Control Systems

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Contents

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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
```

1 Signal Flow Graph

1.1 Mason's Gain Formula

1.2 Matrix Formula

2 Bode Plot

2.1 Introduction

2.1.1. The asymptotic Bode phase plot of

$$G(s) = \frac{k}{(s+0.1)(s+10)(s+p_1)} \tag{2.1.1.1}$$

with k and p_1 both positive, is shown below. Find the value of p_1.

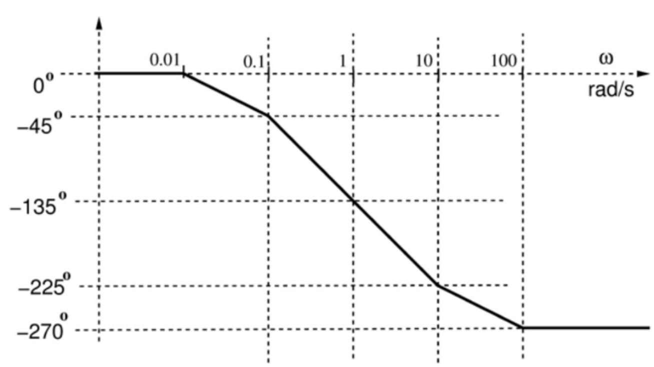

Fig. 2.1.1

Solution: Phase of this transfer function,

$$\phi(\omega) = -\tan^{-1}\left(\frac{\omega}{0.1}\right) - \tan^{-1}\left(\frac{\omega}{10}\right) - \tan^{-1}\left(\frac{\omega}{p_1}\right) \tag{2.1.1.2}$$

From the plot,

$$-45^\circ = -\tan^{-1}\left(\frac{0.1}{0.1}\right) - \tan^{-1}\left(\frac{0.1}{10}\right) - \tan^{-1}\left(\frac{0.1}{p_1}\right) \tag{2.1.1.3}$$

p_1 is approximately 1, i.e, for p_1 in 0.95 to 1.05 the ϕ is approximately equals to -45°.

2.1.2. Find the value of p_1 using bode phase plot properties.

Solution: In asymptotic Bode plot for a single pole, the phase at pole is -45° and the phase changes from 0 to -90 in 2 decades i.e, from $pole/10$ to $10 \times pole$.
Bode phase plot for a transfer function having pole at p

$$\phi(\omega) = \begin{cases} 0 & 0 < f < p/10 \\ -45 \times (\log(f) - \log(p/10)) & p/10 < f < 10p \\ -90 & 10p < f \end{cases} \tag{2.1.2.1}$$

Adding the bode phase plots corresponding to the 0.1,10.

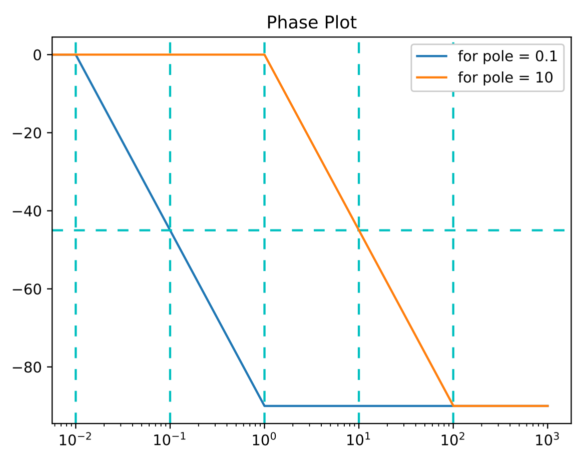

Fig. 2.1.2

The values before the 0.1 does not change when compared to figure 2.1.1, so $p_1/10$ is greater than or equal to 0.1.
In the plot obtained by adding these two plots the slope at 0.1 doesnt change, but in figure 2.1.1 there is a change so $p/10 = 0.1$

$$\implies p_1 = 1 \tag{2.1.2.2}$$

The following code plots Fig. 2.1.2

```
codes/ee18btech11037.py
```

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

5.5 Example

6 Nyquist Plot

7 Compensators

7.1 Phase Lead

7.2 Example

8 Gain Margin

8.1 Introduction

8.2 Example

9 Phase Margin

10 Oscillator

10.1 Introduction

10.2 Example