# 計算機組織 (Computer Organization)

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## 內容綱要

- 1. Historical perspective of computer
- 2. Instruction set and hardware description language
- 3. Evaluation of computer performance
- 4. Arithmetic for computer
- 5. Verilog-HDL: Hardware description language
- 6. Data path and control of computer
- 7. Enhancing CPU performance with pipelining
- 8. Memory hierarchy: cache and virtual memory
- 9. I/O devices and bus

- 學分數：3
- 修習年級：大三, 大四
- 預修科目：Introduction to Digital System, High-Level programming language

- 教科書：
  - David A. Patterson and J. L. Hennessy, Computer Organization & Design: The hardware/software interface, 2nd edition, Morgan Kaufman Publishers, Inc., 1998

- 參考書：
  - The 80x86 Family Design, Programming, and Interfacing, 2nd edition, Uffenbeck, 1998

- 成績計算：
  - Mid-term Examination 30%
  - Homework and Project 35%
  - Final Examination 35%

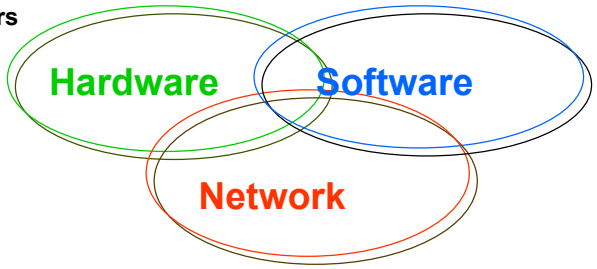


# Chapter 1



# 1.1 Introduction

- Computers have led to a third resolution for civilization ➠ information revolution taking place alongside the agricultural and industrial revolutions.
- Computer technology (hardware ➠ software ➠ network) fiction :
  - Automatic teller machines
  - Computers in automobiles
  - Laptop computers
  - World Wide Web






# Schedule

**Figure 1.3** Microprocessor chips began to flourish in the late 1970s. The January 1979 issue of *BYTE* magazine illustrates one point of view on how these chips are made. (Reprinted courtesy of Robert Tinney Graphics and BYTE Publications, Peterborough, N.H.)

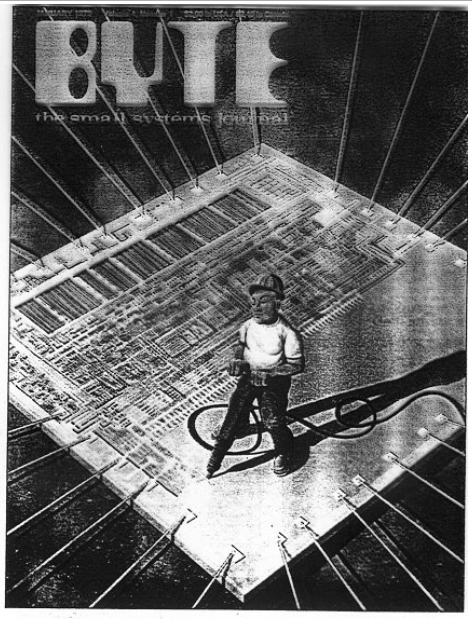


**Figure 1.5** In 1982, using ads such as this, IBM began selling the idea of a *personal computer* or *PC*. (Reprinted courtesy of BYTE Publications, Peterborough, N.H.)

"My own IBM computer. Imagine that."

One nice thing about having your own IBM Personal Computer is that it's *yours*. For your business, your project, your department, your class, your family and, indeed, for yourself.

Of course, you might have thought owning a computer was too expensive. But now you can relax.

The IBM Personal Computer starts at less than $1,600* for a system that, with the addition of one simple device, hooks up to your home TV and uses your audio cassette recorder.

You might also have thought running a computer was too difficult. But you can relax again.

Getting started is easier than you might think, because IBM has structured the learning process for you. Our literature is in *your* language, not in "computerese." Our software *involves* you, the system *interacts* with you as if it was made to—and it was.

That's why you can be running programs in just one day. Maybe even writing your *own* programs in a matter of weeks.

For ease of use, flexibility and performance, no other personal computer offers as many advanced capabilities. (See the box.)

But what makes the IBM Personal Computer a truly useful tool are software programs selected by IBM's Personal Computer Software Publishing Department. You can have programs in business, professional, word processing, computer language, personal and entertainment categories.

You can see the system and the software in action at any ComputerLand® store or Sears Business Systems Center. Or try it out at one of our IBM Product Centers. The IBM Data Processing Division will serve those customers who want to purchase in quantity.

*Your* IBM Personal Computer. Once you start working with it, you'll discover more than the answers and solutions you seek: you'll discover that getting there is half the fun. Imagine that.

IBM

IBM PERSONAL COMPUTER SPECIFICATIONS
"ADVANCED FEATURES FOR PERSONAL COMPUTERS"

The IBM Personal Computer and me.

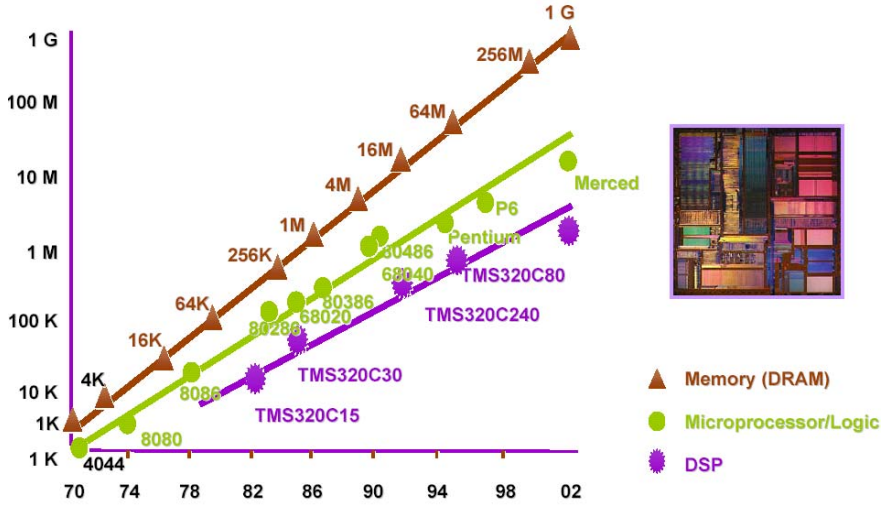


7

18 MICROCOMPUTERS AND MICROPROCESSORS

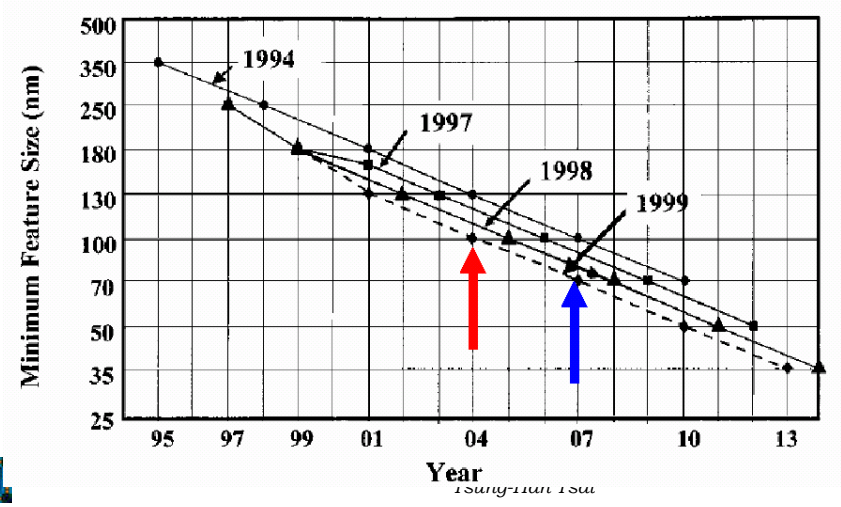
**Figure 1.7** The CRAY-1 supercomputer. (Photo courtesy of Smithsonian)


## Accelerating Technology and Complexity






## Silicon Process Roadmaps



## The evolution of Information Industry




## System Revolution

1999-2000

| | | | | |
|---|---|---|---|---|
| Discrete Component Era | ····▶ | LSI/VLSI Era | ····▶ | SOC/SLI Era |
| Mainframe Era | ····▶ | PC Era | ····▶ | Post PC Era |
| Mainframe Computer | ····▶ | PC | ····▶ | IA |

Internet Appliance
Information Appliance

## 1.1 Introduction

- **The New York Times has estimated that the average American comes into contact with about 60 microprocessors every day [Camposano, 1996]**
  - **Latest top-level BMWs contain over 100 microprocessors**
- **Why learn this stuff?**
  - **You want to know the operation principle of computer ➠ Not just plug-and-play like others**
  - **you need to make a purchasing decision or offer "expert" advice**
  - **you want to design computer hardware and its application : Leading EE&CE industry in Taiwan**
  - **you want to build software people use (need performance)**
  - **you want to call yourself a "computer scientist"**



## 數位: 二進 位

| 1 | 0 |
|---|---|
| 高電壓 | 低電壓 |
| 高電流 | 低電流 |
| 男 | 女 |
| 天 | 地 |
| 真 | 假 |
| 對 | 錯 |

# 數位系統術語

BIT:位元 (For machine)

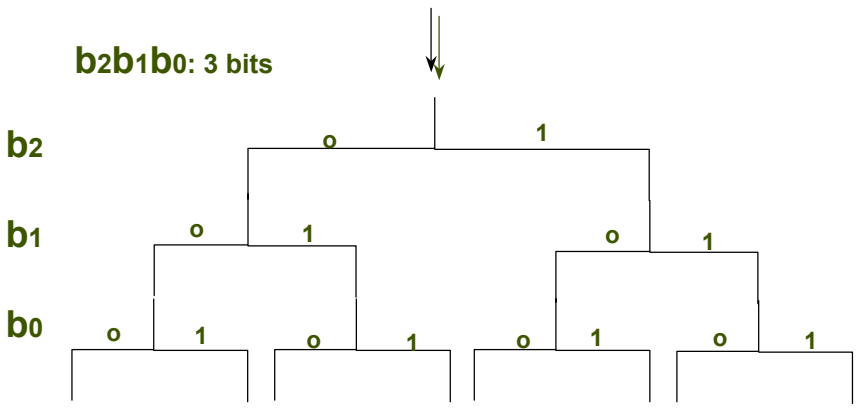
BYTE:位元組, 8bits (Text)

WORD:字元 ,8bits,
16bits, 32bits, 64bits

(Information: Code, Number, etc.)



# 二進 位之應用:抉擇 / 狀態




抉擇 / 狀態: $2^3$

High-level language program (in C)

```
swap(int v[], int k)
{int temp;
   temp = v[k];
   v[k] = v[k+1];
   v[k+1] = temp;
}
```

C compiler

Assembly language program (for MIPS)

```
swap:
      muli $2, $5,4
      add  $2, $4,$2
      lw   $15, 0($2)
      lw   $16, 4($2)
      sw   $16, 0($2)
      sw   $15, 4($2)
      jr   $31
```

Assembler

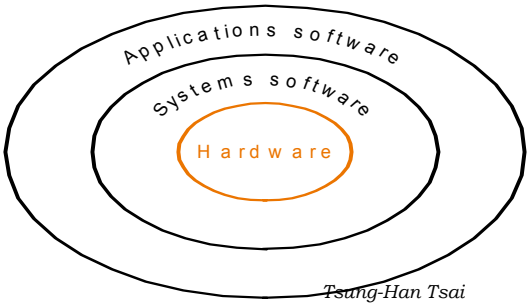
Binary machine language program (for MIPS)

```
00000000101000010000000000000000
00000000100011110000000000000001
10001100011000100000000000000000
10001100010000110000000000000100
10101100011000100000000000000000
10101100010000110000000000000100
00000011111000000000000000001000
```



# 1.2 What is a computer?

- **Components:**
  - **input (mouse, keyboard, Fig.1.4)**
  - **output (display,Fig.1.4, printer, speaker)**
  - **memory (disk drives,Fig.1.12, DRAM, SRAM, CD)**
  - **processors**
  - **network**
- **Our primary focus: the processor (data path and control)**
  - **implemented using millions of transistors**
  - **Impossible to understand by looking at each transistor**

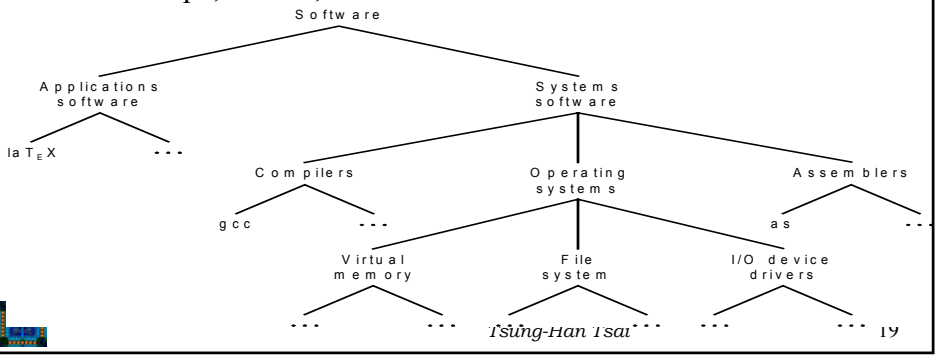



## 1.2 What is a computer?

•Software is categorized by its use

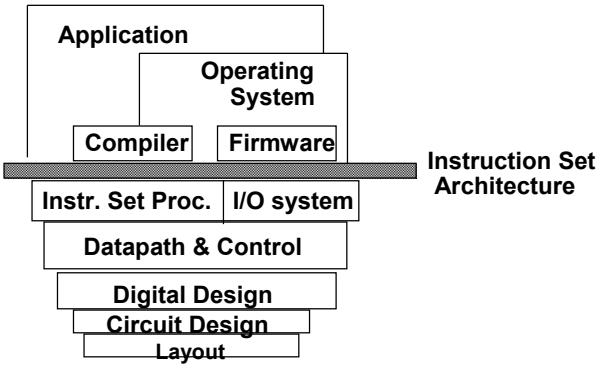
•System software: Programs aimed at programmer and provides services that are useful ; Operating system, compiler, etc.

•Application software: program aimed at computer users; Netscape, Words, etc.



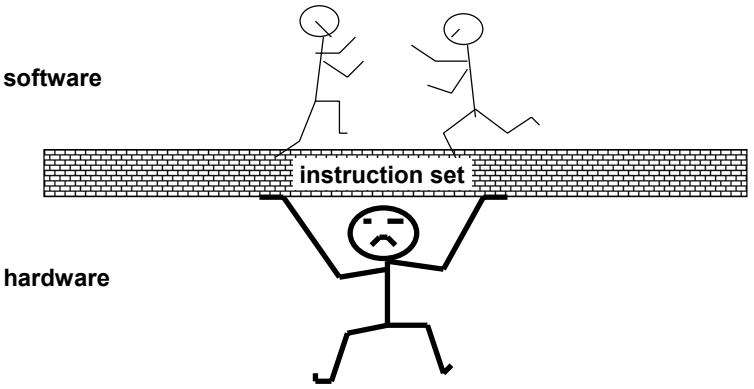



## What is Computer Architecture?




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

## The Instruction Set: a Critical Interface





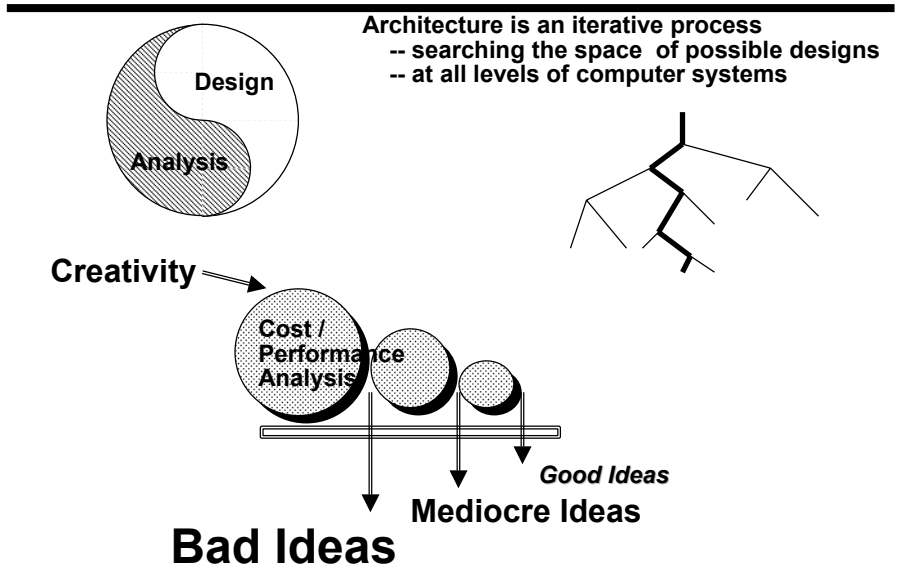

## Instruction Set Architecture

- **A very important abstraction**
  - **interface between hardware and low-level software**
  - **standardizes instructions, machine language bit patterns, etc.**
  - **advantage: *different implementations of the same architecture***
  - **disadvantage: *sometimes prevents using new innovations***

  ***True or False: Binary compatibility is extraordinarily important?***

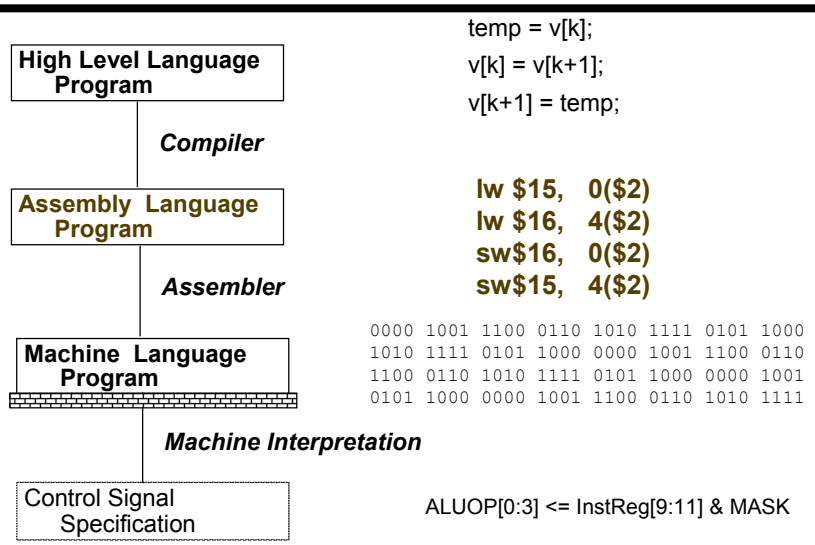
- **Modern instruction set architectures:**
  - **80x86/Pentium/K6, PowerPC, DEC Alpha, MIPS, SPARC, HP**

# Measurement and Evaluation

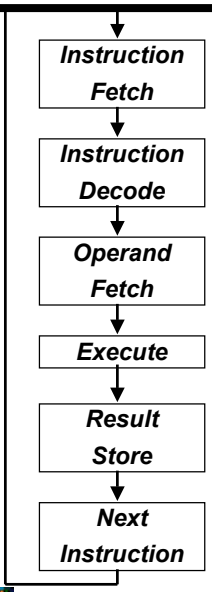





# Levels of Representation (Software View)




## Execution Cycle




**Obtain instruction from program storage**

**Determine required actions and instruction size**

**Locate and obtain operand data**

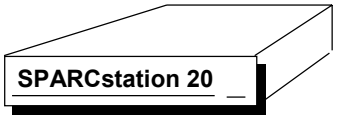
**Compute result value or status**

**Deposit results in storage for later use**

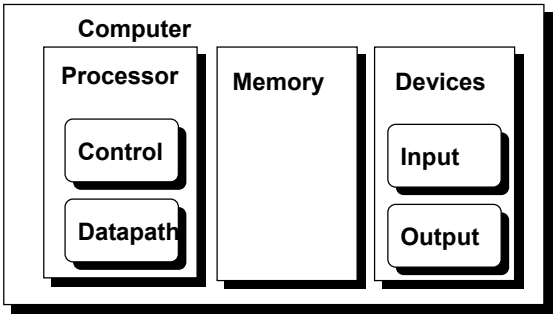
**Determine successor instruction**



## Levels of Organization (Hardware View)

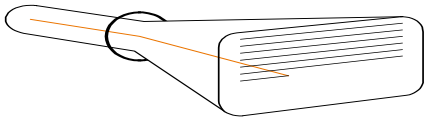


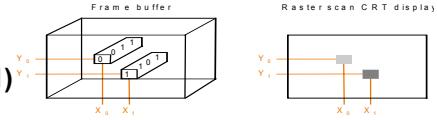

Workstation Design Target:
25% of cost on Processor
25% of cost on Memory
(minimum memory size)
Rest on I/O devices,
power supplies, box



# 1.3 Major components

- Input devices : ?
  - Mouse:Fig.1.5
- Output devices : ?
  - Raster Cathode ray Tube (CRT)
  - Liquid Crystal Displays ( LCD)






- Motherboard (Fig.1.8, Fig.1.11)
- Integrated circuits or chips
  - Memory chips : Dynamic Random Access memory (DRAM), Static Random Access memory (SRAM)
  - PC chip set: graphic, sound, I/O controller
  - Central Processor Unit (CPU), Fig.1.9
- Data storage
  - Primary memory (main memory) :DRAM, SRAM
  - Secondary memory: (Zip) floppy disk, hard disk and optical Compact Disk (CD)
- A simple view of computer organization is shown in Fig.1.10 that consists of five components



# 1.4 ICs for Computer

Fig.1.14 DRAM

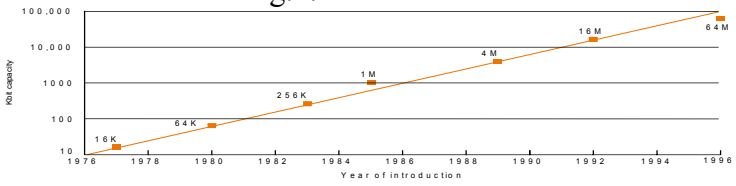
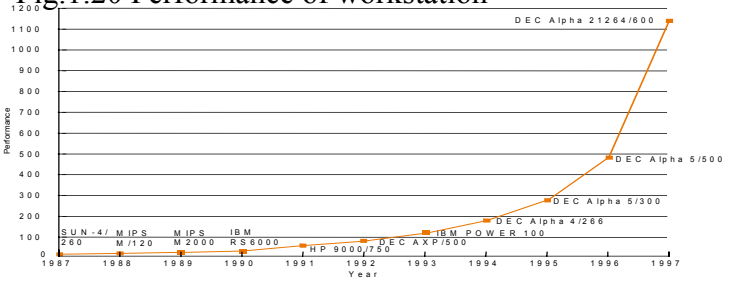



Fig.1.20 Performance of workstation



## Integrated Circuits (IC) 積體電路之演進

- **Integrated Circuits (IC) in silicon (Kilby) :1959**
  - **1960: SSI < 100 transistors**
  - **1966: MSI < 1000 transistors**
  - **1969: LSI < 10000 transistors**
  - **1975: VLSI > 10000 transistors**
  - **1985: VLSI > 100000 transistors**
  - **2000: VLSI > 10,000,000 transistors**
- **ROM (Read Only Memory): 1967**
  - **2000: 4M is very common**
- **RAM (Random Access Memory): 1970**
  - **1973: 16 K**
  - **1978: 64 K**
  - **1982: 256K**
  - **1986: 1M**
  - **1994: 16M**
  - **1997:64M**
  - **2000: 256M**
- **Microprocessor: 1969 by Intel**
  - **1971: 4 bits**
  - **1972: 8 bits**
  - **Late 1970s: 16 bits**
  - **1986, i386 : 32 bits**
  - **1993, Pentium : 32 bits 2001, Pentium 4: 2GHz**
- **Digital Signal Processor (DSP): 1 GOPS (G Operations Per Second)**
- **Operational Amplifier (analog) : 1964**
- **Analog-to-Digital Converter (ADC ,A/D)**
  **Digital-to-Analog converter (DAC, D/A)**



## *Computer* 之演進

♥**1946:First electronic calculator (ENIAC),**
**University of Pennsylvania⇨**
**18,000 vacuum tubes,**
**occupy 10*13 $m^2$; binary number,**
**boolean logic (Von Newman)**

♥**1946: IBM603⇨first commercial electronic computer**

♥**1948: IBM604⇨4000 machines were sold;**
**The beginning of computer industry**

♥**1998: 多媒體電腦, 一千美金**

## Where we are headed

- A specific instruction set architecture (Chapter 3)
- Performance issues (Chapter 2) *vocabulary and motivation*
- Arithmetic and how to build an ALU (Chapter 4)
- Verilog_HDL: Hardware description language
- Constructing a processor to execute our instructions (Chapter 5)
- Pipelining to improve performance (Chapter 6)
- Memory: caches and virtual memory (Chapter 7)
- I/O and Bus (Chapter 8)

**Key to a good grade: read the book (not just the note), form discussion group and do the home works yourself!**