ELC 471
VLSI DESIGN

Course Information **Professor: Orlando Hernandez**

Fall 2008: MR 2:00PM–3:20PM, W 11:00AM–11:50AM, AR 144

Course Description: Structured design methodologies for VLSI systems. Topics include switching models, device equations, combinational and sequential systems design, simulation, timing, verification, and tools for computer-aided design.

Instructor Information:
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Office Hours:
Monday 3:30 PM - 4:50 PM
Thursdays 10:00 AM - 11:20 AM
By appointment (send me email)
And whenever my office door is open

Textbook: *CMOS VLSI Design: A Circuits and Systems Perspective*, Third Edition, by Neil E. Weste and David Harris, Addison-Wesley, 2005.
ISBN 0-321-14901-7

Prerequisite: **Digital Circuits and Microprocessors (ENGR 312)**
Electronics (ELEC 251)
~~Computer Architecture and Organization (ELEC 451)~~

Grading Policy:
Homework 10%
Homework will be announced for each chapter after the chapter has been covered.
Mid-Term Exam 25%
Final Exam 25%
Design Projects 40% (10% for Project #1, 10% for Project #2, and 20% for Project #3)

Tips for Success:
Read the book sections prior to their discussion in class.
Do as much homework as possible. Attempt to do all the problems, even the ones that have not been assigned.
Do not be shy about asking questions, either during class or outside of the class.

Tentative Agenda:

Week	Topics	Reading
1 Monday 8/25	**CMOS PROCESSING TECHNOLOGY** Silicon Semiconductor Technology: An Overview Basic CMOS Technology CMOS Process Enhancements	CHAPTERS 1, 2, 3
2 Monday 9/1	**CMOS PROCESSING TECHNOLOGY** Layout Design Rules Latchup Technology Related CAD Issues **MOS TRANSISTOR THEORY** Introduction MOS Device Design Equations	

Tentative Agenda (continued):

Week	Topics	Reading
3 Monday 9/8	**MOS TRANSISTOR THEORY** The Complementary CMOS Inverter – DC Characteristics Static Load MOS Inverters The Differential Inverter The Transmission Gate The Tristate Inverter	
4 Monday 9/15	**MOS TRANSISTOR THEORY** Bipolar Devices **CIRCUIT CHARACTERIZATION AND PERFORMANCE ESTIMATION** Resistance Estimation Capacitance Estimation Inductance Switching Characteristics	CHAPTERS 4, 5
5 Monday 9/22	**CIRCUIT CHARACTERIZATION AND PERFORMANCE ESTIMATION** CMOS-Gate Transistor Sizing Power Dissipation Sizing Routing Conductors Charge Sharing Design Margining	
6 Monday 9/29	**CIRCUIT CHARACTERIZATION AND PERFORMANCE ESTIMATION** Yield Reliability Scaling of MOS Transistor Dimensions **CMOS CIRCUIT AND LOGIC DESIGN** CMOS Logic Gate Design Basic Physical Design of Simple Logic Gates	CHAPTERS 6, 7
7 Monday 10/6	**TRANSISTOR-LEVEL VLSI DESIGN TOOLS** **DISCUSSION OF DESIGN PROJECT #1** **CMOS CIRCUIT AND LOGIC DESIGN** CMOS Logic Structures Clocking Strategies I/O Structures Low-power Design	
8 Monday 10/13	**TEST #1 (MIDTERM)** **CMOS DESIGN METHODS** Design Strategies CMOS Chip Design Options Design Methods Design-capture Tools	CHAPTER 8
9 Monday 10/20	**CMOS DESIGN METHODS** Design Verification Tools Design Economics	

Tentative Agenda (continued):

Week	Topics	Reading
10 Monday 10/27	**DISCUSSION OF DESIGN PROJECT #2** **CMOS DESIGN METHODS** Datasheets **INTRODUCTION TO VHDL** **INTRODUCTION TO VERILOG** **CHIP-LEVEL VLSI DESIGN TOOLS**	
11 Monday 11/3	**CMOS TESTING** The Need for Testing Manufacturing Test Principles Design Strategies for Test Chip- Level Test Techniques System-Level Test Techniques Layout Design for Improved Testability	CHAPTER 9
12 Monday 11/10	**CMOS SUBSYSTEM DESIGN** Datapath Operations Memory Elements Control	CHAPTERS 10, 11
13 Monday 11/17	**DISCUSSION OF DESIGN PROJECT #3** **CMOS SYSTEM DESIGN EXAMPLE** A TV Echo Canceller	CHAPTER 12
14 Monday 11/24	**CMOS SYSTEM DESIGN EXAMPLE** A 6-bit Flash A/D	
15 Monday 12/1	**CMOS SYSTEM DESIGN EXAMPLE** A Core RISC Microcontroller	
16 Monday 12/8 Monday 12/15	**TEST #2 (FINAL)**	

Educational Objectives

(What TCNJ engineers should be able to accomplish during the first few years after graduation)

The School of Engineering at the College of New Jersey seeks to prepare its graduates:

- To contribute to the economic development of New Jersey and the nation through the ethical practice of engineering;
- To become successful in their chosen career path, whether it is in the practice of engineering, in advanced studies in engineering or science, or in other complementary disciplines;
- To assume leadership roles in industry or public service through engineering ability, communication skills, teamwork, understanding of contemporary global and socio-economic issues, and use of modern engineering tools;
- To maintain career skills through life-long learning and be on the way towards achieving professional licensure.

Electrical and Computer Engineering Program Outcomes

(What TCNJ Electrical and Computer Engineering students are expected to know and be able to do at graduation. What knowledge, abilities, tools and skills the program gives the graduates to enable them to accomplish the Educational Objectives)

The Program Outcomes listed below are expected of all graduates of the Electrical or Computer Engineering Program.

ECE graduates will have:

a. an ability to apply knowledge of mathematics, science and engineering;
Students use binary math and Boolean algebra in homework problems, projects, and exams.

b. an ability to design and conduct experiments, as well as to analyze and interpret data;
Students perform projects that involve experimental hardware setups.

c. an ability to design a system, component, or process to meet desired needs;
Students perform projects that involve design.

d. an ability to function in multidisciplinary teams;

e. an ability to identify, formulate and solve engineering problems;
Students perform projects that involve the solution of engineering problems.

f. an understanding of professional and ethical responsibility;

g. an ability to communicate effectively;

h. the broad education necessary to understand the impact of engineering solutions in a global and societal context;

i. a recognition of the need for and an ability to engage in life-long learning;

j. a knowledge of contemporary issues;

k. an ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
Students use the Mentor IC design tools, the Xilinx ISE design tools, ModelSim, FPGAs, and CPLDs.

l. an ability to analyze and design complex electrical and electronic devices;

m. an ability to analyze and design software and systems containing hardware and software components.

Course Objectives:*

Objective 1: To provide the student with the necessary background to complete CMOS designs. [a, b, c, e, k, n]

Objective 2: To enable the student to assess which particular design style to use on a given design, from Field Programmable Gate Arrays to full custom design. [e, k, n]

Topics Covered:

1. MOS Transistor Theory
2. CMOS Processing Technology
3. Circuit Characterization and Performance Estimation
4. CMOS Circuit and Logic Design
5. CMOS Design Methods
6. CMOS Testing
7. CMOS Subsystem Design

Evaluation:

A. Examinations
B. Homework
C. Project Assignments

Performance Criteria:**

Objective 1:

1.1 Students will understand CMOS chip implementation options ranging from FPGAs to full custom layout. [A, B, C]
1.2 Students will demonstrate an understanding of design issues such as speed, power dissipation, and clocking and subsystem design. [A, B, C]
1.3 Students will demonstrate various methods of designing a testable CMOS circuit. [A, B]

Objective 2:

2.1 Students will demonstrate the trade-offs between implementation, design complexity, and time to market. [A, B, C]
2.2 Students will be familiar with a variety of CMOS design automation options and various design tools used for CMOS design. [C]

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* Small letters in brackets refer to the Program Outcomes
** Capital letters in brackets refer to the evaluation methods used to assess student performance

ELC 471: ADDITIONAL INFORMATION

DESCRIPTION OF DESIGN ACTIVITY

In this course, students will do three design activities. These are the design of a complex digital logic gate, the design of a sequential element, and the design of digital controller in the form of a Finite State Machine (FSM). The first two are industry grade assignments.

REALISTIC CONSTRAINTS

Economic: The cost reduction impact of Very Large Scale Integration (VLSI) semiconductor circuits in the price and performance of modern electronic equipment is covered in this course. The economic tradeoffs of different implementation models for VLSI circuits are also covered, as is the economic impact of VLSI design and test on product yield and profitability.

Environmental: The impact of smaller and more powerful integrated circuits that require less electrical power is discussed in light of the environmental benefits of electronic equipment that requires less energy and less physical space. The issues related to environmentally dangerous chemical substances that are used to manufacture integrated circuits (ICs) are also covered.

Manufacturability: This course covers the manufacturability issues of ICs extensively: manufacturability design rules manufacturability checks by computers, cost of manufacturing tooling, and cost of manufacturing equipment.

Ethical: Issues dealing with intellectual property, as they relate to the design of ICs are discussed in this course.

Health and Safety: The health and safety issues related to dangerous chemical substances that are used to manufacture integrated circuits (ICs) are covered.

Social Impact: The impact that the high levels of functionality possible in modern VLSI circuits has had in the advancement of capabilities of electronic equipment is discussed. Faster, less expensive, and more energy efficient ICs have fueled the advances in the computer industry, which in turn has impacted society greatly. The impact that computers have had in society is

discussed: new computer related laws, computer piracy, hacking, computer crimes, as well as the benefits of computers for society in terms of how society works, learns, and is entertained in entirely new ways that did not exist before the advent of current VLSI technologies.

MODERN ENGINEERING TOOLS

Students get to use the following VLSI design tools: schematic entry, circuit simulation, VLSI layout, circuit extraction, and manufacturability checkers. These tools are part of Mentor Graphics' IC Nanometer Design software suite. Mentor is one of the top two tool vendors.

COMPUTER USAGE

Students use computers during design portion of the course to run the engineering tools, and to prepare reports on design and reading assignments.

FEEDBACK MECHANISMS

Homework: Homework problems are assigned and graded. Not all the problems are graded. These are selected randomly, but students do not know in advanced which problems are going to be graded, so they are behooved to do all assigned problems. These problems are a mixture of analysis and design problems.

Examinations: Students are given a mid-term examination and a final one.

Design Reports: Students are graded on design reports, which include not only the technical aspects, but also the level of communication skills. There are three design assignments.