1

Control Systems

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CONTENTS

1	Polar Plot		1
	1.1	Introduction	1
2	Bode Plot		1
	2.1	Gain and Phase Margin	1
3	PID Controller		2
	3.1	Introduction	

Abstract—The objective of this manual is to introduce control system design at an elementary level.

Download python codes using

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

1 Polar Plot

1.1 Introduction

2 Bode Plot

- 2.1 Gain and Phase Margin
- 2.1. An aircraft roll control system can be represented by a block diagram shown in 2.1 with

$$G(s) = \frac{10K}{s(s+1)(s+5)}$$
 (2.1.1)

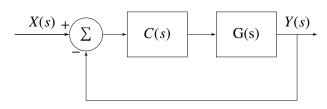


Fig. 2.1

Design a lag compensator C(s) for a 60° phase margin and an appropriate error constant of 5.

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Solution: For unity feedback we have Velocity error constant (K_v)

$$K_{v} = \lim_{s \to 0} sG(s) \tag{2.1.2}$$

$$\lim_{s \to 0} \left(\frac{10K}{(s+1)(s+5)} \right) = 5 \tag{2.1.3}$$

$$\implies K = 2.5 \tag{2.1.4}$$

From Fig.2.2

Phase Margin = 3.94°

Gain Crossover Frequency = 2.04 rad/s

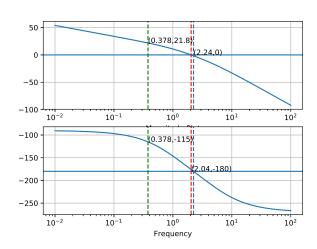


Fig. 2.2: Graph 1

2.2. Finding Lag Compensator (C(s)) to yield a Phase margin of 60°

Solution:

$$C(s) = \frac{1}{\beta} \frac{\left(s + \frac{1}{\tau}\right)}{\left(s + \frac{1}{\tau\beta}\right)}$$
 (2.2.1)

Phase Margin required = 60°

$$\angle C(j\omega) = -180^{\circ} + 60^{\circ} + 5^{\circ}$$
 (2.2.2)

$$\angle C(j\omega) = -115^{\circ} \tag{2.2.3}$$

For phase lag network 5° is added.

To obtain graph in Fig.2.2 use the following code:

codes/ee18btech11048_1.py

From Fig.2.2

$$\angle C(j\omega) = -115^{\circ}$$

$$\implies \omega = 0.37 rad/s$$

$$\implies$$
 Gain =21.8dB

Calculating β :

$$-20\log\frac{1}{\beta} = 21.8$$
$$\implies \beta = 12.3$$

$$\implies \beta = 12.3$$

Calculating $\frac{1}{\tau}$:

$$\frac{1}{\tau} = \frac{0.37}{10}$$

$$\implies \frac{1}{\tau} = 0.037$$

$$C(s) = \frac{s + 0.037}{12.3s + 0.037}$$
 (2.2.12)

2.3. Plotting the overall graph for C(s)G(s). Refer Fig 2.3

$$C(s)G(s) = \frac{s + 0.037}{12.3s + 0.037} \frac{25}{s(s+1)(s+5)}$$
(2.3.1)

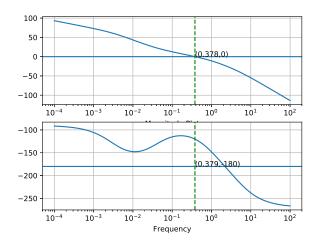


Fig. 2.3: Graph 2

Phase Margin = 60°

To obtain graph in Fig.2.3 use the following

code:

codes/ee18btech11048 2.py

3 PID Controller

3.1 Introduction