Lecture 1:
Computer Architecture and Technology

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Advanced Computer Architectures

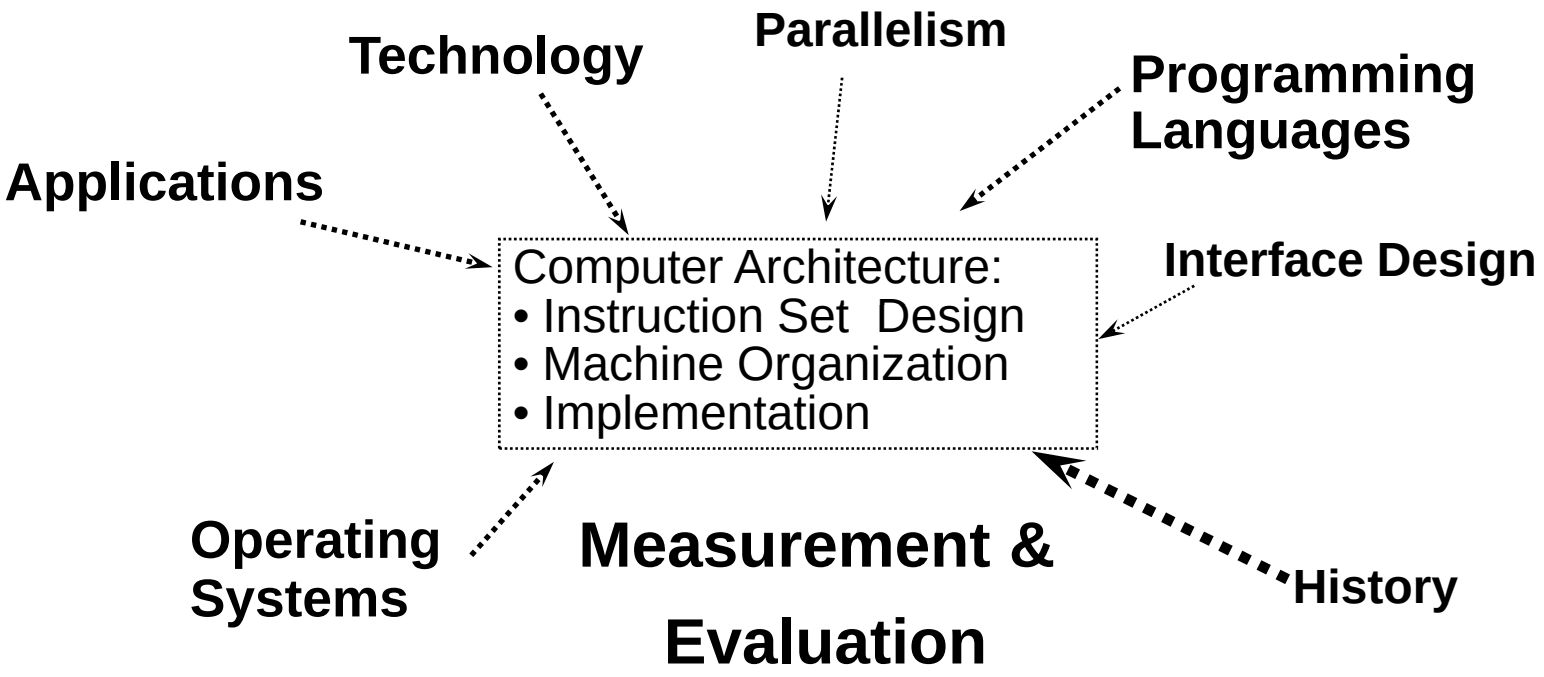
CSE 533

Today's Lecture

- Course Objectives, Format, and Grading
- Course Prerequisites and Content
- Introduction to Computer Architecture
- Computer Technology
- Computer Components

Course Objective

- **Course Objective : To give students a clear understanding of the architecture and organization of modern computers, and the cost and performance tradeoffs involved in there design.**



Class Goals

- **Show you how to understand modern computer architecture in its rapidly changing form - discuss fundamental ideas, plus real world examples.**
- **Provide you with an understanding of current and future trends in computer architecture**
- **Show you how to design by leading you through the process on challenging problems**
- **Make the class informative and enjoyable. So ...**
  - **ask questions**
  - **offer feedback on the course**
  - **come to lecture and office hours**
  - **learn from those around you <u>but submit individual work</u>**

Lecture Format

- Lectures presented from Power Point slides & transparencies
- Examples worked on the board
- Copies of slides, homeworks and other information can be downloaded from the course home page at:

  http://cse.yeditepe.edu.tr/~gkucuk/courses/cse533
- Readings from the book are assigned to complement the lectures.
- Look over the notes and the material from the book before coming to class.
- Class is designed to be interactive => ask and answer questions.
- Office Hours: M 14:00-15:50, T 11:00-11:50 or by appointment, A-409.

Grading

- **Grading for the course is as follows:**
  - **Homeworks & Quizzes: 10%**
  - **Programming Projects: 10%**
  - **Paper Presentation 10%**
  - **Final Project 20%**
  - **Midterm Exam : 20%**
  - **Final Exam : 30%**
- **Homework**
  - **Due at the start of class**
  - **Encouraged to work together, but make sure work is your own**
- **Exams**
  - **Open book and open note (most likely)**
  - **Makeup exams given only under extreme circumstances**
  - **Final is comprehensive**

Course Info

- Please give me feedback whenever you have questions/concerns - feedback form on web page or just stop by my office
- Email for course related questions:

  gkucuk@cse.yeditepe.edu.tr

Course Content

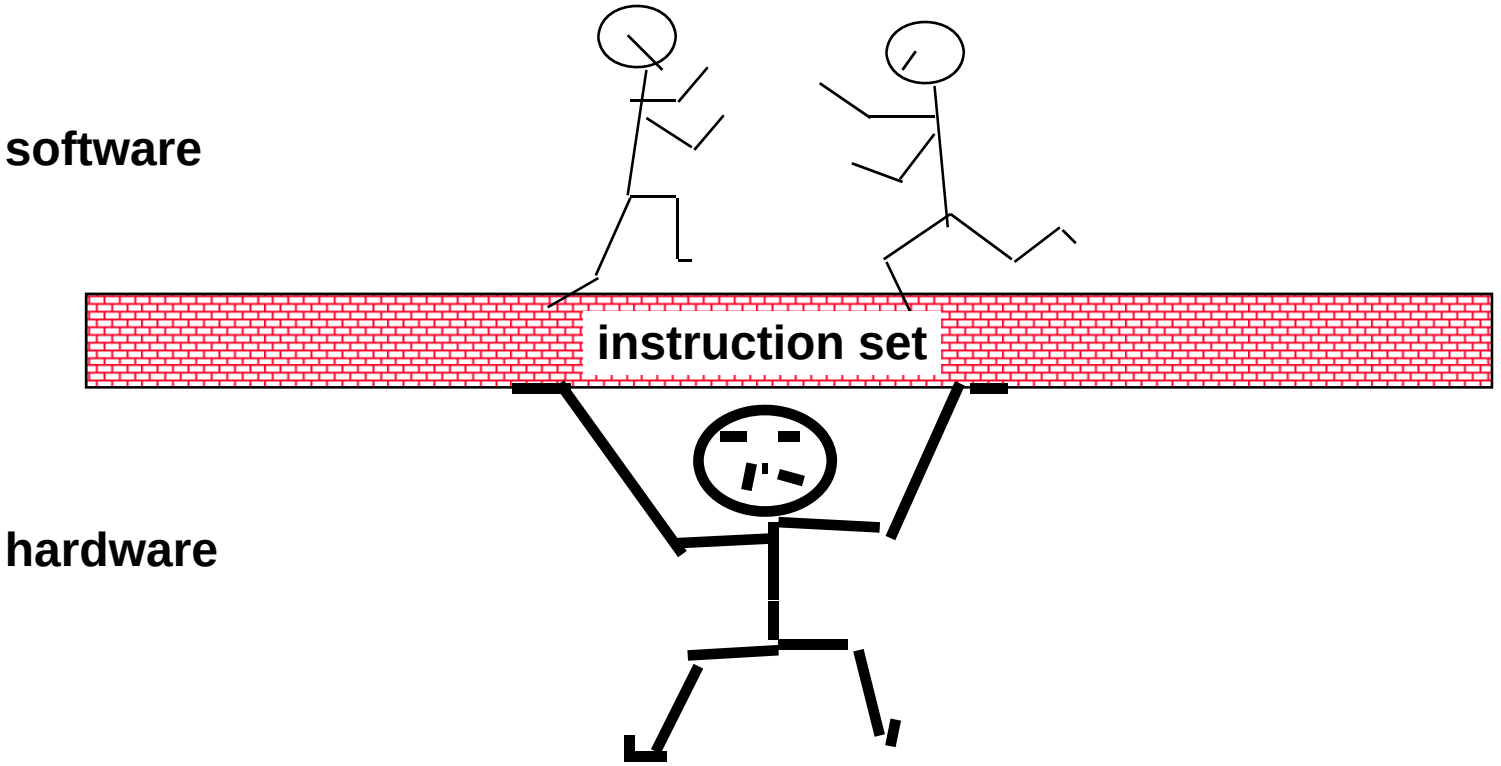
- **Text book: *Computer Architecture: A Quantitative Approach, 2nd Ed.*, Hennessy and Patterson, Morgan Kaugman, 1997.**
  - **Supplementary: Modern Processor Design: Fundamentals of Superscalar Processors, J.P.Shen and M.H.Lipasti, 2003.**
- **Topics covered include :**
  - **Computer Architecture and Technology**
  - **Computer Performance**
  - **Computer Instruction Sets**
  - **Computer Arithmetic**
  - **Processor Design**
  - **Pipelined Processors**
  - **Memory System Design**
  - **Input/Output System Design**

What is “Computer Architecture”

- **Computer Architecture is the design of the computer at the hardware/software interface.**
- **Computer Architecture = Instruction Set Architecture + Machine Organization**

Instruction Set Design	Machine Organization
Computer Interface	Hardware Components
Compiler/System View	Logic Designer’s View

The Instruction Set: a Critical Interface



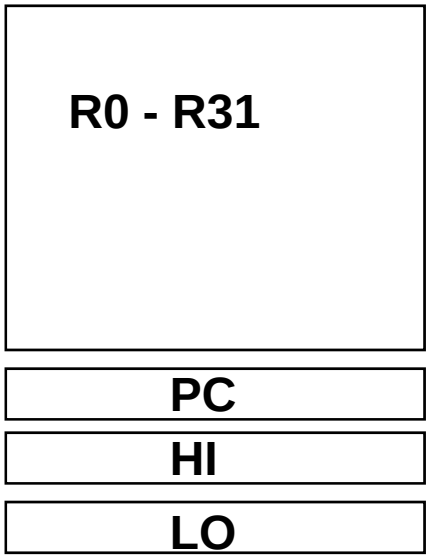
Instruction Set Architecture

- Instruction set architecture is the attributes of a computing system as seen by the assembly language programmer or compiler. This includes
  - Instruction Set (what operations can be performed?)
  - Instruction Format (how are instructions specified?)
  - Data storage (where is data located?)
  - Addressing Modes (how is data accessed?)
  - Exceptional Conditions (what happens if something goes wrong?)
- A good understanding of computer architecture is important for compiler writers, operating system designers, and general computer programmers.

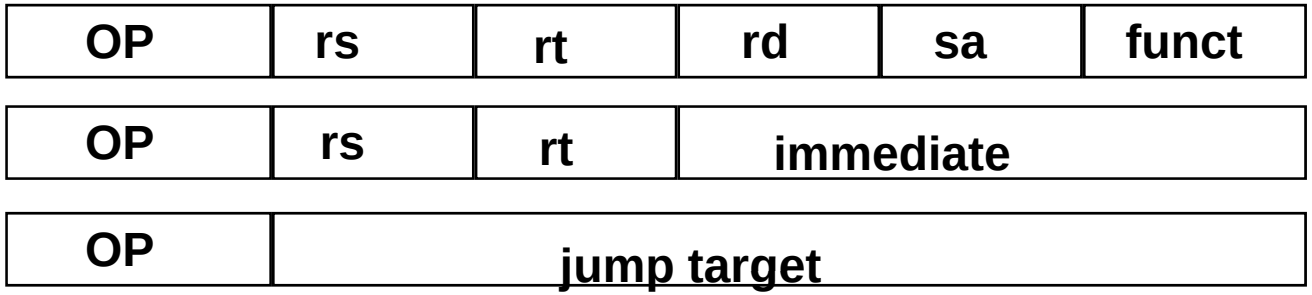
MIPS R3000 Instruction Set Architecture (Summary)

- **Instruction Categories**
  - Load/Store
  - Computational
  - Jump and Branch
  - Floating Point
  - Memory Management
  - Special

Registers



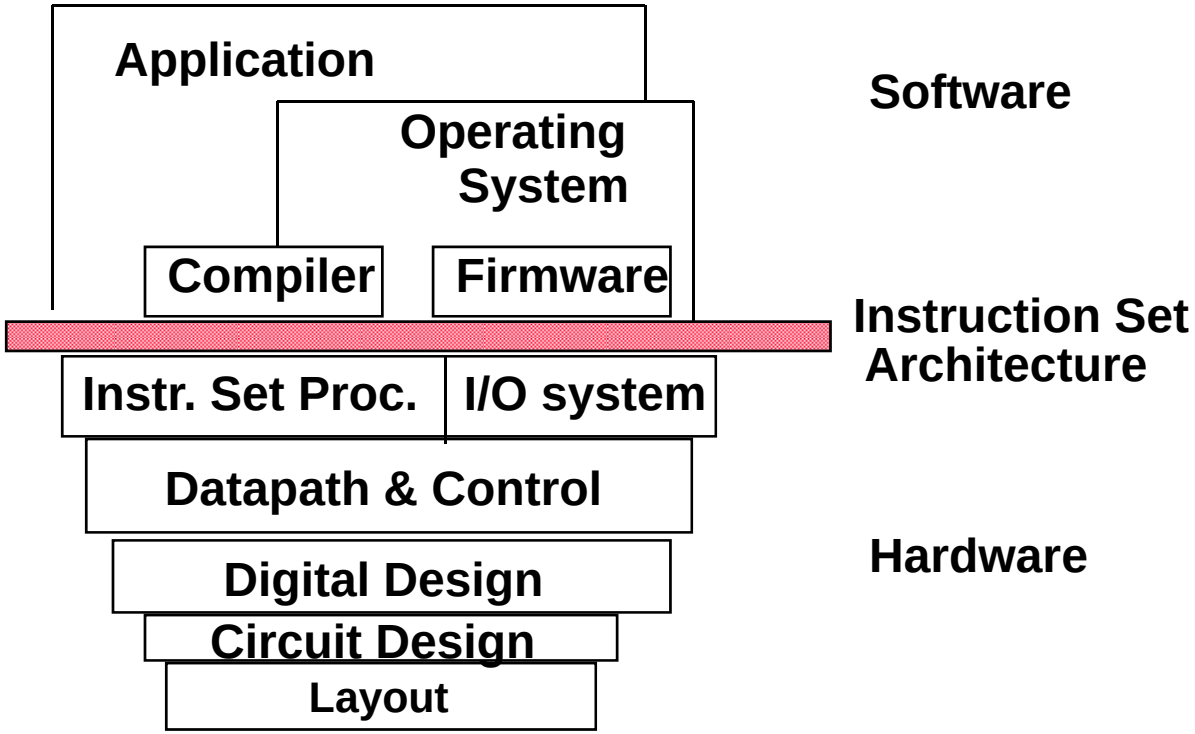
3 Instruction Formats: all 32 bits wide



Machine Organization

- **Machine organization is the view of the computer that is seen by the logic designer. This includes**
  - **Capabilities & performance characteristics of functional units (e.g., registers, ALU, shifters, etc.).**
  - **Ways in which these components are interconnected**
  - **How information flows between components**
  - **Logic and means by which such information flow is controlled**
  - **Coordination of functional units to realize the ISA**
- **Typically the machine organization is designed to meet a given instruction set architecture.**
- **However, in order to design good instruction sets, it is important to understand the how the architecture might be implemented.**

Key considerations in "Computer Architecture"

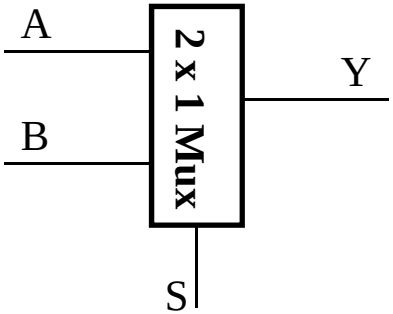


- Coordination of many levels of abstraction
- Under a rapidly changing set of forces
- Design, Measurement, and Evaluation

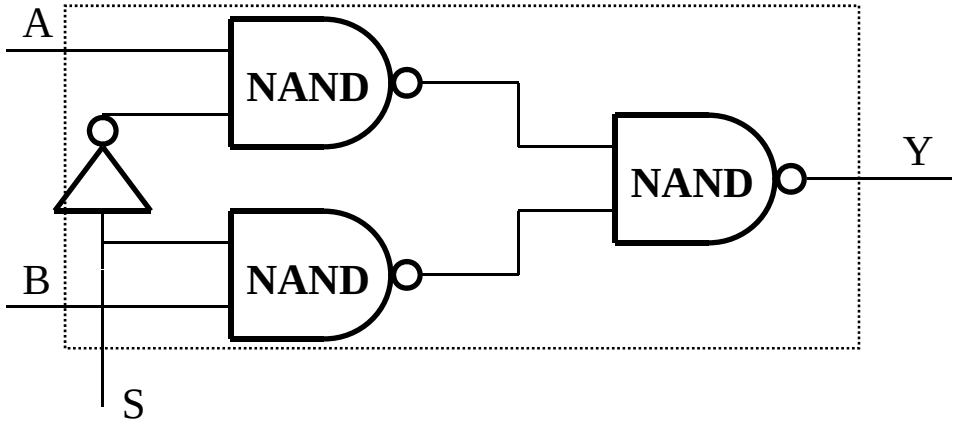
Levels of abstraction

- An important concept in computer architecture is the use of various levels of abstractions.
- Each level of abstraction consists of
  - an interface (outside view of what it does), and
  - an implementation (inside view of how it works)

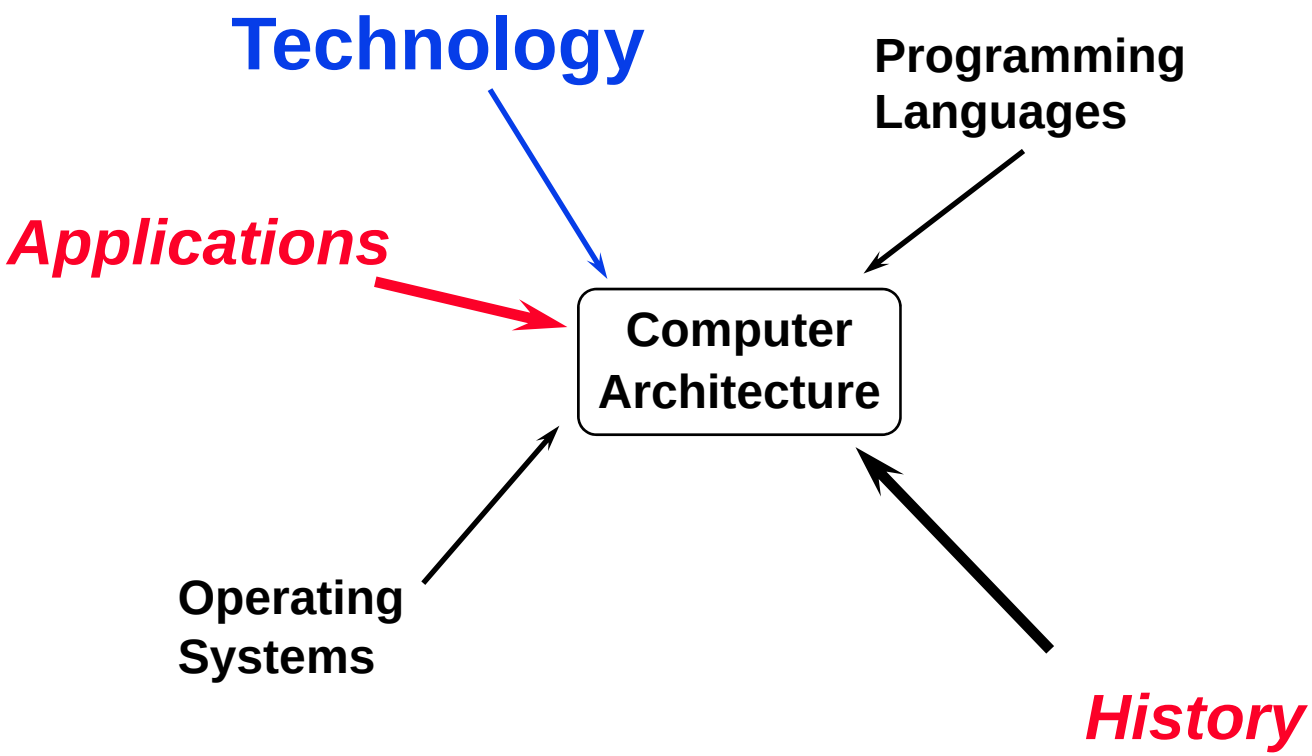
Interface



Implementation



Forces on Computer Architecture

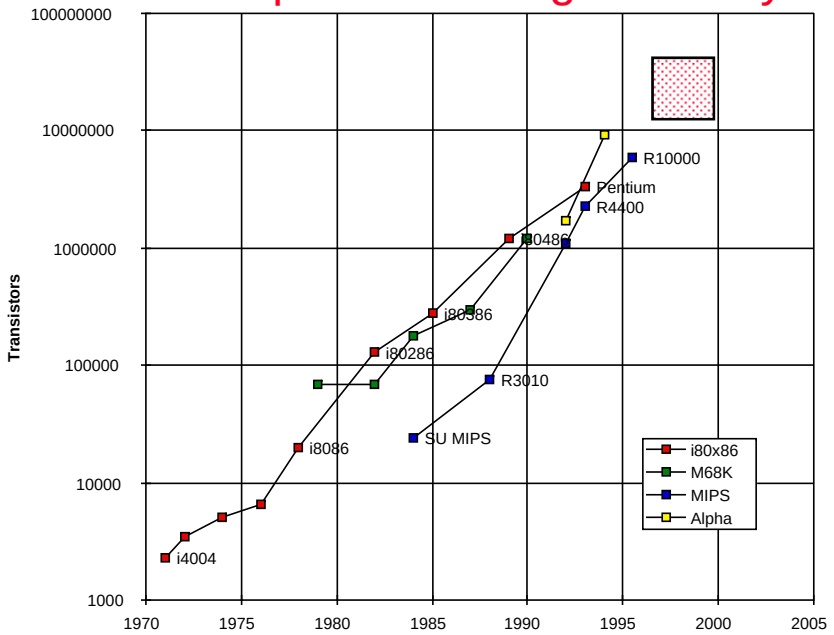


Technology Trends

DRAM chip capacity

DRAM	
Year	Size
1980	64 Kb
1983	256 Kb
1986	1 Mb
1989	4 Mb
1992	16 Mb
1996	64 Mb
1999	256 Mb
2002	1 Gb

Microprocessor Logic Density



- In 1985, the single-chip 32-bit processor and the single-board computer emerged
- By 2002, we will have entire computer systems on a single chip.

Technology trends

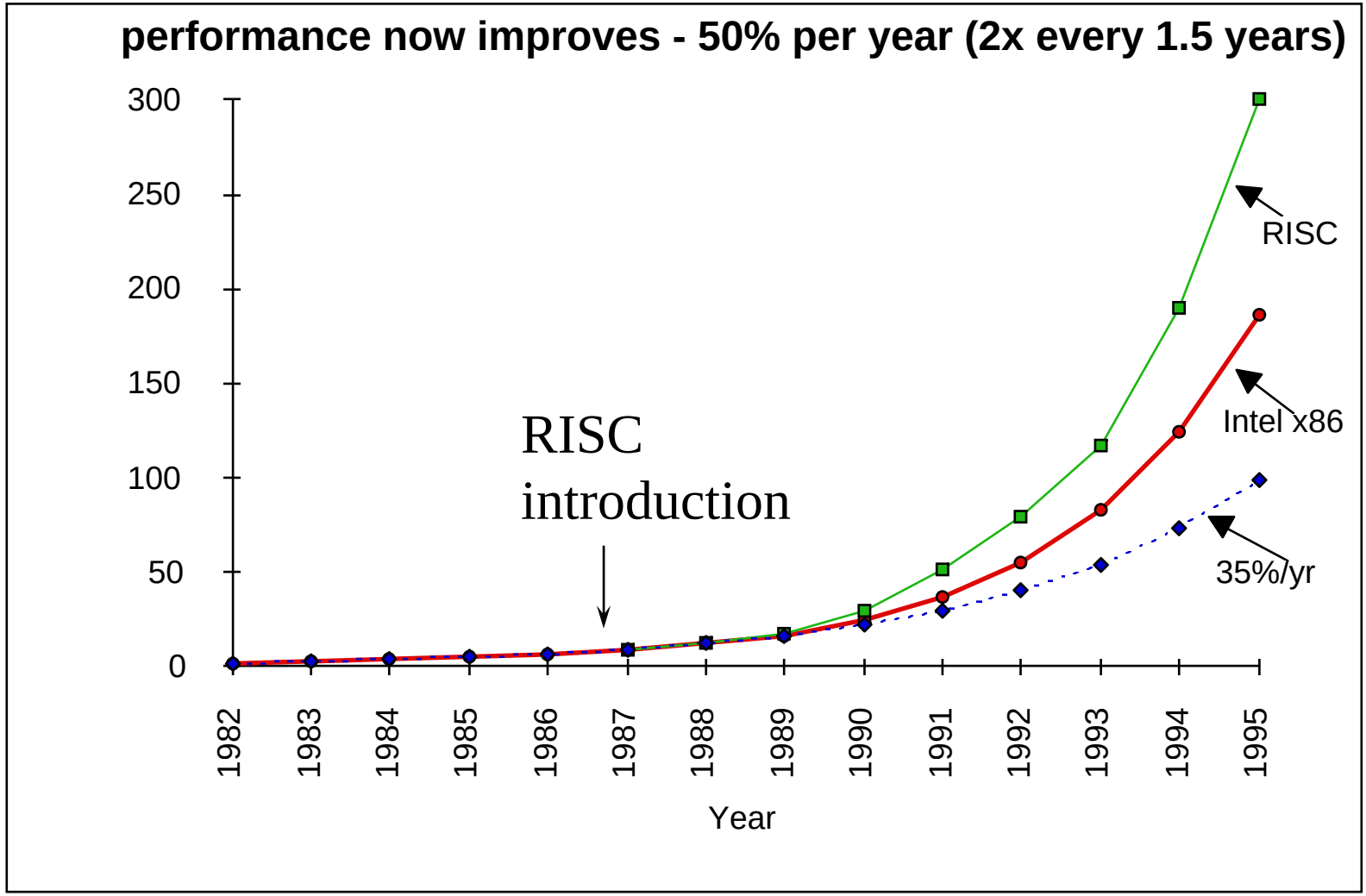
- **Processor**
  - logic capacity: increases about 30% per year
  - clock rate: increases about 20% per year
  - performance: increases about 50% per year
- **Memory**
  - DRAM capacity: increases about 60% per year (4x every 3 years)
  - performance: increases about 3.4% per year
- **Disk**
  - capacity: about 60% per year
  - performance: increases about 3.4% per year
- **Network Bandwidth**
  - Bandwidth increasing more than 100% per year!
- **What impact does this have on future computer systems?**
- **What impact does this have on design decisions?**

Technoloy Trends

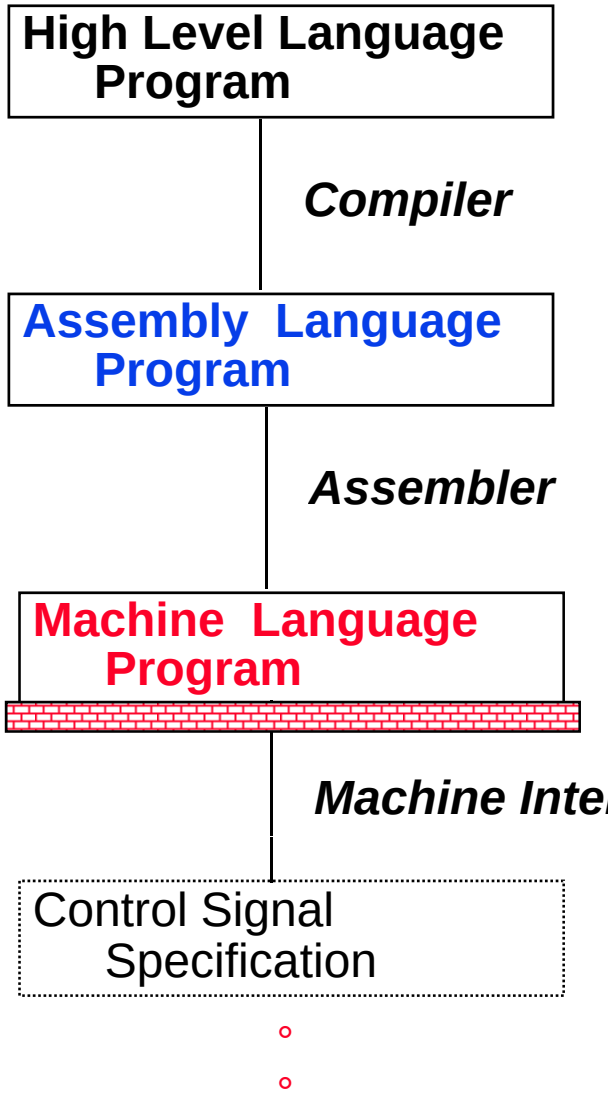
Year of First Shipment	1995	1998	2001	2004	2007	2010
Minimum Feature Size (μm)	0.35	0.25	0.18	0.13	0.10	0.07
Memory						
Bits/chip	64Mb	256Mb	1Gb	4Gb	16Gb	64Gb
Cost/bit (millicents)	0.017	0.007	0.003	0.001	0.005	0.0002
Microprocessor logic (high volume)						
Transistors/cm^2	4M	7M	13M	25M	50M	90M
Memory cache (bits/cm^2)	2M	6M	20M	50M	100M	300M
Cost/transistor (millicents)	1	0.5	0.2	0.1	0.05	0.02
ASIC logic (low volume)						
Transistors/cm^2	2M	4M	7M	12M	25M	40M
Design cost/transistor (millicents)	0.3	0.1	0.05	0.03	0.02	0.01

Source: National Technology Roadmap for Semiconductors, 1994.

Processor Performance



Levels of Representation




```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

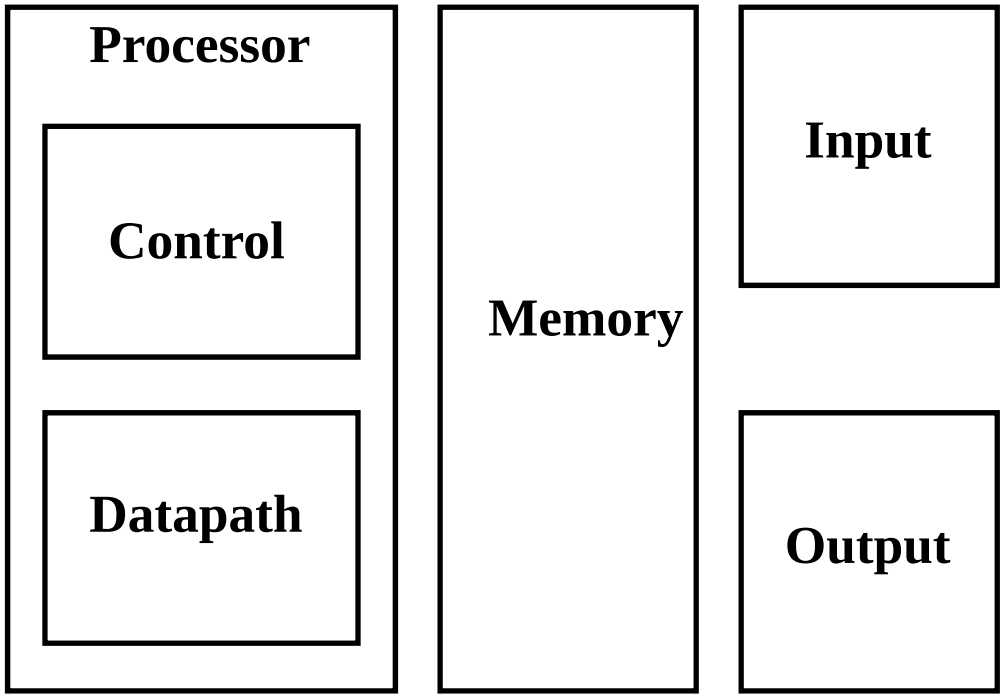
```
lw$15,  0($2)
lw$16,  4($2)
sw      $16,  0($2)
sw      $15,  4($2)
```

```
0000 1001 1100 0110 1010 1111 0101 1000
1010 1111 0101 1000 0000 1001 1100 0110
1100 0110 1010 1111 0101 1000 0000 1001
0101 1000 0000 1001 1100 0110 1010 1111
```

ALUOP[0:3] <= InstReg[9:11] & MASK

The Big Picture

° Since 1946 all computers have had 5 main components

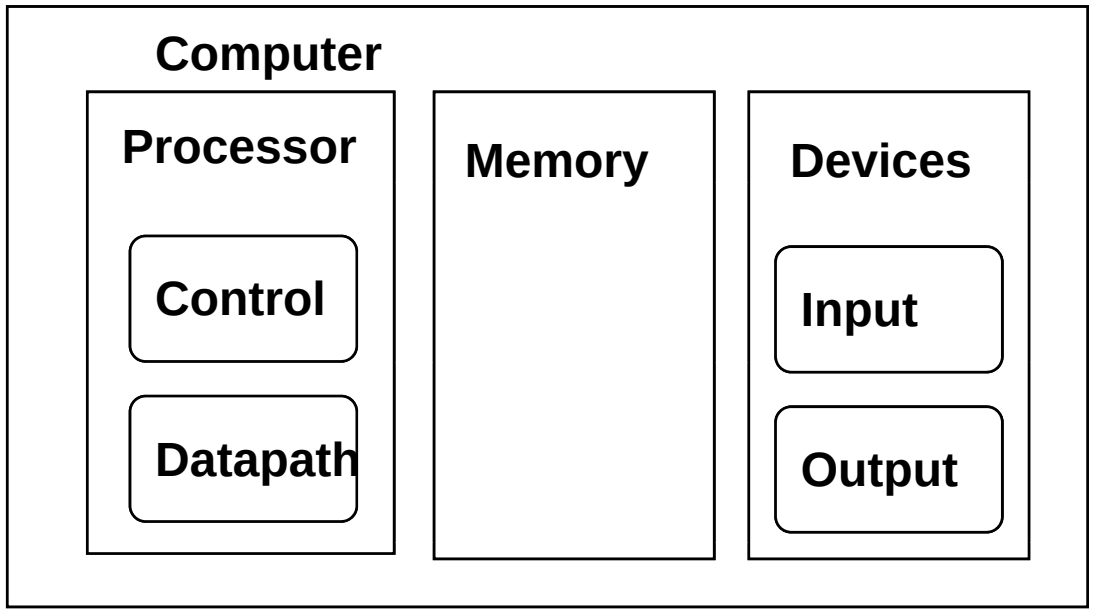


Components of a Computer

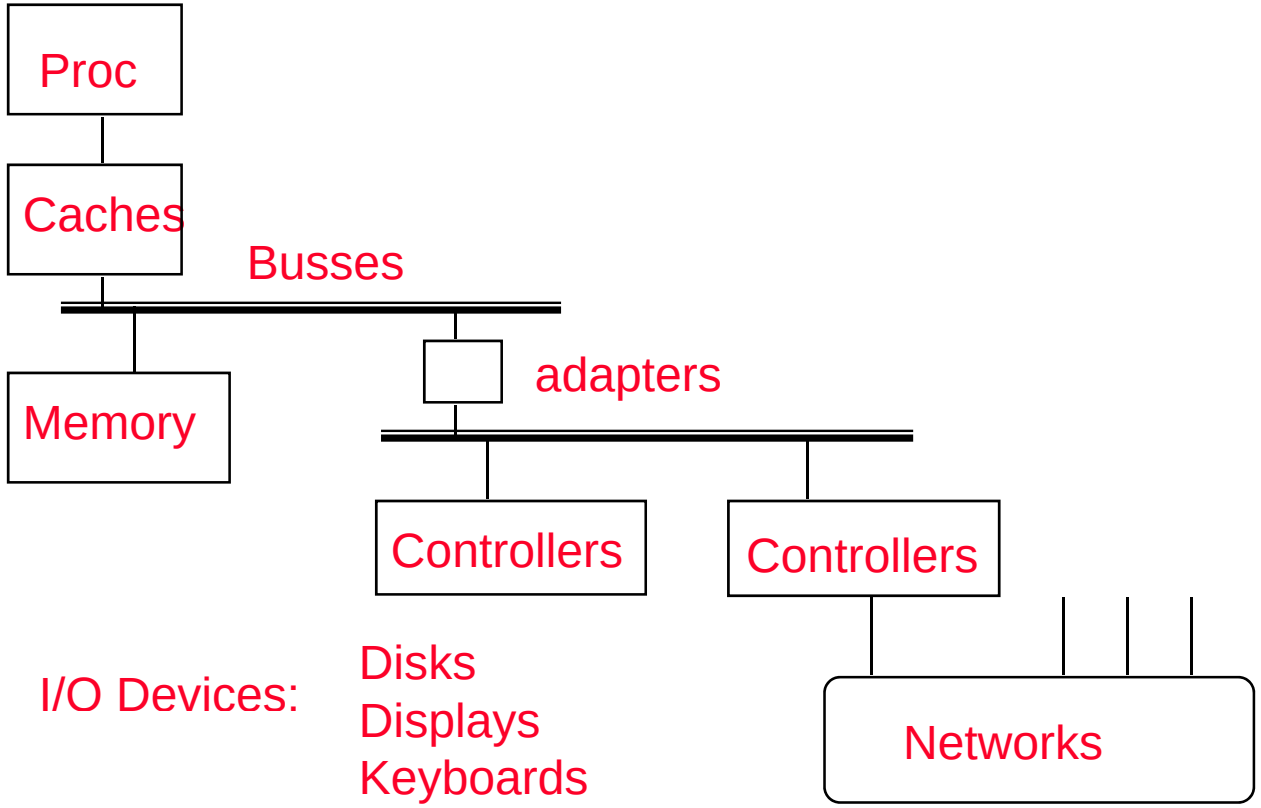
- **The functions of the different computer components are**
  - **datapath - performs arithmetic and logic operations**
    - **e.g., adders, multipliers, shifters**
  - **memory - holds data and instructions**
    - **e.g., cache, main memory, disk**
  - **input - sends data to the computer**
    - **e.g., keyboard, mouse**
  - **output - gets data from the computer**
    - **e.g., screen, sound card**
  - **control - gives directions to the other components**
    - **e.g., bus controller, memory interface unit**

Relative Cost of Computer Components

Workstation Design Target:
25% of cost on Processor
25% of cost on Memory
Rest on I/O devices,
power supplies, box



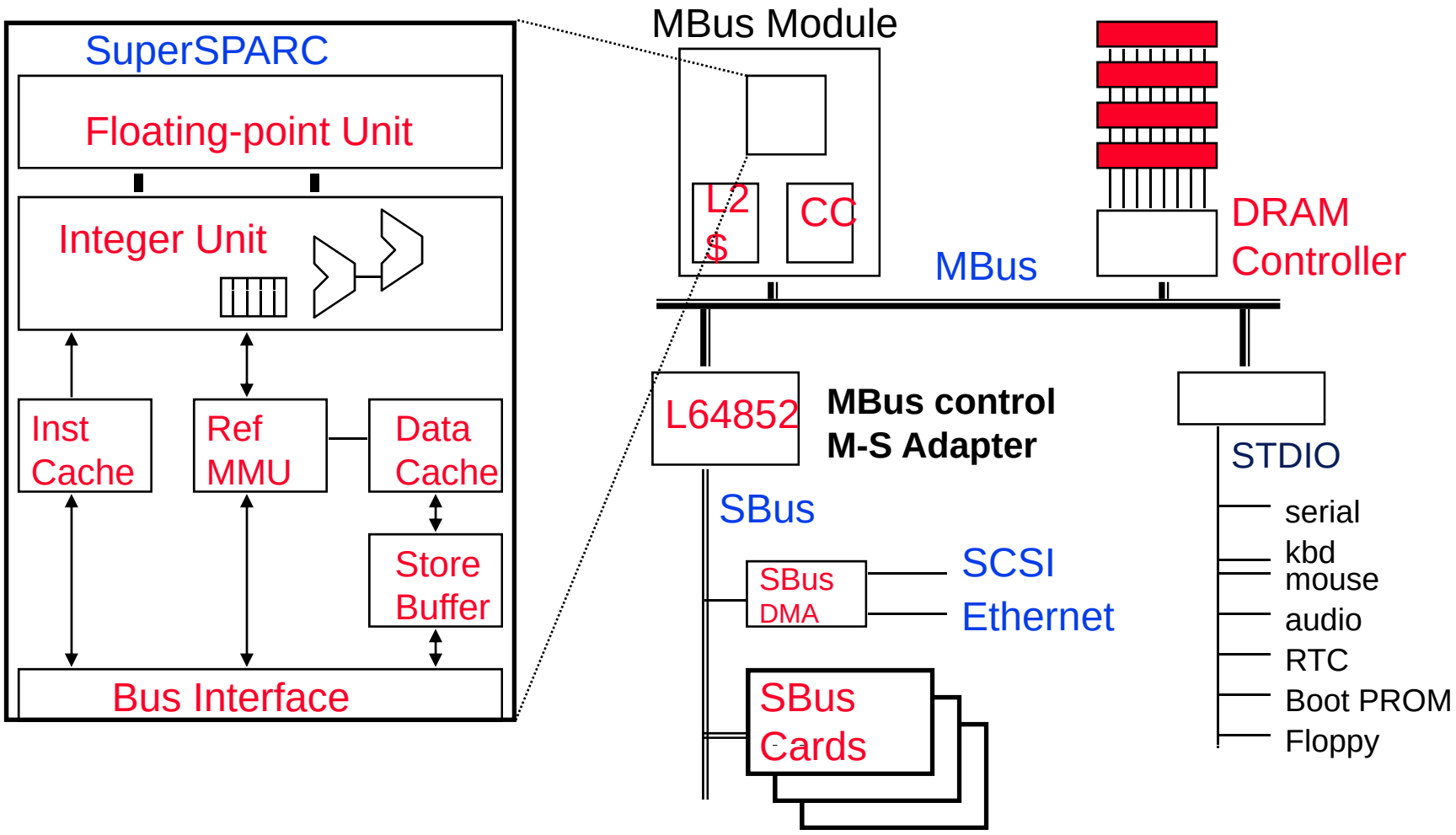
Computer System Components



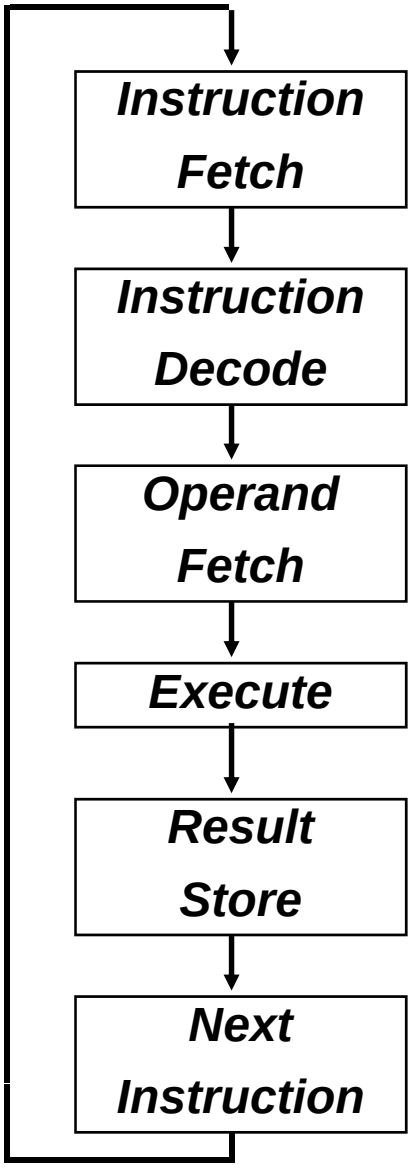
- **All have interfaces & organizations**

Example Organization

° **TI SuperSPARC^{tm} TMS390Z50 in Sun SPARCstation20**



Instruction Execution



Obtain instruction from program storage

Determine required actions and instruction size

Locate and obtain operand data

Compute result value or status

Deposit results in storage for later use

Determine successor instruction

Summary

- Computer Architecture includes the design of the Instruction Set Architecture (programmer's view) and the Machine Organization (logic designer's view).
- Levels of abstraction, which consist of an interface and an implementation are useful to manage designs.
- Processor performance increases rapidly, but the speeds of memory and I/0 have not kept pace.
- Computer systems are comprised on datapath, memory, input devices, output devices, and control.
- By next class:
  - read over all of Chapter 1 and Sections 2.1 to 2.3