An Assessment of Laboratories and Materials Teaching Hardware-Software Co-Design

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Outline

- Background and Motivation
- Laboratory Design
- Laboratory Equipment
- Experiments
- Evaluation

Background

- Hardware and software developed separately in past
- Increasingly risky
  - Systems on a Chip
  - Short market windows
  - Difficult to partition hardware and software
- Co-Design reduces number of prototypes and time-to-market
- Rapidly growing demand

Background

- Hardware-Software Co-design fundamental to digital systems design
- Undergraduates in CpE, EE, and CS should be introduced to this concept
- Developed software and laboratories which introduce Co-design at the junior level

Laboratory Objective

- Teach concepts of microcontrollers and hardware-software co-design
  - Hardware-Software partitioning
  - Re-use of intellectual property (IP)
  - Hardware-Software co-simulation
  - Embedded software in C and ASM
  - Communication with external devices
  - Real-time systems

Course Design

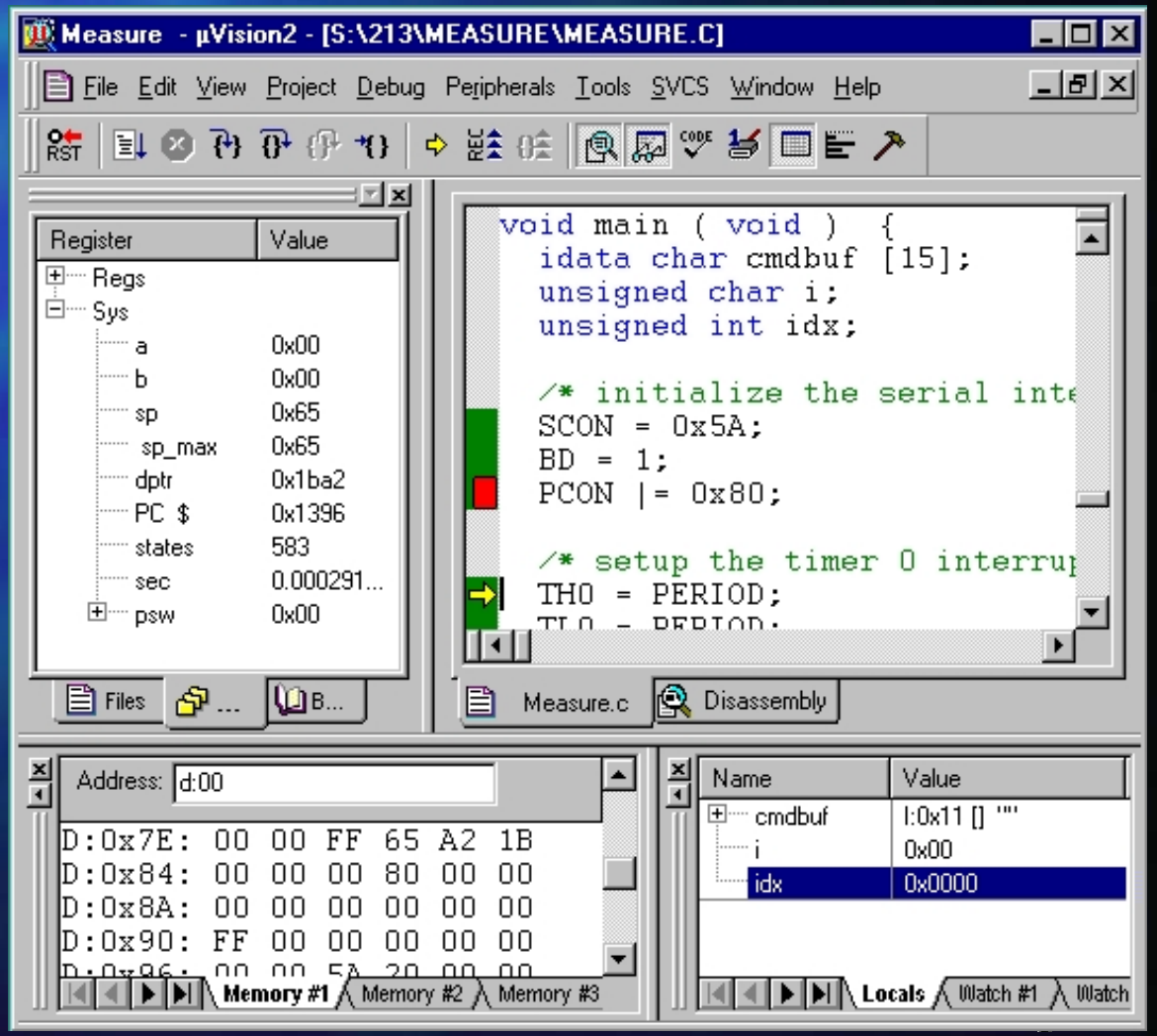
- Associated course
  - Junior level
  - Focused on 8051 microcontroller
  - Mix of CpE, EE, and CS students
  - Lab is not required
- Student background
  - C++
  - Electronic design automation tools
  - Rapid prototyping with FPGAs

Experiment Outline

- Develop and simulate software
- Develop and simulate hardware
- Co-simulate hardware and software
- Verify design in hardware

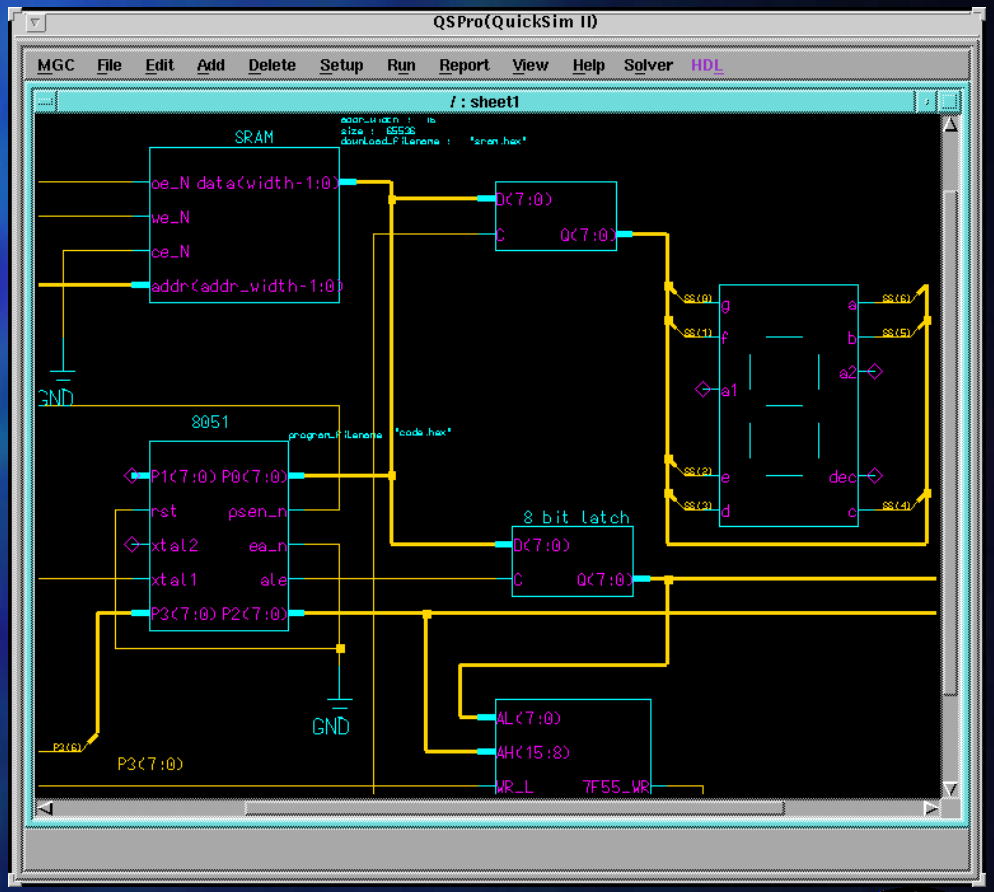
Laboratory Equipment

- Keil Software Development Tools
  - C and ASM
  - 8051 software simulation
  - Free evaluation software



Laboratory Equipment

- Mentor Graphics design automation tools
- 8051 simulation model
  - Clock-cycle accurate
  - Executes compiler-generated code
  - Complete functionality



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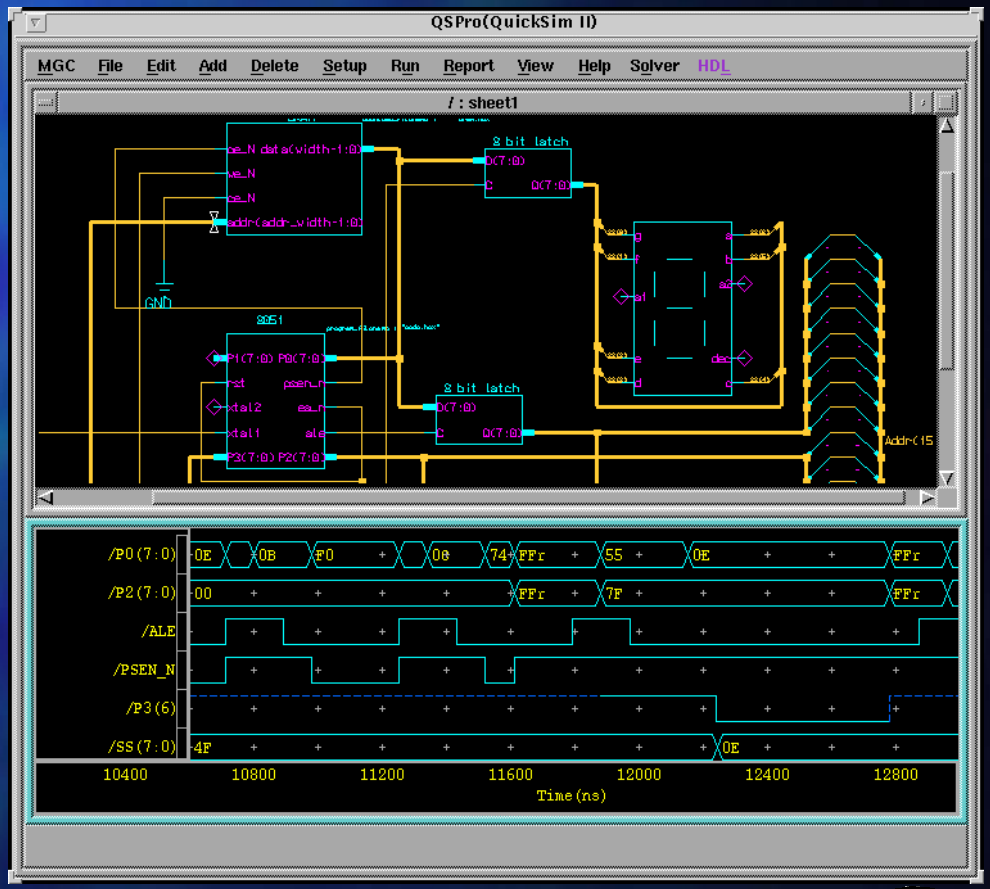

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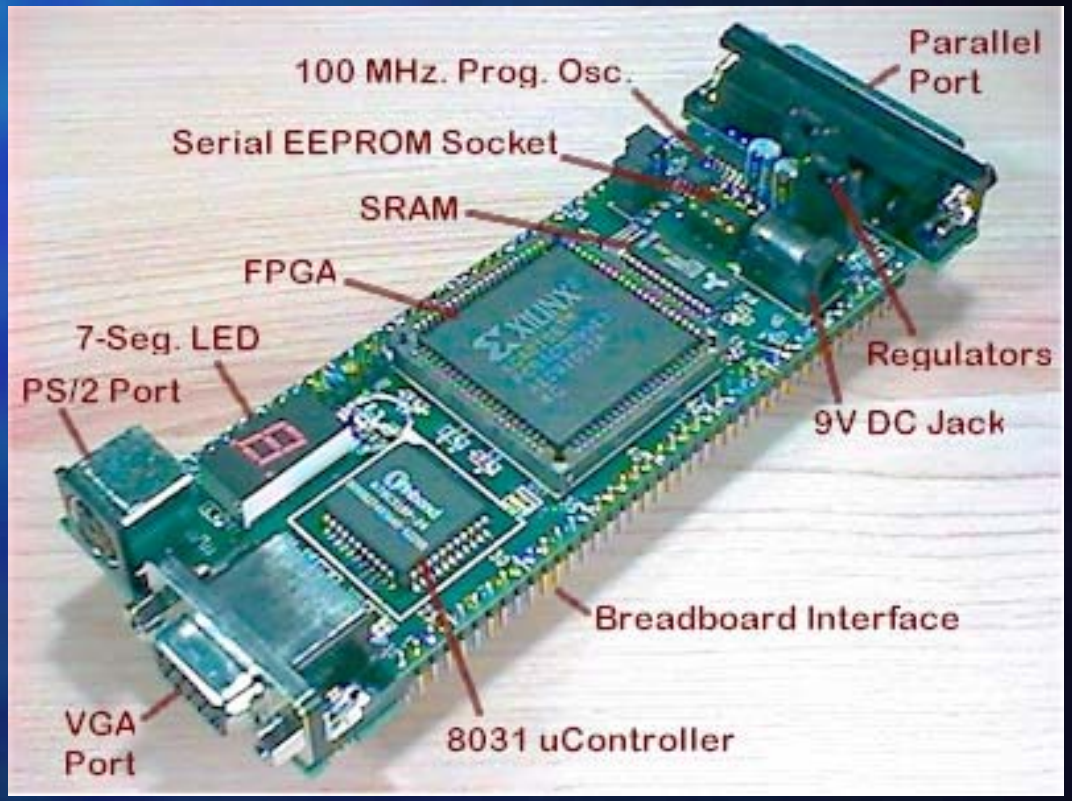
Laboratory Equipment

- XS40 board by Xess corporation
  - 8031 microcontroller
  - Xilinx FPGA
  - VGA port
  - 7-segment LED
  - Generous pin-probe points

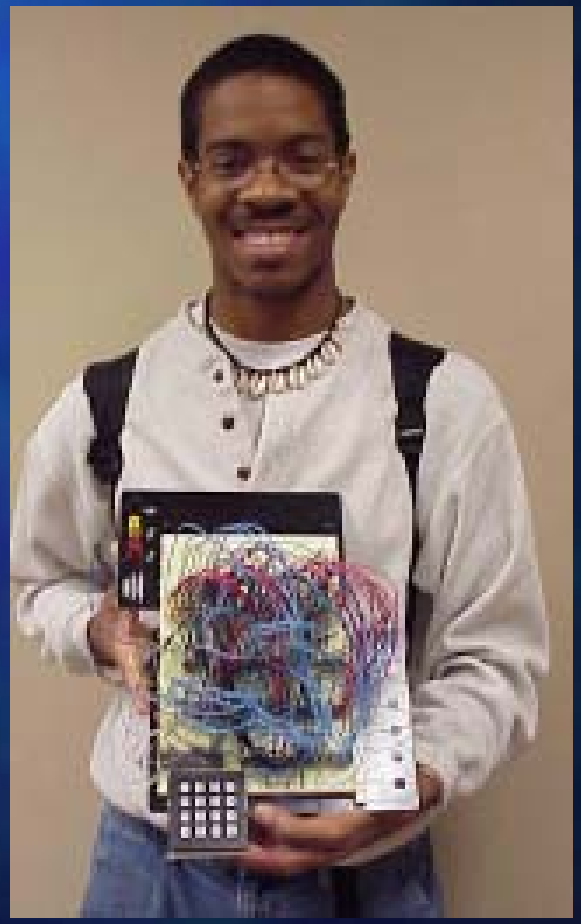


Experiments

- Several labs developed
  - Introduction to Hardware-Software Co-Simulation
  - Hardware-Software Co-Verification
  - Extending the 8051 with External Hardware
  - Design with intellectual property: Creating a VGA display
  - Bi-directional serial communication with interrupts

Projects

- Digital LCD alarm clock
- Virtual pet
- MP3 player controller
- "Pong" game
- Automatic pet feeder
- Simon game



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Evaluation

- Technical accuracy of models
- Educational effectiveness of labs

Evaluation of Models

- Standard software-testing methodologies
  - White-box testing
  - ASM and VHDL testbenches
  - Code coverage (line coverage, decision coverage, etc)
- Evaluation in lab by students and instructors
- Bugs found and eliminated

Evaluation of labs

- Instruments:
  - Non-credit examination
  - Course grades
  - Student and instructor surveys
  - Faculty observations
- Compared students who did and did not take the lab
- 4 semesters (170 students)

Evaluation of Labs

- Students who took the lab:
  - Performed 33% better on evaluation exam
  - Received 20-30% higher final grade in lecture course
    - About 1 letter grades higher on tests
- Results largely independent of race or sex
- Little difference between students in other CpE courses

Surveys and Observations

- Significantly more microcontrollers in senior design course
- Steady increase in students taking lab
- Students appreciate usefulness of concepts taught
- Students particularly enjoy project
  - Apparently do not apply principals from lab

Conclusions

- Hardware models are accurate
- Labs teach fundamental concepts of hardware-software co-design
- Labs improve performance in the lecture course
- Additional labs under development

Additional Information

- http://www.umr.edu/~daryl/nsf-ccli/
  - WEB SEMINAR on Thursday, August 2nd, 1:00 Central Time.
- daryl@umr.edu or hjp@umr.edu.

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