National Tsing Hua University

COMPUTER ARCHITECTURE

計 算 機 結 構

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為什麼電腦不用十進位而用二進位？

Signal: Two States (二進制)

對、錯

本土化、非本土化

陰、陽

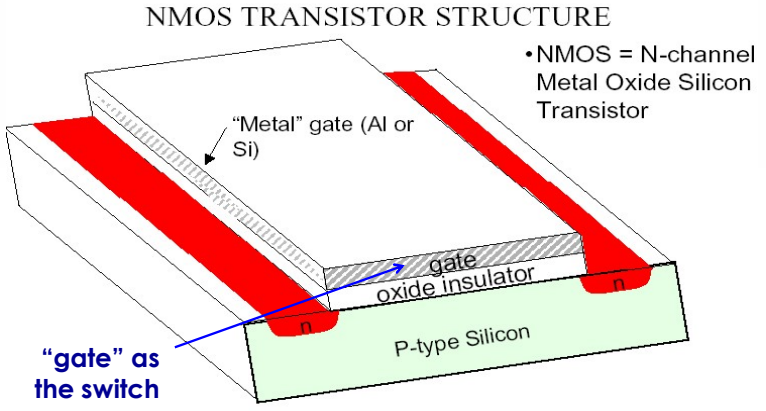
high、low

正、反

真、偽

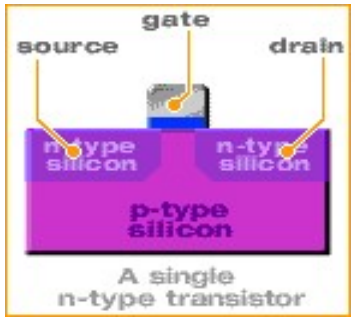
勝、負

Switch (電子開關)



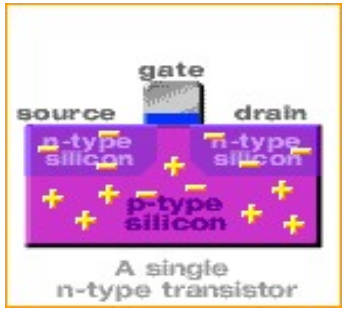
A Working Transistor (1/5)

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



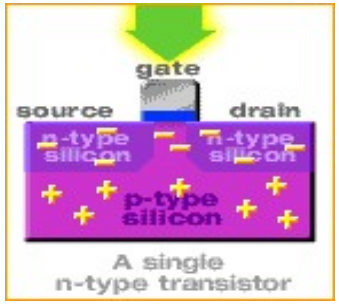
A Working Transistor (2/5)

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 (3/5)

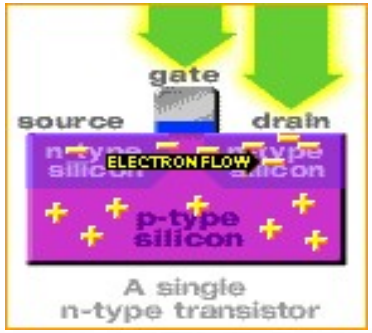
When positive voltage is applied to the gate, electrons in the
p-silicon are attracted to the area under the gate forming an
electron channel between the source and the drain.



A Working Transistor (4/5)

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.

開



A Working Transistor (5/5)

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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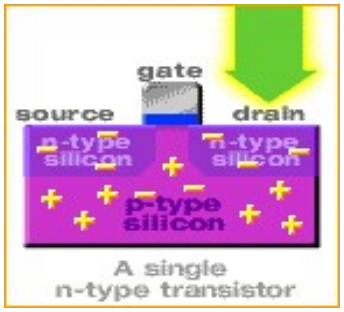


相關電壓電流特性

及電路分析等知識

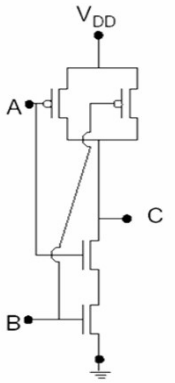
我們是在_____課中介紹的

答：「電子電路學」「超大型積體電路設計」

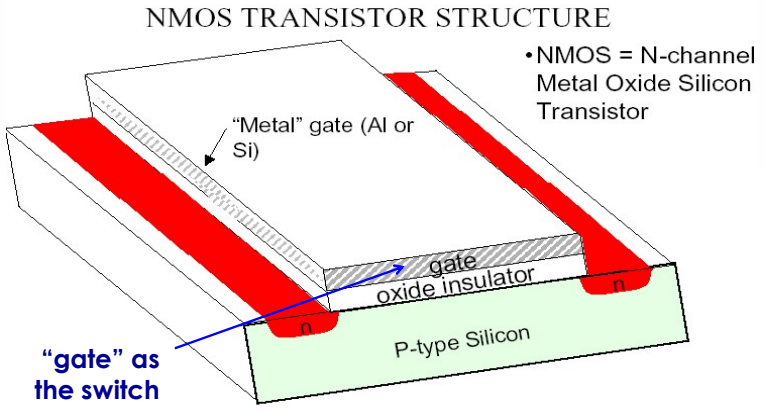
有了開關就可以做邏輯閘

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

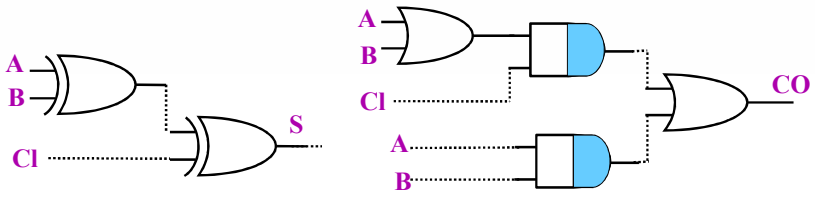


Switch (電子開關)



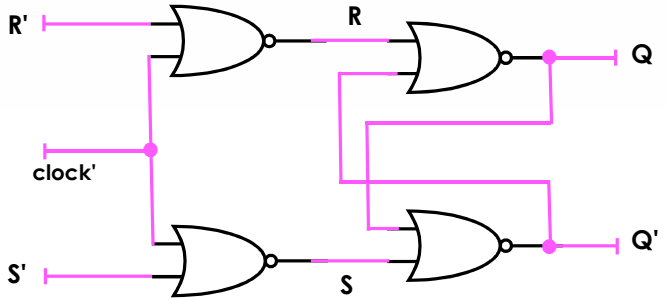
有了邏輯閘就可做邏輯電路

加法器：



也可以做記憶元件

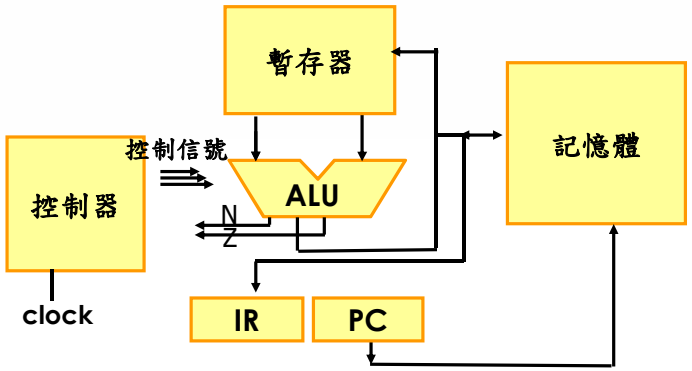
可存一個bit的東西：



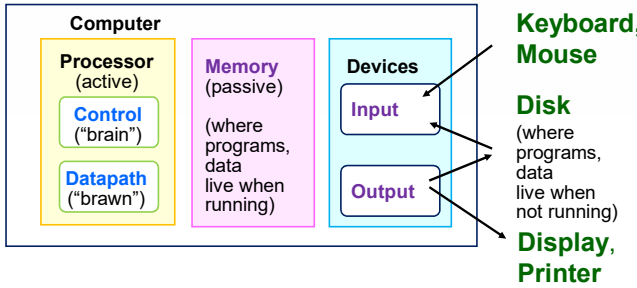
這部份的學問叫_____

答：「數位邏輯設計」

最後，電腦的主要部份就都可以做了



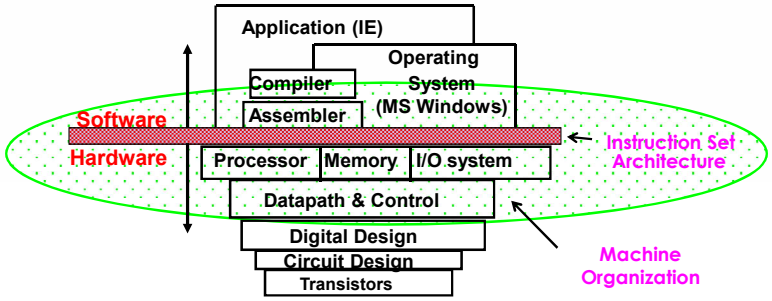
Basic Organization of Any Computer



Computer Organization

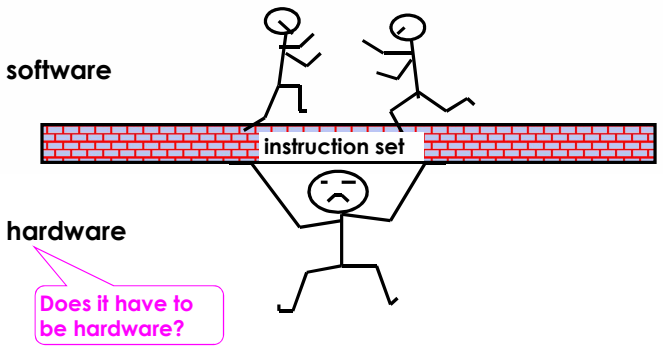
- Capabilities and performance characteristics of principal functional units, e.g., registers, ALU, shifters, ...
- Ways in which these components are interconnected (*structure*)
- Information flows between components (*data, datapath*)
- Logic and means by which such information flow is controlled (control logic)
- *Register Transfer Level* (RTL) description

What is Computer Architecture?



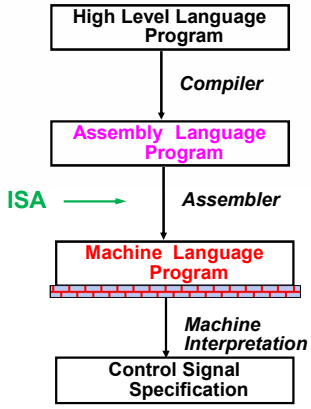
Computer Architecture =
Instruction Set Architecture
+ Machine Organization

Instruction Set as a Critical Interface



Coordination of many levels of abstraction

Another Perspective




```
temp = v[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
```

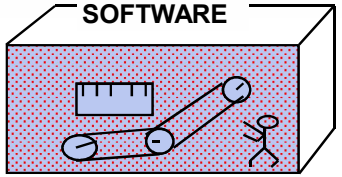
ALUOP[0:3] <= InstReg[9:11] & MASK

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

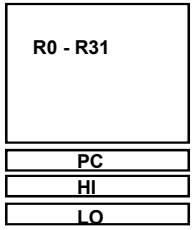


MIPS R3000 ISA

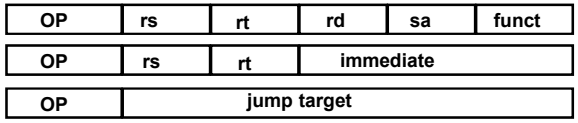
Instruction categories:

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

Registers



3 Instruction Formats: all 32 bits wide



Example ISA

Digital Alpha	(v1, v3)	1992-97
HP PA-RISC	(v1.1, v2.0)	1986-96
Sun Sparc	(v8, v9)	1987-95
SGI MIPS	(MIPS I, II, III, IV, V)	1986-96
Intel	(8086,80286,80386, 80486,Pentium, MMX, SIMD, IA-64, ...)	1978-
ARM	(v1,v2...v8)	1985-

Why Do Computer Architecture?

- RAPID CHANGES
- It is exciting!
- It has never been more exciting!
- It impacts every other aspect of electrical engineering and computer science

Flipped Classroom

Flipped Classroom

- Before class:
  - Watch video and learn it by yourself (or group study)
  - Submit two question-and-answers to iLMS by *each group* before noon every Friday
- In class:

  First part:
  - Question and answer (for general question)

  Second part:
  - Group study or individual student tutored by TAs and teacher
  - A set of questions discussed in each group

  Third part:
  - Tournament
  - Submission of final answer sheet per group

Flipped Classroom

- After class
  - Review the course and take a quiz online after each class
  - Complete three homework assignments
  - Take midterm and final exams
  - Submit one final project

Group Performance

- Forming study groups. Each group has 5-6 students.
  - For members in the same group, their group performance will be the same
  - Advanced learner will help less advanced learner!
- Group performance (in each class period)
  - First part: Student participation and interaction with teacher (teacher asks question or students raise question) – each group has at most 2 points
  - Second and third parts:
    - Group discussion : prepare your answers
    - Tournament – 2 points are given to the two groups (*Q-group* and *A-group*)
    - Submission of answer sheet – 1 point

In Class – Second & Third Parts

- Group Discussion:
  - TA will select several questions from the questions uploaded by each group and give a question sheet at the beginning of part 2
  - Group discussion
- Tournament: 2 points
  - TA selects some questions from question sheet (*Q-group*)
  - TA randomly select one member of groups whose question is not selected to answer the question (*A-group*)
  - If *A-group* can not answer the question, a member randomly selected from *Q-group* has to give the answer
  - The question is answered on the blackboard
  - 2 points are given to these two groups based on their performance
- Submission: 1 point
  - Your group answer-sheet at the end of class

In Class – Second & Third Parts

- Second and third parts:
  - TA is the moderator
  - Each group prepares two question-and-answers and upload the questions to http://lms.nthu.edu.tw by Friday noon.
  - Moderator checks all questions and may ask some groups to reload questions if there is too much duplication among groups.
  - Good question is important. If it is selected by TA in tournament, it is worth 2 points!

After Class – Quiz

- Quiz contains a set of single or multiple choice questions
- Quiz is uploaded before 20:00 every Monday after class
- Questions are all from the question sheet !!
- Complete the quiz before Thursday noon each week
- Grading: Total number of correct answers/total number of answers x 5%

Course Administration

授課老師: 黃婷婷

- 辦公室: 資電442　　電話: 31310
  email: tingting@cs.nthu.edu.tw

助教:

陳衍昊 yhchen@cs.nthu.edu.tw　　Online office hours: 星期二 19:00~21:00
孫勤昱 s102062801@m102.nthu.edu.tw　　Online office hours: 星期三 19:00~21:00
洪奕文 s106062802@m106.nthu.edu.tw　　Online office hours: 星期四 19:00~21:00
周猷翔 s108062591@m108.nthu.edu.tw　　Online office hours: 星期五 19:00~21:00

上課時間:

- CS4100-00:　星期一　13:20-16:00

上課地點:　DELTA 台達 109
課程網頁:　http://www.cs.nthu.edu.tw/~tingting/cs4100.html

Text Book

Computer Organization and Design: The Hardware/Software Interface, 5th ed.
David Patterson and John Hennessy, 2013

Topics Covered

Computer Organization and Design: The Hardware/Software Interface, D. Patterson and J. Hennessy

Topic
Introduction
The Role of Performance
Instructions: Language of the Machine
Arithmetic for Computers
The Processor: Datapath and Control
Enhancing Performance with Pipelining
Exploiting Memory Hierarchy

Prerequisite

Prerequisite courses:

- **Logic design**

Expected Course Workload

- Learn MIPS instruction set
- Learn processor emulators and benchmarking
- 1 final project
- One mid-term and one final examination
- Grade breakdown
  - In-class performance 25%
  - Quizzes 5%
  - Assignments & Final project 10%
  - Midterm Exam (Nov 4): 30%
  - Final Exam (Dec 30): 30%

Resource on Internet to Help Your Learning

- Course Website
  http://www.cs.nthu.edu.tw/~tingting/cs4100.html
- ShareCourse (Please register)
  http://www.sharecourse.net/sharecourse/course/view/courseInfo/1954
- FB粉絲專頁 (TA online office)
  https://www.facebook.com/NTHU-Arch-2019-Fall-2127926427528915/
- Open Course Ware (OCW)
  http://ocw.nthu.edu.tw/ocw/index.php?page=course&cid=76&

Course Problems

- Cannot attend the class
  - One absence is allowed but no point of group performance will be given for that class
  - Two absents => you don't have to come any more
- Cannot be in the class on time
  - Late = absent
- Cannot turn in homework on time
  - No late homework is accepted
- What is cheating?
  - Study together in group is encouraged
  - Work must be your own. Copying is cheating!