Transport Phenomena in Solid State Devices – EE 471

School of Engineering and Science

Spring 2018

Meeting Times:	Tuesday	5:00 –5:50 pm
	Friday	3:00 – 5:30 pm
Instructor:	Prof. Bryan Ackland	
Contact Info:	Burchard 211, backland@stevens.edu, (201) 216-8096	
Office Hours:	Wednesday 9:30 am – 11:30 am	
	Thursday 10:00 am – 12:00 noon	
	Other times by appt. or just stop by my office	
Course Web:	http://personal.stevens.edu/~backland/Courses/Course471_Spring_18.htm	
Prerequisite(s):	E 232 – Design IV	
	E 245 – Circuits and Systems	
Corequisite(s):	None	
Cross-listed with:	None	

COURSE DESCRIPTION

This course provides an introduction to the underlying phenomena and operation of solid state electronic and optical devices essential to the functioning of computers, communications and other electronic systems. Semiconductor properties are explained and analyzed in terms of charge carrier concentrations and quantum energy band diagrams. Concepts of carrier drift (due to electric fields) and carrier diffusion (due to density gradients) are combined with those of carrier generation and recombination to produce continuity and diffusion equations for the analysis of solid state devices. Optical energy absorption and emission is related to band gap energy levels in solid-state materials. Explanations and models of the operation of PN and metal-oxide-semiconductor junctions are used to describe the operation of devices including diodes, MOS transistors, photodiodes and lasers.

The course also covers the fabrication and design of CMOS digital integrated circuits. Techniques for estimating the performance and power dissipation of CMOS circuits are explained. Students are also introduced to SPICE circuit simulation as a means of verifying the function and performance of CMOS transistor level circuits. Students complete a project in which they use SPICE to analyze the behavior of solid state devices and compare their results to theoretical predictions

LEARNING OBJECTIVES

After successful completion of this course, students …

- Understand the difference between conductors, insulators and semiconductors and how very small levels of dopant impurities can drastically change the electrical properties of semiconductor materials.
- Understand the concepts of valence and conduction bands, holes and electrons, band gap, Fermi level and majority and minority carrier densities and how these affect device behavior.

- Understand the role of electric fields and density gradients in the transport of charge in semiconductors; the dependence of resistivity on carrier mobility and carrier density and the relationships between charge, electric field and potential in semiconductor devices
- Understand the development of device models for the PN junction diode from the underlying physical laws governing carrier generation and recombination.
- Understand the interaction of photons with atoms and carriers and how these interactions lead to the development of photodiodes, solar cells, LEDs and semiconductor lasers.
- Understand the band structure and behavior of the MOS capacitor and the concepts of carrier accumulation, depletion and inversion.
- Understand the derivation of simple models that describe the operation of the MOS transistor in the cut-off, linear and saturation regions, and the impact of short-channel effects on the performance of these devices.
- Understand how MOS transistors can be used to build digital circuits, including the physical layout of simple CMOS gates. The student will be able to predict the area, performance and power dissipation of CMOS gates given transistor sizes and process device parameters.
- Understand the basic principles underlying the fabrication of semiconductor devices.

FORMAT AND STRUCTURE

This course is comprised of two lectures (one 50 minute and one 150 minute) per week.

COURSE MATERIALS

Textbook(s): Modern Semiconductor Devices for Integrated Circuits, Chenming Hu, Publisher: Prentice Hall, ISBN: 0-13-608525-3, 2010.

Other Ref: (1) Semiconductor Physics and Devices, 4th edition, D. Neaman, McGraw Hill, ISBN 978-0-07-352958-5, 2012.

(2) CMOS VLSI Design: A Circuits and Systems Perspective, 4th Edition, N. Weste and D. Harris, Publisher: Addison Wesley, ISBN: 0-321-54774-8, 2010.

Materials: Stand-alone scientific calculator

COURSE REQUIREMENTS

Attendance Counts towards 5% of final grade. Each student is permitted (2) unexcused absences per semester without penalty.

Participation Up to (2) grade points bonus will be awarded to students who participate by frequently asking and answering questions in class

Homework There are usually nine (9) homework assignments throughout the course. All assignments count equally towards 20% of the final grade. All assignments should be submitted on the due date during class to the professor via hard copy. Homework assignments will be graded and returned within two class periods.

Project Students will complete a project of their own choosing in which they simulate a single device or a small circuit and compare the simulated performance with that predicted by the models they have developed in the course. The project is graded according to difficulty, accuracy of the results and quality of the presentation.

Exams There will be two exams in this course; a midterm and a final. The final exam is cumulative. The midterm will be taken in class according to the published class schedule. The final exam will normally take place during exam week; the time and place will be determined by the Registrar.

GRADING PROCEDURES

Grades will be based on:

Attendance	(5 %)
Homework	(20 %)
Project	(15 %)
Midterm	(30 %)
Final	(30 %)

ACADEMIC INTEGRITY

Undergraduate Honor System

Enrollment into the undergraduate class of Stevens Institute of Technology signifies a student's commitment to the Honor System. Accordingly, the provisions of the Stevens Honor System apply to all undergraduate students in coursework and Honor Board proceedings. It is the responsibility of each student to become acquainted with and to uphold the ideals set forth in the Honor System Constitution. More information about the Honor System including the constitution, bylaws, investigative procedures, and the penalty matrix can be found online at http://web.stevens.edu/honor/

The following pledge shall be written in full and signed by every student on all submitted work (including, but not limited to, homework, projects, lab reports, code, quizzes and exams) that is assigned by the course instructor. No work shall be graded unless the pledge is written in full and signed.

"*I pledge my honor that I have abided by the Stevens Honor System*."

Reporting Honor System Violations

Students who believe a violation of the Honor System has been committed should report it within ten business days of the suspected violation. Students have the option to remain anonymous and can report violations online at www.stevens.edu/honor.

EXAM ROOM CONDITIONS

The following procedures apply to exams for this course. As the instructor, I reserve the right to modify any conditions set forth below by printing revised Exam Room Conditions on the exam.

1. Students may use the following devices during exams. Any electronic devices that are not mentioned in the list below are not permitted.

Device	**Permitted?**	
	Yes	No
Laptops		X
Cell Phones		X
Tablets		X
Smart Watches		X
Google Glass		X
Stand-alone calculator	X	

2. Students may use the following materials during exams. Any materials that are not mentioned in the list below are not permitted.

Material	Permitted?	
	Yes	No
Handwritten Notes	X	
Typed Notes	X	
Textbooks	X	
Other reference books	X	

3. Students are not allowed to work with or talk to other students during exams.

LEARNING ACCOMODATIONS

Stevens Institute of Technology is dedicated to providing appropriate accommodations to students with documented disabilities. Student Counseling and Disability Services works with undergraduate and graduate students with learning disabilities, attention deficit-hyperactivity disorders, physical disabilities, sensory impairments, and psychiatric disorders in order to help students achieve their academic and personal potential. They facilitate equal access to the educational programs and opportunities offered at Stevens and coordinate reasonable accommodations for eligible students. These services are designed to encourage independence and self-advocacy with support from SCDS staff. The SCDS staff will facilitate the provision of accommodations on a case-by-case basis. These academic accommodations are provided at no cost to the student.

Disability Services Confidentiality Policy

Student Disability Files are kept separate from academic files and are stored in a secure location within the office of Student Counseling, Psychological & Disability Services. The Family Educational Rights Privacy Act (FERPA, 20 U.S.C. 1232g; 34CFR, Part 99) regulates disclosure of disability documentation and records maintained by Stevens Disability Services. According to this act, prior written consent by the student is required before our Disability Services office may release disability documentation or records to anyone. An exception is made in unusual circumstances, such as the case of health and safety emergencies.

For more information about Disability Services and the process to receive accommodations, visit https://www.stevens.edu/sit/counseling/disability-services. If you have any questions please contact:

Lauren Poleyeff, Psy.M., LCSW - Disability Services Coordinator and Staff Clinician in Student Counseling and Disability Services at Stevens Institute of Technology at lpoleyef@stevens.edu or by phone (201) 216-8728.

INCLUSIVITY STATEMENT

Stevens Institute of Technology believes that diversity and inclusiveness are essential to excellence in education and innovation. Our community represents a rich variety of backgrounds, experiences, demographics and perspectives and Stevens is committed to fostering a learning environment where every individual is respected and engaged. To facilitate a dynamic and inclusive educational experience, we ask all members of the community to:

- be open to the perspectives of others
- appreciate the uniqueness their colleagues
- take advantage of the opportunity to learn from each other
- exchange experiences, values and beliefs
- communicate in a respectful manner
- be aware of individuals who are marginalized and involve them
- keep confidential discussions private

TYPICAL COURSE SCHEDULE
(Go to course website for exact schedule and homework due dates)

Week	Topic(s)	Notes	Homeworks
1	Class organization Introduction to Solid State Circuits	Lecture 0 Lecture 1	
	Electrons and Holes in Semiconductors	Lecture 2	
2			HW1
	Transport in Semiconductors	Lecture 3	
3			HW2
	Generation & Recombination	Lecture 4	
4	PN Junction	Lecture 5	HW3
5	Optoelectronic Devices	Lecture 6	HW4
6	Midterm Review		
	Midterm Exam		
7	Midterm Solutions		
	MOS Capacitor	Lecture 7	
8			HW5
	MOS Transistor	Lecture 8	
9			HW6
	CMOS Digital Circuits	Lecture 9	
10			
	SPICE Simulation	Lecture 10	HW7 Project
11	CMOS Fabrication & Layout	Lecture 11	HW6

12	CMOS Delay & Transient Response	Lecture 12	HW8
13	CMOS Power Dissipation	Lecture 13	HW9
14	Final Review		
15	Final Exam		