LOCUS - User's Guide

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LOCUS

USER'S GUIDE

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LOCUS

USER´S GUIDE

J. Wieslander

INTRODUCTION.

LOCUS is an interactive program for interactive design of linear single input single output systems using the root locus technique. The program originates from Imperial College and is largely unaltered. The display output subroutine has been rewritten, and some modification to the logical flow of the program has been incorporated.

This guide will give a general description of the structure of the program and how to use it.

GENERAL.

The user communicates with two different subroutines:

a) MASTER, which inputs or modifies the user's system and/or controller,

b) RLOCUS, which inputs the locus calculation parameters, e.g. step size, area of interest etc., and controls some plotting parameters.

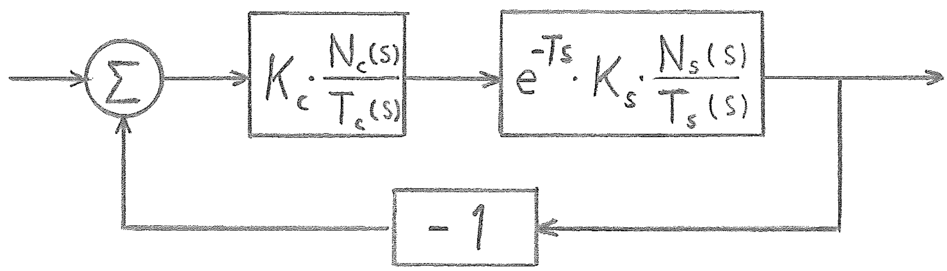
NB1. MASTER and RLOCUS have different sets of commands. You have to know which program you are talking with.

NB2. Input is in <u>fixed</u> format.

a) Commands are 3 characters long.
b) Some variables are input as 1 digit integers.
c) Most input is in E13.6-format. Rule of thumb: Allow at least 1 position to the sign (blank or minus), then input a floating point number. Do not forget the decimal point! Append an exponent if you like. Total length must be within the 13 positions allowed by the format.

MODEL.

The model is a single closed loop one with a system and a controller.



$$N_{c,s}(s) = \Pi(s + z_i)$$

$$T_{c,s}(s) = \Pi(s + p_i)$$

Note that the controller and the system is treated separately and that the system may contain a pure time delay.

The design package has two modes of operation: "system uncompensated" or "system compensated". In the first mode the controller is taken as a pure gain, K_c, regardless of the values of N_c and T_c that may have been input, i.e. the root locus for the system only is plotted. In the mode "system compensated" the poles and zeroes of T_c and N_c are included. Note that if the value of the delay is zero it is of no consequence whether the transfer functions represent a continuous or discrete time system. Thus the program can be used for the design of digital controllers as well as continuous.

COMMANDS AND THEIR MEANINGS.

I. Subroutine MASTER.

RET - return, restart MASTER.

CHE - check, output controller and system specifications.

NEW - new, read in new system and controller specifications.

CON - controller, read in controller specifications.

CGA - controller gain, read in controller gain.

SGA - system gain, read in system gain.

DEL - delay, read in system delay.

MOD - modify, modify a pole or a zero in the system or in the controller. Note, good practice is to first use command CHE.

ORD - order, change the order of the nominator or denominator in the controller or the system. Note, good practice is to first use command CHE.

ROO - root locus, go to the root locus plotter.

II. Subroutine RLOCUS.

First time through or after executing the command NEW in MASTER, you will execute the commands STE, ERR and ARE automatically. Otherwise EXE is executed immediately on entry.

RET - return, MASTER is called back.

CHE - check, the current locus calculation parameters are displayed.

EXE - execute, compute the root locus and plot it on the display.

STE - step, read in the locus step size. A too large value will give a poor plot, a too small value gives storage overflow. CHE will give an index of the storage utilization, keep it larger than 0.6. Often a reasonable first try is 0.1.

ERR - error bound, read in the error bound. It must be less than 0.1*STEP. A good first try might be 0.01*STEP.

ARE - area of interest, read in the maximum and minimum values along the real (X) and the imaginary (Y) axes. Only the part of the locus within this area is computed and only those closed loop poles that will fall within this area can be computed.

PHA - phase angle, read in the phase angle in degrees. Normal (and initial) value is 180°. If the controller has a negative gain change the phase to 0° rather than use a negative value on the gain.

COM - compensation, change to the mode "system compensated" from "system uncompensated" or vice versa. In the last mode initially.

ITE - iteration limit, read in new iteration limit; initiated to 10.

UNI - unit circle, complement the switch that causes a unit circle to be drawn or not.

GAI - gain, read in a new value on the controller gain and display the positions of the closed loop poles. Note that this value always is included in the calculation of the closed loop poles, regardless of the compensation mode.

ZTA - zeta, read in a value of the damping coefficient. A positive value will cause the curve of constant damping ratio to be drawn for a discrete time system. Zero or negative damping will remove the curve from the plot.

CZT - continuous zeta, read in a value of the damping coefficient. Lines of constant damping ratio for a continuous time system will be drawn. Zero or negative value removes the lines.

SMA - sigma circle, input a sigma value and a sampling interval. The mapping defined by the continuous-discrete time transformation maps points to the left of $R_c(S)$ = sigma to the inside of the sigma circle. Thus the sigma circle is a curve of constant speed of response. Positive or zero value of sigma will inhibit the circle from being plotted.

CLP - closed loop poles, output numeric values of the closed loop poles if previously calculated.

RTL - root locus, output numeric values of all points on the root locus.

ERROR AND DIAGNOSTIC MESSAGES.

This is in the present implementation the only output that is not on the display.

"INVALID COMMAND".

The command was not recognized or it was impossible to execute it. E.g. RTL cannot be executed unless EXE has been performed previously. Similarly MOD is not recognized by RLOCUS.

"RUBBISH".

A numerical input had an illogical value. E.g. XMIN>XMAX.

"STARTING POINT ITERATION NOT WITHIN BOUND AFTER 10 ITERATIONS".

The routine which searches the boundary of the area of interest to find branches crossing that boundary has found a branch crossing to which it is not able to converge to within the error bound specified. This may be caused by too small an error bound or the boundary passing very close to a pole, zero, or branch point.

"ERROR NOT WITHIN BOUND AFTER 10 ITERATIONS. BRANCH ABANDONED".

While following the locus, the routine is unable to converge to within the error bound specified. This is caused by specifying the error bound too small for the case under consideration. (Accuracy is example dependent and machine limited.) This is most likely to occur when approaching a break point as the diagram is most sensitive to small errors in angle function near these points. An increase in step size may help in these cases.

"SET-OFF DIRECTION AT BREAK POINT NOT FOUND".

The break point set-off direction routine is unable to find a branch corresponding to trial set-off angles. Try decreasing the error bound, then try varying the step size. Accuracy is machine limited.

"POLE-ZERO CANCELLATION, CALCULATION ABORTED".

A zero is less than twice the step size from a pole so that it is not possible to ensure a correct diagram. Reduce the step size or perform the cancellation in the transfer function.

"LOCUS POINT STORAGE LIMIT EXCEEDED, LOCUS TRUNCATED".

The locus point storage arrays are full and so calculation has been terminated before the diagram is complete. If the complete diagram is required, reduce the area of interest, increase the step size, or divide the area of interest into segments and plot the segments separately.

"CLOSED LOOP POLE STORAGE OVERFLOW".

The closed loop pole storage arrays are full, so that not all the closed loop poles can be found. Decrease the area of interest to include fewer closed loop poles.

EXAMPLES.

Figure 1. This figure shows the output from command CHE in MASTER. The following output shows the available commands to use next. The reference to the User's Guide does not apply and will be altered in the next version.

Figure 2. This figure shows the output from command CHE in RLOCUS. Note the storage density 0.91 which indicates a good storage utilization and that even a moderate decrease in step size would lead to a storage overflow error. After the request for a new command follows the output generated by CLP. Note that the number of poles displayed does not neccessarily equal the system order.

Figure 3. This figure shows the root locus for the system and controller displayed in fig. 1. Four closed loop poles fall on the lines indicating a damping ratio of 0.7. The fifth closed loop pole is outside the area of interest and is not shown.

Figure 4. This figure shows the different utilities available. The unit circle and the circle of constant speed of response is shown. The latter is drawn for σ = -.75 and sampling time .5 sec. Also curves for constant damping ratio 0.6 are shown both for the continuous - time and discrete - time case.

Figure 5. Here the start up procedure of LOCUS from XCT and XCU files on DEC-tape is shown. This applies to the software system as it stands in Sept. -72.

Fig 1. Output from CHE in MASTER.

```
CONTROLLER SPECIFICATION
GAIN=    1.0000
ORDER OF NUMERATOR=1
        *      REAL     ** IMAGINARY *
ZERO(1)=  -0.50000        0.00000
ORDER OF DENOMINATOR=1
        *      REAL     ** IMAGINARY *
POLE(1)=   -3.5000        0.00000


SYSTEM SPECIFICATION
SYSTEM DELAY=  0.00000
GAIN=    10.000
ORDER OF NUMERATOR=1
        *      REAL     ** IMAGINARY *
ZERO(1)=   -1.0000        0.00000
ORDER OF DENOMINATOR=4
        *      REAL     ** IMAGINARY *
POLE(1)=   0.00000        0.00000
POLE(2)=   0.00000        0.00000
POLE(3)=   -1.5000        0.00000
POLE(4)=   -2.5000        0.00000


TYPE COMMAND RET,CHE,NEW,CON,CGA,SGA,DEL,MOD,ORD,
OR ROO.
SEE USERS GUIDE P. 2.
```

```
STEP SIZE=  7.00000E-02
LOCUS STORAGE DENSITY: 0.91
ERROR BOUND=  6.00000E-03
AREA OF INTEREST
XMAX=    1.0000                 XMIN=   -4.0000
YMAX=    2.5000                 YMIN=   -2.5000
SYSTEM COMPENSATED.
PHASE ANGLE=    180.00      DEGREES
ITERATION LIMIT=10
UNIT CIRCLE NOT DRAWN.
CIRCLE OF CONSTANT SPEED OF RESPONSE NOT DRAWN.
CURVE OF CONSTANT DAMPING RATIO NOT DRAWN.
LINE OF CONSTANT DAMPING RATIO WILL BE DRAWN.

- - - - - - - - - - - - - - - - - - - - - - -


TYPE COMMAND RET,CHE,EXE,STE,ERR,ARE,PHA,COM,ITE,UNI,GAI,ZTA,CZT,SMA,CLP,
OR RTL.
SEE USERS GUIDE P. 2.
CONTROLLER GAIN=    1.0000
NUMBER OF CLOSED LOOP POLES DISPLAYED= 4
INTERPOLATED POSITION OF CLOSED LOOP POLES-
(X-COORDINATE,Y-COORDINATE)
( -0.5256    , -0.5633    )  ( -0.5256    ,  0.5633    )
( -0.9317    ,  0.9779    )  ( -0.9317    , -0.9779    )

TYPE COMMAND RET,CHE,EXE,STE,ERR,ARE,PHA,COM,ITE,UNI,GAI,ZTA,CZT,SMA,CLP,
OR RTL.
SEE USERS GUIDE P. 2.
```

Fig 2. Output from CHE and CLP in RLOCUS.

Fig 3. Root locus plot.

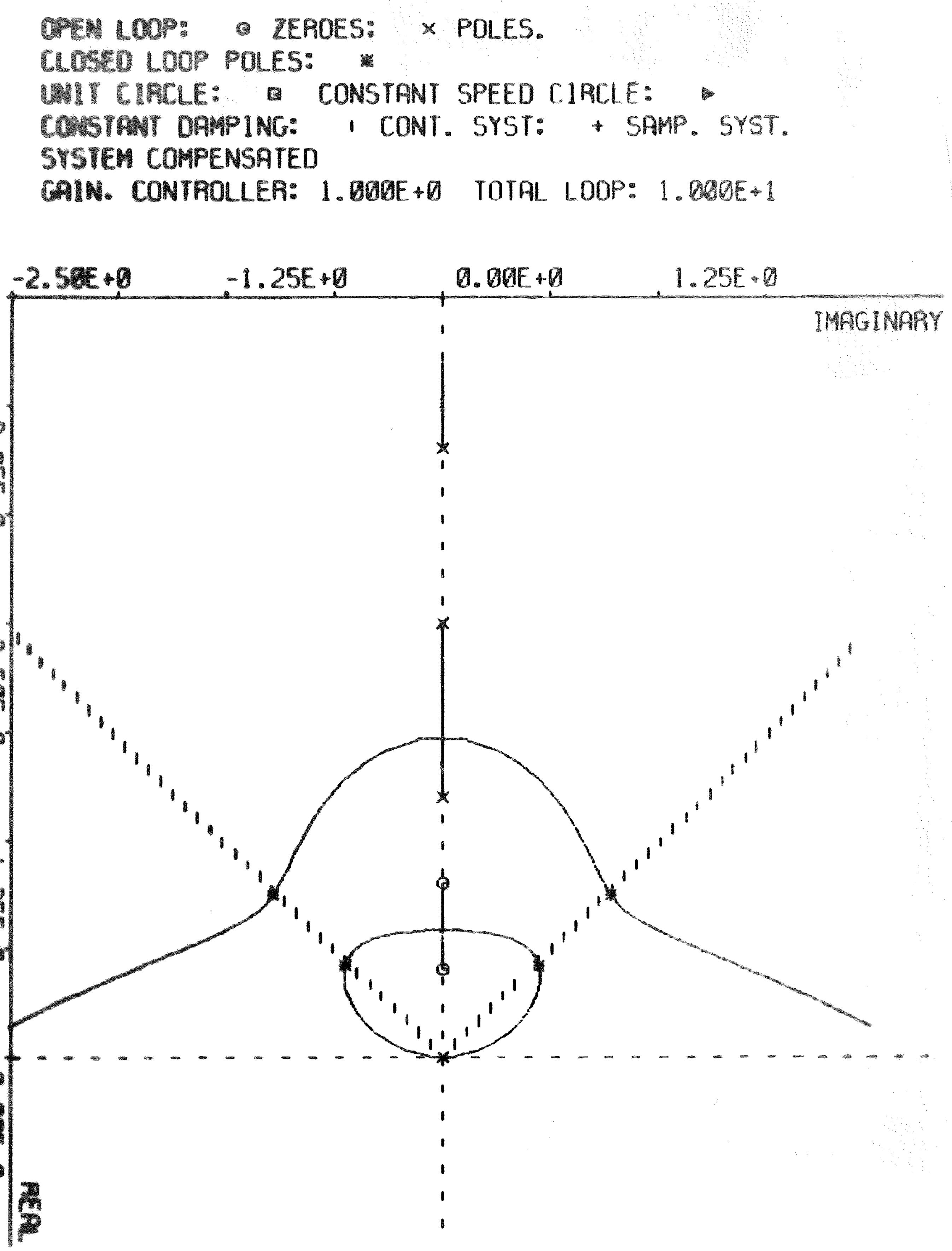


Fig 4. Design aids.

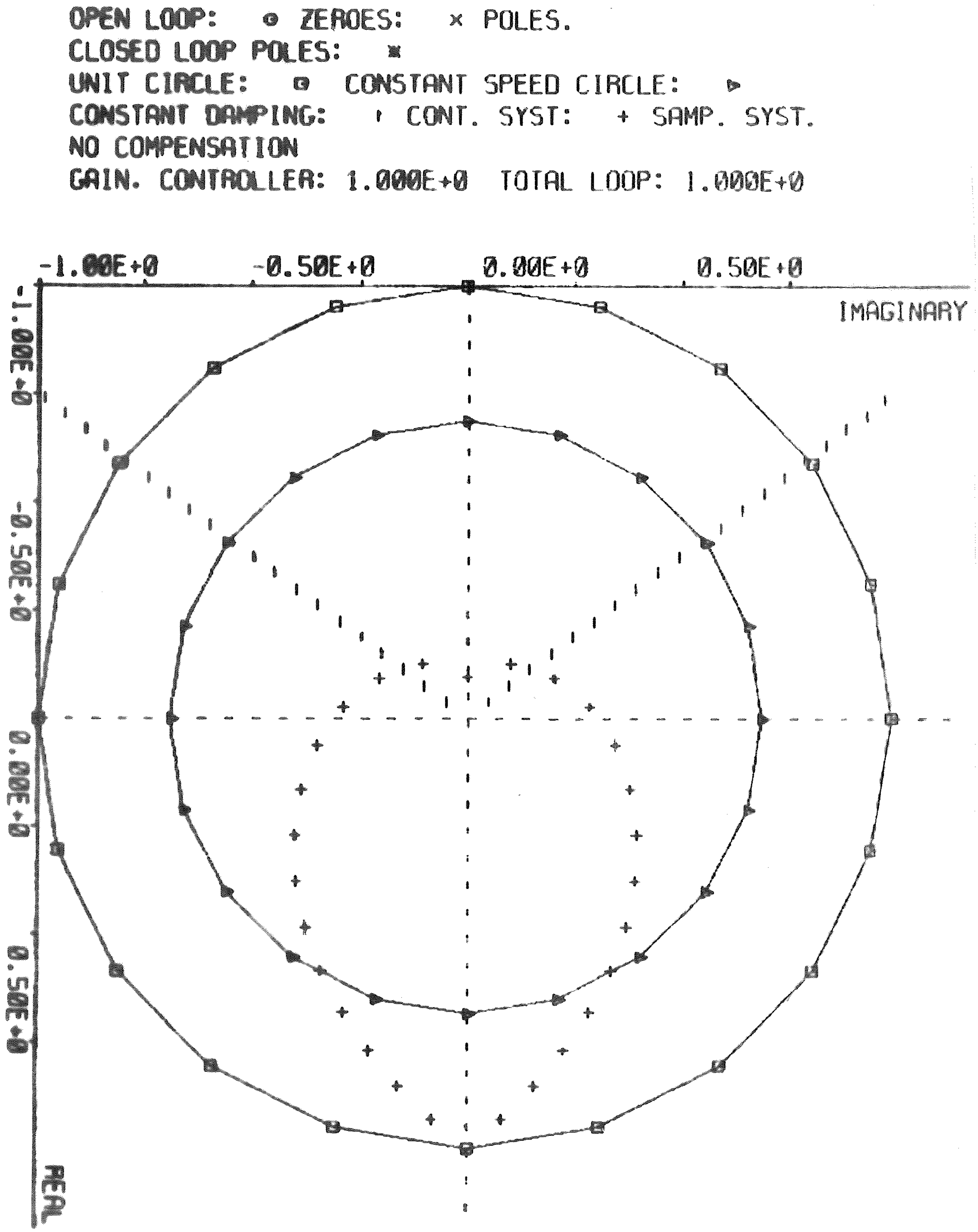


Fig 5. Starting procedure.

```
DOS-15 V1A
$PIP

DOSPIP V6A

>T DK (B)←DT1 LOCUS XCT


DOS-15 V1A
$A DTE1 -14

$ABS

ABSOLUTE V1A
ENTER FILE NAME  >LOCUS


DOS-15 V1A
$A DKA -4/NON 1,2,3,4,5,6,7

$E LOCUS


LOCUS V1A
```