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
```

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.

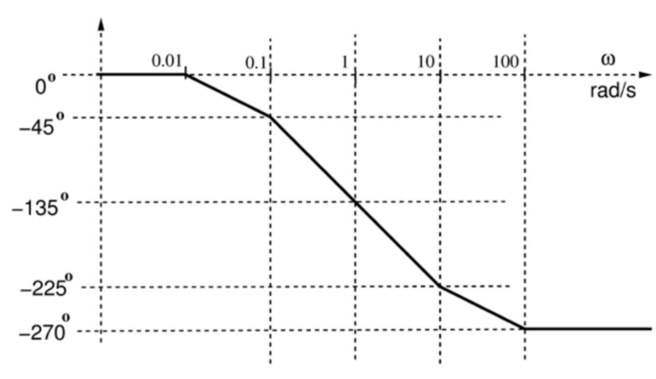

Fig. 2.1.1

Solution: Bode phase plot for a transfer function having a single pole at p

$$\phi(\omega) = \begin{cases} 0 & 0 < \omega < \frac{p}{10} \\ -45 \times \left(\log\left(\frac{10\omega}{p}\right)\right) & \frac{p}{10} < \omega < 10p \\ -90 & 10p < \omega \end{cases} \tag{2.1.1.2}$$

Phase plot of the transfer function (2.1.1.1),

$$\phi(\omega) = \begin{cases} 0 & 0 < \omega < 0.01 \\ -90 - 45\log(\omega) & 0.01 < \omega < 0.1 \\ -135 - 90\log(\omega) & 0.1 < \omega < 10 \\ -180 - 45\log(\omega) & 10 < \omega < 100 \\ -90 & 100 < \omega \end{cases} \tag{2.1.1.3}$$

phase plot by considering only 0.1 and 10 poles is

$$\phi(\omega) = \begin{cases} 0 & 0 < \omega < 0.01 \\ -90 - 45\log(\omega) & 0.01 < \omega < 100 \\ -180 & 100 < \omega \end{cases} \tag{2.1.1.4}$$

By comparing 2.1.1.3 and 2.1.1.4, $\phi(\omega)$ remains same till 0.1 so,

$$\frac{p_1}{10} = 0.1 \tag{2.1.1.5}$$

$$\implies p_1 = 1 \tag{2.1.1.6}$$

the bode phase plots corresponding to the poles 0.1 and 10.

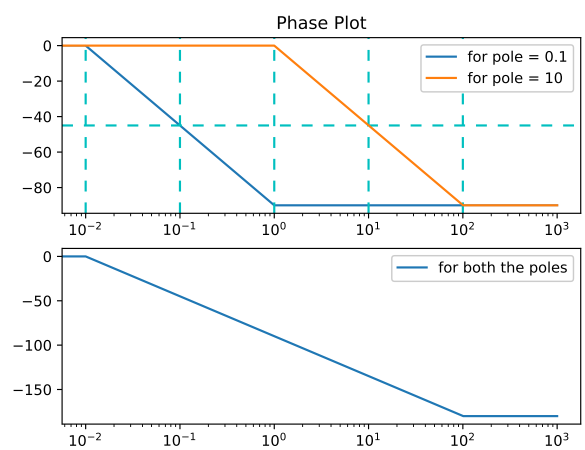

Fig. 2.1.1

2.1.2. Find the value of p_1 using phase of the transfer function.

Solution:

$$\phi(\omega) = -\tan^{-1}\left(\frac{\omega}{0.1}\right) - \tan^{-1}\left(\frac{\omega}{10}\right) - \tan^{-1}\left(\frac{\omega}{p_1}\right) \tag{2.1.2.1}$$

From the plot,

$$-45^\circ = -\tan^{-1}\left(\frac{0.1}{0.1}\right) - \tan^{-1}\left(\frac{0.1}{10}\right) - \tan^{-1}\left(\frac{0.1}{p_1}\right) \tag{2.1.2.2}$$

p_1 is approximately 1, i.e, for p_1 in 0.95 to 1.05 the ϕ is approximately equals to $-45°$. The following code plots Fig. 2.1.1

```
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*