

Fall 2022 (111-1)

控制系統
Control Systems

Unit 6L
Compensation Characteristics
and Design Considerations

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- **PD Control**
- Adds **phase lead** at all frequencies above the break point.
- If there is no change in gain on the **low-frequency asymptotic**,
- **PD compensation will increase**
 - the **crossover frequency** and
 - the **speed of response**.
- The **increase** in **magnitude** of the frequency response
at the higher frequencies
will **increase** the system's **sensitivity** to noise

▪ Lead Compensation

- Adds **phase lead** at a frequency band

between the two break points,
which are usually selected to bracket the crossover frequency.

- If there is no change in gain on the **low-frequency asymptotic**,
- **Lead compensation will increase**
 - the **crossover frequency** and
 - the **speed of response**.

- PI Control
- **Increases** the frequency-response **magnitude** at frequencies below the break point, thereby **decreasing** steady-state **error**.
- It also contributes **phase lag** below the break point, which must be kept **at a low enough frequency** to avoid **degrading the stability** excessively

- **Lag Compensation**
- **Increases** the frequency-response **magnitude**
at frequencies below the two break points,
thereby **decreasing** steady-state **error**.
- Alternatively, with suitable adjustments in **K**,
Lag Compensation can be used
to **decrease** the frequency-response **magnitude**
at frequencies above the two break points
- So that, ω_c yields an acceptable PM.

- Lag Compensation
- Lag Compensation also contributes phase lag
between the two break points,
which must be kept at frequencies low enough
to keep the phase decrease
from degrading the PM excessively
- The Lag Compensation
will typically provide a slower response
than using Lead Compensation.

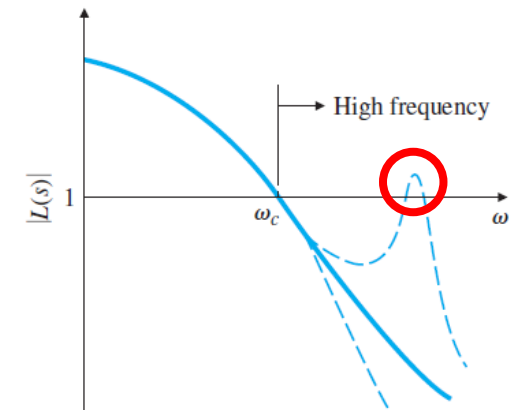
- Characteristics of the **OL Bode Plot** of the loop gain determine performance with respect to:
 - steady-state error, low-frequency errors,
 - and **dynamic response**, including **stability margins**.
- Other properties of **feedback** include:
 - reducing the effects of **sensor noise**
 - and **parameter changes** on the performance of system.
- Design for **acceptable errors**
 - due to command inputs and disturbances
 - can be thought of as placing a **lower bound**
 - on the **low-frequency gain** of the OL system.

- Another aspect of the **sensitivity issue** concerns the **high-frequency portion** of the system.
- To alleviate the effects of **sensor noise**, the **high-frequency gain** must be **kept low**.
- For example, a **lead compensation** of one pole, compared with **pure derivative control**, for reducing the effects of **sensor noise** at **high frequencies**.
- Or, **add an extra pole** in the compensation to introduce even **more attenuation** error reduction:

$$D_c(s) = \frac{T_D s + 1}{(\alpha T_D s + 1)^2}$$

- Many systems have **high-frequency dynamic** phenomena (e.g., mechanical resonances, bridge vibration, etc.) that could have an impact on the **stability** of a system.

- Design for **unknown high-frequency dynamics** is to keep the high-frequency gain **low**.
- An unknown high-frequency resonance causes the magnitude **to rise above 1**.
- Can be lowered **by adding extra poles**.
- Refer as **Amplitude** or **Gain Stabilization**.
- On the other hand, to avoid encirclements of -1, by **changing the phase** at a specific frequency (e.g., notch compensation) is referred as **Phase Stabilization**.



- The two aspects of **sensitivity** (**high-** and **low-**frequency behavior) can be depicted **graphically**.
- **Minimum low-frequency gain** allowable for acceptable **steady-state error** and **low-frequency error** performance
- **Maximum high-frequency gain** allowable for acceptable **noise performance** for low probability of **instability** caused by **plant-model errors**.

