Control Systems

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Contents

***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

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

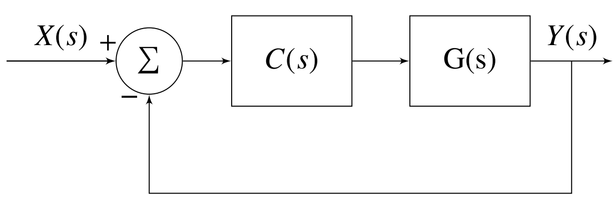

Fig. 2.1

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

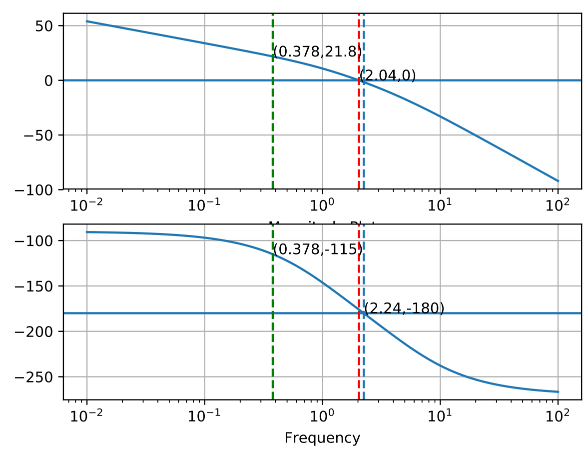

Fig. 2.2: Graph 1

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

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

Phase Margin required = 60°

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

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

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

$$\angle C(j\omega) = -115^\circ \tag{2.2.4}$$
$$\implies \omega = 0.37 rad/s \tag{2.2.5}$$
$$\implies Gain = 21.8 dB \tag{2.2.6}$$
$$\tag{2.2.7}$$

Calculating β :

$$-20 log \frac{1}{\beta} = 21.8 \tag{2.2.8}$$
$$\implies \beta = 12.3 \tag{2.2.9}$$

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

$$\frac{1}{\tau} = \frac{0.37}{10} \tag{2.2.10}$$
$$\implies \frac{1}{\tau} = 0.037 \tag{2.2.11}$$

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

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

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

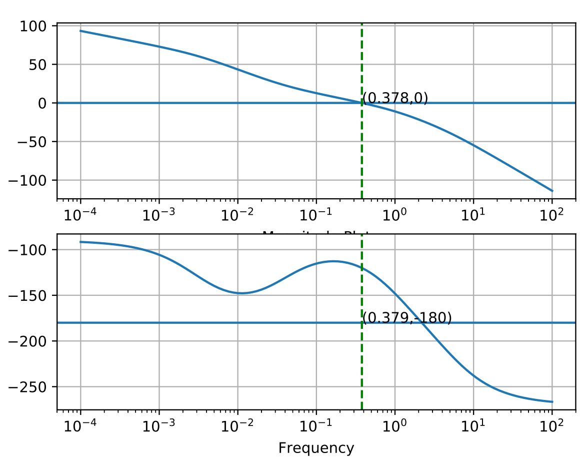

Fig. 2.3: Graph 2

Phase Margin = 60°
To obtain graph in Fig.2.3 use the following code:

```
codes/ee18btech11048_2.py
```

3 PID Controller

3.1 Introduction