U. Wisconsin CS/ECE 552
Introduction to Computer Architecture

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Introduction (Chapter 1)

www.cs.wisc.edu/~karu/courses/cs552/

Slides combined and enhanced by Karu Sankaralingam from work by Falsafi, Hill, Marculescu, Nagle, Patterson, Roth, Rutenbar,Schmidt, Shen, Sohi, Sorin, Thottethodi, Vijaykumar, & Wood

What is Computer Architecture?

- *"Computer Architecture* is the science and art of selecting and interconnecting hardware components to create computers that meet functional, performance and cost goals."

  - WWW Computer Architecture Page

- An analogy to architecture of buildings…

Role of Building Architect

Materials: Steel, Concrete, Brick, Wood, Glass

Design → Plans → Construction → Buildings

Buildings: Houses, Offices, Apartments, Stadiums, Museums

Goals: Function, Cost, Safety, Ease of Construction, Energy Efficiency, Fast Build Time, Aesthetics

Role of Computer Architect

"Technology": Logic Gates, SRAM, DRAM, Circuit Techniques, Packaging, Magnetic Storage, Flash Memory

Design → Plans → Manufacturing → Computer

Computer: PCs, Servers, PDAs, Mobile Phones, Supercomputers, Game Consoles, Embedded

Goals: Function, Performance, Reliability, Cost/Manufacturability, Energy Efficiency, Time to Market

CS/ECE 552 in Context

- CS/ECE 352 – Gates to multiplexors & FSMs
- CS/ECE 354 – High-level language to machine language, a.k.a. Instruction Set Architecture (ISA)

- This course – CS/ECE 552 – puts it all together
  - Implement that logic that provides ISA
  - Must do datapath & control, but no magic!
  - Manage complexity through ABSTRACTION

- Follow-on courses explore trade-offs:752 & 757

Why Study Computer Design

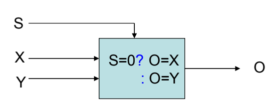
- To design new computers: old designs become obsolete fast
  - new technologies - e.g., denser ICs (technology "push")
  - new user demand - e.g., virtual reality (application "pull")
- To be an informed user
  - a little auto mechanics helps owner rarely, but importantly
- To learn to deal with complexity via abstraction
  - problems that take months and years to complete

Abstraction

- Black boxes
- Difference between interface and implementation
  - Interface - WHAT something does
  - Implementation - HOW it does so

Abstraction - Example

- 2-to-1 Mux
- Interface:



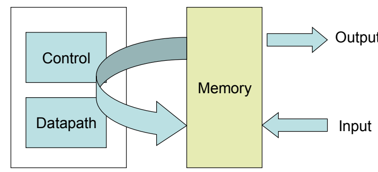
- Implementations
  - gates (fast or slow), pass transistors

What's the Big Deal?

- E.g., x86 interface book
- Worse for computers, in general - a tower of abstraction
  - Application software
  - System software (OS and compiler/assembler/linker)
  - Hardware (CPU, memory, I/O)
- Each interface is complex and implemented with layer below
  - Abstraction keeps unnecessary details hidden
- Thousands of engineers to build one product

Basic Division of Hardware

- In space and time
  - In space



Basic Division of Hardware

- In time
  - Fetch the instruction from memory add r1, r2, r3
  - Decode the instruction - what does this mean?
  - Read input operands read r2, r3
  - Perform operation add
  - Write results write to r1
  - Determine next instruction pc := pc + 4

Why don't old designs work?

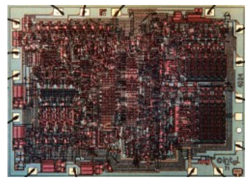
- Evolutionary and revolutionary changes in technology

Date	What	Comments
1947	1st transistor	Bell Labs
1958	1st integrated circuit	Texas Instruments
1971	1st microprocessor Intel 4004	2300 transistors, 108 kHz
1978	Intel 8086	29K Transistors
1989	Intel 80486	1.2M Transistors
1995	Intel Pentium Pro	5.5M Transistors
2003	Intel Pentium4	55M Transistors

Moore's Law(s)

- Technologists will double # transistors per chip doubles every two years (or 18 months)
- Or architects will double performance per chip doubles every two years (or 18 months)
- These can't go on forever, but don't underestimate a trillion dollar industry

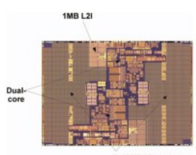
First Microprocessor

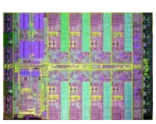


- Intel 4004 [1971]
  - 4-bit data
  - 2300 transistors
  - 10 mm PMOS
  - 108 KHz (.0001 GHz)
  - 12 V
  - 13 mm^2

Some Older Chips!

Intel Pentium IV
- 42 million transistors
- 3.8 GHz
- 0.13μm process
- Could fit ~15,000 4004s on this chip!

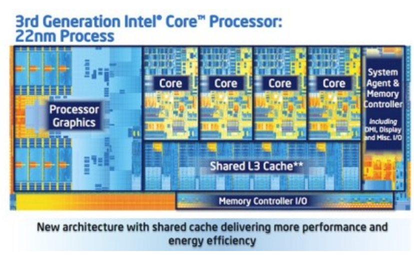




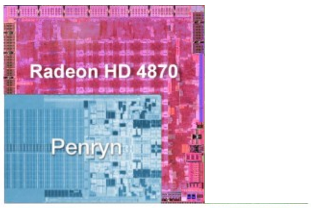
IBM Cell
- 8 vector processors + 1 PPC
- 4 GHz
- 90nm process

Intel Itanium II (Montecito)
- 1.7 billion transistors
- ?? MHz
- 90nm process

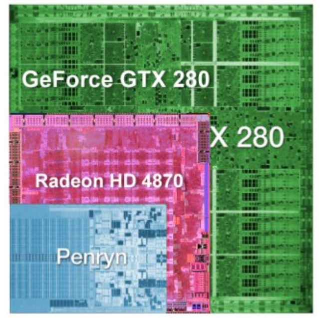
Intel Ivy Bridge



GPUs: AMD Radeon 4870

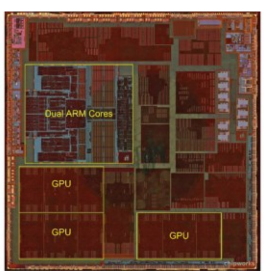


GPUs: Nvidia GTX 280



~1 inch

A6 Chip



Bottom line

- Designers must know BOTH software and hardware
- Compilers, Operating Systems, Networks
- Both contribute to layers of abstraction of computers
- IC costs and performance
- Read the book - Chapter 1 done -
- Throughout the course, read the book (BEFORE lecture)
- Optional reading:
  – Soul of a New Machine, Trace Kidder

Syllabus

- Language of the computer: ISA
- Arithmetic
- Processor Design
- Performance
- Memory
- IO
- Multiprocessors, Advanced processors, GPUs

We will meet in 1221 CS henceforth