RLocData

v1.02

to **Kaveh**,
My “bestest” friend

DISCLAIMER

RLocData v1.02
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Introduction

Root locus (Evans, 1948; 1950) is a powerful graphic method for analysis and design of control systems. Given a feedback control system, the root locus illustrates how the poles of the closed-loop system vary as a system parameter (usually, but not necessarily, the gain) is varied.
As the name of this program suggests, it does NOT plot the root locus. However powerful the 68K Motorola microprocessor may be, plotting the locus on a TI, no matter what the make, would be too time consuming to implement. On the other hand, with the presence of such neat software packages as MATLAB, no engineer would rely on a handheld calculator to design or analyze a control system, or any other system for that matter!
This program provides the engineer with enough *data* (hence the name, RLocData) to do a "sketch" of the root locus, and, even further, to calibrate that sketch to approach a "plot." In so doing, the program strives to provide info on the following key features: *Behavior at infinity*, *Real-axis breakaway and break in points* and *Angles of arrival or departure*, which three will be discussed shortly.

Installation

Upload the file *RLocData.89g* to a folder on your handheld. You must be in this folder when you run the program.
Do not rename any files, or the program will not function properly if it does function at all. You may opt to archive the program files *after* running it for the first time so that TI OS doesn't have to reparse them every time you run the program.

I haven't tested this program on any handheld other than TI-89 but I suppose it should function with no problem, whatsoever, on TI-89 Titanium and Voyage too.

Applicability

The program assumes as default a *negative* feedback and *positive* gain, but this default, by no means, places any restriction on you. Any combination of +/- feedback and +/- gain can be fed to the program using the so-called *shifting* of blocks. Furthermore, both minimum and non-minimum phase systems can be entered with no problem. These features are later illustrated in the examples.

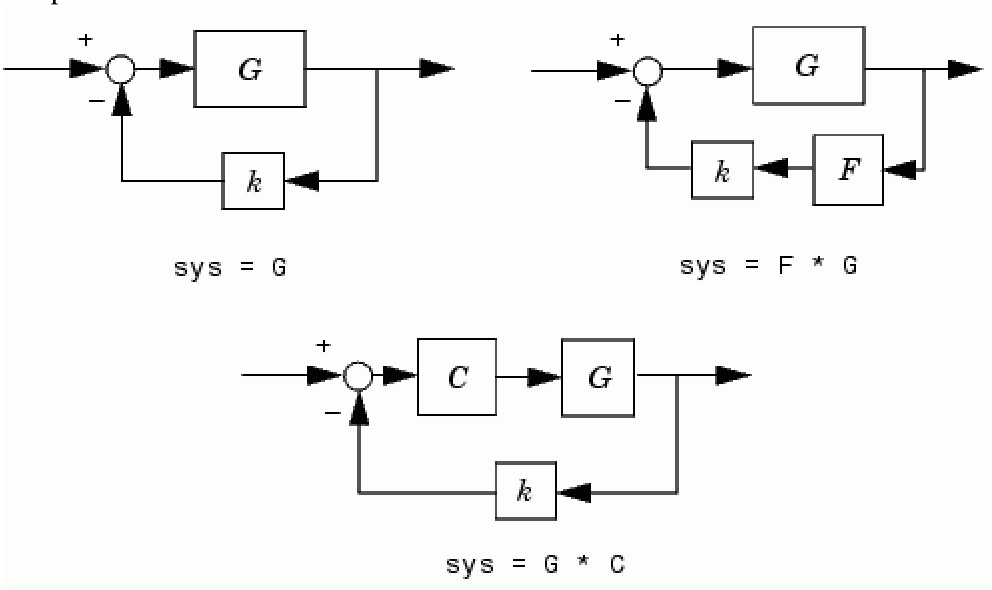
Program Inputs

The program accepts three input arguments in the following syntax,

RLocData(*{zeros}*, *{poles}*, *const*)

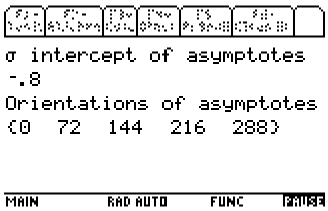
That is, zeros and poles are to be entered in lists, even if they contain only one member, and the const can be entered as a real number. This format complies with that of zpk( ) in MATLAB.
Speaking of zeros and poles, it is in order to emphasize that they are those of the Open-Loop transfer function of the SISO model of the system. (In fact, if we had the poles of our Closed-Loop transfer function already, there was no need to bother using a root locus!)
The following pictures, excerpt from MATLAB help, illustrate what the Open-Loop transfer function would be (captioned as *sys* in the figures) depending on the kind of the feedback

system. The gain parameter, k, may be in the plant's path (in series with G) instead of being in the feedback path.

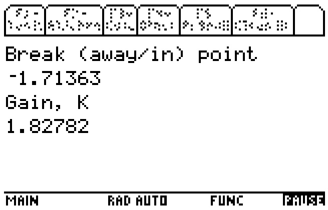


Program outputs

- *Behavior at infinity*. Every function of s has an equal number of poles and zeros *if* we include the infinite poles and zeros as well as finite ones.[1] The root locus approaches straight lines as asymptotes as the locus approaches infinity. The program provides you with the real-axis intercept of the asymptotes, aka centroid, and their angles wrt the positive extension of the real axis. The asymptotes are symmetric about the real axis

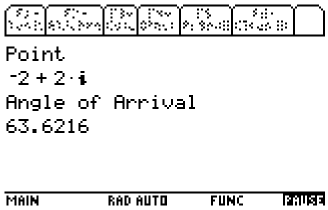


- *Real-axis breakaway and break-in points*. Break points occur where two or more loci join then diverge. There will always be an even number of loci around any break point; for each locus that enters the locus, there must be one that leaves. Only real axis break points are calculated by this program.[2] At a real axis break point, frequency, in radian/sec, equals the absolute of the pole. The corresponding gain of the break point is also reported.



[1] Physical systems have more finite poles than finite zeros. Mathematically, however, and with no relevance to the physics of the problem, a function can have more finite zeros than finite poles.
[2] Although most commonly encountered on the real axis, break points may also occur elsewhere in the complex plane.

- *Angles of Departure and Arrival.* The root locus starts at the open-loop poles and ends at the open loop zeros. In order to sketch the root locus more accurately, we should have the root locus departure angle from the poles and the arrival angle to the zeros.

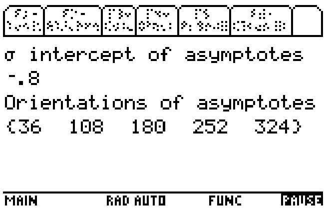


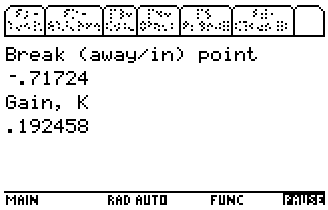
Examples

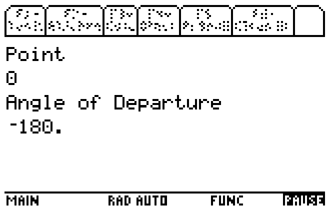
System with repeated poles

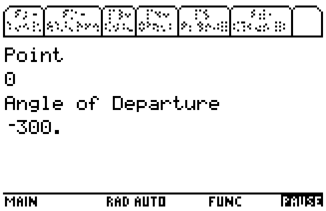
$$\frac{(s+3)}{s^3 (s+1) (s+2) (s+4)}$$

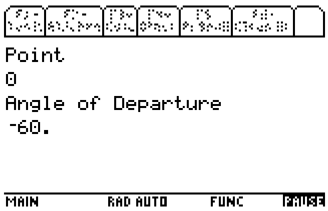
RLocData ({-3},{0,0,0,-1,-2,-4},1)

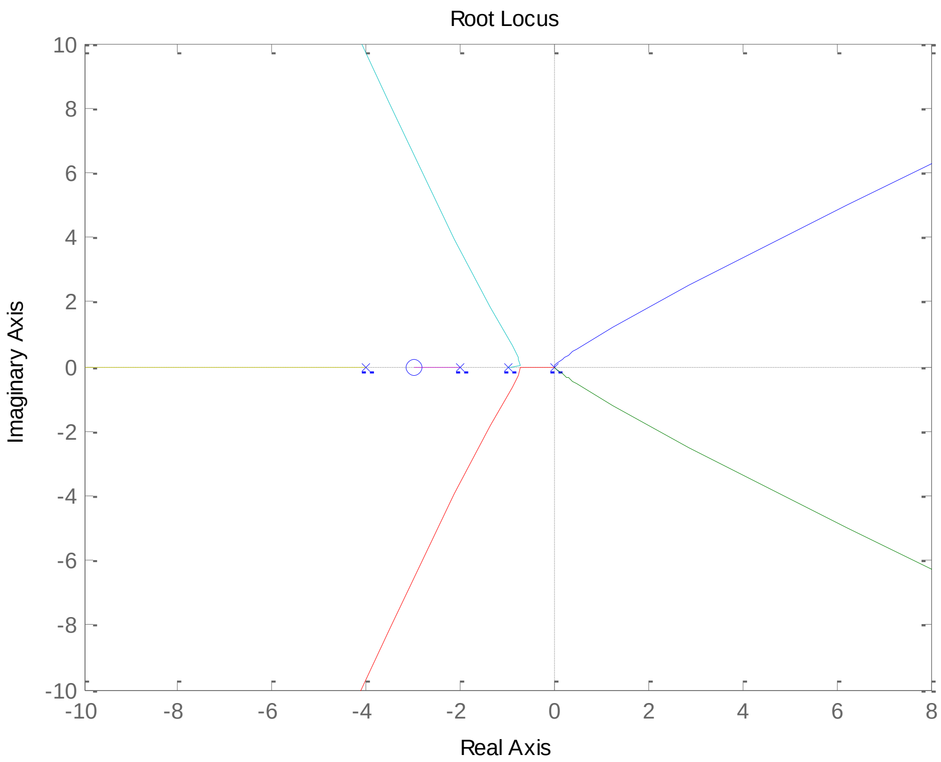












System with negative gain. Suppose we want to sketch the root locus of the previous example as a function of negative gain. We actually need to enter the zpk of the following equivalent system,

$$\frac{-(s+3)}{s^3 (s+1)(s+2)(s+4)}$$

RLocData ({-3},{0,0,0,-1,-2,-4},-1)

Therefore, as the gain of the equivalent system goes through positive values of K, the root locus will be equivalent to that generated by the gain, K, of the original system as it goes through negative values.

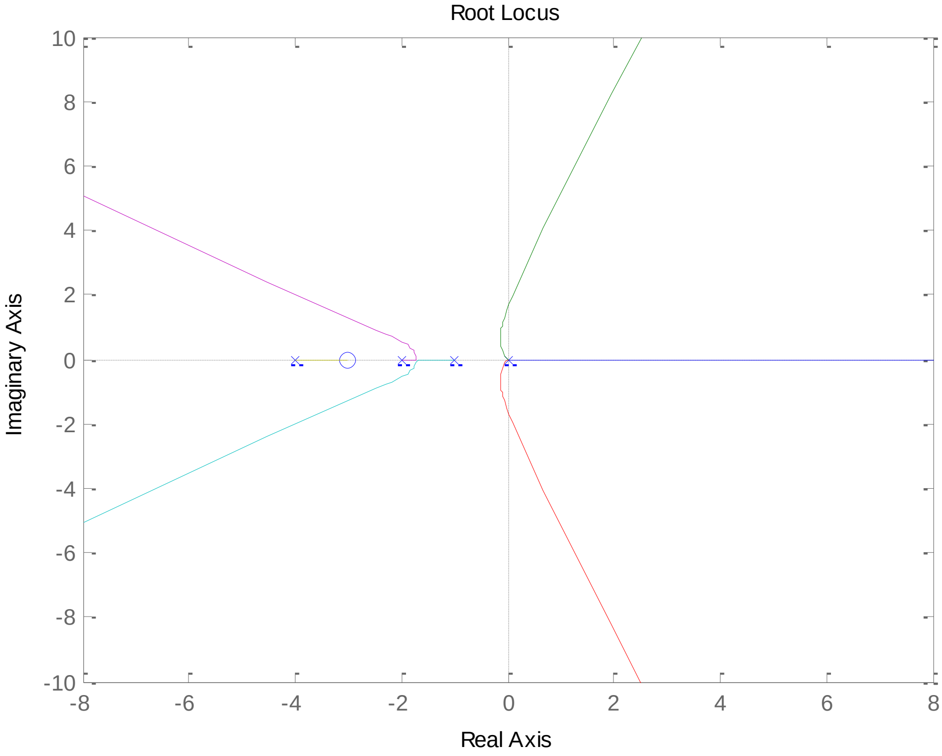
```
σ intercept of asymptotes
-.8
Orientations of asymptotes
{0  72  144  216  288}
MAIN        RAD AUTO      FUNC     PAUSE
```

```
Break (away/in) point
-1.71363
Gain, K
1.82782
MAIN        RAD AUTO      FUNC     PAUSE
```

```
Point
0
Angle of Departure
-120.
MAIN        RAD AUTO      FUNC     PAUSE
```

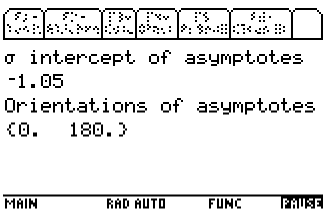
```
Point
0
Angle of Departure
-240.
MAIN        RAD AUTO      FUNC     PAUSE
```

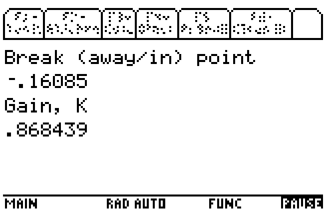
```
Point
0
Angle of Departure
0.
MAIN        RAD AUTO      FUNC     PAUSE
```

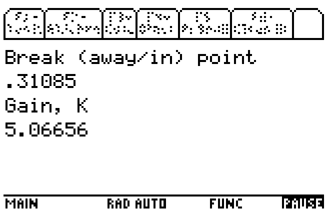


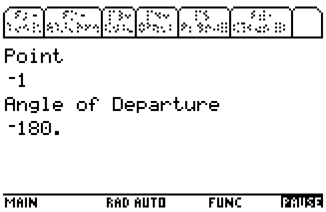
non-minimum phase system[3]

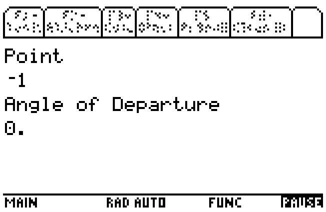
-0.5 (s-0.1)
----
 s (s+1)^2











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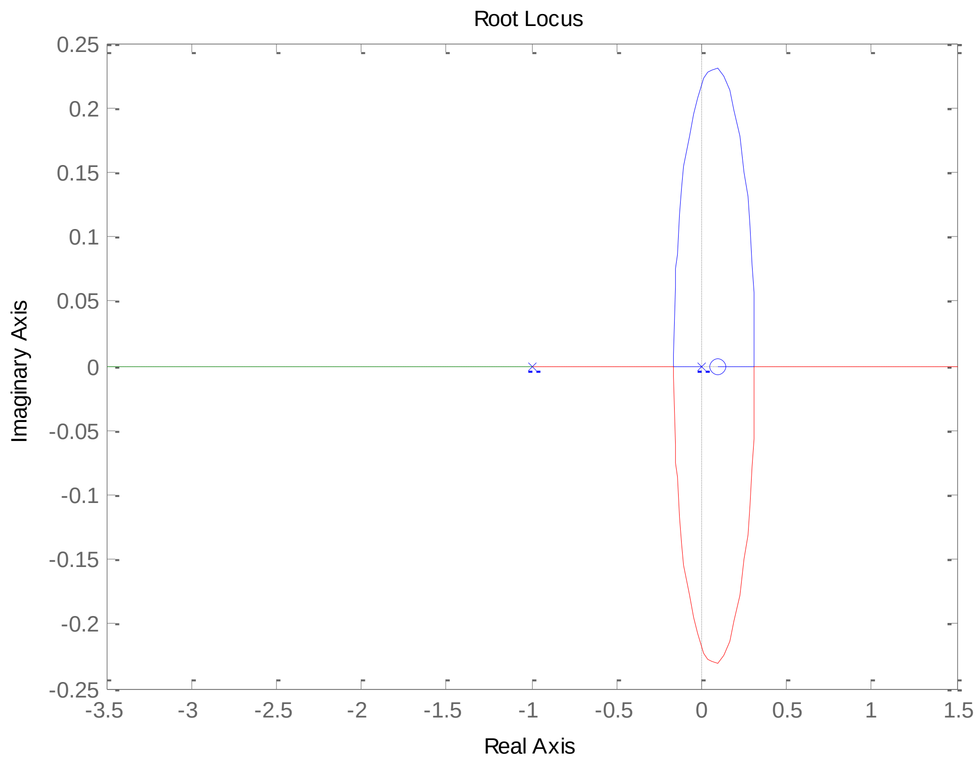
[3] A system with RHP zero(s) and/or pole(s) is called a non-minimum phase system. Refer to texts for non-minimum phase systems features.



System with off real axis zeros and poles.

(s^2 + 4s + 8)

(s+3.5) (s^2 + 2s + 1.25) (s^2 + 12s + 40)

RLocData({-2+2i, -2-2i},{-1+.5i ,-1-.5i ,-6-2i ,-6+2i ,-3.5 },1)

σ intercept of asymptotes
-4.5
Orientations of asymptotes
{60 180 300}

MAIN RAD AUTO FUNC BUSY

Point
-2 + 2·i
Angle of Arrival
63.6216

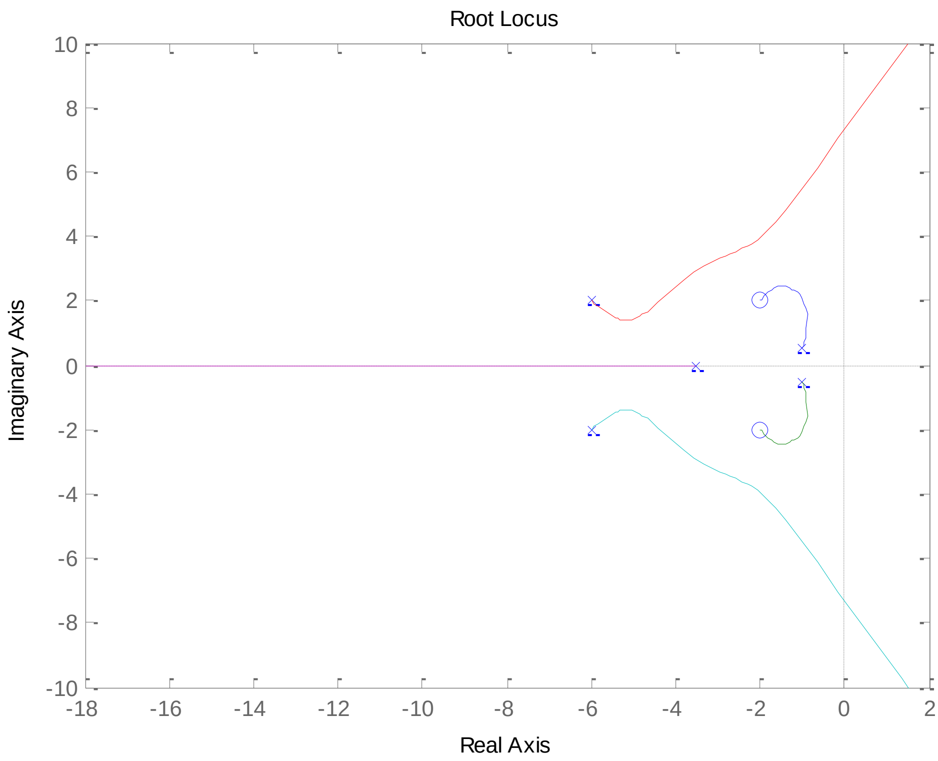
MAIN RAD AUTO FUNC PAUSE

Point
-1. + .5·i
Angle of Departure
-279.287

MAIN RAD AUTO FUNC PAUSE

Point
-6 + 2·i
Angle of Departure
-53.0759

MAIN RAD AUTO FUNC PAUSE



$$\frac{(s^2 + 4s + 8)}{(s+3.5)(s^2 + 2s + 1.25)(s^2 + 12s + 40)^2}$$

RLocData({-2+2i, -2-2i},{-1+.5i ,-1-.5i ,-6-2i ,-6+2i ,-6-2i ,-6+2i ,-3.5 },1)

σ intercept of asymptotes
-5.1
Orientations of asymptotes
{36 108 180 252 324}

MAIN RAD AUTO FUNC PAUSE

Break (away/in) point
-5.42667
Gain, K
45.5116

MAIN RAD AUTO FUNC PAUSE

Break (away/in) point
-4.64856
Gain, K
48.0061

MAIN RAD AUTO FUNC PAUSE

Point
-2 + 2·i
Angle of Arrival
108.622

MAIN RAD AUTO FUNC PAUSE

Point
-1. + .5·i
Angle of Departure
-289.153

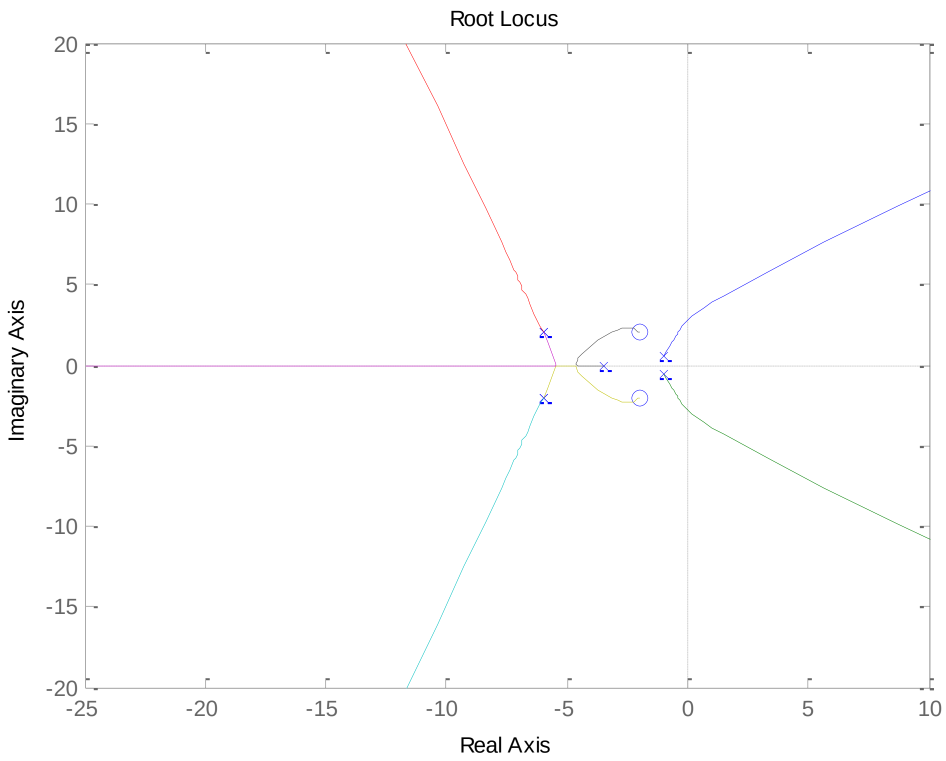
MAIN RAD AUTO FUNC PAUSE

Point
-6 + 2·i
Angle of Departure
-251.538

MAIN RAD AUTO FUNC PAUSE

Point
-6 + 2·i
Angle of Departure
-71.5379

MAIN RAD AUTO FUNC PAUSE



Acknowledgments

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Any suggestions or comments are highly welcome. Feel free to write to OmidLink@hotmail.com.