

課程概述：

In Digital Control, we will learn how to digitally implement the continuous dynamics synthesized by classical control or modern control to function as controllers, observers, filters, or phase-compensators. The implementation is finished in two stages: discrete equivalency and DSP programming. That is, the to-be-implemented continuous-dynamics is firstly transformed into a discrete-equivalent, which is then programmed into some microcontroller as a real-time processor. Unlike most of engineering curriculums that are computer-time technologies, Digital Control is a real-time technology.

The contents of the course are listed as follows.

Preface

Chapter1: Introduction to Digital Control

- 1-1 Discrete synthesis versus discrete equivalents
- 1-2 An example of classical control synthesis
- 1-3 Sampling and ZOH: sequence number
- 1-4 Discrete equivalent: trapezoidal approximation of integrator
- 1-5 Digital implementation of analog computer

Chapter 2: Z Transform

- 2-1 Take first-order dynamics as an introductory example
- 2-2 Long division
- 2-3 Unit-step response
- 2-4 Convolution
- 2-5 Unit pulse that defines transfer function
- 2-6 Z-transform of time-delay
- 2-7 Final-value theorem
- 2-8 Discrete state space

Chapter 3: Frequency Domain

- 3-1 Aliasing
- 3-2 Frequency response
- 3-3 Bode plots
- 3-4 Nyquist Criterion
- 3-5 Stability and robustness
- 3-6 Discrete modes
- 3-7 Discretization $T/2$ delay
- 3-8 Robustness and performance

Chapter 4: Discrete Equivalents

- 4-1 Tustin-1 method
- 4-2 Tustin-0 method
- 4-3 Euler-0 method
- 4-4 Euler-1 method
- 4-5 MPH approximation
- 4-6 Impulse-invariant approximation
- 4-7 Pre-warping Tustin

Chapter 5: Practice in Discrete Equivalence

- 5-1 Holder and sampler: dual structure
- 5-2 ZOH with $T/2$ embedded time-delay: demo in time and frequency domains
- 5-3 Linear holders: zero-order and first-order
- 5-3 Tustin-1 and Tustin-0 equivalents of integrator by convolution
- 5-5 Discrete equivalents of $1/s+1$
- 5-6 Complete bases of linear interpolation
- 5-7 Different kinds of discrete equivalents in discrete Bode plots
- 5-8 Instability induced from the $T/2$ delay embedded in ZOH

Chapter 6: DSP Programming

- 6-1 IIR versus FIR
- 6-2 IIR-S: memorization of current state

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| 6-3 IIR-P: memorization of past inputs and outputs (violates the principle of causality) | | |
| 6-4 IIR-AC: iterative recursion of controllability canonical computer | | |
| 6-5 IIR-AO: iterative recursion of observability canonical computer | | |
| 6-6 IIR-S: Decomposition into a series of subsystems | | |
| 6-7 FIR: finite impulse response | | |
| Chapter 7: Special Issue on Half-a-sample Delay Embedded in ZOH | | |
| 7-1 Viewpoints from temporal signal | | |
| 7-2 Frequency responses of equivalents | | |
| 7-3 Nonlinear digital control: Tustin equivalent plus IIR-AC for van der Pol oscillators | | |
| Chapter 8: DSP-Programming into Microcontroller | | |
| 8-1 Introduction to special-purpose and general-purpose microcontrollers | | |
| 8-2 Overview of Microchip-dsPIC chips | | |
| 8-3 Peripherals and interruption | | |
| 8-4 Matlab-to/from-dsPIC | | |
| 8-5 Coding of IIRs | | |
| 8-6 Coding of signal generators | | |
| 8-7 Example1: Firmware-based instruments | | |
| 8-8 Example 2: Drivers/controllers of DC motors | | |
| 目標： | | |
| This course is mixed with theory and practice suitable for our smart students. To be sure, they are able to catch this attractive and important real-time technology. In the industry of servo-controlled machines, currently we are always the manufacture rather than the designer. Via this course, it is expected that our new generation is encouraged to start changing this situation. Of course, they will be getting to know how to change with this course and the like. | | |
| 教科書 | 1. 自編教科書與講義 2. Norman S. Nise, Control Systems Engineering, 6th ed., John Wiley & Sons, Inc., 2011, Chap 13 3. Karl J. Astrom and Bjorn Wittenmark, Computer-Controlled Systems – Theory and Design, 3 rd ed., Prentice-Hall, 1997 | |
| 教學要點概述 | | |
| 教材編選 teaching materials | <input checked="" type="checkbox"/> 自製簡報(ppt) <input checked="" type="checkbox"/> 課程講義 <input checked="" type="checkbox"/> 自編教科書 <input checked="" type="checkbox"/> 教學程式 <input checked="" type="checkbox"/> 自製教學影片 <input type="checkbox"/> 其他 | |
| 教學方法 teaching methods | <input checked="" type="checkbox"/> 講述 <input checked="" type="checkbox"/> 小組討論 <input checked="" type="checkbox"/> 學生口頭報告 <input checked="" type="checkbox"/> 問題導向學習 <input checked="" type="checkbox"/> 個案研究 <input type="checkbox"/> 其他 | |
| 評量工具 Evaluation tools | <input checked="" type="checkbox"/> 期中考 <input checked="" type="checkbox"/> 期末考 <input type="checkbox"/> 隨堂測驗 <input type="checkbox"/> 隨堂作業 <input checked="" type="checkbox"/> 課後作業 <input type="checkbox"/> 期中報告 <input type="checkbox"/> 期末報告 <input checked="" type="checkbox"/> 專題報告 <input checked="" type="checkbox"/> 評量尺規 <input type="checkbox"/> 其他 | |
| 教學資源 teaching resources | <input checked="" type="checkbox"/> 課程網站 <input checked="" type="checkbox"/> 教材電子檔供下載 <input checked="" type="checkbox"/> 實習網站 | |
| 教師相關訊息 instructor's information | 洪博雄 https://www.tfa-1985.org | |
| 課程大綱 | | 分配時數 |

| 單元主題 | 內容綱要 | 講授 | 示範 | 習作 | 其他 ¹ | 可達成核心能力 |
|-------------------------------|--|--------------------------|----|----|-----------------|------------|
| Introduction | 1. Discrete equivalent versus discrete synthesis 2. Sampling and holding | 3 | | | | |
| Z-Transform | 1. Convolution 2. State-space realization | 3 | | | | D1, D2 |
| Frequency Response | 1. Bode plots 2. Nyquist criterion 3. System identification 4. Stability and robustness | 3 | | | | |
| Discrete Equivalents | 1. A series of discrete equivalents 2. Demo by Matlab | 6 | | | | D1, D2 |
| Discrete Equivalents Practice | 1. Examples study 2. Closed-loop discretization | 3 | | | | |
| DSP Programming | 1. FIR 2. Analog computer 3. IIR | 6 | | | | D1, D2, D4 |
| Special Issues | 1. Discretization induced instability 2. Nonlinear systems | 6 | | | | |
| Microcontroller Coding | 1. Peripheral and interruption 2. DPS-programming 3. Examples | 6 | 6 | 6 | | D1, D2, D4 |
| 可達成核心能力 | | 核心能力達成指標 | | | | |
| D1 | 具機械領域之專業知識 | 具備分析數位系統以及設計數位控制的能力 | | | | |
| D2 | 策劃及執行機械及其相關領域專題研究之能力 | 具備策劃及執行數位控制及其相關領域專題研究之能力 | | | | |
| D4 | 創新思考及獨立解決機械問題之能力 | 具備獨立分析並解決數位控制相關問題之能力 | | | | |

教學要點概述:

| 上課時間 | 上課地點 | 學習成果評量方式 | Office hour | 教學品質評量方式 |
|---------|---|---|-----------------|-----------------------|
| 二 10-12 | 工學院 B 館 116 | <ul style="list-style-type: none"> Midterm exam (30%) Final exam (40%) Homework (10%) Appearance in class (20%) | 星期五 19:00-21:00 | 教學意見調查核心能力重要性及達成度分析問卷 |
| 週次 | 教學與作業進度 | | | 備註 |
| 1 | Chapter1: Introduction to Digital Control | | | |
| 2 | Chapter 2: Z Transform | | | |
| 3 | Chapter 3: Frequency Domain | | | |
| 4 | Chapter 4: Discrete Equivalents Part I | | | |
| 5 | Chapter 4: Discrete Equivalents Part II | | | |

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| 6 | Chapter 5: Practice in Discrete Equivalence Part I | |
| 7 | Chapter 5: Practice in Discrete Equivalence Part II | |
| 8 | Chapter 6: DSP Programming Part I | |
| 9 | Chapter 6: DSP Programming Part II | |
| 10 | Chapter 7: Special Issues Part I | |
| 11 | Chapter 7: Special Issues Part II | |
| 12 | Chapter 8: DSP-Programming into Microcontroller (Lecture) | |
| 13 | Chapter 8: DSP-Programming into Microcontroller (Lecture) | |
| 14 | Chapter 8: DSP-Programming into Microcontroller (Demonstration) | |
| 15 | Chapter 8: DSP-Programming into Microcontroller (Demonstration) | |
| 16 | Chapter 8: DSP-Programming into Microcontroller (Practice) | |
| 17 | Chapter 8: DSP-Programming into Microcontroller (Practice) | |
| 18 | Final exam | |
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