Welcome!

• VLSI Design Workshop
• Andrew Mason
  • Background
    • Associate Professor, Michigan St Univ, East Lansing, Michigan
    • Ph.D., Univ of Michigan, Ann Arbor
    • B.E.E., Georgia Tech, Atlanta Georgia
  • Teaching: 9 years
    • Microelectronics, VLSI & Analog Design
    • Biomedical Instrumentation & Microsystems
  • Research
    • Mixed-signal circuits for sensor readout/interface
    • Bioelectrochemical sensor arrays
    • Neural signal processing hardware (DSP, microcontrollers
    • Low power, hardware efficient, adaptive, “smart” microsystem
Indo-US Collaboration for Engineering Education
Bringing Two Countries Together

*: Where I have lived

Where are you from?
Getting To Know You

• VLSI Teaching Experience
  • none: _6___
  • 1-3 years: _15___
  • 4-6 years: _11___
  • 7-9 years: _____
  • 10+ years: _____

• Education Level
  • BS: _1___
  • MS: ___20___
  • PhD: ___11___

• Current Job
  • Instructor: ___12___
  • Professor: ___20___ (teaching & research)
  • Administrator: _____
Getting to Know You

• Does your VLSI course include homework?
  • Yes ___45%___
  • No _____

• Does your course include lab assignments?
  • Yes ___85%___
  • No _____

• Does your course include a major design project?
  • Yes ___30%___
  • No _____

• What software tools do you use?
  • Cadence ___5___
  • Mentor Graphics _6___
  • Tanner ___8___
  • Synopsys __3__
  • Xilinx _28___
Day 1 Assignment

• Questionnaire (handout)
  • Questions about your interests & goals for workshop
  • Help me focus activities this week
  • Complete tonight & return tomorrow morning
Workshop Objectives

• Present VLSI Design in typical USA university
  • curriculum
  • course components
  • course content
• Discuss issues in teaching VLSI Design in India
  • work toward solutions
• Present & discuss effective teaching practices
• Exercise & evaluate your teaching skills
• Discuss role of research in education and present “new technology” topics
Workshop Approach

- Interactive lectures
  - notes & additional resources posted on a website
- Discussion sessions (DIS)
  - challenges & solutions
- Break-out group (BOG) work
  - effective teaching practices
- Evening homework
  - preparation for in-class lectures
- Flexible schedule: adjust to your needs
- Workshop Website:  http://www.egr.msu.edu/~mason/iucee.html
  - materials for this workshop
  - update with discussion notes throughout workshop
# Workshop Schedule

- **Tentative daily schedule:** may adjust to suit participant interests

<table>
<thead>
<tr>
<th>Time</th>
<th>DAY 1</th>
<th>DAY 2</th>
<th>DAY 3</th>
<th>DAY 4</th>
<th>DAY 5</th>
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</thead>
<tbody>
<tr>
<td>9:00</td>
<td>common session</td>
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<tr>
<td>9:30</td>
<td>Introduction; VLSI Curriculum; Course</td>
<td>Course content: CMOS logic, layout,</td>
<td>Teaching skills; effective lectures</td>
<td>DIS: Research in Education</td>
<td>Research: MEMS &amp; Sensors</td>
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<tr>
<td>10:00</td>
<td>Content Overview</td>
<td>sequential logic</td>
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<tr>
<td>10:30</td>
<td>DIS: Research in Education</td>
<td></td>
<td></td>
<td>New tech. resources</td>
<td></td>
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<tr>
<td>11:00</td>
<td>Components of VLSI Course</td>
<td>Course content: CMOS logic, layout,</td>
<td>Teaching resources; effective homework,</td>
<td>Trends in VLSI</td>
<td>Research: Analog/Mixed-Signal</td>
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<tr>
<td>11:30</td>
<td></td>
<td>sequential logic</td>
<td>exams, labs</td>
<td></td>
<td>Research: Bioelectrochemical System on Chip</td>
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<tr>
<td>12:00</td>
<td>lunch</td>
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<td>12:30</td>
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<td>2:00</td>
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<tr>
<td>2:30</td>
<td>DIS: Challenges to Teaching VLSI</td>
<td>Advanced/grad topics &amp; courses</td>
<td>BOG: Example Problems</td>
<td>BOG: New Technology Lectures</td>
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<tr>
<td>3:00</td>
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<td></td>
<td>BOG: VLSI Course Content Lectures</td>
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<tr>
<td>3:30</td>
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<td>BOG: Lecture Topics</td>
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<tr>
<td>4:00</td>
<td>DIS: VLSI Lab Component</td>
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<tr>
<td>4:30</td>
<td>Free Time</td>
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<tr>
<td>5:00</td>
<td>Questionnaire</td>
<td>Course Lecture</td>
<td>Course Lecture</td>
<td>New Tech Lecture</td>
<td></td>
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</table>
Undergrad VLSI Curriculum

- **Year 1**
  - Math & Science

- **Year 2**
  - Digital Logic Fundamentals
    - number systems, Boolean logic, digital functions, HDL basics

- **Year 3**
  - Microelectronic Circuits
    - semiconductor device models/circuits, small signal analysis, amps
  - Microprocessors
    - microprocessor structure, Assembly language, peripheral functions

- **Year 4**
  - **VLSI Design** (focus: physics, models, layout, CMOS logic)
  - HDL/FPGAs, Operating Systems, Comp. Arch., Networks

*Degree and Sample Programs for EE and CpE at Mich St. Univ available on workshop website*
Discuss Curriculum

• How does this compare/differ to programs in India?
  •
  •
  •

• Is curriculum appropriate for India (or US!)?
  • Does curriculum meet student needs?
    • early motivation
    •
  • Does curriculum meet industry needs?
    •
    •
  • Is it suitable for existing educational programs?
    •
    •
VLSI-Related Course Content

- VLSI Design
- Computer Architecture
- Embedded Systems
- Operating Systems
- HDL/ FPGAs
- Networks
- System/ Software

Science

Device/ Hardware

Applied
Chip Development Cycle

Design Methodologies

- **Top Down Design**
  - coded circuit functionality for rapid design
  - digital only
  - covered in *HDL/FPGA*

- **Bottom Up Design**
  - transistor-level design with focus on circuit performance
  - digital & mixed signal
  - covered in *VLSI Design*
VLSI Design Textbooks

  • probably the most common VLSI text in USA; a bit advanced for some programs

  • easy to teach and learn from; great coverage of layout; Verilog chapter


• ASI C, Smith
Course Topics I

- **CMOS Logic**
  - MOSFET switch, Boolean logic in CMOS

- **CMOS Technology**
  - layers, process flow, parasitics, fabrication techniques
  - critical to understanding performance issues

- **CMOS Layout**
  - design rules, layout principles, stick diagram, cell hierarchy
  - essential for analog/mixed-signal and microsystems

- **MOSFET Physics & Models**
  - semiconductor physics, diode & MOSFET models, CMOS capacitances
  - content varies based on student background

Detailed topic schedule for my VLSI Design course is on the workshop website
Course Topics II

• Digital Gate Analysis
  • transient & DC timing analysis of INV
  • transient & DC analysis of NAND/NOR & beyond
  • static and dynamic power analysis
  • design for performance: transistor sizing
  • critical for cell library design & performance optimization

• Cell Layout & Chip Floorplanning
  • standard cell layout structure, multi-cell layout, power & signal routing, use of metal layers, floorplanning
Course Topics III

• Structure & Operation of Digital Functions
  • Basic Gates (Mux, En/Decoder, FF, Shifters, Registers, etc.)
  • Arithmetic Circuits, mainly adders (Manchester in CMOS)
  • Memory (SRAM, DRAM, ROMs, PROMs, PLA, FPGA)

• Design Project
  • Microprocessor datapath with ALU, SRAM, and shifter

• Advanced Logic Structures
  • dynamic, differential, pass-gate

• Submicron Issues
  • MOSFET submicron models, design considerations/limits, submicron technology (physical structures)
Why These Topics?

Most VLSI-related jobs will be HDL-level design (particularly in India?), sales, or testing. Why not focus on HDL design instead of cell-level design?

• Fundamental science of integrated circuits essential to university-level degree
• Provides understanding of the real/physical operation of electronics; helps students to adapt to evolving technologies
• Critical knowledge for advanced topics
  • low power submicron design
  • analog mixed-signal design
  • MEMS, sensors, microsystems
Discuss Content

• How does this compare/differ to content in India?
  •
  •
  •

• Is content appropriate for India (or US!)?
  • Does it meet student needs?
    •
    •
  • Does it meet industry needs?
    •
    •
• Is it suitable for existing educational programs?
  •
  •
Course Components

- Lectures
- Homework
- Exams
- Lab Assignments & Design Project
- Professional Skills development

Discuss Course Components

- How do these compare to your VLSI course?
  - 
  - 
- Which components are most challenging?
  - 
  -
Course Components: Lectures

• Objective of Lecture Component
  • motivate students
    • enthusiastic, interactive presentation
    • real world (career) relevance
    • “show & tell”
  • teach basic principles
    • equations: clear and as simple as possible
    • figures: illustrate all possible concepts
      A picture is worth 1000 words
  • work example problems
    • extraction of information from problem statement
    • use of equations
    • managing units!

• Discuss Lecture Notes
  • writing on board vs. pre-prepared notes
  • distribute notes or have students write in class
Course Components: Homework

• Objective of Homework
  • motivation to study
  • memorization through experience
  • practice working with new parameters and quantities
    • learning to manage units
  • develop practical feel for realistic values/quantities

• Homework should be a complement to lectures, not an extension into new concepts/material
  • homework content
    • focus on most important course topics
    • expand on examples; integrate concepts into more complex problems
  • time required?
Course Components: Exams

• Objective of Exams
  • motivation to study
  • highlight most important principles
  • provide comparative analysis for grading

• Elements of Exam
  • broad assessment of course knowledge (definitions, terms, etc.)
  • lesser assessment of understanding
  • problems vs. concept assessment?
  • exam reviews?
  • time required?
Course Components: Labs & Projects

• Objective of Lab/Project
  • practical experience with lecture concepts
  • skill with CAD tools; job training
  • motivation factor: thrill of seeing things work

• Elements of Lab/Project
  • topic of Open Discussion session later today
Course Components: Professional Skills

• What are Professional Skills?
  • communication
    • technical writing
    • oral presentations
    • interview skills (confidence)
  • use of engineering software, instruments, etc.
  • knowing where to look for needed information

• All undergraduate courses should contribute to development of Professional Skills
  • choose elements that fit your course & interests
  • better to provide good experience with few elements than bad/weak coverage of all
Open Discussion:
Lab Component

Agenda

• Survey lab components in your courses
  • What do you currently do for lab assignments?

• Outline an example lab sequence

• Discuss alternatives & improvements

NOTE: This session was not covered in the actual workshop
Lab Component: Survey

• Does your current VLSI Design course include
  • schematic entry ______
  • analog simulation ______
  • layout ______
  • DRC, LVS checking ______

• Describe typical lab assignments for your course
  •
  •
  •
  •
  •

• Would you like to (or plan to) expand your lab assignments?
  • What are your challenges doing this?.
Lab Component: Example Lab Sequence

- Prof. Mason’s labs for ECE410: VLSI Design
  - all lab assignments, tutorials, guide documents available at www.egr.msu.edu/classes/ece410/mason/
- Individual Labs (all 1 week labs, ~4-8 hours each, with written report)
  - **Lab 1**: Schematic entry & functional simulation of CMOS INV, NAND & NOR gate
    - focus on learning schematic entry and simulation tools
  - **Lab 2**: Layout, DRC & LVS of INV, NAND & NOR gates
    - focus on learning layout and checking tools
  - **Lab 3**: Schematic, layout, DRC & LVS of MUX(2:1) and XOR
    - focus on layout optimization; design to meet size requirements
  - **Lab 4**: Timing analysis of INV, NAND & NOR gates
    - focus on learning analog simulation tools and DC/transient analysis of logic gates
  - **Lab 5**: Advance simulation: Parametric analysis
    - focus on learning how tools can help design for performance goals; transistor sizing
- Group Labs (done in groups of 3 students)
  - **Lab 6**: Flip-flops, shift registers and counters (schematic, layout, simulation)
    - focus on simulation of complex digital circuits & multi-cell layout
  - **Lab 7**: Introduction to place & route tools
  - Labs 8-10: Related to major team design project
Lab Component: Example Design Project

• Prof. Mason’s design project for ECE410: VLSI Design
  • full description & guide documents available at www.egr.msu.edu/classes/ece410/mason/

• Assignment
  • Design an 8-bit microprocessor datapath
  • Components
    • 8x8 SRAM
    • 8-bit ALU (8-16 functions)
    • barrel shifter
  • Goals
    • proper function and focus on 1 performance parameter (size, speed, power)
    • competitive grading: can expand functionality
  • Tools used
    • schematic entry & functional simulation
    • layout, DRC, LVS
    • detailed timing simulations

• Grading
  • Labs 8-10: Weekly TA check-off of progress
  • Demonstration: in-lab demo to instructor
  • Reports: detailed design report graded by instructor
Lab Component: Alternatives

• What aspects of example lab suit your course?
  •
  •
  •
  •
  •

• How can you improve your labs?
  •
  •
  •
  •
  •