

Lecture 19: Frequency-Response Design (I);
Practice Problems for Quiz II

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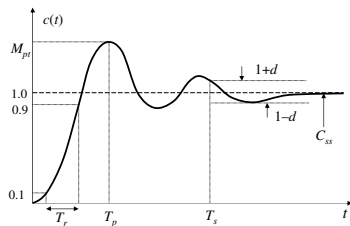
Control system specifications in terms of
frequency responses

- Steady-state accuracy
 - Question 1: How to reduce steady-state error for step input?
 - Question 2: What is the definition of system type and how does that relate to steady-state error?
 - For small errors at any frequency, the loop gain must be large
 - If we can design the system to have a high open-loop gain over a wide band of frequencies, the system will track input signals composed of these frequencies very well

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Control system specifications in terms of
frequency responses

- Steady-state accuracy
- Transient response
 - Question: What are the definitions of rise time, peak value of signal (overshoot), and the settling time?



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Control system specifications in terms of
frequency responses

- Steady-state accuracy
- Transient response
 - Question: What are the definitions of rise time, peak value of signal (overshoot), and the settling time?
 - Rise time is closely related to the closed-loop system bandwidth (what is bandwidth?)

$$\omega_B T_r \cong \text{constant}$$

- In general, if we desire to reduce the rise time by a factor of 2, it is necessary to increase the closed-loop system bandwidth by a factor of approximately two

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Control system specifications in terms of
frequency responses

- Steady-state accuracy
- Transient response
 - Question: What are the definitions of rise time, peak value of signal (overshoot), and the settling time?
 - Rise time is closely related to the closed-loop system bandwidth (what is bandwidth?)
 - Settling time is also related the closed-loop system bandwidth
 - If we want to decrease the settling time, the closed-loop transfer function poles must be shifted to the left in the s -plane, thereby reducing the time constant
 - Shifting the closed-loop poles to the left generally increases the system bandwidth
 - Hence to decrease the system's response time, the closed-loop system's bandwidth must be increased

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Control system specifications in terms of
frequency responses

- Steady-state accuracy
- Transient response
 - Question: What are the definitions of rise time, peak value of signal (overshoot), and the settling time?
 - Rise time is closely related to the closed-loop system bandwidth (what is bandwidth?)
 - Settling time is also related the closed-loop system bandwidth
 - Overshoot is related to resonance and stability margin
 - Resonance appears as a peak in the closed-loop frequency response
 - Resonance in the closed-loop system can occur only if the relative stability margins of the system are small

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Control system specifications in terms of frequency responses

- Steady-state accuracy
- Transient response
- **Relative stability**
 - Usually control systems with adequate stability margins have phase margins of **45 degrees** or higher and gain margins of **8 dB** or higher

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Control system specifications in terms of frequency responses

- Steady-state accuracy
- Transient response
- Relative stability
- **Sensitivity**
 - For good sensitivity in the forward path of the control system, the loop gain is made large over as wide a band of frequencies as possible
 - However, in general, increasing the loop gain degrades the stability margins—so we need a trade-off

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Control system specifications in terms of frequency responses

- Steady-state accuracy
- Transient response
- Relative stability
- Sensitivity
- **Disturbance rejection**
 - In order to reduce the effects of the disturbance of the output, we must make the gain of the open-loop function large over the frequency band of the disturbance

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Practice problems for Quiz II

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Problem 1: Plot Nyquist diagrams for

$$G_1(s)H_1(s) = \frac{1}{s(s-1)}$$
$$G_2(s)H_2(s) = \frac{e^{-Ts}}{s+p}, \quad p > 0$$

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Problem 2: Determine the gain and phase margins for the system with the following open function

$$G_1(s)H_1(s) = \frac{1}{s}$$
$$G_2(s)H_2(s) = Ke^{-Ts}, \quad 0 < K < 1$$

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Problem 3: Construct the Bode diagrams for the open-loop transfer function

$$G(s)H(s) = \frac{2(s+2)}{s^2-1}$$

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Modular Snake Robot
Robotics Institute
Carnegie Mellon University
Howie Choset

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References

- C. L. Phillips and R. D. Harbor. Feedback Control Systems, 4th Edition, Prentice Hall, 2000.
- http://digg.com/gadgets/Modular_Snake_Robot_Compilation_Video

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