

Control Systems

G V V Sharma*

CONTENTS

1	Signal Flow Graph	1
1.1	Mason's Gain Formula . . .	1
1.2	Matrix Formula	1
2	Bode Plot	1
2.1	Introduction	1
2.2	Example	1
3	Second order System	1
3.1	Damping	1
3.2	Example	1
4	Routh Hurwitz Criterion	1
4.1	Routh Array	1
4.2	Marginal Stability	1
4.3	Stability	1
4.4	Example	1
5	State-Space Model	1
5.1	Controllability and Observability	1
5.2	Second Order System	1
5.3	Example	1
5.4	Example	1
6	Nyquist Plot	1
7	Compensators	2
7.1	Phase Lead	2
7.2	Example	2
8	Gain Margin	2
8.1	Introduction	2
8.2	Example	2
9	Phase Margin	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. Using the Nyquist criterion , find out whether the system is stable or not

$$G(s) = \frac{20}{s(s+1)} \quad (6.1.1)$$

$$H(s) = \frac{s+3}{s+4} \quad (6.1.2)$$

*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.

6.2. Solution:

$$G(s)H(s) = \frac{20(s+3)}{s(s+1)(s+4)} \quad (6.2.1)$$

$$= \frac{20s+60}{s^3+5s^2+4s}$$

$$1+G(s)H(s) = \frac{s^3+5s^2+24s+60}{s^3+5s^2+4s} \quad (6.2.2)$$

6.3. Nyquist Stability Criterion can be expressed as:

$$Z = N + P \quad (6.3.1)$$

Where:

Z = number of roots of $1+G(s)H(s)$ in right-hand side (RHS) of s -plane (It is also called zeros of characteristics equation)

N = number of encirclement of critical point $1+j0$ in the clockwise direction

P = number of poles of open loop transfer function (OLTF) [i.e. $G(s)H(s)$] in RHS of s -plane.

$Z=N+P$ is valid for all the systems whether stable or unstable. For the stable system, $Z=0$, So for the stable system $N = -P$.

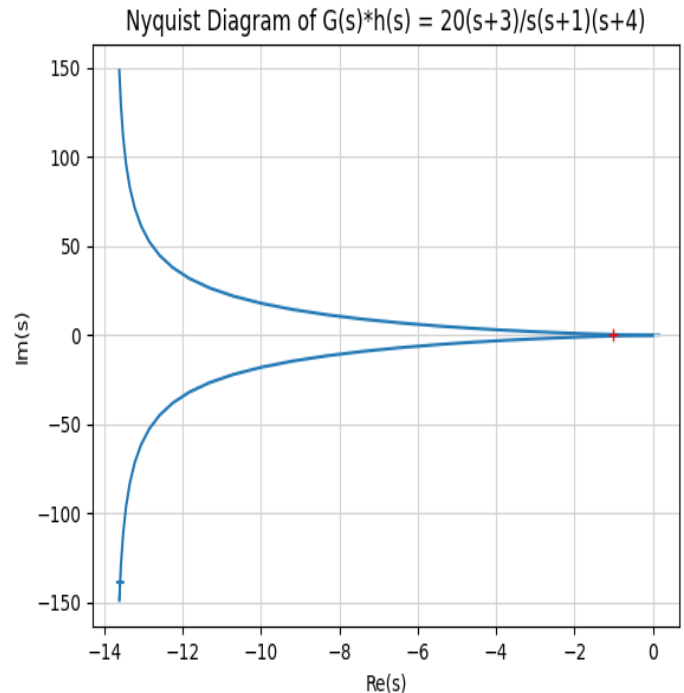
if $p = 0$

there will be no Encirclement of Nyquist plot and the system is stable

$$G(s)H(s) = \frac{20(s+3)}{s(s+1)(s+4)} \quad (6.3.2)$$

$$\text{Here } P = 0 \quad (6.3.3)$$

$$\text{Then } N = 0 \quad (6.3.4)$$



by seeing the we conclude that $N = 0$ and $P = 0$

hence the system is stable (6.3.5)

verify the answer with python code
<https://github.com/srikanth2001/EE2227-control-systems/tree/master/codes>

7 COMPENSATORS

7.1 Phase Lead

7.2 Example

8 GAIN MARGIN

8.1 Introduction

8.2 Example

9 PHASE MARGIN

10 OSCILLATOR