《数字集成电路设计》

课程教学大纲

1、课程基本信息

课程类型	总学时为学时数	☑理论课（含上机、实验学时）			
	总学时为周数	□实习　□课程设计　□毕业设计			
课程编码	7235321	总学时	32	学分	2
课程名称	数字集成电路设计				
课程英文名称	Design of Digital Integrated Circuits				
适用专业	微电子科学与工程				
先修课程	（7069201）模拟电子技术、（7087611）数字电子技术、（7005321）半导体物理、（7119421）专用集成电路设计				
开课部门	信息学院电子工程系（微电子）				

2、课程性质与目标

本课程为微电子科学与工程专业本科生必修课。为学生今后从事数字集成电路的设计、制造及应用研究等工作打下坚实的基础，目的是让学生熟悉数字集成电路的常用电路结构、工作原理等的学习，掌握数字集成电路相关的基本知识，了解设计方法和流程以及数字集成电路设计中需要考虑的各种因素，培养学生数字集成电路方面理论和实践能力。

课程目标 1：学生应掌握数字集成电路相关的基本知识；

课程目标 2：学生应了解常用电路结构、工作原理，影响数字集成电路性能的各种因素；

课程目标 3：学生应能实际进行数字集成电路的设计；

课程思政目标：根据课程的特点和育人要求，充分发挥课程所承载的育人功能，强化学生的学习体验和学习效果。坚定爱党爱国爱专业的理想信念、厚植爱国主义思想、加强品德修养，培育学生科学精神、创新精神、工匠精神。

3、课程教学基本内容与要求

第一章 绪论

（一）教学基本内容

1.1 CMOS 电路的发展历史、CMOS 电路的发展现状

1.2 版图设计软件和 MOSIS 概念

1.3 BJT/CMOS/Bi－CMOS 电路简介

（二）教学基本要求

1、掌握：数字集成电路的发展历史及发展现状

2、理解：版图设计软件和 MOSIS 概念

3、了解：集成电路的基本设计和加工流程

第二章 集成电路基本结构和制作工艺

（一）教学基本内容

2.1 CMOS 集成电路的基本制造工艺

2.2 BJT 集成电路结构和工艺

2.3 Bi－CMOS 制造工艺

2.4 版图设计规则

（二）教学基本要求

1、掌握：集成电路加工的基本工艺流程

2、理解：集成电路工艺流程

3、了解：CMOS、BJT 及 BiCMOS 结构和工艺，版图设计规则

第三章 集成电路中的元器件

（一）教学基本内容

3.1 MOS 晶体管的基本原理和模型参数

3.2 双极晶体管的基本原理和模型参数

3.3 集成电路中的无源元件

3.4 集成电路中互连线的寄生效应

（二）教学基本要求

1、掌握：MOS 和 BJT 基本原理和模型参数，集成电路中无源元件及寄生效应

2、理解：MOS 和 BJT 模型参数意义，集成电路中无源元件结构及寄生效应分析

3、了解：集成电路中基本元件

第四章 MOS 反相器

（一）教学基本内容

4.1 自举反相器

4.2 耗尽负载反相器（E/D）

4.3 CMOS 反相器

4.4 CMOS 反相器直流和瞬态特性

4.5 CMOS 反相器直流和瞬态特性的 SPICE 模拟仿真

（二）教学基本要求

1、掌握：MOS 反相器的差异和功能

2、理解：反相器电路结构

3、了解：MOS 反相器的作用和原理，以及 SPICE 仿真

第五章　静态 CMOS 逻辑电路

（一）教学基本内容

5.1 CMOS 与非门的分析与设计

5.2 CMOS 或非门的分析与设计

5.3 任意组合逻辑的实现

5.4 类 NMOS 电路结构和特性

5.5 MOS 传输门逻辑结构和特性

（二）教学基本要求

1、掌握：CMOS 与非门/或非门、组合逻辑及传输门的特性

2、理解：CMOS 逻辑电路

3、了解：CMOS 与非门/或非门的设计、CMOS 逻辑门实现及传输门逻辑结构和特性

第六章 动态 CMOS 逻辑电路

（一）教学基本内容

6.1 P-E 动态 CMOS 逻辑电路结构及特性

6.2 DominoCMOS 电路的结构及特性

6.3 C^2MOS 电路的结构及特性

（二）教学基本要求

1、掌握：各种 CMOS 逻辑电路结构及特点

2、理解：各种 CMOS 逻辑电路工作原理

3、了解：P-E 动态 CMOS 逻辑电路、DominoCMOS 电路、C^2MOS 电路的结构及特性

第七章 CMOS 逻辑电路的功耗

（一）教学基本内容

7.1 CMOS 逻辑电路的功耗来源（动态功耗、短路功耗和静态功耗）

7.2 影响功耗的一些主要因素的分析

（二）教学基本要求

1、掌握：CMOS 逻辑电路的功耗

2、理解：CMOS 逻辑电路功耗的分析方法

3、了解：CMOS 逻辑电路的功耗来源及影响功耗的一些主要因素

第八章 双极型逻辑电路

（一）教学基本内容

8.1 TTL 逻辑电路

8.2 ECL 逻辑电路

（二）教学基本要求

1、掌握：双极型逻辑电路

2、理解：双极型逻辑电路特点

3、了解：TTL/ECL 逻辑电路

第九章 基本的 BiCMOS 逻辑电路

（一）教学基本内容

9.1 BiCMOS 反相器的结构与特性

9.2 基本的 BiCMOS 逻辑门

9.3 BiCMOS 与 CMOS 性能比较

（二）教学基本要求

1、掌握：基本的 BiCMOS 逻辑电路

2、理解：BiCMOS 逻辑电路

3、了解：基本的 BiCMOS 逻辑电路结构与特性

第十章 MOS 存储器

（一）教学基本内容

10.1 MOS 存储器的分类，存储器的总体结构

10.2 DRAM 和 SRAM 的单元结构

（二）教学基本要求

1、掌握：MOS 存储器的分类，存储器的总体结构

2、理解：存储器的技术指标

3、了解：DRAM 和 SRAM 的单元结构

4、课程学时分配

教学内容	讲授	实验	上机	课内学时小计	课外学时
第一章　绪论	2			2	
第二章　集成电路基本结构和制作工艺	4			4	

第三章　集成电路中的元器件	2			2	
第四章　MOS 反相器	6			6	
第五章　静态 CMOS 逻辑电路	4			4	
第六章　动态 CMOS 逻辑电路	4			4	
第七章　CMOS 逻辑电路的功耗	2			2	
第八章 双极型逻辑电路	4			4	
第九章 基本的 BiCMOS 逻辑电路	2			2	
第十章 MOS 存储器	2			2	
合　计	32			32	

5、实践性教学内容的安排与要求

本课程与单独设置的《数字集成电路设计实验》实验课程相配合，通过实践使学生加深对理论的认识，增强处理问题的能力。

6、教学设计与教学组织

本课程是微电子专业必修课，学生在熟悉前期的集成电路课程基础上，通过本课程学习能掌握数字集成电路设计的基本原理和方法，建立起从基本模块到系统的分析方法和设计流程，为后续的专业课程的学习奠定坚实的理论基础和实践能力。

本课程结合教学内容与要求、学生学习基础、课程性质与目标等因素，充分利用现代信息技术等教学手段，设计合适的学生学习的教学教法。

通过本课程精心的教学设计与教学组织，并结合文献及相关数字集成电路设计的最新发展趋势，开展思政教育，提高学生对专业的认知程度及学习主动性，将立德树人的日常要求与学生的学习态度和学习目的有机结合，实现专业教育与思政教育的统一。

7、教材与参考资料

1.教材

《数字集成电路分析与设计》， 杨兵译，国防工业出版社 2013，ISBN：9787118085686

2.参考资料

《CMOS 电路设计、布局和仿真》，陈中建译，机械工业出版社 2005，ISBN：7111165047

8、课程考核方式与成绩评定标准

本课程考核采用闭卷考试形式，考核内容包括教材及课堂讲授涉及的知识点、理论和方法，考核要求学生掌握本课程的主要理论知识和基本测试方法。本课程成绩采用百分制，总评成绩由平时成绩和期末成绩两部分组成，平时成绩占30% （其中出勤成绩占10%，作业成绩占10%，实验成绩占10%），期末考试成绩占70%。

本课程考核注重过程性考核，通过理论知识学习、实验及考试等手段，全方位调动学生积极主动的学习精神和学习热情，将立德树人的日常要求与课程考核实现有机结合，使思政教育的学习效果在课程考核方式中得到充分体现。

9、大纲制(修)订说明

制定大纲需要阅读与课程相关的参考文献和专著，并熟悉相关软件的使用。

大纲执笔人：杨兵
大纲审核人：张静
开课系主任：张静
开课学院教学副院长：宋威
制（修）订日期：2022 年 2 月

Design of Digital Integrated Circuits
syllabus

1、Basic Information of Course

<table>
<tr><td rowspan="2">Course Type</td><td>Total hours:
Class hours:</td><td colspan="4">☑ Theory courses (including computer and experiment hours)</td></tr>
<tr><td>Total hours:
Weeks</td><td colspan="4">□Practicum □Course design □Graduation design</td></tr>
<tr><td>Course Code</td><td>7235321</td><td>Course hours</td><td>32</td><td>Credits</td><td>2</td></tr>
<tr><td>Course Name</td><td colspan="5">数字集成电路设计</td></tr>
<tr><td>Course Title</td><td colspan="5">Design of Digital Integrated Circuits</td></tr>
<tr><td>Applicable Speciality</td><td colspan="5">Microelectronics Science and Engineering</td></tr>
<tr><td>Prerequisites</td><td colspan="5">（7069201）Analog Electronics、（7087611）Digital Electronics、（7005321）Semiconductor Physics、（7119421）Application Specific Integrated Circuit Design</td></tr>
<tr><td>Department</td><td colspan="5">Department of Electronic Engineering, School of Information</td></tr>
</table>

2、Description and Learning Outcomes

This course is a compulsory course for undergraduates majoring in microelectronics science and engineering. Lay a solid foundation for students to engage in the design, manufacturing and Application Research of digital integrated circuits in the future. The purpose is to make students familiar with the study of common circuit structure and working principle of digital integrated circuits, master the basic knowledge related to digital integrated circuits, understand the design methods and processes and various factors to be considered in the design of digital integrated circuits, Cultivate students' theoretical and practical abilities in digital integrated circuits.

Objective 1：Students should master the basic knowledge of digital integrated

circuits;

Objective 2：Students should understand the common circuit structure, working principle and various factors affecting the performance of digital integrated circuits;

Objective 3：Students should be able to actually design digital integrated circuits;

Ideological and political objectives of the course：According to the characteristics and educational requirements of the course, give full play to the educational function carried by the course, and strengthen students' learning experience and learning effect. Strengthen the ideals and beliefs of loving the party, the country and the profession, cultivate patriotism, strengthen moral cultivation, and cultivate students' scientific spirit, innovative spirit and craftsman spirit.

3、Contents and Requirements

Chapter 1　Overview

（一）Contents

1.1 The development history and current situation of CMOS circuits

1.2 Layout design software and mosis concept

1.3 Brief introduction of BJT / CMOS / Bi-CMOS circuit

（二）Requirements

1、Master：Development history and current situation of digital integrated circuits

2、Understand：Layout design software and mosis concept

3、Know：Basic design and processing flow of integrated circuit

Chapter 2　Basic structure and manufacturing technology of integrated circuit

（一）Contents

2.1 Basic manufacturing technology of CMOS integrated circuit

2.2 BJT integrated circuit structure and technology

2.3 Bi-CMOS manufacturing process

2.4 Design rule

（二）Requirements

1、Master：Basic process flow of integrated circuit processing

2、Understand：Integrated circuit process flow

3、Know：CMOS, BJT and BiCMOS structures and processes, layout design rules

Chapter 3　Components in integrated circuits

（一）Contents

3.1 Basic principle and model parameters of MOS transistor

3.2 Basic principle and model parameters of bipolar transistor

3.3 Passive components in integrated circuits

3.4 Parasitic effects of interconnects in integrated circuits

（二）Requirements

1、Master：Basic principles and model parameters of MOS and BJT, passive components and parasitic effects in integrated circuits.

2、Understand：The significance of MOS and BJT model parameters, the structure of passive components in integrated circuits and the analysis of parasitic effects.

3、Know：Basic components in integrated circuits.

Chapter 4　MOS inverter

（一）Contents

4.1 Bootstrap inverter

4.2 Depleted load inverter (E / D)

4.3 CMOS inverter

4.4 DC and transient characteristics of CMOS inverter

4.5 SPICE simulation of DC and transient characteristics of CMOS inverter

（二）Requirements

1、Master：Differences and functions of MOS inverters

2、Understand：　Inverter circuit structure

3、Know：The function and principle of MOS inverter and SPICE simulation

Chapter 5　Static CMOS logic circuit

（一）Contents

5.1 Analysis and design of CMOS NAND gate

5.2 Analysis and design of CMOS nor gate

5.3 Implementation of arbitrary combinational logic

5.4 Structure and characteristics of NMOS like circuits

5.5 Logic structure and characteristics of MOS transmission gate

（二）Requirements

1、Master：Characteristics of CMOS NAND gate / NOR gate, combinational logic and transmission gate

2、Understand：Basic static CMOS logic circuit

3、Know：Design of CMOS NAND gate / NOR gate, implementation of CMOS logic gate and logic structure and characteristics of transmission gate

Chapter 6　Dynamic CMOS logic circuit

（一）Contents

6.1 Structure and characteristics of P-E dynamic CMOS logic circuit

6.2 Structure and characteristics of domino CMOS circuit

6.3 Structure and characteristics of c^2mos circuit

（二）Requirements

1、Master：Various CMOS logic circuit structures and characteristics

2、Understand：Working principle of various CMOS logic circuits

3、Know：Design of P-E dynamic CMOS logic circuit, domino CMOS circuit and c^2mos circuit Structure and characteristics

Chapter 7 Power consumption of CMOS logic circuits

（一）Contents

7.1 Power sources of CMOS logic circuits (dynamic power consumption, short-circuit power consumption and static power consumption)

7.2 Analysis of some main factors affecting power consumption

（二）Requirements

1、Master：Power consumption of CMOS logic circuits

2、Understand：Analysis method of CMOS logic circuit power consumption

3、Know：The power source of CMOS logic circuit and some main factors affecting power consumption

Chapter 8 Bipolar logic circuit

（一）Contents

8.1 TTL logic circuit

8.2 ECL logic circuit

（二）Requirements

1、Master：Bipolar logic circuit

2、Understand：Characteristics of bipolar logic circuit

3、Know：TTL / ECL logic circuit

Chapter 9 Basic BiCMOS logic circuit

（一）Contents

9.1 Structure and characteristics of BiCMOS inverter

9.2 Basic BiCMOS logic gate

9.3 Performance comparison between BiCMOS and CMOS

（二）Requirements

1、Master：Basic BiCMOS logic circuit

2、Understand：BiCMOS logic circuit

3、Know：Basic BiCMOS logic circuit structure and characteristics

Chapter 10 MOS memory

（一）Contents

10.1 Classification of MOS memory and overall structure of memory

10.2 Cell structure of DRAM and SRAM

（二）Requirements

1、Master：Classification of MOS memory and overall structure of memory

2、Understand：Technical specifications of memory

3、Know：Cell structure of DRAM and SRAM

4、Time Allocation

Contents	Lecture	Experiment	Computer	In-class hours	Outside school hours
Chapter 1 Overview	2			2	
Chapter 2 Basic structure and manufacturing technology of integrated circuit	4			4	
Chapter 3 Components in integrated circuits	2			2	
Chapter 4 MOS inverter	6			6	

Chapter 5 Static CMOS logic circuit	4			4	
Chapter 6 Dynamic CMOS logic circuit	4			4	
Chapter 7 Power consumption of CMOS logic circuits	2			2	
Chapter 8 Bipolar logic circuit	4			4	
Chapter 9 Basic BiCMOS logic circuit	2			2	
Chapter 10 MOS memory	2			2	
total	32			32	

5、Contents and Requirements of Practice

This course is combined with the experimental course of digital integrated circuit design experiment, which is set separately. Through practice, students can deepen their understanding of theory and enhance their ability to deal with problems.

6、Teaching Design and Teaching Organization

This course is a compulsory course for microelectronics majors. On the basis of being familiar with the early integrated circuit courses, students can master the basic principles and methods of digital integrated circuit design through this course, establish the analysis methods and design processes from basic modules to systems, and lay a solid theoretical foundation and practical ability for the subsequent professional courses.

This course combines the teaching content and requirements, students' learning basis, course nature and objectives, and makes full use of modern information technology and other teaching means to design appropriate teaching methods for students' learning.

Through the careful teaching design and teaching organization of this course, and in combination with the latest development trend of literature and relevant digital integrated circuit design, carry out ideological and political education, improve students' cognition of the major and learning initiative, organically combine the daily requirements of establishing morality and cultivating people with students' learning attitude and learning purpose, and realize the unity of professional education and

ideological and political education.

7、Textbook and Reference

1. Textbook

《Digital Integrated Circuits Analysis and Design》 Translated by Yang Bing，National Defence Industry Press,2013,ISBN: 9787118085686

2. Reference

《CMOS circuit Design、Layout and Simulate》,Translated by Chen Zhongjian,China Machine Press, 2005,ISBN: 7111165047

8、Assessment Method and Achievement Evaluation Standard

The assessment of this course adopts the form of closed book examination. The assessment content includes the knowledge points, theories and methods involved in teaching materials and classroom teaching. The assessment requires students to master the main theoretical knowledge and basic test methods of this course. The score of this course adopts the hundred mark system. The total score is composed of usual score and final score. The usual score accounts for 30% (including attendance score of 10%, homework score of 10%, experimental score of 10%) and final exam score of 70%.

The assessment of this course focuses on the process assessment. By means of theoretical knowledge learning, experiment and examination, students' active learning spirit and learning enthusiasm are mobilized in an all-round way, and the daily requirements of Building Morality and cultivating people are organically combined with the course assessment, so that the learning effect of Ideological and political education can be fully reflected in the course assessment method.

9、Explanation

To make the outline, you need to read the references and monographs related to the course, and be familiar with the use of relevant software.

Written by： Yang Bing
Authorized by： Zhang Jing
Dean of the dept： Zhang Jing
Dean of the college： Song Wei
Date: 2022.02