

# Control Systems

G V V Sharma\*

## CONTENTS

<b>1</b>	<b>Signal Flow Graph</b>	1	<b>10</b>	<b>Oscillator</b>	2
1.1	Mason's Gain Formula . . .	1	10.1	Introduction . . . . .	2
1.2	Matrix Formula . . . . .	1	10.2	Example . . . . .	2
<b>2</b>	<b>Bode Plot</b>	1	<i>Abstract</i> —This manual is an introduction to control systems based on GATE problems. Links to sample Python codes are available in the text.		
2.1	Introduction . . . . .	1	Download python codes using		
2.2	Example . . . . .	1	svn co <a href="https://github.com/gadepall/school/trunk/control/codes">https://github.com/gadepall/school/trunk/control/codes</a>		
<b>3</b>	<b>Second order System</b>	1			
3.1	Damping . . . . .	1	1 SIGNAL FLOW GRAPH		
3.2	Example . . . . .	1	1.1 Mason's Gain Formula		
<b>4</b>	<b>Routh Hurwitz Criterion</b>	1	1.2 Matrix Formula		
4.1	Routh Array . . . . .	1	2 BODE PLOT		
4.2	Marginal Stability . . . . .	1	2.1 Introduction		
4.3	Stability . . . . .	1	2.2 Example		
4.4	Example . . . . .	2	3 SECOND ORDER SYSTEM		
<b>5</b>	<b>State-Space Model</b>	2	3.1 Damping		
5.1	Controllability and Observability . . . . .	2	3.2 Example		
5.2	Second Order System . . . . .	2	4 ROUTH HURWITZ CRITERION		
5.3	Example . . . . .	2	4.1 Routh Array		
5.4	Example . . . . .	2	4.2 Marginal Stability		
5.5	Example . . . . .	2	4.3 Stability		
<b>6</b>	<b>Nyquist Plot</b>	2	4.3.1. A closed loop system has the characteristic equation given by		
<b>7</b>	<b>Compensators</b>	2	$s^3 + Ks^2 + (K + 2)s + 3 = 0 \quad (4.3.1.1)$		
7.1	Example . . . . .	2	Determine the condition for K for which the system is stable.		
<b>8</b>	<b>Gain Margin</b>	2	<b>Solution:</b> Computing the Routh array for the given characteristic equation, we get-		
8.1	Introduction . . . . .	2			
8.2	Example . . . . .	2			
<b>9</b>	<b>Phase Margin</b>	2			

\*The author is with the Department of Electrical Engineering, Indian Institute of Technology, Hyderabad 502285 India e-mail: gadepall@iith.ac.in. All content in this manual is released under GNU GPL. Free and open source.

$$\begin{vmatrix} s^3 & 1 & K+2 & 0 \\ s^2 & K & 3 & 0 \\ s & \frac{K^2+2K-3}{K} & 0 & 0 \\ s^0 & 3 & 0 & 0 \end{vmatrix} \quad (4.3.1.2)$$

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-

$$K > 0 \text{ and } \frac{K^2 + 2K - 3}{K} > 0 \quad (4.3.1.3)$$

$$\Rightarrow K > 0 \text{ and } (K - 1)(K + 3) > 0 \quad (4.3.1.4)$$

$$K > 0 \text{ and } (K > 1 \text{ or } K < -3) \quad (4.3.1.5)$$

$$\Rightarrow K > 1 \quad (4.3.1.6)$$

$$(4.3.1.7)$$

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

codes/ee18btech11039/routh\_array.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