Course Title: Introduction to VLSI Circuits
Course Code: EL421
Credit Structure (L-T-P-Cr): (3-0-2-4)
Semester: Autumn, 2019
Prerequisites (if any)/Desired Skill Set: Basic Electronics
Instructor: Prof. Tapas Kumar Maiti

Course Objective: The goal of this course is to give the students an understanding and practical implementation of different CMOS circuits, required to carry out a complete VLSI chip design with Silicon CMOS technology. The students will acquire key concepts and skills to become a good IC designers.

Course Content: This course is an introduction to VLSI with focus on CMOS circuits. It will start with VLSI devices and technology where MOS transistor functioned as core, and basic CMOS inverter characteristics. The course consists of three parts: (i) interactive classroom lectures, (ii) practical exercises using software tools, and (ii) project. The course will cover following topics.

Classroom Lecture:
1. Introduction to VLSI
   - Semiconductor Market • Technology Trends • Processor-Chip Development • Design Challenges • Design Methodologies • System-on-Chip Design
2. Physics of MOS Transistors
   - Semiconductor Device Physics • MOSFETs Characteristics • MOSFETs Operation
3. VLSI Process Technology
   - CMOS Fabrication Process • Single Crystal Si-Substrate Growth • Material Transfer Technologies • Pattern Transfer Technologies • Material Removal Technologies • Design Rules • CMOS Layout • Sticks Diagram • Packaging
4. MOSFET Modeling and Simulation
   - VLSI Device Simulation • SPICE Model (Level-1, Level-2, Level-3, BSIM, HiSIM, PSP, etc.) • Circuit Simulation
5. CMOS Inverter
   - CMOS Inverter • Voltage Transfer Characteristic • Inverter Gain • Noise Margins • Transient Response • Rise-Time and Fall-Time • Propagation Delay • Fan-In and Fan-Out • Static Power • Dynamic Power • Leakage • µProcessor Power
6. Static and Dynamic CMOS Logic
   - Pseudo n-MOS Logic • Pass-Transistor Logic • Precharge-Evaluate (PE) Logic • Domino Logic
7. Combinational and Sequential Logic Circuits
   - Combinational Circuit Definition • Logic Depth of a Combinational Circuit • Sequential Circuit Definition • Conventional Sequential Circuit • Ratioed Logic • Latches • Flip flops • Registers • CMOS Schmitt trigger • Monostable and Astable Circuits
8. Clock and Timing
   - Role of the Clock in VLSI Circuits • Clocked Elements • Clock Distribution • Timing Definitions • Synchronous Timing • Timing Constraints • Flip-Flop Based Timing • Latch Timing
9. VLSI Interconnects
   - Resistance, Inductance, and Capacitance, • Vias • RC Delay • Delay Through Metal Layers • Crosstalk • Ground Bounce • Layout Out a Bond Pad
10. VLSI Design Methodologies
    - Introduction to TinyCPU • Full-Custom Design • Semi-Custom Design • Cell-Based Design • Array-Based Design • Floor Planning • Design for Testability • Manufacturing Faults and Test Principles • System-Level Testing • Advanced VLSI • SoC
Lab Assignments:
1. MOSFETs $I_d$-$V_g$/$I_d$-$V_d$ Simulation with SPICE
2. MOSFETs $I_d$-$V_g$/$I_d$-$V_d$ Simulation with SPICE for Different Lg
3. MOSFET Transient Simulation
4. Design, Layout, and Simulation of a CMOS Inverter
5. CMOS Inverter Delay and Power Analysis
6. Design, Layout, and Simulation of a Ring Oscillator
7. Placement of Circuit Layouts in a Pad-Frame for Fabrication

Course Project: AI Chip Design

Practical Information: Visits to the VLSI design research facilities of the VLSI Lab #205. CMOS circuit and layout design shall be carried out in Cadence software.

Suggested Textbook:
2. CMOS VLSI Design: A Circuits and Systems Perspective by Weste & Harris, 3rd ed, Addison Wesley, 2005

References for Project:

Course Evaluation Policy:
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<th>Component</th>
<th>Percentage</th>
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<tr>
<td>In-Semester Examination</td>
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<td>End-Semester Examination</td>
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<td>Labs</td>
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