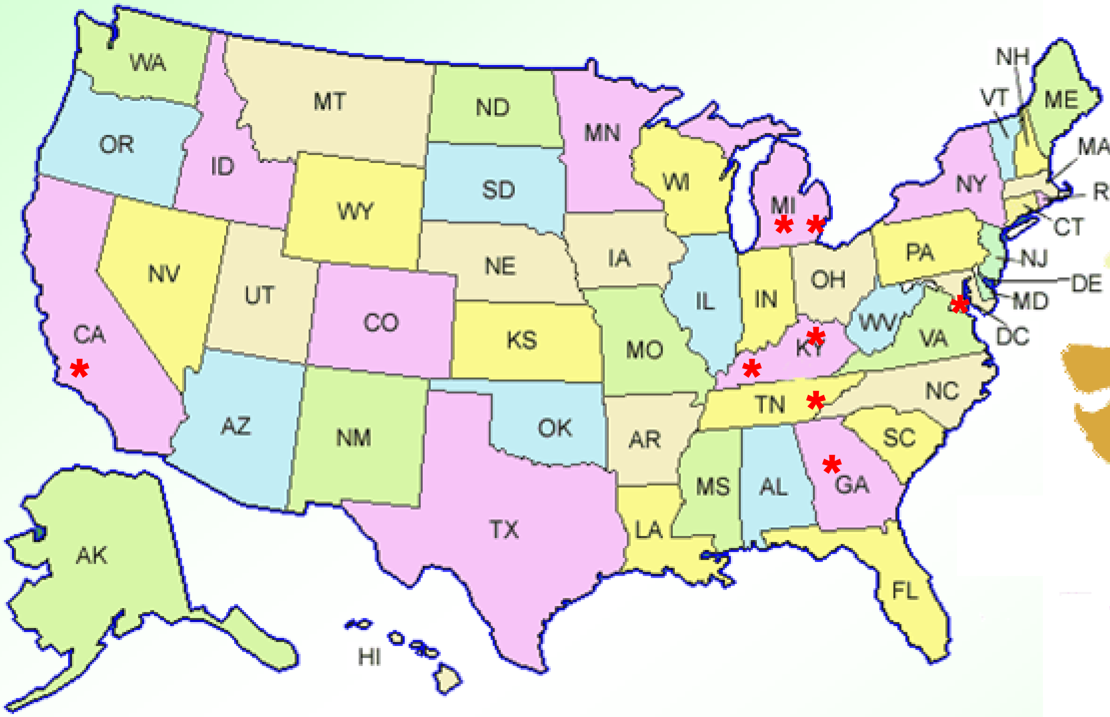
Welcome!

- 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

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
9:00	*common session*	*common session*	*common session*	*common session*	*common session*
9:30	Introduction; VLSI Curriculum; Course Content Overview	Course content: technology & device models	Teaching skills; effective lectures	**DIS: Research in Education**	Research: MEMS & Sensors
10:00					
10:30				New tech. resources	
11:00	Components of VLSI Course	Course content: CMOS logic, layout, sequential logic	Teaching resources; effective homework, exams, labs	Trends in VLSI	Research: Bioelectrochemical System on Chip
11:30				Research: Analog/Mixed-Signal	
12:00					
12:30	*lunch*	*lunch*	*lunch*	*lunch*	*lunch*
1:00					
1:30	*common session*	*common session*	*common session*	*common session*	*common session*
2:00					
2:30	**DIS: Challenges to Teaching VLSI**	Advanced/grad topics & courses	**BOG: Example Problems**	**BOG: VLSI Course Content Lectures**	**BOG: New Technology Lectures**
3:00					
3:30		**BOG: Lecture Topics**			
4:00	**DIS: VLSI Lab Component**		**BOG: Homework Problems**		**DIS: Summary & Take Home Lessons**
4:30		***Free Time***		**DIS: Engaging in Research**	
5:00					
	Questionnaire	*Course Lecture*	*Course Lecture*	*New Tech Lecture*	

Undergrad VLSI Curriculum

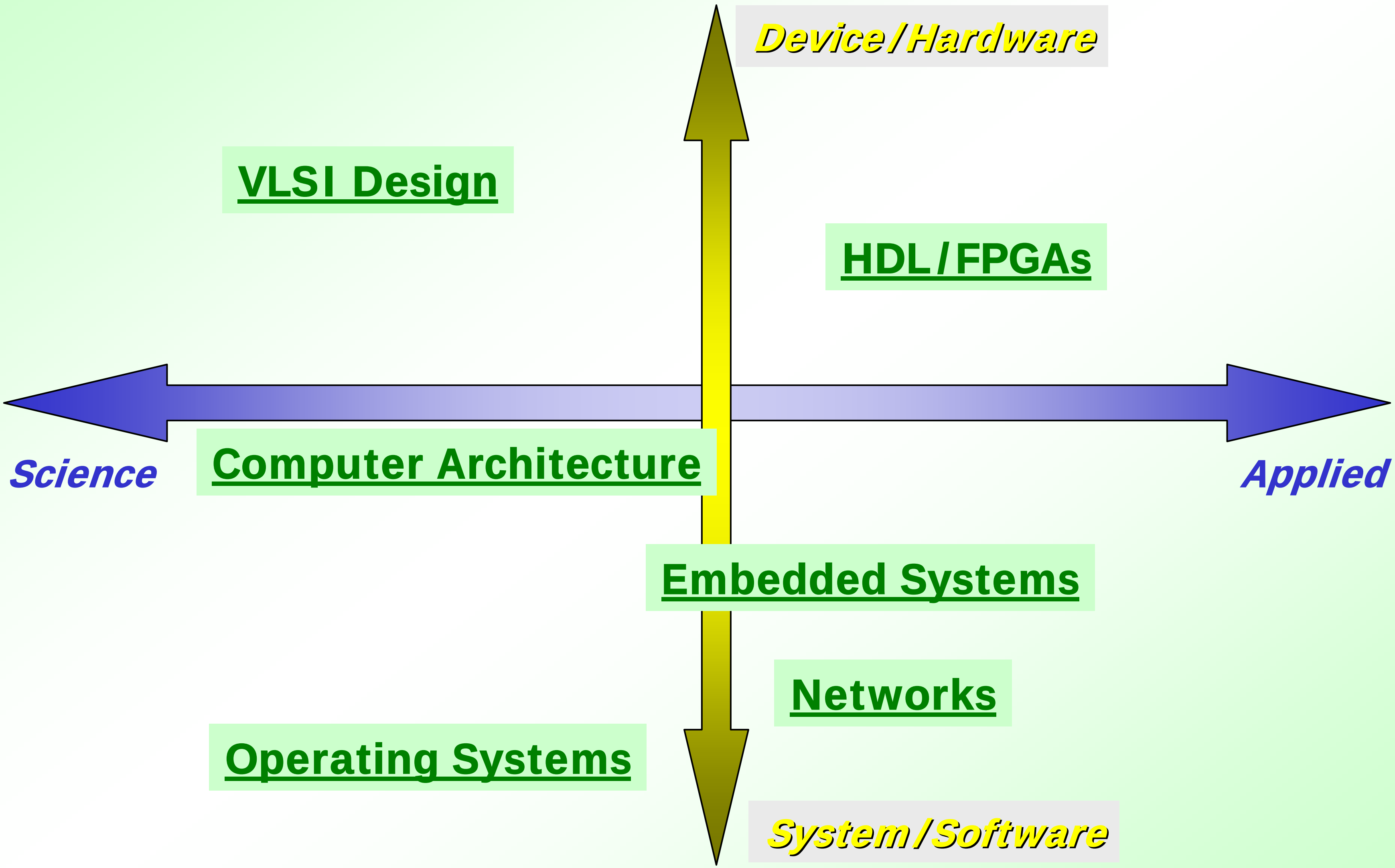
- Year 1
  - Math & Science
- Year 2
  - Digital Logic Fundamentals
    - number systems, Boolean logic, digital functions, HDL basics
- Year 3
  - Microelectronic Circuits
    - semiconductor device models/circuits, small signal analysis, amps
  - Microprocessors
    - microprocessor structure, Assembly 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?
    - .
    - .

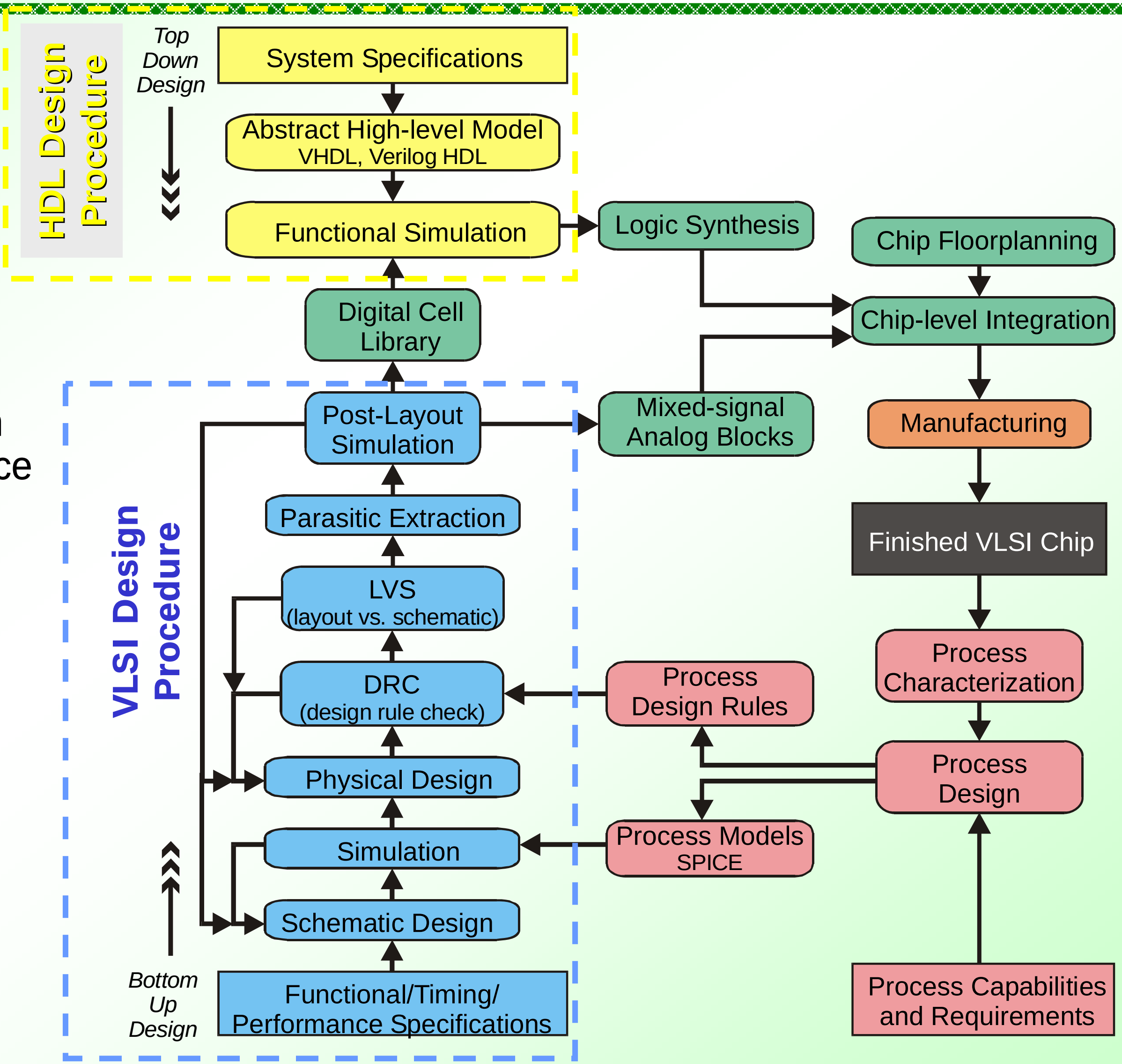
VLSI-Related Course Content



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

- Rabaey, Chandrakasan, Nikolic, Digital Integrated Circuits: A Design Perspective, 2nd Ed., Prentice Hall, 2003. ISBN 0-13-597444-5
  - probably the most common VLSI text in USA; a bit advanced for some programs
- J. Uyemura, Introduction to VLSI Circuits and Systems, Wiley, 2002. ISBN 0-471-12704-3
  - easy to teach and learn from; great coverage of layout; Verilog chapter
- Kang and Leblebici, CMOS Digital Integrated Circuits: Analysis and Design, 3rd Ed., McGraw Hill, 2003. ISBN 0-07-119644-7
- Weste and Harris, CMOS VLSI Design, 3rd Ed., 2005, ISBN 0-321-14901-7
- K. Martin, Digital Integrated Circuit Design, 2000, ISBN 0-19-512584-3
- R. J. Baker, CMOS Circuit Design, Layout, and Simulation, 2nd Ed., Wiley, 2008. ISBN 978-0-470-22941-5
- ASIC, Smith

Course Topics I

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

- 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*

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 were 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 do 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?
  - .
  - .
  - .
  - .
  - .