CMP2203 Digital Logic

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

Rationale

Digital Logic is the foundation of computer engineering. The logic design area covers the digital building blocks, tools, and techniques in the design of computers and other digital systems. This course is designed to introduce students to switching theory, combinational and sequential logic circuits, and memory elements.

Objectives

- Explain the purpose and role of digital logic in computer engineering.
- Emphasize digital logic design as one of the topic areas that differentiate computer engineers from electrical engineers and computer scientists.

Course Outline

1. ***History and Overview***
   - Reasons for study
   - influential persons
   - important topics such as logic circuits, switching, memory, registers, and digital systems; importance of Boolean algebra
   - meaning and importance of sequential logic
   - contrast the meaning of gates, circuits, combinational circuits, and modules
2. ***Switching Theory***
   - Number systems and codes; Binary Arithmetic; Boolean and switching algebra
   - Representation and manipulation of switching functions
   - Minimization of switching functions
   - Incompletely specified switching functions
3. ***Combinational Logic Circuits***
   - Basic logic gates (AND,OR,NOT,NAND,NOR,XOR)
   - Realization of switching functions with networks of logic gates
   - 2-level networks: AND-OR,OR-AND,NAND-NAND,NOR-NOR
   - Multi-level networks
   - properties of logic gates (technology, fan-in, fan-out, propagation delay)
   - Elimination of timing hazards/glitches
4. ***Modular Design of Combinational Circuits***
   - Design of medium scale combinational logic modules
   - Multiplexers, demultiplexers, decoders, encoders, comparators
   - Arithmetic functions (adders, subtracters, carry lookahead)
   - Multipliers, dividers; Arithmetic and logic units (ALUs)
   - Hierarchical design of combinational circuits using logic modules
5. ***Memory Elements***
   - Unclocked and clocked memory devices (latches, flip flops); Level vs. edge-sensitive, and master-slave devices ; Basic flip flops (SR, D, JK, T); Asynchronous flip flop inputs (preset, clear); Timing constraints (setup time,

hold time) and propagation delays Data registers (selection, clocking, timing); Random-access memory (RAM)

6. ***Sequential Logic Circuits***
   - Finite state machines (FSMs), clocked and unclocked; Mealy vs. Moore models of FSMs; Modeling FSM behavior: State diagrams and state tables, timing diagrams, algorithmic state machine charts
   - Analysis of synchronous and asynchronous circuits
   - Design of synchronous sequential circuits: State minimization, state assignment, next state and output equation realization
   - Sequential functional units: Data registers, shift registers, counters, sequence detectors, synchronizers, debouncers, controllers
7. ***Digital Systems Design***
   - Hierarchical, modular design of digital systems
   - Synthesis of digital circuits from HDL models
   - Design principles and techniques: Bridging conceptual levels – top down/bottom up, divide and conquer, iteration, satisfying a behavior with a digital structure
   - Functional units, building blocks and LSI components: Adder, shifter, register, ALU, and control circuits, tri-state devices and buses
   - Control concepts: Register transfer notation, major control state, sequences of micro-operations, conditional execution of micro-operations
   - Timing concepts: System timing dependencies, sequencing, clock generation, distribution, and skew
   - Programmable logic devices (PLDs) and field-programmable gate arrays (FPGAs), PLAs, ROMs, PALs, complex PLDs
8. ***Modeling and Simulation***
   - Schematic capture
   - Hierarchical schematic modeling for complex systems
   - Digital system modeling with hardware description languages (VHDL, Verilog)
   - Other modeling techniques (timing diagrams, register transfer languages, state diagrams, algorithmic state machines)
   - Functional simulation of combinational and sequential circuits
   - Timing models of digital circuit elements: Propagation delay, rise/fall time, setup and hold times, pulse widths
   - Timing simulation to measure delays and study signals subject to timing constraints
9. ***Formal Verification***
   - Relationship of good design practice to formal verification
   - Comparison and contrast of formal verification, validation, testing, and reliability
   - Verification by model checking ; Verification by proofs ; Verification by equivalence checking ; Verification by simulation and test-benches ; Verification by assertions and verification languages ;Verification by testing ; Economics of verification
   - Other verification: signal integrity, specification, reliability, safety, power, cooling
10. ***Faults Models and Testing***

- Logical (stuck-at) faults (single and multiple)
- Other fault models (bridging, opens, delay faults) ; Yield and defect levels ; Test coverage ; Fault equivalence and dominance ; Fault simulation and fault grading
- Test generation algorithms such as the D-algorithm and PODEM
- Automatic Test Pattern Generation (ATPG): Pseudorandom techniques, deterministic test pattern generation
- Test generation algorithms for sequential circuits ; Memory testing ; PLA testing

11. Design for Testability

- Testability measures (controllability, observability)
- Scan and partial scan design
- BIST and other design for testability techniques
- Boundary scan and the IEEE 1149.1 testability standard ; Ad-hoc methods

Learning Outcomes

- Describe how computer engineering uses or benefits from digital logic.
- Work with binary number systems and arithmetic.
- Derive and manipulate switching functions that form the basis of digital circuits.
- Explain and apply fundamental characteristics of relevant electronic technologies, such as propagation delay, fan-in, fan-out, and power dissipation and noise margin.
- Analyze and design combinational logic networks in a hierarchical, modular approach, using standard and custom logic functions.
- Analyze circuits containing basic memory elements.
- Analyze the behavior of synchronous and asynchronous machines.
- Apply digital system design principles and descriptive techniques

Recommended and Reference Books

[1] Stephen Brown, Zvonko Vranesic, 2004. *Fundamentals of Digital Logic with VHDL Design*, McGraw-Hill Professional. ISBN 0072499389, 9780072499384

[2] Douglas A. Pucknell, 1990. Fundamentals of Digital Logic Design with VLSI Circuit Applications, Prentice-Hall

[3] Ronald J. Tocci, 1995. Digital Systems: Principles & Applications, 6th ed., Prentice Hall.