

Control Systems

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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>

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1 SIGNAL FLOW GRAPH

1.1 Mason's Gain Formula

1.2 Matrix Formula

2 BODE PLOT

2.1 Introduction

2.2 Phase

3 SECOND ORDER SYSTEM

3.1 Damping

3.2 Peak Overshoot

3.3 Settling Time

4 ROUTH HURWITZ CRITERION

4.1 Routh Array

4.2 Marginal Stability

4.3 Stability

5 STATE-SPACE MODEL

5.1 Controllability and Observability

5.2 Second Order System

6 NYQUIST PLOT

6.1 Introduction

7 COMPENSATORS

7.1 Phase Lead

7.2 Lag Lead

8 GAIN MARGIN

8.1 Introduction

8.2 Example

- 8.1. Plot the Bode magnitude and phase plots for the following system

$$G(s) = \frac{75(1 + 0.2s)}{s(s^2 + 16s + 100)} \quad (8.1.1)$$

Also compute gain margin and phase margin .

Solution: From (8.1.1), we have

$$G(j\omega) = \frac{75(1 + 0.2j\omega)}{j\omega((j\omega)^2 + 16j\omega + 100)} \quad (8.1.2)$$

poles = 0 , -8-6j , -8+6j

zeros = -5

Gain and phase plots are shown in Fig 8.1

The following code plots Fig 8.1

```
codes/ee18btech11049.py
```

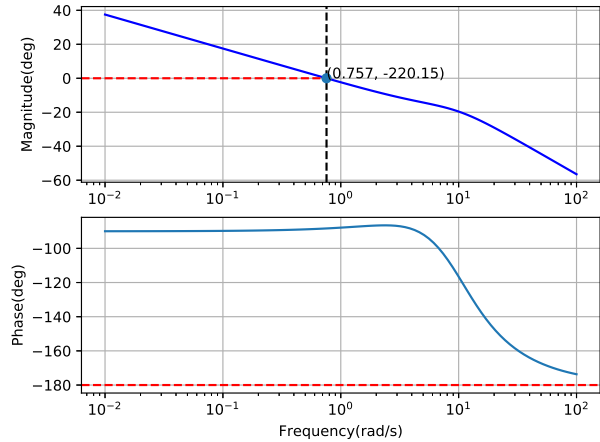


Fig. 8.1: a

- 8.2. Find $\angle G(j\omega) + 180^\circ$, where ω is frequency when gain = 1 . This is known as *phase margin* (PM)

Solution:

$$\frac{75 \sqrt{\omega^2 + 25}}{\omega \sqrt{(\omega + 6)^2 + 64} \sqrt{(\omega - 6)^2 + 64}} = 1 \quad (8.2.1)$$

Solving (8.2.1) (or)

from Fig 8.1 frequency at which gain = 1 , is gain crossover frequency ω_{gc} .

$$\Rightarrow \omega_{gc} = 0.757 \quad (8.2.2)$$

$$\angle G(j\omega_{gc}) = -88.3 \quad (8.2.3)$$

$$\Rightarrow PM = 91.7 \quad (8.2.4)$$

- 8.3. Find $-G(j\omega)$ db , where ω is frequency when phase = -180° . This is known as *gain margin* (GM)

Solution: From Fig 8.1 ,we can say that phase never crosses -180° . So , the gain margin is *infinite*. Which means we can add any gain , and the equivalent closed loop system never goes unstable.

9 PHASE MARGIN

9.1 Introduction

10 OSCILLATOR

10.1 Introduction

11 ROOT LOCUS