

Review for Principles of Automatic Control (Classical Control)

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Review for Principles of Automatic Control

- ◆ Automatic control principle is a **mainly theoretical course** for **aerospace engineering**. It is a basic and the required course also. It closely around the automatic control system introduces the basic theory and application of the control system analysis and design method of physical concept, is a theoretical and practical course.



Review for Principles of Automatic Control

- ◆ It demands the students **understand** and **master** the **basic concepts**, automatic control Automatic control system of the **basic working principle** and **mathematical models** clearly. Students are also required to **master** the automatic control system **analysis methods**, including **design of feedback control systems**, **properties and advantages of feedback systems**, **time-domain and frequency-domain performance measures**, **stability and degree of stability**. It also covers **root locus method**, **Nyquist criterion**, **frequency-domain design**, and **state space methods**.



How to get high score?

- ◆ **Attendance for classroom : 5%**
- ◆ **Homework: 15%**. Main inspection to the master degree of knowledge, oral and written expression ability .
- ◆ **Course design : 30%**. Main evaluation analysis and problem solving, creative work, process information, oral and written expression ability.
- ◆ **Final Exam : 50%**. Main assessment to the basic concept, principle and the typical example of the master degree.



How to get high score?

◆ Final Exam (Dec.27.2011 8AM-10AM 中院106)

1. Blank Filling Question ($10 \times 1' = 10'$) [填空题] (1')
2. Judge Statements ($5 \times 1' = 5'$) [判断题] (3')
3. Abbreviated Question ($10' \times 2 = 20'$) [简答题]
4. Comprehensive Question (65') [综合题]
(Q1-15'; Q2-20'; Q3-15'; Q4-15')

Note: Red score is Modern Control Parts

Requirement: Answer in English.



Requirements for Chapter 1

- ◆ **Concepts for AC (automation control)**
- ◆ **Classical Control Theory & Modern Control Theory**
 - ◆ The object of study is a single-input, single output system - single-variable systems.
 - ◆ The object of study is a multi-input, multiple output - multi-variable system.
- ◆ **Concepts for A open-loop control system and A closed-loop control system (feedback control system)**
 - ◆ **Features:** there is no feedback loop between system's output and input side. The output has no influence on control effect of the system.
 - ◆ **Features:** There's a feedback loop between the measuring component and the output signal.



Requirements for Chapter 1

- ◆ Components of a typical **closed-loop** control system (feedback control system)
- ◆ Typical **open-loop & closed-loop** system examples .
 - ◆ Temperature control system in an office
 - ◆ Cruise control in a car
 - ◆ Automatic Tracking System of the Artillery



Requirements for Chapter 2

- ◆ Typical Dynamic Model Examples
 - ◆ Dynamic of Mechanical System
 - ◆ Models of Electric Circuits
- ◆ Seven Steps of Analyzing and Studying a Dynamic System
- ◆ Understand **“Tri-domain” models and mutual relations**
 - ◆ **Differential equation**(time domain)
 - ◆ **Transfer function**(complex frequency domain)
 - ◆ **Frequency response**(frequency domain)



Requirements for Chapter 2

- ◆ **The definition of transfer function**
- ◆ **The Dynamic Models and Typical Elements**
- ◆ **Write transfer functions for typical System Models**



Requirements for Chapter 3

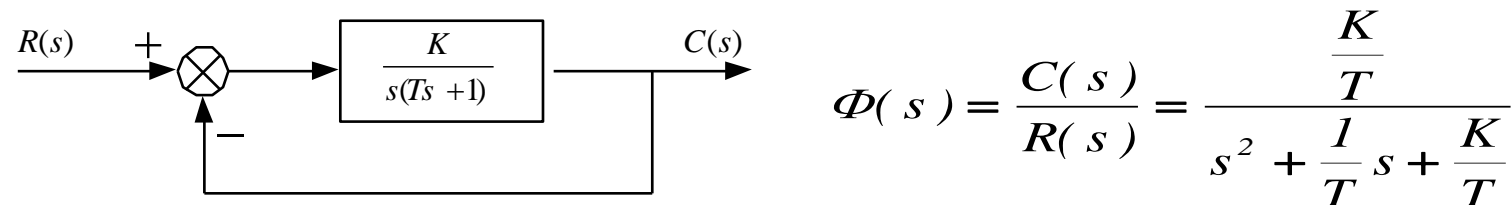
- ◆ **The Signal-Flow Graph Models and Mason's rule**
- ◆ **The definition of Stability**
- ◆ **The Routh-Hurwitz Stability Criterion**
 - ◆ **The Necessary and Sufficient Conditions for Stability**
 - ◆ **Three steps of Routh-Hurwitz criterion**
 - ◆ **Special Cases of Routh-Hurwitz criterion**
- ◆ **Steady-state Analysis in Time Domain**
- ◆ **The Type for Control system with poles number**
- ◆ **Calculate the Steady-state coefficients**



Requirements for Chapter 3

◆ Dynamic Analysis in Time Domain

◆ Dynamic Performance Index, special for Transient Response of **second-order system**



the standard form $\Phi(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$

$$\omega_n^2 = \frac{K}{T} \quad 2\zeta\omega_n = \frac{1}{T} \quad \begin{array}{ll} \omega_n & \text{--- undamping natural frequency} \\ \zeta & \text{--- damp radio} \end{array}$$

The characteristic equation of the second-order system

$$s^2 + 2\zeta\omega_n s + \omega_n^2 = 0 \quad (0 < \zeta < 1)$$



Requirements for Chapter 3

◆ Special for Transient Response of second-order system

- ◆ Damped and undamped natural frequencies
- ◆ Damping ratio
- ◆ Maximum overshoot
- ◆ Peak time
- ◆ Rise time
- ◆ Delay time
- ◆ Settling time based on 5% tolerance
- ◆ Steady-state error
- ◆ Final value of the system output
- ◆ Draw sketch for the output $c(t)$ based on the calculation



Requirements for Chapter 4

- ◆ The definition of the root locus of a basic feedback system
- ◆ The root locus has a close relation with a system performances.(Stability / Steady-state/ Dynamic characteristics)
- ◆ sketching Root Locus(Rule #11)
- ◆ System Analysis Using the Root Locus



Requirements for Chapter 5

- ◆ The definition of the frequency-Response Design Method and its relationship with root locus method
- ◆ How to calculate the Frequency characteristics
 - ◆ $A(\omega)$ -Amplitude frequency characteristics
 - ◆ $\varphi(\omega)$ -phase frequency characteristics
 - ◆ $U(\omega)$ -real frequency characteristics; real part of $G(j\omega)$
 - ◆ $V(\omega)$ - virtual frequency characteristics; the imaginary part of $G(j\omega)$



Requirements for Chapter 5

- ◆ The diagram methods for the Frequency characteristics
 - ◆ The polar figure-**Nyquist Plots**
 - ◆ The logarithmic coordinates figure-**Bode Plots**
(What advantages of working with Bode Plots?)
- ◆ The Typical element analysis with Nyquist Plots/ Bode Plots
- ◆ **The Typical system Stability Analysis with Bode Plots(The Nyquist Stability Criterion)**



Requirements for Chapter 5

- ◆ Frequency domain of steady-state analysis
- ◆ Stability Margins
 - ◆ Gain Margin(GM) 增益裕度
 - ◆ Phase Margin(PM) 相角 (位) 裕度
- ◆ **0 type , I type and II type system** steady-state analysis with Bode plots



Requirements for Chapter 6

- ◆ The definition of **System calibration**
- ◆ The main three correction methods
 - series calibration
 - feedback calibration
 - compound calibration



Requirements for Chapter 6

◆ Different domain dynamic performance indicators

	Time domain (Differential equation- Analytic method)	Complex domain (transfer function- Locus root diagram)	Frequency domain (Frequency characteristics- Nyquist or Bode diagram)
<u>Stability</u>	The characteristics of the movement equation root has a negative real part, the system stability	The pole distribution of the closed-loop transfer function are in the left brain of plane S plane, the system stability	Phase Margin(PM)>0; Gain Margin(GM)>0; the system stability
<u>Steady characteristics</u>	Which are decided by the coefficient of motion equation	The greater of open loop root locus gain system which is corresponding to operation or work situation, the error ess smaller	Depends on the low frequency characteristics of the system, <i>if</i> case of the model number is same, in the low frequency band, the greater of amplitude, the error ess smaller
<u>Dynamic characteristics</u>	Transient time : t_s Maximum overshoot: σ_p (t_r, t_p, t_d) The shorter t_s , the smaller σ_p , the better of system dynamic characteristics	Mainly depends on the system dominant pole position. The main characteristic parameters: Damping ratio: ζ Natural frequency: ω_n Dominant pole distance the imaginary axis more close, and the more powerful vibration	Mainly depends on the frequency characteristic frequency characteristics. The main parameters: Phase Margin(PM): γ Crossover frequency: ω_c The smaller γ , system Oscillation more formidable; the bigger ω_c , the faster system response(the quickly response speed)



Requirements for Chapter 6

- ◆ PID controller and control laws
 - ◆ PI
 - ◆ PD
 - ◆ PID
- ◆ Commonly used correction network and its characteristics



Special concepts

(1) Understand the three performance indexes and their relationship

- ◆ **Stability (稳定性)**
- ◆ **Steady-state characteristics (稳态特性)**
- ◆ **Dynamic characteristics (动态特性)**



Special concepts

(2) Stability criterion

- ◆ Routh-Hurwitz criterion(Time Domain) Chap3
- ◆ System stability Analysis Using the Root Locus (complex frequency domain) Chap4
- ◆ Nyquist stability criterion(frequency domain) Chap5



Special concepts

- ◆ A transfer function of Typical **closed-loop** system examples and Its signal flow graph
 - ◆ Electric Circuit System
 - ◆ Mechanic System (Spring – Mass – Damper)
 - ◆ Position Tracking System (Complex Control System)



Good Luck!

- ◆ Any questions ,Please contact me or assistant teacher, Mr. Xu Xiaohang

