chapter 1

Computer Architecture and Design

• What is in this course?
  – In-depth understanding of the inner-operations of a high-performance processor, processor evolution, and trade-offs present at the hardware/software boundary
    » performance/cost/implementation complexity
    » tradeoff in fast/slow operations
  – experience with the design process in the context of a large complex digital system design
    » functional specification --> control and datapath --> physical implementation
  – you are prepared to accept a job as a digital ASIC designer.

chapter 1

My Goal

• Teach you how to design by leading you through the process of each unit used in modern computer
• We will finish the whole book and supplement new material for techniques used in newly announced processors and I/O Buses
  – textbook “Computer Organization and Design ; The Hardware/Software Interface” by Patterson and Hennessy, Morgan Kaufmann Publisher
• What is Your Goal!

chapter 1

What is Computer Architecture

• Computer Architecture
  – Computer architecture = Instruction set architecture plus computer organization
  – Instruction Set Architecture (ISA)
    » ISA specifies data types and data structures, storage elements, instruction formats, operation code set, modes of addressing and accessing data items, exceptional conditions
  – Computer Organization
    » functions and characteristics of functional units
    » functional units connections
    » information flow between functional units
    » how functional units are controlled
    » register transfer level description
Computer Architecture and Design

- layout (lowest level)
- circuit design
- digital design
- datapath & control
- instruction set proc. and I/O system
- compiler and firmware
- operating system
- application (highest level)

Factors affect computer architecture

- technology
- applications
- operating systems
- programming languages
- history

Technology trends

<table>
<thead>
<tr>
<th>capacity</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x in 3 years</td>
<td>2x in 3 years</td>
</tr>
<tr>
<td>4x in 3 years</td>
<td>1.4x in 10 years</td>
</tr>
<tr>
<td>DRAM</td>
<td>disk</td>
</tr>
</tbody>
</table>

Performance Trend

Performance Trends

- Introduction of RISC (reduced instruction set computer)
Computer Architecture

• computer architecture
  – is an iterative process to search the space of all possible designs at all levels of computer systems

MIPS R3000 Instruction Set Architecture

• Instruction Category
  – load/store
  – computational
  – jump and branch
  – floating point
    » coprocessor
  – memory management
  – special

instruction formats: all 32 bits

<table>
<thead>
<tr>
<th>op</th>
<th>rs</th>
<th>rt</th>
<th>rd</th>
<th>shamt</th>
<th>funct</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>jump target address</td>
</tr>
</tbody>
</table>

MIPS R3000

High Level Language program

compilation
Assembly language program
assembler
Machine language program

lw $15, 0($2);
lw $16, 4($2);
sw $15, 0($2);
sw $16, 4($2);

0010 1001 0001 1010 0011 0011 1100 1010

Instruction execution cycle

Instruction fetch
  – obtain instruction from program storage

Instruction decode
  – determine required actions and instruction size

Operand fetch
  – locate and obtain operand data

Execute
  – compute result value or status

Result store
  – deposit results in storage for later use

Next instruction fetch
Computer system components

- proc., cache, buses, memory, adapters, controllers, network interface, I/O devices

Summary

- Computers have five components
  - processor: datapath
  - processor: control
  - memory
  - input devices
  - output devices

- All memory are not “born” equal
  - Cache memory: fast, expensive, and placed closer to processor
  - Main memory: cheap, we can put more main memory

- Input and output devices
  - wide range of speed: graphics vs. keyboard
  - wide range of requirements: speed, standard, cost, etc.