Control Systems

G V V Sharma*

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*The author is with the Department of Electrical Engineering, Indian Institute of Technology, Hyderabad 502285 India e-mail: gadepall@iith.ac.in.

***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
```

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1.1 Mason's Gain Formula

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6.1 Polar plots

6.1. Plot the polar plot of

$$G(s) = \frac{1}{(s^2)(s+1)(s+2)}. \tag{6.1.1}$$

Solution: For polar plot we have to plot magnitude of $G(s)$ versus its phase by varying ω from 0 to ∞.
First substitute,

$$s = j\omega \tag{6.1.2}$$

Now the magnitude will be

$$|G(j\omega)| = \frac{1}{(\omega^2)(\sqrt{1+\omega^2})(\sqrt{1+4\omega^2})} \tag{6.1.3}$$

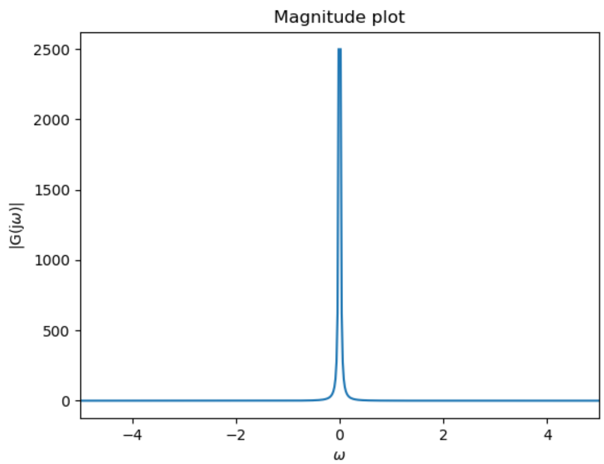

Fig. 6.1: (a)

Similarly phase ϕ can be determined by,

$$\phi = -\tan^{-1}(0) - \tan^{-1}(\omega) - \tan^{-1}(2\omega) \tag{6.1.4}$$

The phase of first term is π or can be $-\pi$ since it is a negative real number.

$$\implies \phi = 180^\circ - \tan^{-1}(\omega) - \tan^{-1}(2\omega) \tag{6.1.5}$$

Now we have to sweep ω from 0 to ∞.
So at $\omega = 0$,

$$|G(j\omega)| \xrightarrow{0} \infty \tag{6.1.6}$$

And phase,

$$\angle G(j\omega) = 180^\circ \tag{6.1.7}$$

At $\omega = \infty$

$$|G(j\omega)| \xrightarrow{\infty} 0 \tag{6.1.8}$$

And phase,

$$\angle G(j\omega) = 0^\circ \tag{6.1.9}$$

For a complete plot we have to put various values of ω in eq. 6.1.5 and eq. 6.1.3 for magnitude and phase respectively. Thus the polar plot looks like,

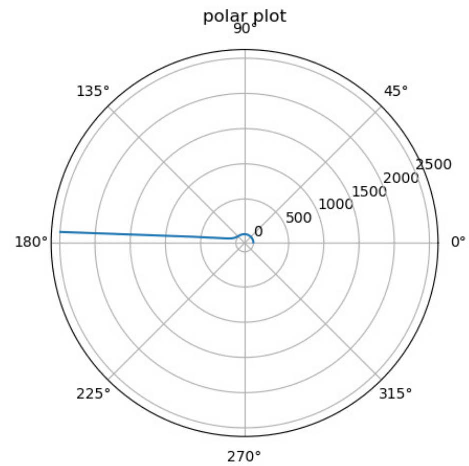

Fig. 6.1: (b)

To take a closer look at how phase is changing in smaller ranges of $|G(j\omega)|$.

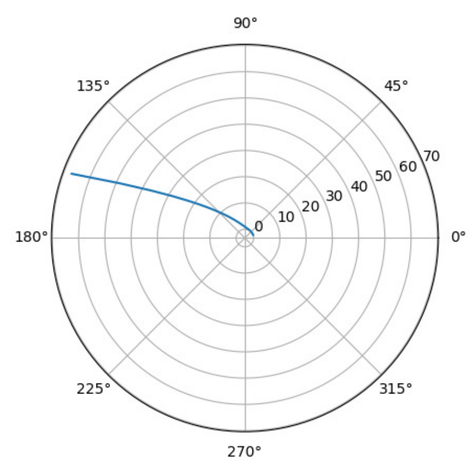

Fig. 6.1: (c)

The following python code generates Fig . 6.1 (a), Fig . 6.1 (b) and Fig. 6.1 (c)

```
codes/ee18btech11028.py
```

7 Compensators

7.1 Phase Lead

7.2 Example

8 Gain Margin

8.1 Introduction

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9 Phase Margin

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