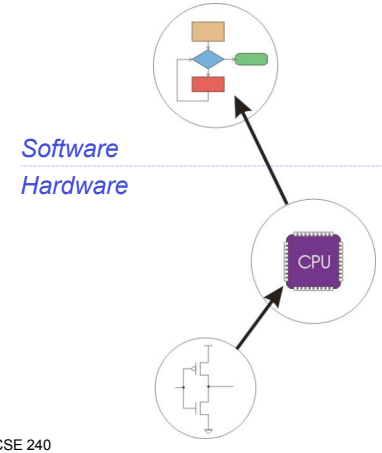
Chapter 1
Welcome Aboard

Computer System: Layers of Abstraction



Software

Application Program

Algorithms

Language

Hardware

Instruction Set Architecture
(and I/O Interfaces)

Microarchitecture

Circuits

Devices

Recurring Themes

Abstraction

- Allows us to manage seemingly insurmountable complexity
- One billion components require abstraction

Hardware v. Software

- Separation of hardware and software is artificial

Recurring Theme #1: Abstraction

Abstraction hides details

Examples

- "Turn off the light!"
- "Stick out your tongue."

Computing examples

- Java methods
- C functions
- LC-3 instructions
- Logical gates
- Transistors

Bottom line

- Often best to operate at highest level of abstraction
- Dangerous to completely ignore lower levels of abstraction

Recurring Theme #2: Hardware v. Software

Artificial distinction

Greatness arises from blurring the HW/SW line

- RISC
- MMX/SSE
- IA-64 EPIC
- RAW/Trips. . .

Bottom line

- We really care about *computation*
- Hardware best understood by those who know software
- Software best understood by those who know hardware

Very Big Ideas

Universality

- All computers can compute the same thing*

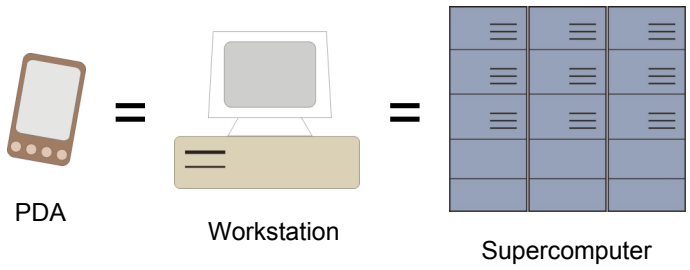
Layered Abstraction

- We can build very complex systems from simple components

Big Idea #1: Universal Computing Device

All computers *can* computing exactly the same things*

*given enough time and memory

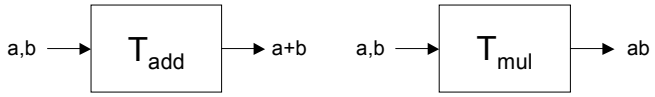


Turing Machine

Mathematical model of a device that can perform any computation – Alan Turing (1937)

- Ability to read/write symbols on an infinite "tape"
- State transitions, based on current state and symbol

Every computation can be performed by some Turing machine. ***(Turing's thesis)***

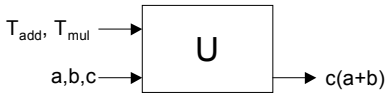


Turing machine that adds *Turing machine that multiplies*

Universal Turing Machine

Turing described a Turing machine that could implement all other Turing machines

- **Inputs: data, plus a description of computation (Turing machine)**



Universal Turing Machine

U is programmable – so is a computer!

- **Instructions are part of the input data**
- **A computer can emulate a Universal Turing Machine, and vice versa**

Therefore, a computer is a universal computing device!

From Theory to Practice

In theory

- **Computers can compute anything that's possible to compute**
- **Given enough *memory* and *time***

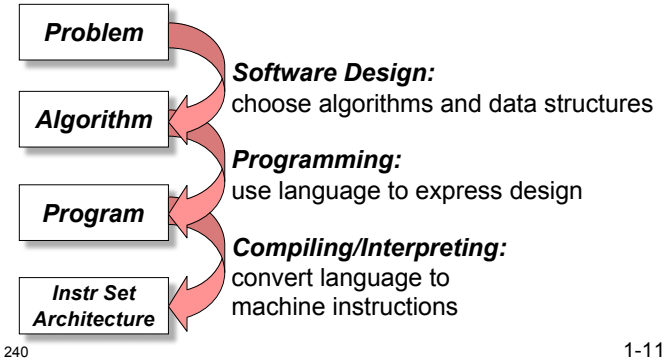
In practice

- **Solving *real* problems requires computing under constraints**
- **Time**
  - **Weather forecast, next frame of animation, ...**
- **Cost**
  - **Cell phone, automotive engine controller, ...**
- **Power**
  - **Cell phone, handheld video game, ...**

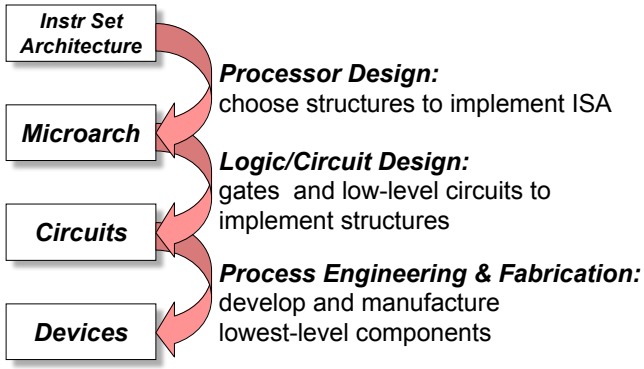
Big Idea #2: Layered Abstraction

How do we solve a problem using a computer?

- **Systematic sequence of transformations between layers of abstraction. . .**



Deeper and Deeper…



Descriptions of Each Level

Problem Statement
- Stated using "natural language"
- May be ambiguous, imprecise

Algorithm
- Step-by-step procedure, guaranteed to finish
- Definiteness, effective computability, finiteness

Program
- Express the algorithm using a computer language
- High-level language, low-level language

Instruction Set Architecture (ISA)
- Specifies the set of instructions the computer can perform
- Data types, addressing mode

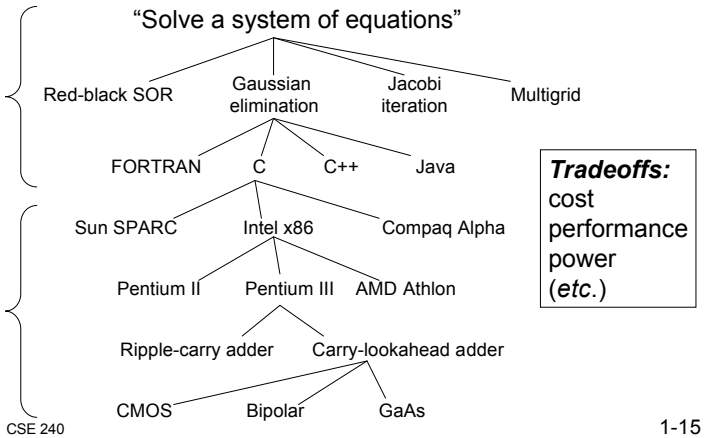
Descriptions of Each Level (cont.)

Microarchitecture
- Detailed organization of a processor implementation
- Different implementations of a single ISA

Logic Circuits
- Combine basic operations to realize microarchitecture
- Many different ways to implement a single function (*e.g.,* addition)

Devices
- Properties of materials, manufacturability

Many Choices at Each Level



Tradeoffs:
cost
performance
power
(*etc.*)

Course Outline

Bits and Bytes
- How do we represent information using electrical signals?

Digital Logic
- How do we build circuits to process information?

Processor and Instruction Set
- How do we build a processor out of logic elements?
- What operations (instructions) will we implement?

Assembly Language Programming
- How do we use processor instructions to implement algorithms?
- How do we write modular, reusable code? (subroutines)

I/O, Traps, and Interrupts
- How does processor communicate with outside world?

C Programming
- How do we write programs in C?
- How do we implement high-level programming constructs?

Next Time

Lecture

- Chapter 2: Bits and Bytes

Reading

- Chapter 2 - 2.5

Quiz

- Don’t forget!

Upcoming

- Homework 1 due on Fri 16 September