeros, depending on which of the two polynomial buttons was originally clicked.

### **Output Window**

The shape of the cursor varies with the operating mode of the program. When it is an arrow cursor the following things can be done :

- the order of individual poles and zeros can be interrogated directly from the locus plot by placing the tip of the arrow on them.
- the locus plot can be scrolled left, right, up and down by pressing the corresponding arrow key on the keyboard.
- any part of the plane may be magnified by dragging a rectangle (rubber box) over it with the mouse. The locations of the sides of the dragged rectangle then become the boundaries of the plane.

## 7. Program Limitations

Although ROOTLOCS is quite robust, it is not possible to guarantee that all PZ patterns will be handled without problem. In order to minimise the occurrence of incomplete plots, or conditions which may cause the program to hang, the following situations should be avoided as far as possible :

- Closely spaced PZ - PZ spacings which are very small compared with the size of the plane ( less than 1/100 th of its diagonal ) may cause the program to freeze. If this should happen, the user should either reduce the size of the plane or approximate the closely spaced PZ with multiple order singularities.
- PZ on boundaries of Plane - open loop poles and zeros that lie on the boundaries of the plane may cause the program to miss some locus branches. Therefore, although this happens only rarely, it is best to play safe and choose boundaries that do not cut through any PZ

If the above rules are observed, ROOTLOCS can be relied on to handle even the most difficult plots successfully. As evidence of this, the user is invited to plot the locus of a system consisting of three poles at (0,0) (0,0) (-9,0) and a single zero at (-1,0). This

system is characterised by three intersecting locus branches (i.e. multiple roots) on the negative real axis - a situation which some other locus plotters, especially those based on root finding algorithms, often fail to cope with satisfactorily.

## **8. Literature**

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