

# Control Systems

G V V Sharma\*

## CONTENTS

<b>1</b>	<b>Signal Flow Graph</b>	1
1.1	Mason's Gain Formula . . .	1
1.2	Matrix Formula . . . . .	1
<b>2</b>	<b>Bode Plot</b>	1
2.1	Introduction . . . . .	1
2.2	Example . . . . .	1
<b>3</b>	<b>Second order System</b>	1
3.1	Damping . . . . .	1
3.2	Example . . . . .	1
<b>4</b>	<b>Routh Hurwitz Criterion</b>	1
4.1	Routh Array . . . . .	1
4.2	Marginal Stability . . . . .	1
4.3	Stability . . . . .	1
4.4	Example . . . . .	1
<b>5</b>	<b>State-Space Model</b>	1
5.1	Controllability and Observability . . . . .	1
5.2	Second Order System . . . . .	1
5.3	Example . . . . .	1
5.4	Example . . . . .	1
<b>6</b>	<b>Nyquist Plot</b>	1
<b>7</b>	<b>Compensators</b>	2
7.1	Phase Lead . . . . .	2
7.2	Example . . . . .	2
<b>8</b>	<b>Gain Margin</b>	2
8.1	Introduction . . . . .	2
8.2	Example . . . . .	2
<b>9</b>	<b>Phase Margin</b>	2

## 10 Oscillator

2

**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

4.4 Example

### 5 STATE-SPACE MODEL

5.1 Controllability and Observability

5.2 Second Order System

5.3 Example

5.4 Example

### 6 NYQUIST PLOT

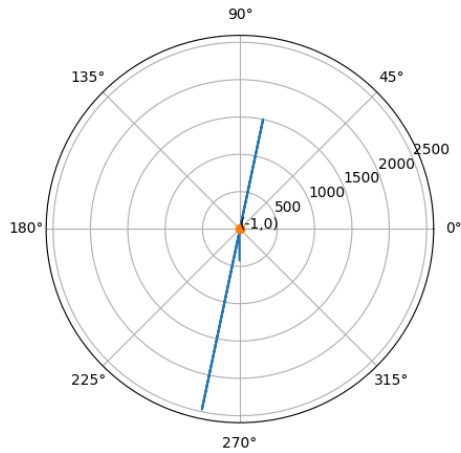
6.1. Plot the polar plot of

$$G(s) = \frac{100(s+5)}{s(s+3)(s^2+4)}. \quad (6.1.1)$$

**Solution:** To plot polar plot, we need to find magnitude and phase of frequency response for different values of  $\omega$  from 0 to  $\infty$ .

The following python code generates the polar plot :

\*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.



codes/ee18btech11042.py

- 6.2. From polar plot we can find the stability of system and polar plots are drawn for open loop transfer functions.
- 6.3. Stability is determined by position of point  $(-1,0)$  w.r.t to polar plot
- 6.4. If  $(-1,0)$  is on the left side of the polar plot then the closed loop system is stable.
- 6.5. If  $(-1,0)$  is on the right side of the polar plot then the closed loop system is unstable.
- 6.6. If  $t(-1,0)$  is on the polar plot then the closed loop system is marginally stable.
- 6.7. Since  $(-1,0)$  is on the polar plot the above system is marginally stable.

## 7 COMPENSATORS

### 7.1 Phase Lead

### 7.2 Example

## 8 GAIN MARGIN

### 8.1 Introduction

### 8.2 Example

## 9 PHASE MARGIN

## 10 OSCILLATOR