

课程详述

COURSE SPECIFICATION

以下课程信息可能根据实际授课需要或在课程检讨之后产生变动。如对课程有任何疑问，请联系授课教师。

The course information as follows may be subject to change, either during the session because of unforeseen circumstances, or following review of the course at the end of the session. Queries about the course should be directed to the course instructor.

1.	课程名称 Course Title	功率半导体器件与应用 Power Semiconductor Devices and Application
2.	授课院系 Originating Department	电子与电气工程系 Department of Electrical and Electronic Engineering
3.	课程编号 Course Code	EE347
4.	课程学分 Credit Value	3
5.	课程类别 Course Type	专业选修课 Major Elective Courses
6.	授课学期 Semester	春季及秋季 Spring and Fall
7.	授课语言 Teaching Language	中英双语 English & Chinese
8.	授课教师、所属学系、联系方式（如属团队授课，请列明其他授课教师） Instructor(s), Affiliation & Contact (For team teaching, please list all instructors)	化梦媛，电子与电气工程系，huamy@sustc.edu.cn Mengyuan HUA, Department of Electrical and Electronic Engineering, huamy@sustc.edu.cn
9.	实验员/助教、所属学系、联系方式 Tutor/TA(s), Contact	无 NA
10.	选课人数限额(可不填) Maximum Enrolment (Optional)	

11. 授课方式 Delivery Method	讲授 Lectures	习题/辅导/讨论 Tutorials	实验/实习 Lab/Practical	其它(请具体注明) Other (Please specify)	总学时 Total
学时数 Credit Hours	48	0	0	0	48
12. 先修课程、其它学习要求 Pre-requisites or Other Academic Requirements	EE203 固态电子学 Solid-State Electronics Or EE204 半导体器件导论 Introduction to Semiconductor Devices				
13. 后续课程、其它学习规划 Courses for which this course is a pre-requisite	无 NA				
14. 其它要求修读本课程的学系 Cross-listing Dept.	无 NA				

教学大纲及教学日历 SYLLABUS

15. 教学目标 Course Objectives

本课程通过对功率半导体器件、驱动及保护电路、交流-直流(AC-DC)变换电路、直流-直流(DC-DC)变换电路、直流-交流(DC-AC)变换电路、交流-交流(AC-AC)变换电路、软开关技术等内容的学习，来培养学生理解掌握各种电力电子器件（包括 pn 结，p-i-n 结，BJT，HBT，MOSFET，JFET，晶闸管，IGBT，III-V 族宽禁带半导体器件等）的基本工作原理、基本特性、主要参数和应用知识，掌握磁性元器件、电容原件的基本设计方法。根据设计要求，能够合理选择各种常用电力电子器件，并能设计功率半导体器件的驱动、缓冲、保护等外围电路。使学生掌握功率半导体器件设计理论和初步的设计制作经验，为学生以后开展功率半导体器件领域的研究、设计与应用开发做好铺垫。

This course will involve the introduction of power semiconductor devices, driver and protection circuits, (AC-DC) rectifier, (DC-AC) inverter, (AC-AC) cycloconverter, (DC-DC) chopper, soft switching et al. Based on the study, students will understand the operation principles, electrical characteristics, basic performance and application of various power semiconductor devices (including pn junction, p-i-n junction, BJT, MOSFET, JFET, IGBT, III-V based power electronics, et al.), as well as the fundamental design methodology of power semiconductor devices for applications in convertors and invertors. The students should have the ability of choosing suitable power devices to design the gate driver and protection circuit according to specific requirements. In general, this course will give students a good overview of the power semiconductor device techniques and applications, which will be helpful for their further investigation and study in the semiconductor field.

16. 预达学习成果 Learning Outcomes

通过功率半导体器件与应用的学习，学生应达到以下要求：

1. 熟悉功率半导体器件，包括 **pn 结**，p-i-n 结，BJT，HBT，MOSFET，JFET，晶闸管，IGBT，III-V 族宽禁带半导体器件等。（粗体表示要求有深刻理解）；
2. 熟悉交流-直流(AC-DC)变换电路、直流-直流(DC-DC)变换电路、直流-交流(DC-AC)变换电路、交流-交流(AC-AC)变换电路、软开关技术；
3. 了解功率半导体器件的驱动、缓冲、保护等外围电路；
4. 掌握各类电能变换的基本原理、各电力电子变换装置的电路结构、基本原理、控制方法、设计计算；
5. 具有初步设计、调试、分析电力电子变换装置的基本能力。

The students will meet the requirements below after learning this course:

1. Familiar with power semiconductor devices, including **p-n junction**, p-i-n junction, **BJT**, HBT, **MOSFET**, JFET,

<p>Thyristor, IGBT, III-V wide-bandgap power electronics, et al. (Bold means requiring in-depth understanding);</p> <p>2. Understand the basic concepts of converters, including (AC-DC) rectifier, (DC-AC) inverter, (AC-AC) cycloconverter, (DC-DC) chopper, and soft switching techniques;</p> <p>3. Know about the driver, snubber and protection circuits</p> <p>4. Understand the basic operation principles of energy conversation and the circuit structure, design methodology, control principles of various power converters;</p> <p>Have the ability of designing, adjusting, and analysis the power semiconductor convertors</p>

17. 课程内容及教学日历（如授课语言以英文为主，则课程内容介绍可以用英文；如团队教学或模块教学，教学日历须注明主讲人）

Course Contents (in Parts/Chapters/Sections/Weeks. Please notify name of instructor for course section(s), if this is a team teaching or module course.)

序号	章节	内容	学时
1	绪论	功率半导体器件发展，典型功率器件，单极功率器件，双击功率器件，理想器件特性	1 学时
2	材料特性和输运物理	基本特性，电阻率，复合寿命，击穿电压，结终端设计	2 学时
3	异质结整流器	功率二极管和 p-i-n 整流器基本原理，金属-半导体接触，导通阻断特性，器件电容，器件工艺，应用，和封装	3 学时
4	功率 MOS 场效应晶体管	器件元胞结构和工作原理，阻断电压，正向导通特性，功率 MOSFET 结构设计，输运特性，栅极电荷，体二极管，开关特性，高频区域优化。	4 学时
5	功率双极结型晶体管和晶闸管	功率双极结型晶体管电流增益，输出/导通/开关特性。晶闸管工作原理，结构和应用	3 学时
6	绝缘栅双极晶体管	基本器件结构，工作和输出特性，通态阻断特性，饱和电流模型，功耗优化，寿命控制技术	3 学时
7	新型功率开关器件	宽禁带半导体功率器件（包括 GaN HEMT，SiC MOSFET），及其他新型功率开关器件	4 学时
8	功率半导体器件的驱动与保护	晶体管的驱动与保护、电流型自关断器件的驱动、电压型自关断器件的驱动、自关断器件的保护等内容。	4 学时
9	课程期中考试	课程期中测试	3 学时
10	交流-直流(AC-DC)变换	单相可控整流电路、三相可控整流电路、可控整流的逆变工作状态、电容滤波的不控整流电路、整流电路的谐波及功率因数、大功率整流电路等内容。	3 学时
11	直流-直流(DC-DC)变换	DC-DC 变换的基本控制方式、基本直流斩波电路、晶闸管斩波器、桥式可逆斩波器等内容。	3 学时
12	直流-交流(DC-AC)变换	逆变电路概述、负载谐振式逆变电路、强迫换流式逆变器、逆变电路的多重化与多电平化*、脉宽调制型(PWM)逆变电路、PWM 整流技术*等内容。	3 学时
13	交流-交流(AC-AC)变换	交流调压电路、交-交变频电路、矩阵式变换电路*等内容。	2 学时
14	谐振软开关技术	谐振软开关电路	2 学时
15	电力电子技术应用	晶闸管-直流电动机调速系统、晶闸管无换向器电机、异步电机变频	2 学时

	气工程中的应用	调速系统、变速恒频发电、有源电力滤波器（APF）、不间断电源（UPS）、静止无功补偿（SVC、静止无功发生器（SVG）、高压直流输电（HVDC）、灵活交流输电系统（FACTS）等内容，可根据需要选择部分内容介绍。	
16	课程期末报告	分组课程项目报告	6 学时
No.	Chapter	Content	Period
1	Introduction	Development of power semiconductor devices, ideal and typical power devices, Unipolar and bipolar power devices, ideal device characteristics	1
2	Material Properties and Transport Physics	Fundamental properties, carrier mobility, resistivity, recombination lifetime, breakdown voltage, edge termination design	2
3	Heterojunction Rectifier	Principles of power p-n and p-i-n rectifier, metal-semiconductor contact, forward conduction, reverse blocking, capacitance, fabrication process, application, and seal	3
4	Power MOSFETs	Device cell structure and operation, reverse blocking, forward conduction, structure design, transfer characteristics, gate charge, body diode, switching performance and optimization for high-frequency application	4
5	Bipolar Junction Transistors and Thyristors	Power bipolar junction transistor structure, current gain, transfer/conduction/reverse blocking characteristics, thyristors work principles, structure design and application	3
6	Insulated Gate Bipolar Transistors (IGBT)	Basic device structures, forward operation and transfer characteristics, reverse blocking, model of saturation current, optimization of energy loss, lifetime control techniques	3
7	Next Generation Power Switching Devices	Wide bandgap semiconductor power devices, GaN HEMT, SiC MOSFET, and the other novel switching power devices	4
8	Driver and Protection Circuit for Power Semiconductor Devices	Transistor driver and protection circuit, current-mode self-shutdown device driver, voltage-type self-shutdown device driver, self-shutdown device protection, etc.	4
9	Mid-Term Test	Mid-Term Test	3
10	AC to DC Rectifier	Single-phase controllable rectifier circuit, three-phase controllable rectifier circuit, inverter working state of controlled rectifier, uncontrolled rectifier circuit of capacitor filter, harmonic and power factor of rectifier circuit, high-power rectifier circuit, etc.	3
11	DC to DC Chopper	The basic control method of DC-DC conversion, basic DC chopper circuit, thyristor chopper, bridge reversible chopper and so on.	3
12	DC to AC Inverter	Overview of inverter circuit, load resonant inverter circuit, forced commutation inverter, multi-level and multi-level inverter circuit, pulse width modulation (PWM) inverter circuit, PWM rectification	3

		technology, etc. .	
13	AC to AC Cyclo-converter	AC voltage regulator circuit, AC-AC inverter circuit, matrix converter circuit, etc.	2
14	Resonant Soft Switching Technology	Resonant soft switching circuits	2
15	Application of Power Electronics Technology in Electrical Engineering	Introduction to thyristor-DC motor speed control system, thyristor commutator motor, asynchronous motor variable frequency speed control system, variable speed constant frequency power generation, active power filter (APF), uninterruptible power supply (UPS), static reactive power compensation (SVC, Static var generator (SVG), high-voltage direct current (HVDC), flexible AC transmission system (FACTS), etc., can be selected according to the needs of some content.	2
16	Final Report	Presentation by group	6

18. 教材及其它参考资料 Textbook and Supplementary Readings

<p>Main Textbook</p> <p>B. J. Baliga, <i>Fundamentals of Power Semiconductor Devices</i>, Springer, 2008, ISBN: 780387473147.</p> <p>Supplemental Textbooks</p> <p>B. El-Kareh and L. N. Hutter, <i>Silicon Analog Components</i>, Springer Publishing, 2015, DOI 10.1007/978-1-4939-2751-7.</p> <p>Farid Medjdoub and Krzysztof Iniewski, Eds., <i>Gallium nitride (GaN) physics, devices and technology</i>, CRC Press, 2015, ISBN 9781482220032.</p>

课程评估 ASSESSMENT				
19. 评估形式 Type of Assessment	评估时间 Time	占考试总成绩百分比 % of final score	违纪处罚 Penalty	备注 Notes
出勤 Attendance				
课堂表现 Class Performance				
小测验 Quiz				
课程项目 Projects		20		
平时作业 Assignments		20		
期中考试 Mid-Term Test		20		
期末考试 Final Exam		0		
期末报告		40		

Final Presentation
其它（可根据需要
改写以上评估方
式）
**Others (The
above may be
modified as
necessary)**

20. 记分方式 **GRADING SYSTEM**

A. 十三级等级制 **Letter Grading**
 B. 二级记分制（通过/不通过） **Pass/Fail Grading**

课程审批 REVIEW AND APPROVAL

21. 本课程设置已经过以下责任人/委员会审议通过
This Course has been approved by the following person or committee of authority

