CS2006: 計算機組織

Course Outline

為什麼電腦不用十進位而用二進位？

二進制只有兩種狀態

軟體、硬體

對、錯

本土化、非本土化

陰、陽

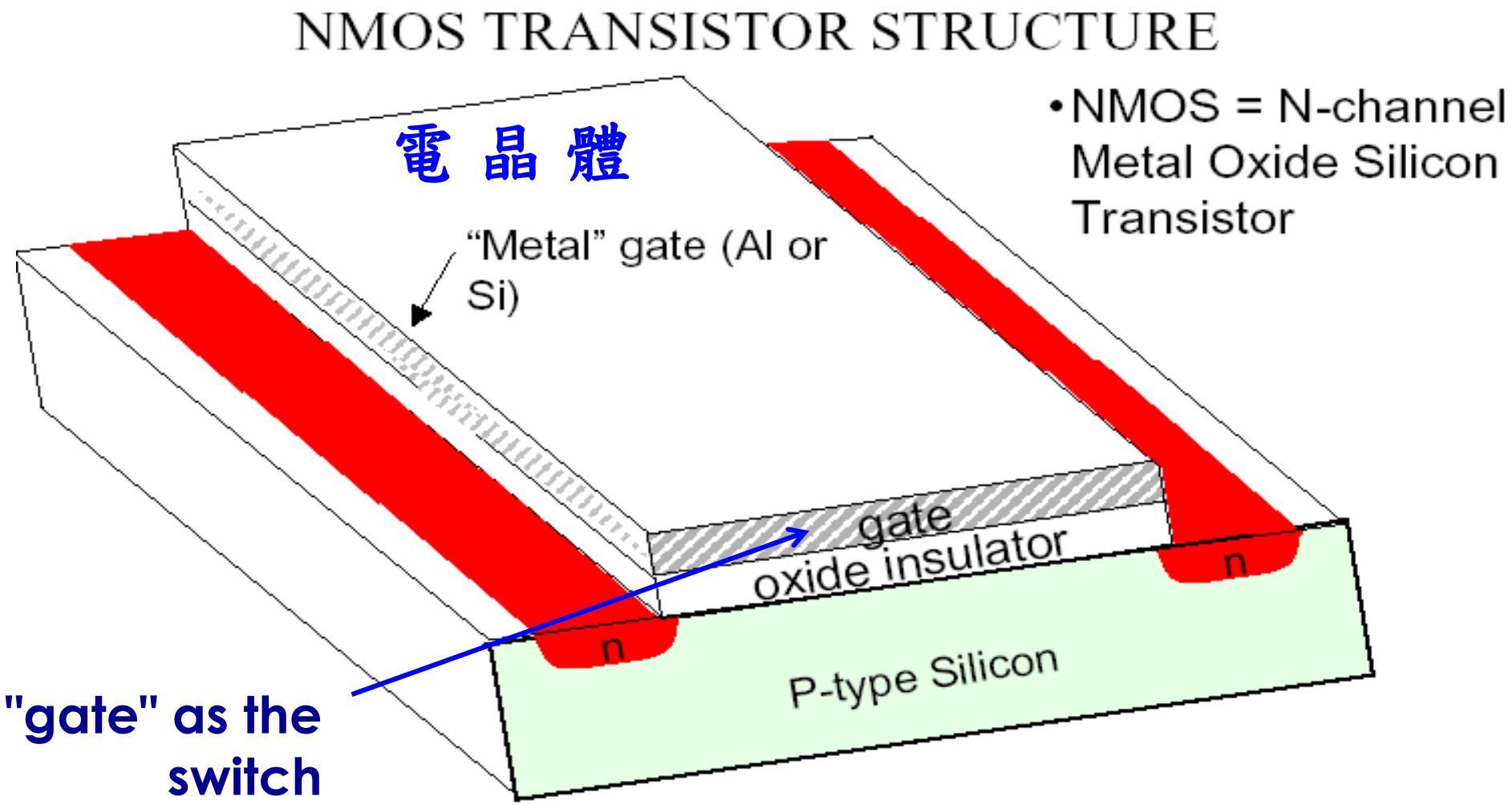
開、關

正、反

真、偽

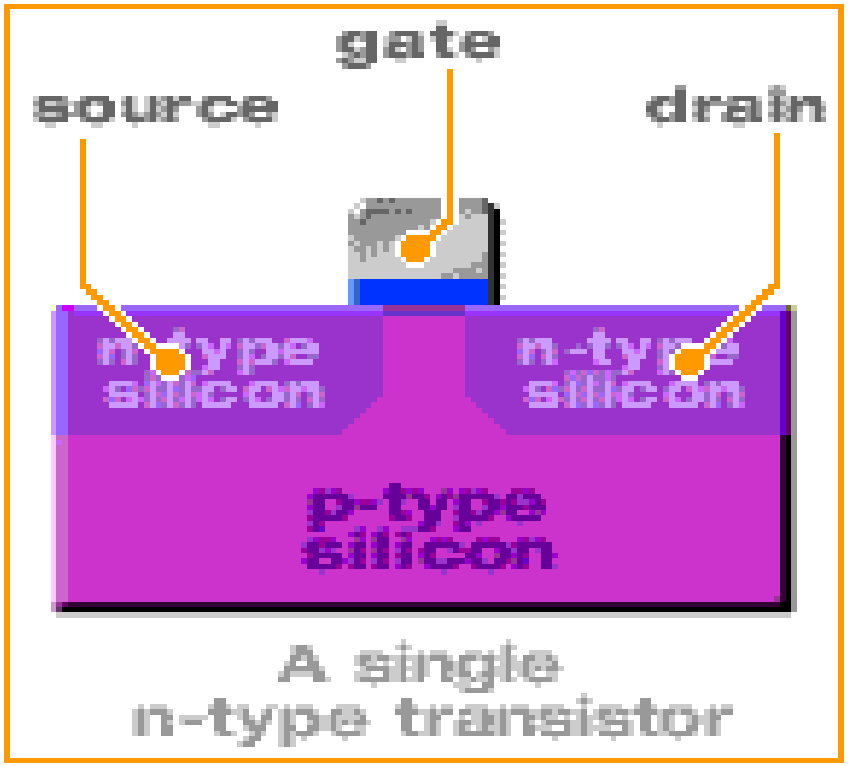
勝、負

如何做出電子開關?


NMOS TRANSISTOR STRUCTURE
電 晶 體
•NMOS = N-channel Metal Oxide Silicon Transistor
"Metal" gate (Al or Si)
gate
oxide insulator
n
n
P-type Silicon
"gate" as the switch

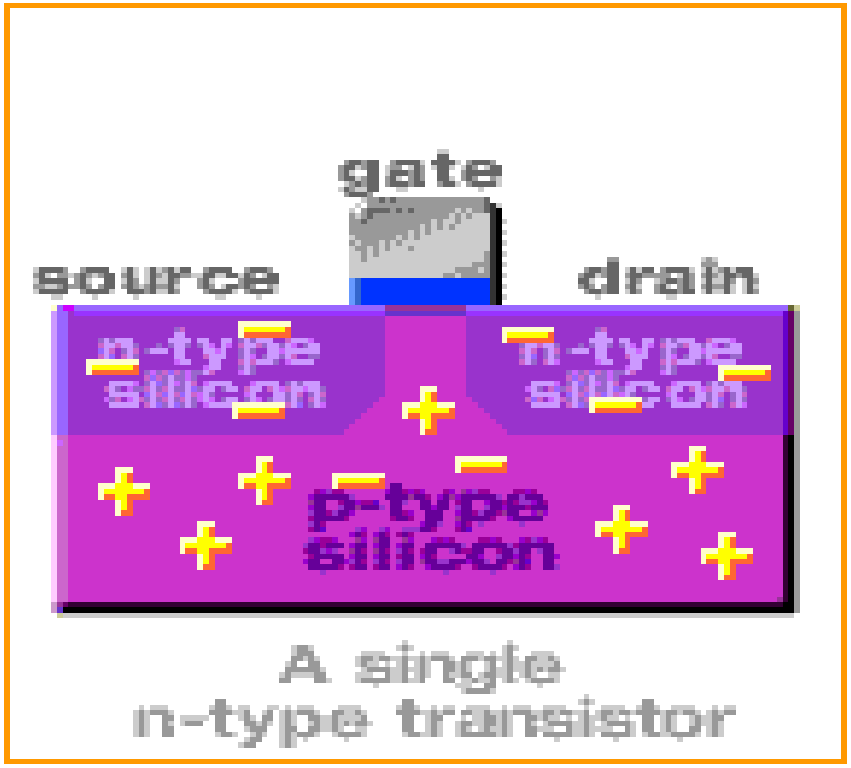
A Working Transistor (1/6)

- Transistors consist of three terminals; the source, the gate, and the drain:



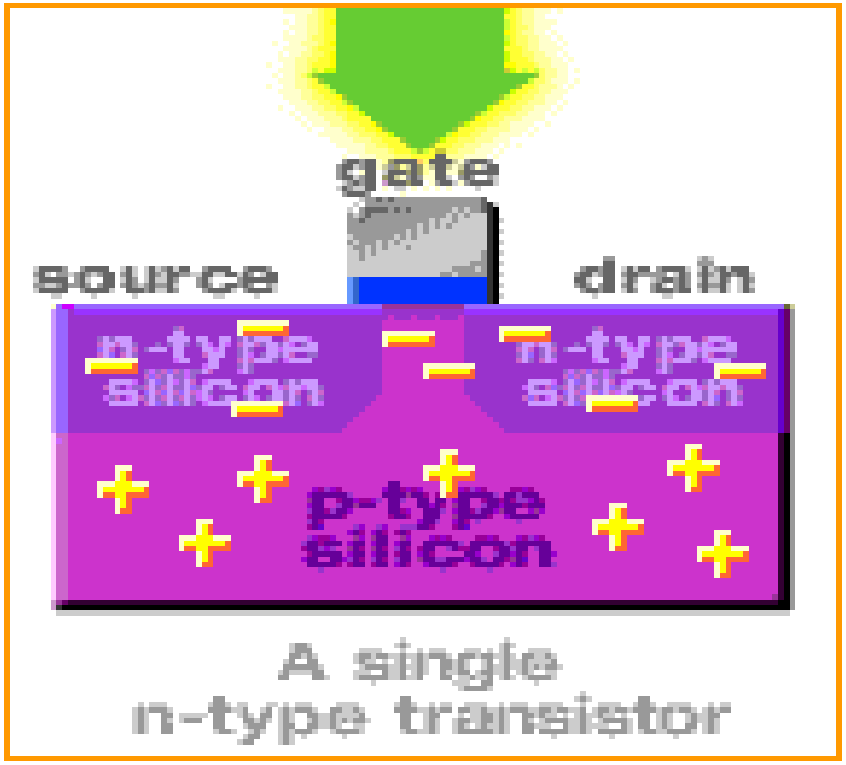
A Working Transistor (2/6)

- In the n-type transistor, both the source and the drain are negatively-charged and sit on a positively-charged well of p-silicon.



A Working Transistor (3/6)

- When positive voltage is applied to the gate, electrons in the p-silicon are attracted to the area under the gate forming an electron channel between the source and the drain.



A Working Transistor (4/6)

- When positive voltage is applied to the drain, the electrons are pulled from the source to the drain. In this state the transistor is on.

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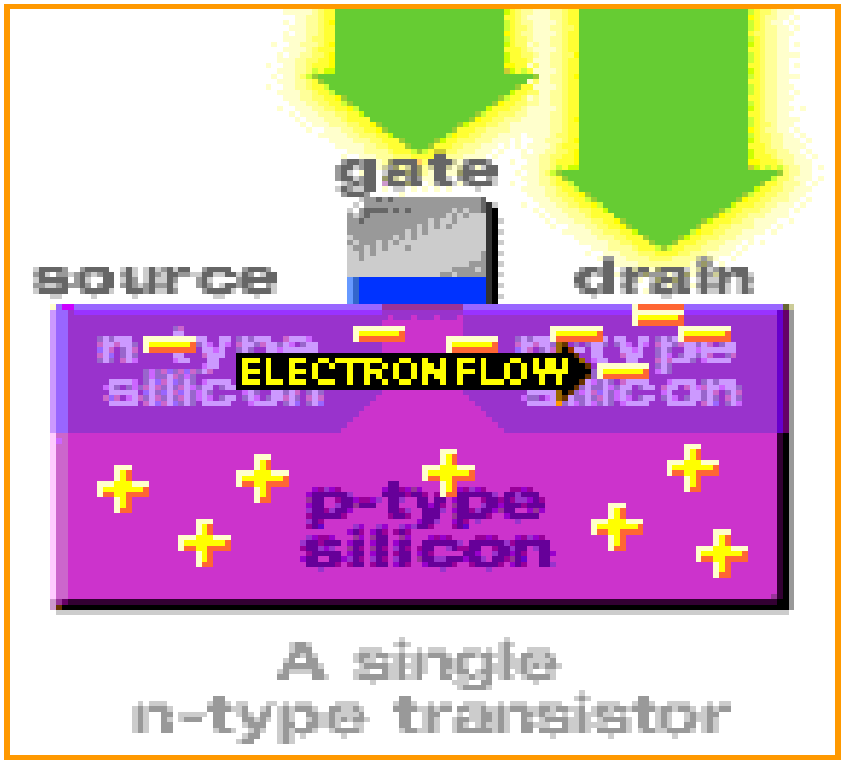

A Working Transistor (5/6)

- If the voltage at the gate is removed, electrons are not attracted to the area between the source and drain. The pathway is broken and the transistor is turned off.

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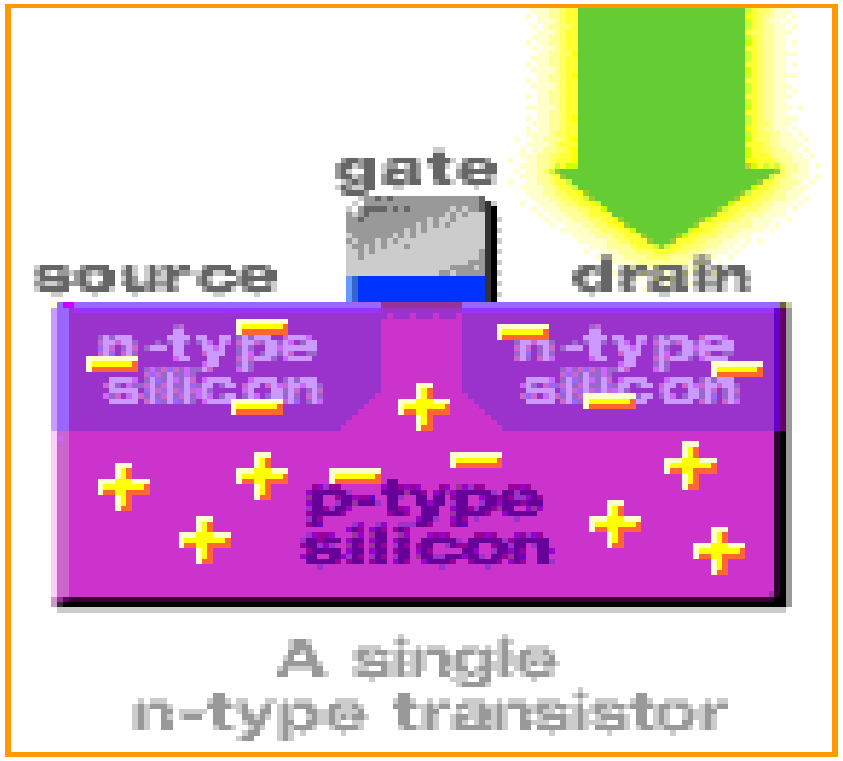
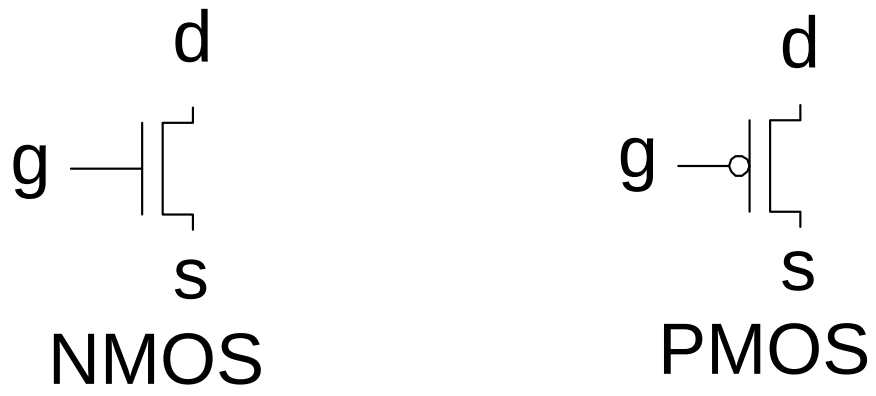


A Working Transistor (6/6)

- There are two major types of MOSes (switches), which operates in different conditions
  - NMOS: g=1, switch on; g=0 switch off
  - PMOS: g=1, switch off; g=0 switch on

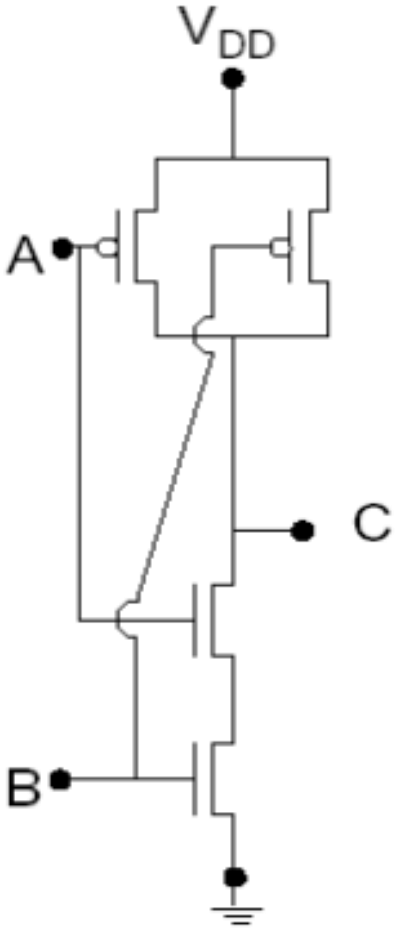


相關電壓電流特性
及電路分析等知識
我們是在_____課中介紹的

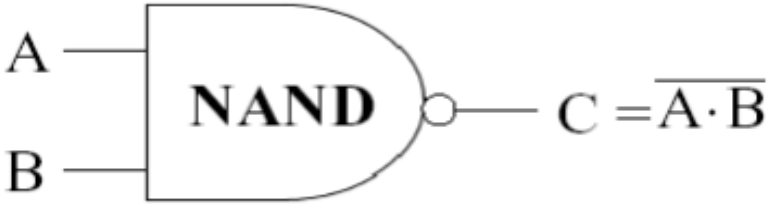
答：「電子電路」、「超大型積體電路設計」

有了開關就可以做邏輯閘

- **CMOS NAND:**

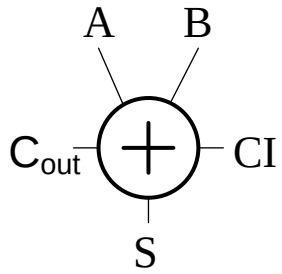


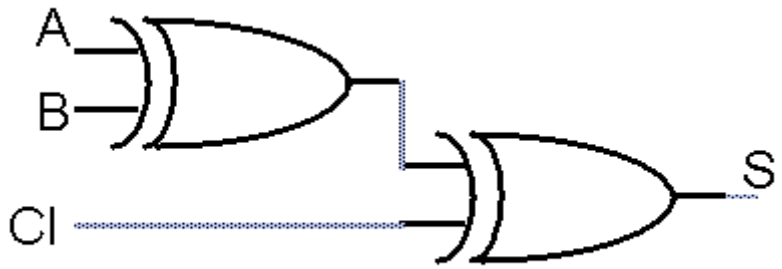
A	B	A B	C= $\overline{A\ B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0



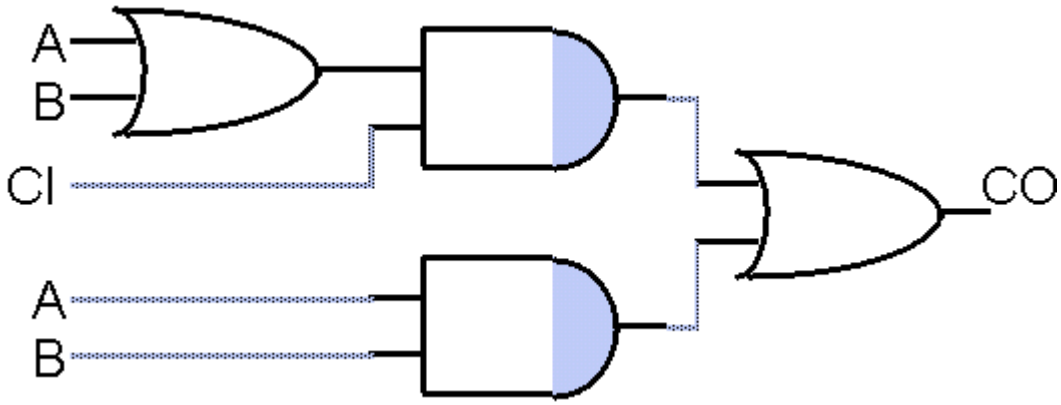
有了邏輯閘就可做邏輯電路

- 加法器：



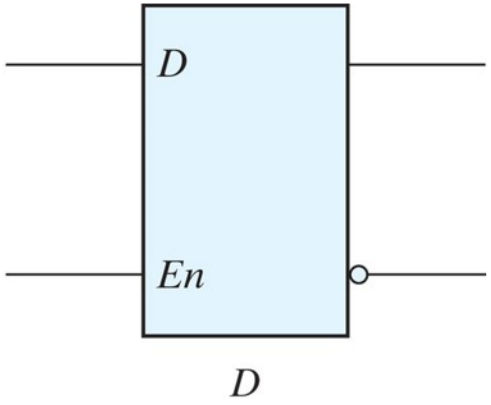


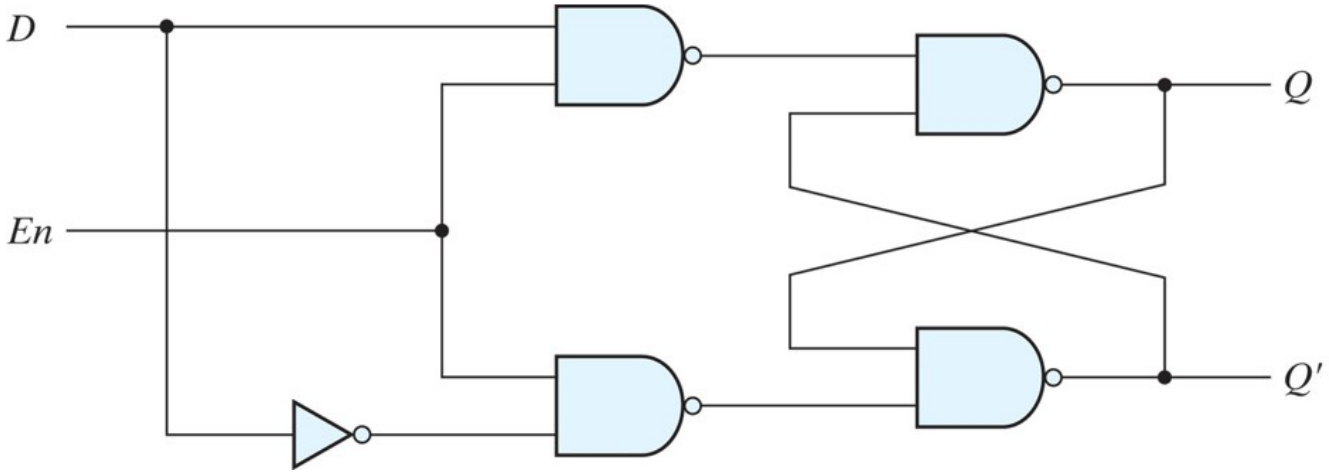
A	B	CI	C_{out}	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1



也可以做記憶元件

- 可以儲存一個bit的元件 (如: Latch, Flip-flop)：



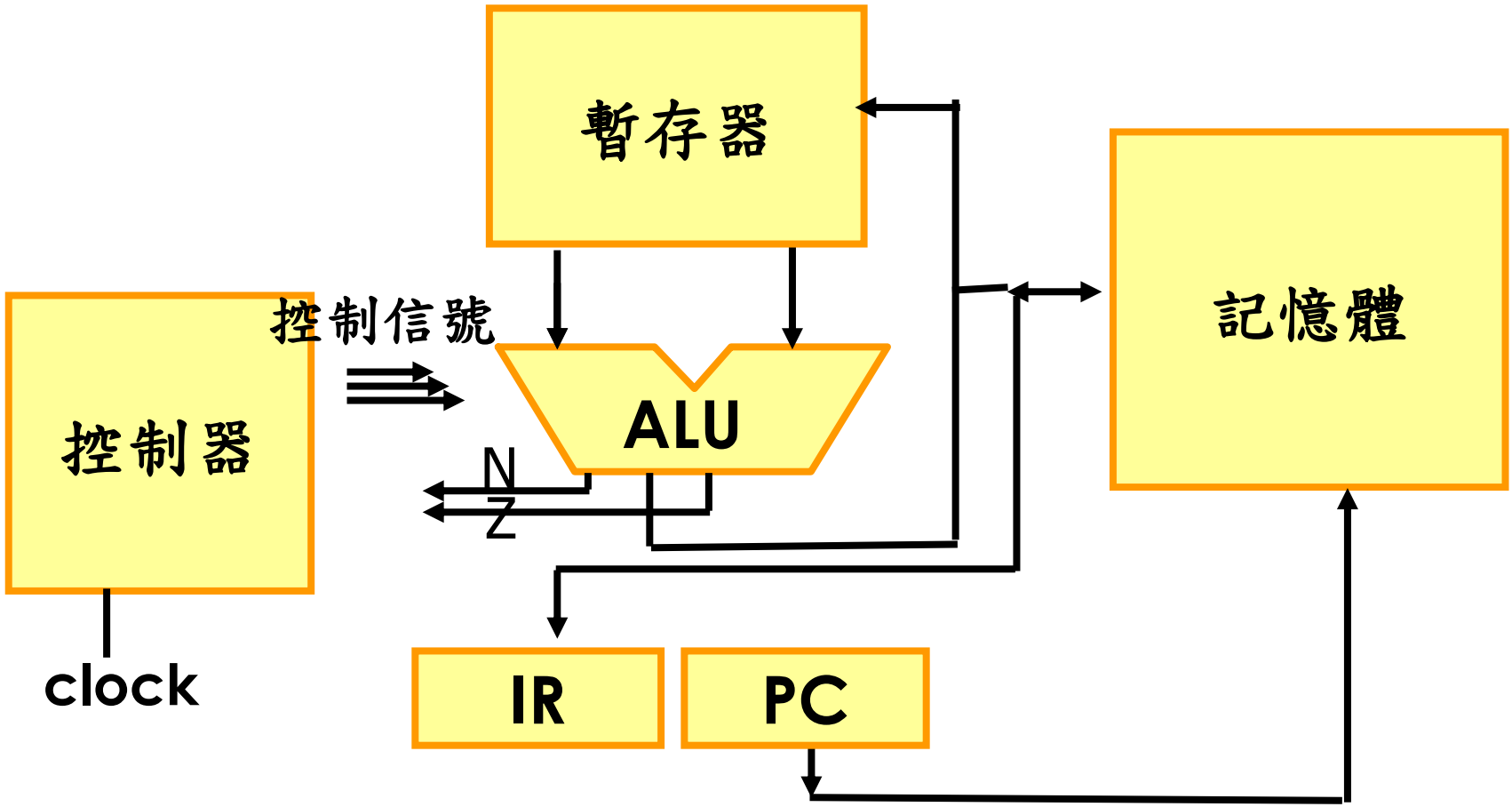


En	*D*	Next state of *Q*
0	X	No change
1	0	$Q = 0$; reset state
1	1	$Q = 1$; set state

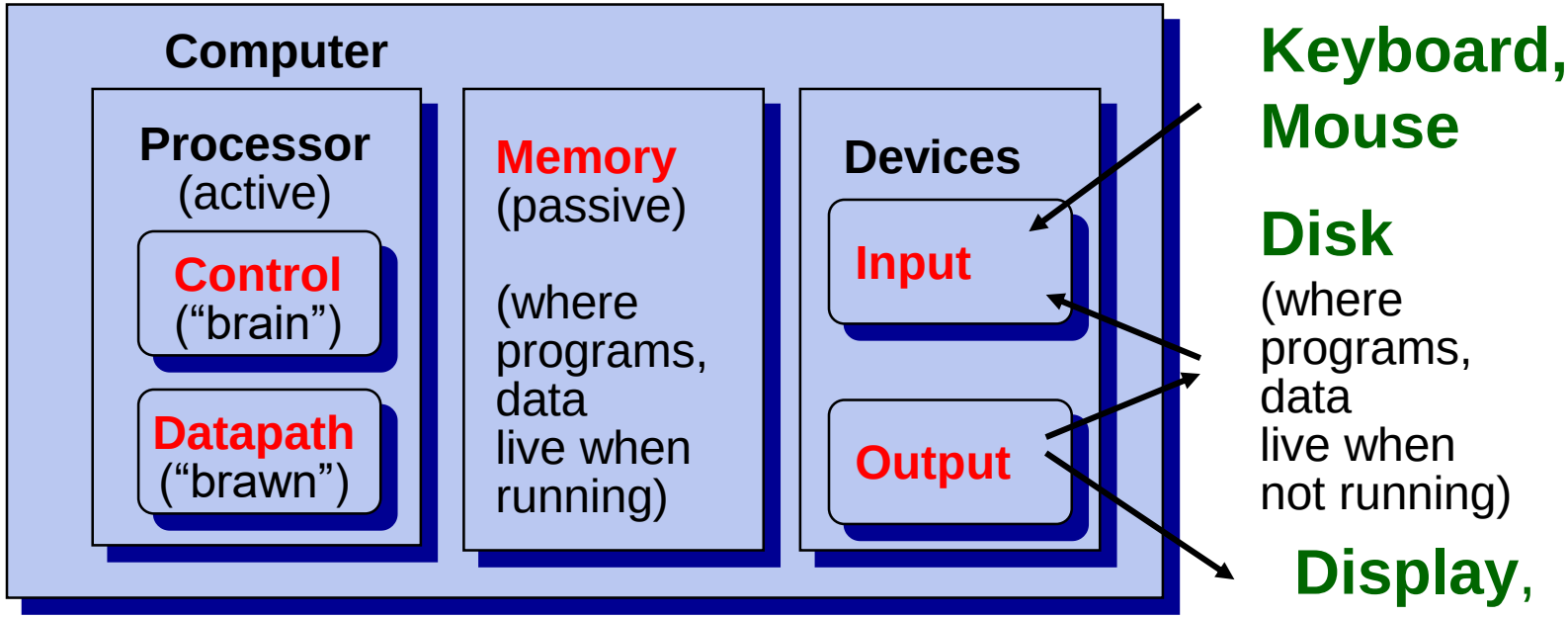
這部份的學問叫_____

答：「邏輯設計」、「數位系統」

於是電腦的主要部份都可以做了



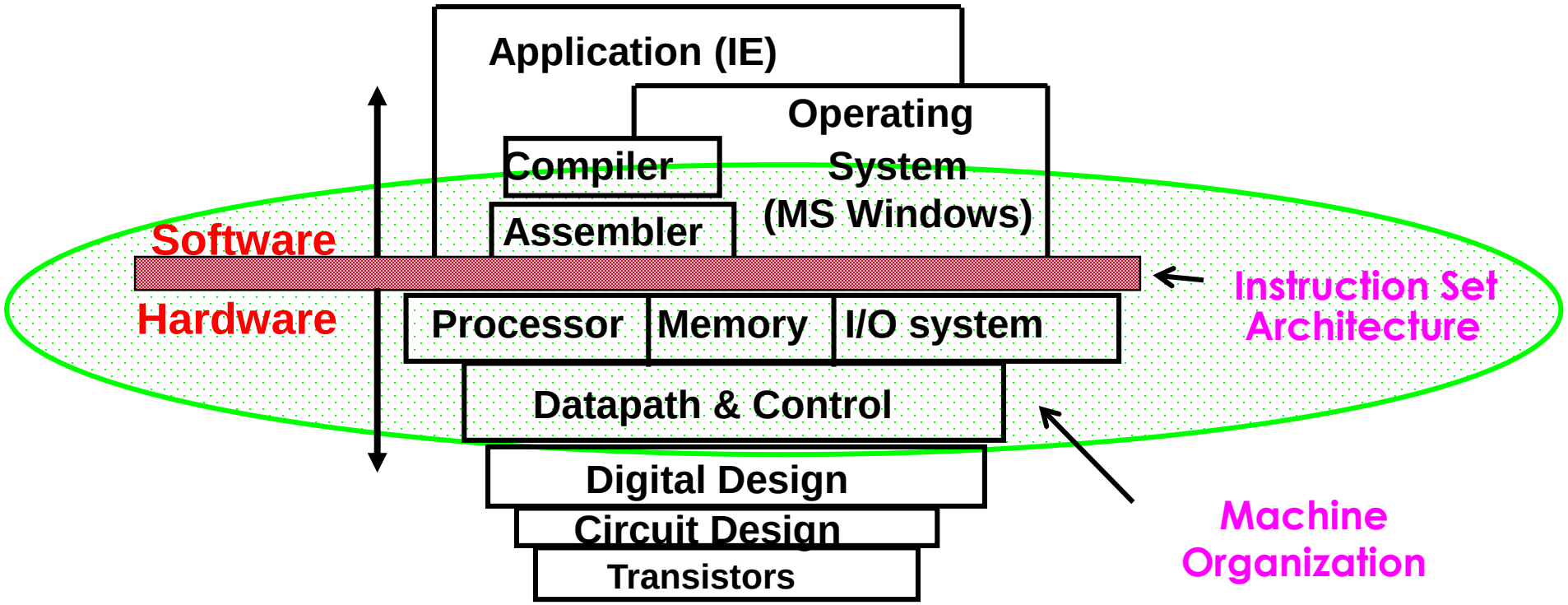
Basic Organization of Any Computer



Computer Organization

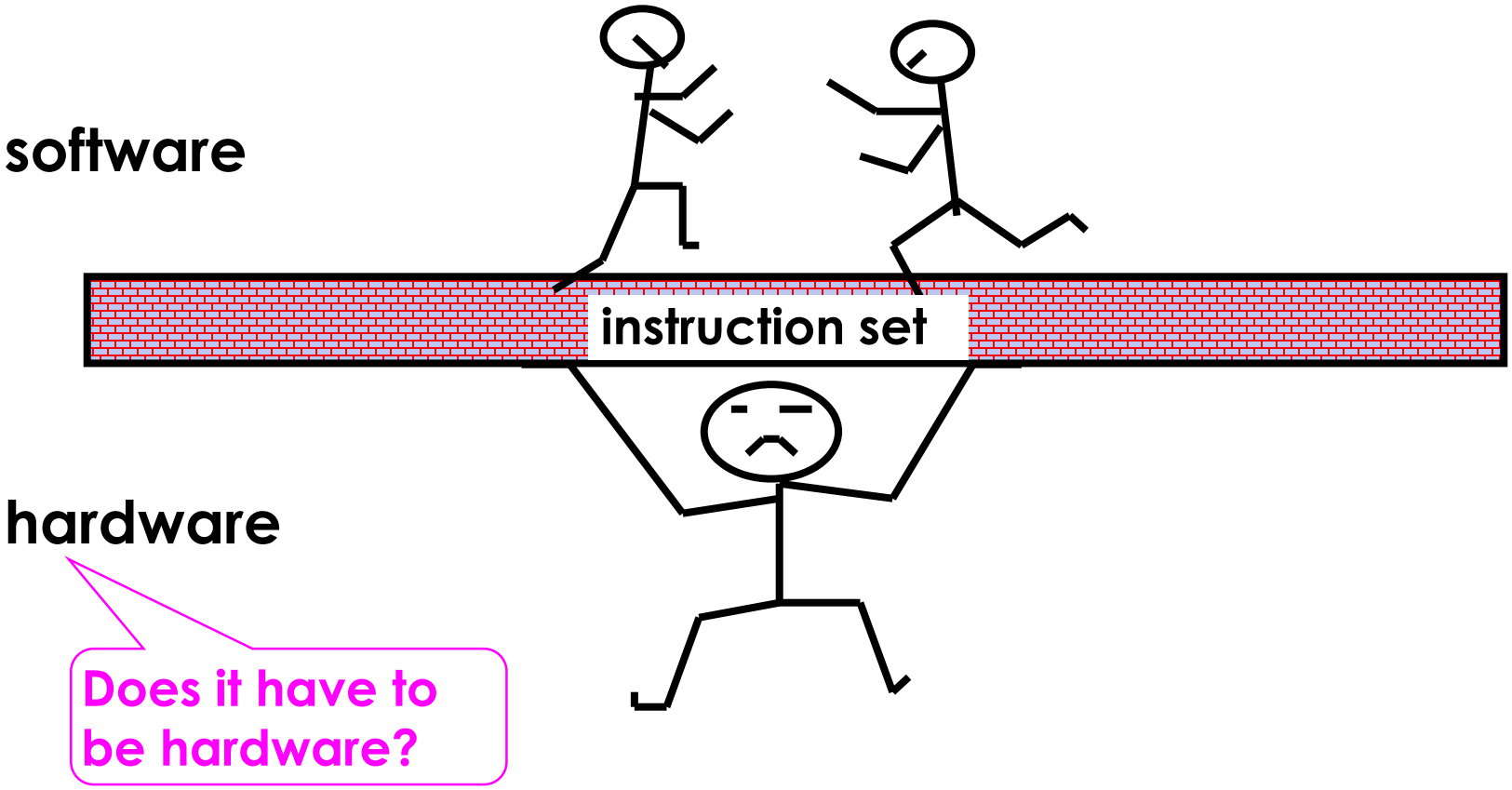
- Capabilities and performance characteristics of principal functional units, ex: registers, ALU, shifters, ...
- Ways in which these components are interconnected (*structure*)
- Information flows between components *(data, datapath*)
- Logic and means by which such information flow is controlled
- *Register Transfer Level* (RTL) description: A digital system is specified at the register transfer level (RTL) when it is specified by:
  - The set of registers
  - The operations performed on the stored data
  - The control that supervises the sequence of operations

What is Computer Architecture?



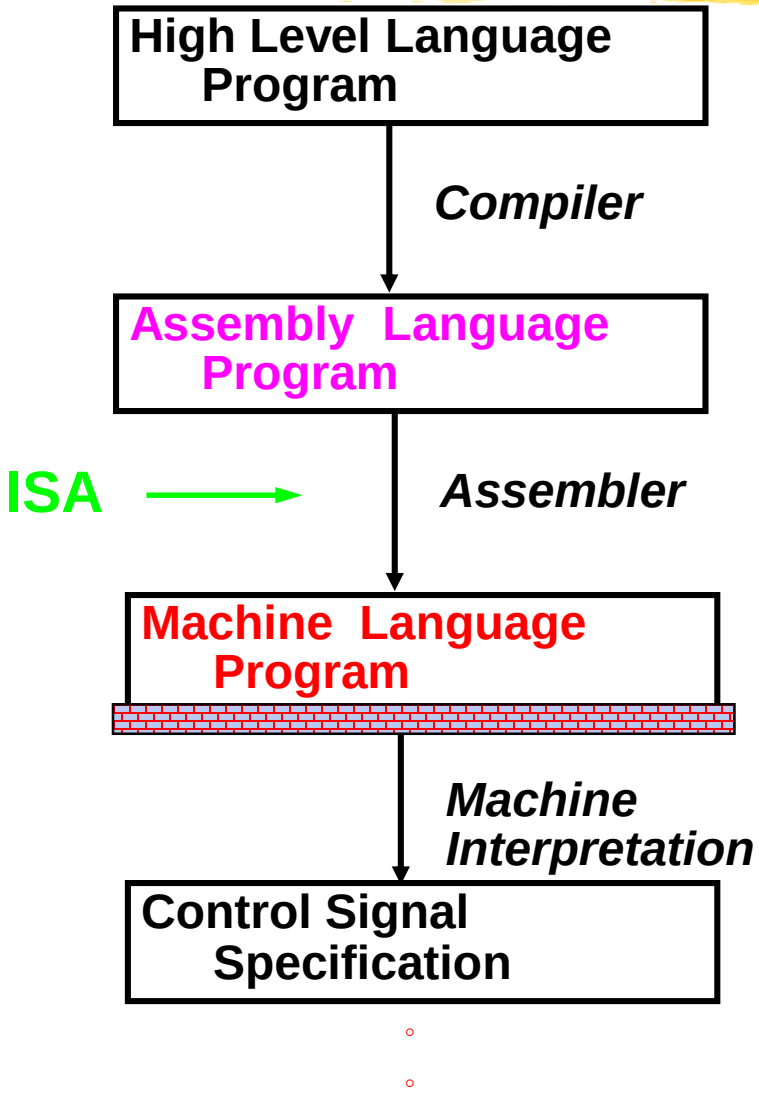
Computer Architecture =
Instruction Set Architecture
+ Machine Organization

Instruction Set as a Critical Interface



- Coordination of many levels of abstraction

Another Perspective




```
temp = v[0];
v[0] = v[1];
v[1] = temp;
```

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

```
1000 1100 0100 1111 0000 0000 0000 0000
1000 1100 0101 0000 0000 0000 0000 0100
1010 1100 0101 0000 0000 0000 0000 0000
1010 1100 0100 1111 0000 0000 0000 0100
```

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

Instruction Set Architecture (ISA)

"... the attributes of a [computing] system as seen by the programmer, *i.e.* the conceptual structure and functional behavior, as distinct from the organization of the data flows and controls, the logic design, and the physical implementation."

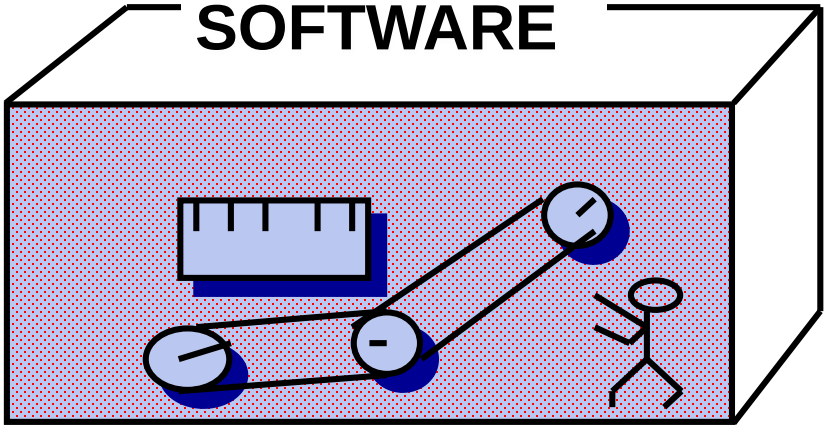
— Amdahl, Blaaw, and Brooks, 1964

Organization of Programmable Storage

Data Types and Data Structures: Encodings and Representations

Instruction Set

Instruction Formats

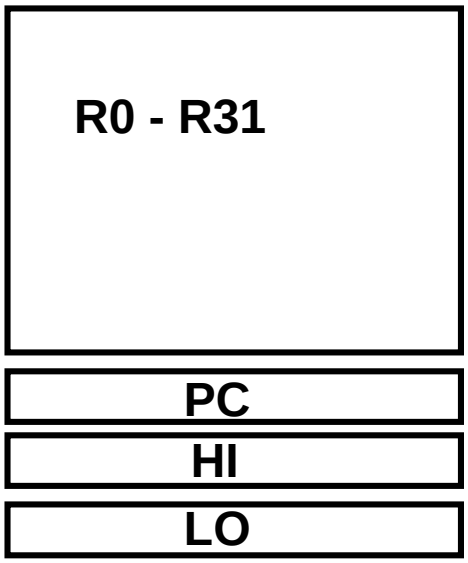


Modes of Addressing and Accessing Data Items and Instructions

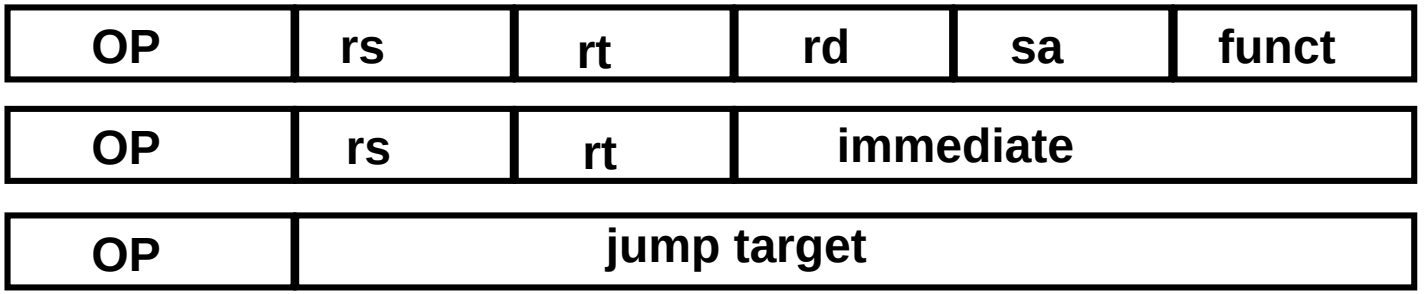
Exceptional Conditions

MIPS R3000 ISA

- Instruction categories:
  - Load/Store
  - Computational
  - Jump and Branch
  - Floating Point
    - coprocessor
  - Memory Management
  - Special



3 Instruction Formats: all 32 bits wide



ISA Examples

32-bit → 32/64-bit

HP PA-RISC	v1.1, v2.0	1986-96
Digital Alpha	v1, v3	1992-97
Intel x86	**8086,80286,80386, 80486,Pentium, MMX, SIMD, IA-64, x86-64...**	**1978-2019**
Wave MIPS	**MIPS I, II, III, IV, V, MIPS32/64 r6**	**1985-2014**
ARM	**ARM v1~v8.6-A**	**1985-2019**
Oracle Sparc	**v8, v9**	**1987-93 …**
IBM Power	**POWER v1~v3.1**	**1990-2020**
RISC-V	**RISC-V v1~v2.2**	**2010-2019**

Why Do Computer Architecture?

- RAPID CHANGES
- It is exciting!
- It has never been more exciting! 丶(*˚▽˚*)ノ
- It impacts every other aspect of computer science and electrical engineering

Course Administration

- 授課老師: 劉一宇
  - 研究室: T4-305-2　　電話: 3664
    email: yyliu@mail.ntust.edu.tw
- 助教: 王偉倫、柯承佑、詹舜傑、羅元廷
  - 實驗室: RB-309　　電話: 6808
    email: m10915023@mail.ntust.edu.tw
- CS2006:
  - 時間: 星期二 10:20-12:10, 星期三 9:10-10:00
  - 地點: TR-409-1
- Office Hour:
  - 星期二 13:00-15:00
  - 考量大家可能有排課，請以e-mail提前預約時段 (可預約其他時段)

Text Book

Computer Organization and Design: The Hardware/Software Interface, 4th ed.,
David Patterson and John Hennessy, 2010

RISC, RAID

2017 Turing Award

史丹福大學
前校長

Topics Covered

Computer Organization and Design: The Hardware/Software Interface, 4th ed., David Patterson and John Hennessy, 2010

Topic	Chapter
Introduction	1
The Role of Performance	1
Instructions: Language of the Machine	2
Arithmetic for Computers	3
The Processor: Datapath and Control	4
Enhancing Performance with Pipelining	4
Exploiting Memory Hierarchy	5
Storage and Other I/O Topics	6
Multicores, Multiprocessors and Clusters	7

Prerequisite

- **Prerequisite courses:**
  - **Digital Logic Design**
  - **C/C++ Programming**

Expected Course Workload

- 4-5 project assignments
- 2-3 Quizzes will be given in class
- One midterm and one final examination
- Grade breakdown in points, denote as %
  - Project Assignments 40% (35 - 45%)
  - Quizzes 10% (10 - 15%)
  - Midterm Exam 25% (20 - 30%)
  - Final Exam 25% (20 - 30%)
  - Extra bonus points for Q&A in Moodle Discussion Forum
  - Notice that the lump sum points could exceed 100%
    - In that case, final score is based on interpolation between 0 and 99

Code of Honor

- What is cheating?
  - It's simple: just be HONEST!
  - Study together in groups is encouraged
  - Work must be your own
  - Copy is definitely a cheating act
- Cannot make examinations
  - No makeup examinations
- Cannot turn in homework on time
  - Late homework will be given 0 score

Online Interactive Quiz

- 請帶手機、平板、筆電到教室
- 連線至App Store安裝Socrative Student Version
- https://socrative.com/apps/

- Room Name: NTUSTCA
- Your name: 學號 (英文要大寫)

Measures for COVID-19 Outbreak

- In case of in-campus COVID-19 outbreak (i.e., class suspension), our class would be moved to "cloud".
  - Online lectures: YouTube (flipped classroom)
  - Livestream demo, Q&A: WebEx, YouTube
  - Q&A discussion: Moodle
  - Project score ratio may be increased.
  - ...
  - Class information would be announced in NTUST Moodle.

YouTube Reference

https://www.youtube.com/c/YiYuLiu