Control Systems

G V V Sharma*

Contents

*The author is with the Department of Electrical Engineering, Indian Institute of Technology, Hyderabad 502285 India e-mail: gadepall@iith.ac.in.

***Abstract*—This manual is an introduction to control systems based on GATE problems.Links to sample Python codes are available in the text.**

Download python codes using

```
svn co https://github.com/gadepall/school/trunk/
    control/codes
```

1 Signal Flow Graph

1.1 Mason's Gain Formula

1.2 Matrix Formula

2 Bode Plot

2.1 Introduction

2.2 Example

3 Second order System

3.1 Damping

3.2 Example

4 Routh Hurwitz Criterion

4.1 Routh Array

4.2 Marginal Stability

4.3 Stability

A closed loop system has the characteristic equation given by

$$s^3 + Ks^2 + (K+2)s + 3 = 0 \tag{4.3.1}$$

For this system to be stable, which one of the following conditions should be satisfied?
(A) 0 < K < 0.5 (B) 0.5 < K < 1 (C) 0 < K < 1 (D) K > 1

Solution: Computing the Routh array for the given characteristic equation, we get-

$$\begin{vmatrix} s^3 \\ s^2 \\ s \\ s^0 \end{vmatrix}\begin{vmatrix} 1 & K+2 & 0 \\ K & 3 & 0 \\ \frac{K^2+2K-3}{K} & 0 & 0 \\ 3 & 0 & 0 \end{vmatrix} \tag{4.3.2}$$

According to the Routh-Hurwitz stability criterion, for the system to be stable there should be no sign changes in the first column of the Routh array. That means-

$$K > 0 \text{ and } \frac{K^2 + 2K - 3}{K} > 0 \tag{4.3.3}$$

$$\Rightarrow K > 0 \text{ and } (K-1)(K+3) > 0 \tag{4.3.4}$$

which gives us

$$K > 0 \text{ and } (K > 1 \text{ or } K < -3). \tag{4.3.5}$$

Note that K cannot be negative.

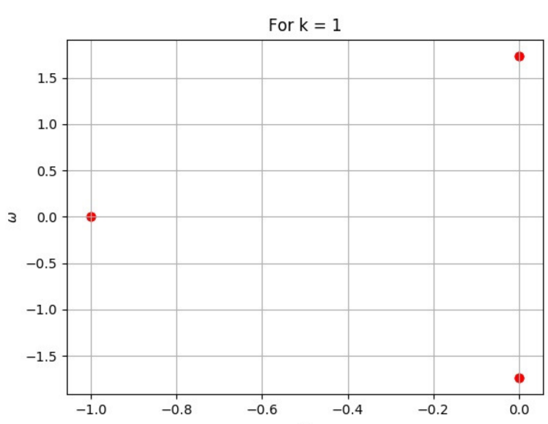
$$\Rightarrow K > 1 \tag{4.3.6}$$

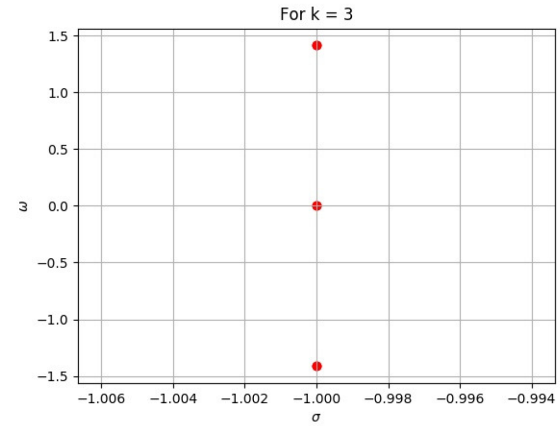
The program to compute the routh-array and stabilty for different values of K.

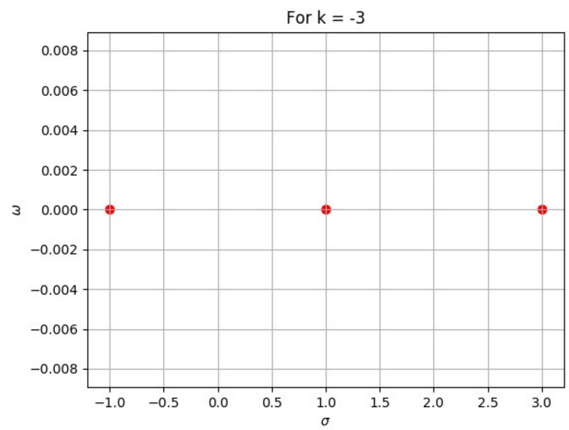
codes/ee18btech11039/routh_array.py

The program for plotting the poles of the system for different values of K.

codes/ee18btech11039/pole_plot.py







4.4 Example

5 State-Space Model

5.1 Controllability and Observability

5.2 Second Order System

5.3 Example

5.4 Example

5.5 Example

6 Nyquist Plot

7 Compensators

7.1 Example

8 Gain Margin

8.1 Introduction

8.2 Example

9 Phase Margin

10 Oscillator

10.1 Introduction

10.2 Example