# 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 Fig. 2.2 with G($s$) in feedback system, whose error $K_v$ = 5. Determine K

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

2.2. The block diagram is given by Fig.2.2

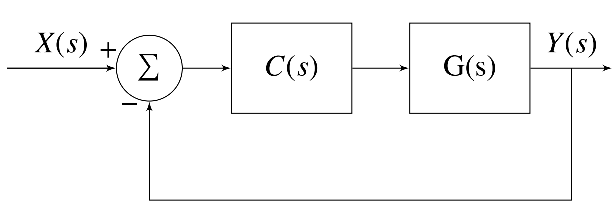


Fig. 2.2

2.3. **Solution:** For unity feedback we have Velocity error constant ($K_v$)

$$K_v = \lim_{s \to 0} sG(s) \tag{2.3.1}$$

$$\lim_{s \to 0} \left( \frac{10K}{(s+1)(s+5)} \right) = 5 \tag{2.3.2}$$

$$\implies K = 2.5 \tag{2.3.3}$$

It's Phase Margin = 3.94°
and Gain Crossover Frequency = 2.03 rad/s
Refer Fig. 2.3 for plot G($s$).

```
codes/es17btech11002_1.py
```

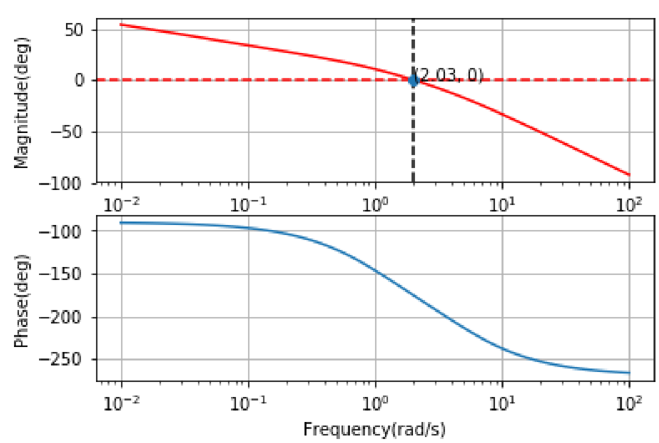


Fig. 2.3

2.4. Design a Lag-Lead Compensator to yield a Phase margin($PM$) of 60°
**Solution:** Compensator required phase angle ($\phi_m$) and Phase Margin Frequency $\left(\omega_{pm}\right)$,

$$\phi_m = -(180° + \theta) + PM + 5 = 65° \tag{2.4.1}$$

$$\omega_{pm} = 1.25 rad/s. \tag{2.4.2}$$

Attenuation factor ($\alpha\beta$) is given by

$$\alpha = 0.5 \tag{2.4.3}$$

$$\beta = 20 \tag{2.4.4}$$

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Lead and Lag Compensator Design Parameter is given in TABLE 2.4 And Compensator ob-

| Zeros/Poles | Parameter | Value |
|---|---|---|
| $z_{lead}$ | $\omega_{pm}\sqrt{\alpha}$ | 0.279 |
| $p_{lead}$ | $\frac{z_{lead}}{\alpha}$ | 5.590 |
| $z_{lag}$ | $0.1\omega_{pm}$ | 0.125 |
| $p_{lag}$ | $\frac{z_{lag}}{\beta}$ | 0.00625 |

TABLE 2.4: Zeroes and Poles

tained has transfer function

$$G_c(s) = \frac{(s+0.279)(s+0.125)}{(s+5.590)(s+0.00625)} \tag{2.4.5}$$

2.5. Plot the graph after adding Lead-Lag compensator.
**Solution:** Refer Fig2.5 for plot $G(s)G_c(s)$.

codes/es17btech11002_2.py

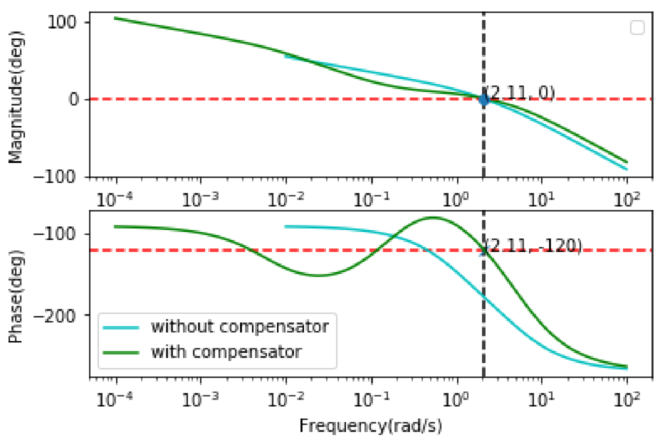


Fig. 2.5

**NOTE :** The idea of using a lead-lag network is to provide the attenuation of a phase-lag network and the lead-phase angle of a phase-lead network. This points should be noted while designing a controller, and parameters to be changed accordingly to get exact results.

## 3 PID Controller

### *3.1 Introduction*