Introduction

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CSE 502 — CompArch (1)

• Computer Architecture is
  ... the *science* and *art* of selecting (or designing) and interconnecting hardware and software components to *create computers* ...

• Computer Architecture has changed a lot in the past 10-15 years
  – When I was a student, it was mostly about superscalar, out-of-order pipelines and cache coherence
  – Now we have many-cores, GPUs, data centers and accelerators
These changes happened because we hit multiple walls in processor/system design:
- ILP wall
- Power wall
- Memory wall
- Network wall (recently)

Also because application domains emerged whose demands couldn’t be met with conventional processors:
- AR and VR
- LTE and future mobile protocols
- Big data
- Data driven science
- Deep learning
- etc.
CSE 502 — CompArch (3)

• In this course, first we learn what conventional processors look like internally
  – Instruction sets
  – Pipelining
  – Processor front-end (instruction fetch and decode)
  – Processor back-end (execution core)
  – Memory hierarchy (caches, DRAM, prefetching, etc.)
  – Superscalar and out-of-order execution
  – Branch prediction and speculation
  – Vector execution
  – ...
CSE 502 — CompArch (4)

• Then some more recent stuff (circa ~2000)
  – Multi-cores and multi-processors
  – Hardware multi-threading
  – Cache coherence and consistency

• And finally cutting-edge topics (as many as time permits)
  – GPUs
  – Warehouse Scale Computers
  – Accelerators
  – Etc.
CSE 502 — CompArch (5)

• “Computer Architecture” is an umbrella term
  – *Interface* exposed to system software (compiler and OS)
    • In particular, Instruction Set Architecture (ISA) of processors
  – *Micro-architecture*: internal organization of components

• This course is mostly about *micro-architecture*
  – E.g., what’s inside the processor (CPU)
  – What implications this has on software
Why Study CompArch (1)
Why Study CompArch (2)

Sources of performance improvement:

• Improvements in semi-conductor technology
  – Faster transistors
  – More transistors

• Improvements in computer architecture
  – *Computer architects work to turn the additional resources into speed/power savings and new functionality*

In this class, we will study some of the cool techniques invented by computer architects to make this possible!
Why Take CSE 502?

• You need one more qualifier/graduation requirement
  × *Bad answer!*

• You want to become a computer architect
• You want to learn what’s inside a processor
  – Because you’re curious (and there is no computer w/o a processor)
  – To write better/faster application code
  – To write system software (OS, compiler, etc.)
• Computer architecture is cool and intellectually fascinating
  – BTW, what is the most complicated man-made artifact?
  – Consider: there are billions of individually designed and verified transistors in a modern processor chip
  ✓ *More like it!*
Course Format

• I will deliver most lectures

• There might be a few student presentations
  – Mostly on newer topics

• This is a project-intensive course
  – Learn why things are the way they are, first hand
  – We will “build” the behavioral model of a real CPU
Hardware Design Process

Conceptual Design → Behavioral Implementation → Evaluation

Packaging → Manufacturing → Layout → Structural Implementation
Course Project

• Goal: design and implement a SPARCv8 processor
  – Preferably a super-scalar, out-of-order one 😊

• We’ll use SystemVerilog HDL for implementation
  – Don’t panic! We’ll cover the necessary background
  – Hopefully, will help you think and design like a HW designer

• I’ll provide a cross-compiler and a simulation environment
  – You’ll design and implement the processor
  – See course webpage for details

• No intermediate milestones for the course project
  – This is a graduate course; you should be self-disciplined
  – This flexibility is a rope; you can use it to climb or hang yourself
## Grading

<table>
<thead>
<tr>
<th>What?</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiz 0</td>
<td>0</td>
</tr>
<tr>
<td>Quiz 1</td>
<td>10</td>
</tr>
<tr>
<td>2 Homeworks</td>
<td>10 each</td>
</tr>
<tr>
<td>Course Project</td>
<td>Up to 125</td>
</tr>
<tr>
<td>Midterm</td>
<td>20</td>
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<tr>
<td>Final</td>
<td>20</td>
</tr>
<tr>
<td>Presentation (optional)</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>205</strong></td>
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<table>
<thead>
<tr>
<th>Course Project</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-Stage pipeline + direct-mapped caches</td>
<td>40</td>
</tr>
<tr>
<td>5-Stage pipeline + set-associative caches</td>
<td>45</td>
</tr>
<tr>
<td>Above + super-scalar pipeline</td>
<td>60</td>
</tr>
<tr>
<td>Above + out-of-order execution</td>
<td>80</td>
</tr>
<tr>
<td>Multi-cycle divider and pipelined multiplier on top of any of the above</td>
<td>5 extra</td>
</tr>
<tr>
<td>Branch prediction and speculation on top of the above</td>
<td>10-20 extra</td>
</tr>
<tr>
<td>SMT on top of the above</td>
<td>10-20 extra</td>
</tr>
</tbody>
</table>

- Guaranteed grades: [A, A-, B+, ...] = [95, 90, 85, ...]
  - I may use a curve on top of this if need be
Logistics (1/3)

• Books
  – Highly Recommended (but not strictly required)
    • *Modern Processor Design: Fundamentals of Superscalar Processors* (by Shen & Lipasti)
    • *Computer Architecture: A Quantitative Approach, 6th Ed* (by Hennessy & Patterson)
      – I highly recommend reading both books cover-to-cover if you are targeting systems research

• There will be other required readings
  – SPARC Architecture Manual
  – SystemVerilog tutorials
  – And a few papers or book chapters online
Logistics (2/3)

• Two quizzes
  – Quiz 0 today
    • Does not affect your grade; just to help me assess class background
    • Completion is **required**
    • If you missed the 1st class, come to office hours for it
  – Quiz 1 (in a month or so): to force you read the SystemVerilog tutorials and SPARCv8 manual

• Exams
  – Midterm and final
  – Include everything in class lectures and discussions, blackboard posts, course project and required readings
Logistics (3/3)

• Blackboard
  – Grades will be posted there

• Course forum and newsgroup
  – Also on Blackboard
  – “General Discussions” forum on blackboard

• Working in groups: only permitted on the project
  – Groups may be up to 2 people
  – Should let me know of your groups by Feb 19
Academic Integrity Policy

• You may...
  – Discuss assignment, design, techniques

• You may **not**...
  – Share code
  – Copy from internet
    • Exceptions are possible, but must receive explicit permission
  – In general, every character you hand in should be written by yourself

• If caught, you’ll fail. No exceptions!
Quiz 0