CMP4202 VLSI Systems Design

Period per Week			Contact Hour per Semester	Weighted Total Mark	Weighted Exam Mark	Weighted Continuous Assessment Mark	Credit Units
LH	PH	TH	CH	WTM	WE	WCM	CU
45	30	00	60	100	60	40	4

Rationale

The design of the integrated circuits used to implement computers and associated hardware contains some core material. This core includes basic properties of materials, the structure of inverters, combinational and sequential logic structures, and memories and logic arrays. This is a very broad area and it is expected that there will be a great deal of variation between programs in the coverage of topics outside the core.

Course Content

1. ***History and Overview***
   - Indicate some reasons for studying VLSI and ASIC design
   - Highlight some people that influenced or contributed to the area of VLSI and ASIC design
   - Indicate some important topic areas such as MOS transistors, inverter structure, circuit performance, combinational and sequential circuits, memory and array structures, chip I/O design, and application-specific integrated circuits
   - Describe a transistor and relate it to a semiconductor
   - Indicate the characteristics of a MOS transistor
   - Describe CMOS transistors and contrast them with MOS technologies
   - Describe some sequential logic circuits such as latches and clock distribution
   - Describe the structure of memory design
   - Contrast memory structures with array structures
   - Contrast the advantages of SRAM and DRAM memory devices
   - Describe at which point a circuit becomes a chip
   - Provide some examples of application-specific integrated circuits
   - Explore some additional resources associated with VLSI and ASIC design
   - Explain the purpose and role of VLSI and ASIC design in computer engineering
2. ***Electronic Properties Of Materials***
   - Solid-state materials
   - Electronics and holes
   - Doping, acceptors and donors
   - p- and n-type material
   - Conductivity and resistivity
   - Drift and diffusion currents, mobility and diffusion
3. ***Function Of The Basic Inverter Structure***
   - Connectivity, layout, and basic functionality of a CMOS inverter
   - The CMOS inverter voltage transfer characteristic (VTC)
   - Analysis of the CMOS VTC for switching threshold, V_{OH}, V_{OL}, V_{IH}, V_{IL}, and noise margins
   - Effect of changing the inverter configuration on the CMOS VTC
   - Connectivity and basic functionality of a Bipolar ECL inverter

- Connectivity and basic functionality of a Bipolar TTL inverter

4. ***Combinational Logic structures***
   - Basic CMOS gate design
   - Layout techniques for combinational logic structures
   - Transistor sizing for complex CMOS logic devices
   - Transmission gates
   - Architectural building blocks (multiplexers, decoders, adders, counters, multipliers)
5. ***Sequential Logic Structures***
   - Storage mechanisms in CMOS logic
   - Dynamic latch circuits
   - Static latch and flip-flop circuits
   - Sequential circuit design
   - Single and multiphase clocking
   - Clock distribution, clock skew
6. ***Semiconductor memories and logic arrays***
   - Latches
   - Flip-flops
   - Dynamic read-write memory (DRAM) circuits
   - Static read-write memory (SRAM) circuits
   - Memory system organization
   - Read-only memory circuits
   - EPROM/EEPROM/Flash memory circuits
   - Programmable Logic Array (PLA) circuits
   - FPGA and related devices
   - Sense amplifiers
7. ***Chip input/output circuits***
   - General I/O pad issues
   - Bonding pads
   - ESD Protection circuits
   - Input, Output, Bidirectional, and analog pads
   - VDD and VSS pads

Learning Outcomes

- Identify some contributors to VLSI and ASIC design and relate their achievements to the knowledge area.
- Define a semiconductor.
- Explain the difference between MOS and CMOS transistors.
- Define a sequential circuit.
- Identify some memory devices related to VLSI circuits.
- Define the meaning of a chip.
- Give an example of an ASIC chip design.
- Describe how computer engineering uses or benefits from VLSI and ASIC design.
- Understand the current carrying mechanism and the I/V characteristics of intrinsic and doped semiconductor materials.
- Understand how these quantities reflect the ability of the inverter to operate in the presence of noise.
- Understand how changing the configuration of the inverter and the MOSFETS that make it up changes the VTC and thus the inverter's operation.
- Understand the method to perform circuit design for CMOS logic gates.
- Understand the techniques, such as Euler paths and stick diagrams, used to optimize the layout of CMOS logic circuits.

- Understand how the size for each transistor in a CMOS logic gate can be determined.
- Understand how to use charge storage (capacitance) and feedback to store values in CMOS logic.

- Understand the circuit design, functionality, advantages, and disadvantages of dynamic latches in CMOS.
- Understand how we organize memory systems and why we do not typically organize them in the most simplistic arrangement such as in a one-dimensional word array.
- Understand the basic steps of photolithography, its limitations, and how that determines minimum line width and device sizes.
- Understand the processing steps required for fabrication of CMOS devises and the general results of each step.

Recommended Books and References

[1] David A. Hodges, Horace G. Jackson, and Resve A. Saleh, *Analysis and Design of Digital Integrated Circuits*, Third Edition, , McGraw-Hill, 2004.

[2] Jan M. Rabaey, Anantha P. Chandrakasan, and Borivoje Nikolic, *Digital Integrated Circuits*, Second Edition, Prentice-Hall, 2002.

[3] Neil H. E. Weste and Kamran Eshraghian, *Principles of CMOS VLSI Design,* Second Edition, Addison Wesley, 1993.

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[5] Sung-Mo (Steve) Kang and Yusuf Leblebici *CMOS Digital Integrated Circuits Analysis and Design*, Third Edition, , McGraw-Hill, 2002.

[6] David A. Johns and Ken Martin, *Analog Integrated Circuit Design,* Wiley, 1997.

[7] Roubik Gregorian, *Introduction to CMOS Op-Amps and Comparators*, Wiley, 1999.

[8] R. Jacob Baker,*CMOS: Circuit Design, Layout, and Simulation*, Revised Second Edition, Wiley-IEEE Press, 2008.

[9] R. Jacob Baker, *CMOS Mixed-Signal Circuit Design*, Second EditionWiley- IEEE Press, 2009.

[10] Adel S. Sedra, Kenneth C. Smith, *Microelectronic Circuits*, Fifth Edition, Oxford University Press, 2003.

[11] R. L. Geiger, P. E. Allen, and N. R. Strader, *VLSI Design Techniques for Analog and Digital Circuits*, McGraw-Hill, 1990.

[12] John P. Uyemura, Brooks/Cole, *Physical Design of CMOS Integrated Circuits Using L-Edit*, 1995.

[13] Clein, Newnes, *CMOS IC Layout,* Dan, 2000.

[14] Ron Kielkowski, Inside *SPICE: Overcoming the Obstacles of Circuit Simulation*, Second Edition, McGraw-Hill, Inc., 1998. ISBN 0-07-913712-1

[15] Daniel Foty, *MOSFET Modeling with SPICE*, Prentice Hall, 1997.

[16] Yannis P. Tsividis, *Operation and Modeling of the MOS Transistor*, McGraw- Hill, 1987.

[17] Ben Streetman, Sanyay Banerjee, *Solid State Electronic Devices,* Fifth Edition, Prentice Hall, 2000.

[18] James D. Plummer, Michael D. Deal, Peter B. Griffin, *Silicon VLSI Technology*, Prentice Hall, 2000.