Texas A & M University
Department of Mechanical Engineering
MEEN 364 Dynamic Systems and Controls
Dr. Alexander G. Parlos

Lecture 28: Use of Bode Plots in Dynamic Compensation

The objective of this lecture is to complete the discussion on the use of Bode plots for dynamic compensation in control systems.

A Note of Steady-state Errors

In previous lectures we have seen that the steady-state error of a feedback system decreases as the gain of the open-loop transfer function increases. The low-frequency open-loop gain of a control system is given by

$$KG(j\omega) = K_0(j\omega)^n. \tag{1}$$

As a result, the larger the value of the magnitude of the open-loop DC gain, the lower the steady-state error will be for the closed-loop system. This inference is very useful in compensator design.

Summary of Compensation Characteristics

In many control system design problems a mere change in the controller (proportional) gain cannot satisfy desired specifications. As a result controller dynamics are introduced to alter (compensate) the overall (closed-loop) system dynamics. There are two widely used techniques for dynamic compensation. **Lead compensation** acts mainly to lower the rise time and decrease the overshoot of a feedback loop. It approximates the effects of derivative control. **Lag compensation** acts mainly to lower steady-state error, and as such it approximates the effects of integral control. In many instances, both lead and lag compensation are used simultaneously resulting in lead-lag compensation.

We can summarize the compensation characteristics, as follows:

(1) *PD Compensation:* It adds phase lead at frequencies above the break point. If no changes are made to the low-frequency gain, PD compensation will increase the system bandwidth and speed of response. As a result the system sensitivity to noise will increase.

(2) *Lead Compensation:* It adds phase lead only in between the two break points. Similarly to the PD compensation, the system speed of response will increase. Also, unless adjustments to the low-frequency gains are made the steady-state error of the system will increase.

(3) *PI Compensation:* It increases the magnitude of the frequency response below the break point, resulting in lower steady-state errors. It also adds phase lag beyond the break point, which degrades the overall system stability.

(4) *Lag Compensation:* It increases the frequency response at frequencies below the two break points, and decreases the steady-state error. It also contributes phase lag between the two break points, which must be kept low enough as to not degrade the phase margin (PM), and as a result system stability.

Reading Assignment

See separate file on textbook reading assignments depending on the text edition you own.