Chapter0重点掌握内容：

- 名词解释：计算机科学（computer science）、算法（algorithm）、程序（program）、编程（programming）、软件（software）、硬件（hardware）
- 算法的作用（The Role of Algorithms）
- 摩尔定律（Moore's law）

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What Are We Going to Learn?

- Part I: How does the computer work?
  - Data representation
  - Data manipulation
  - Operating system
  - Computer network

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- Part II: How to make computers work?
  - Algorithm
  - Programming
  - Software engineering
  - Data abstraction

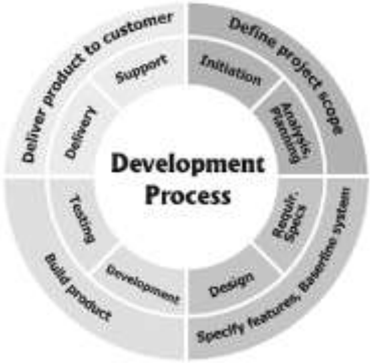
Chef Justin's
Prawn Provencale
at Park Plaza Gardens
(Yield: 1 serving)

4 jumbo prawns
1 tablespoon minced garlic
1 tablespoon olive oil
2 tablespoons minced red onion
3 tablespoons chopped fresh tomatoes
Juice of 1/2 fresh lemon
3 ounces chicken stock
1 teaspoon julienned basil or more to taste
1 teaspoon chopped Italian parsley
Pinch of crushed pepper
2 tablespoons butter
Salt and pepper to taste
3 large croutons

1. Sauté prawns with garlic, olive oil, onion and tomatoes, until shrimp is golden.
2. Add lemon juice, chicken stock, basil, parsley, crushed red pepper, butter and salt and pepper to taste. Let simmer to reduce to sauce consistency.
3. To serve, position three large croutons on a plate. Place prawns in the center. Pour sauce mixture on top.

[illegible]

Savoring Secrets



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- Part III: What do computers work for?
  - Database
  - Computer graphic
  - Artificial intelligence
  - Theory of computation

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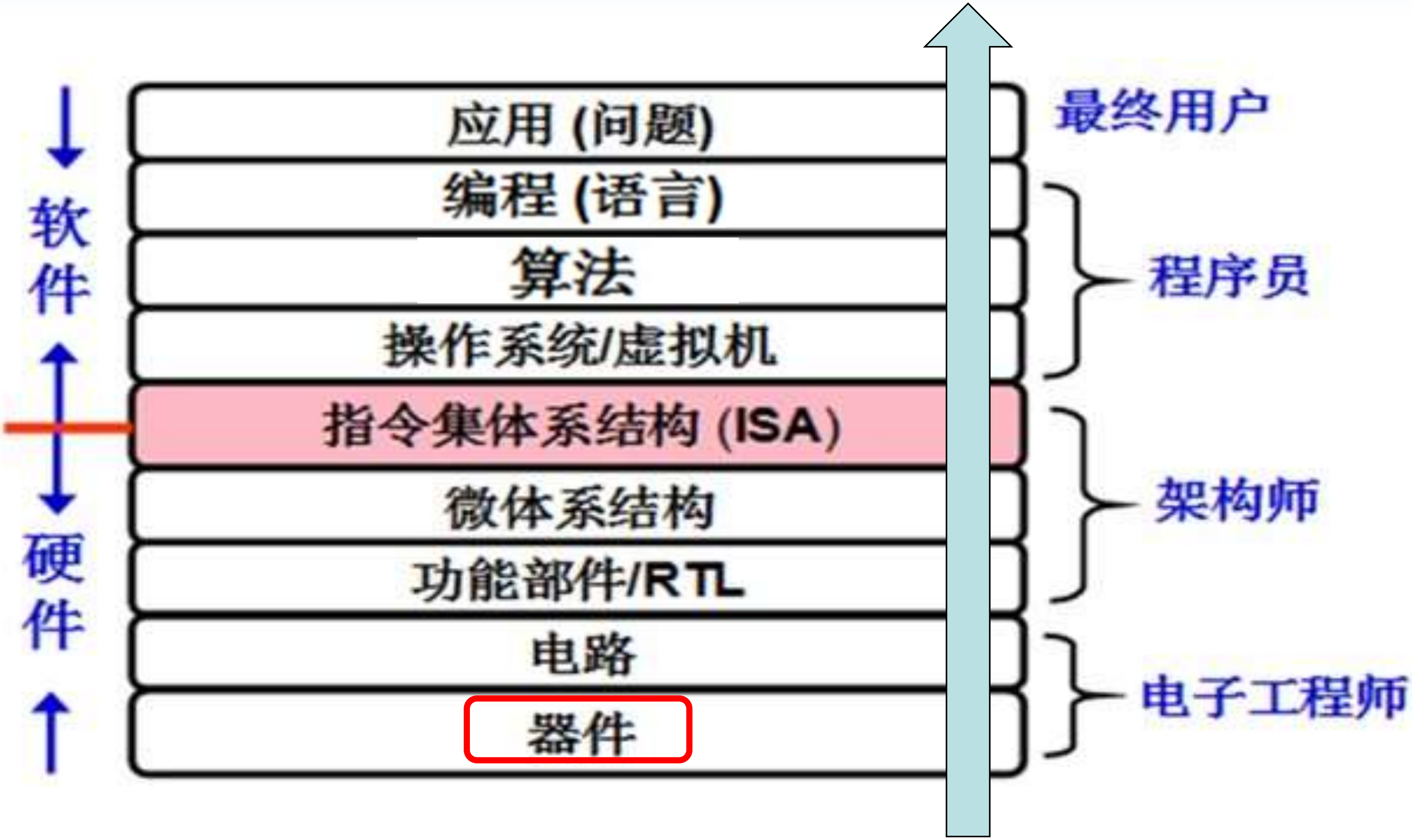

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Chapter 1

Data Storage

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- 1.1 Bits and their storage
- 1.2 Main memory
- 1.3 Mass storage
- 1.4 Representing information as bit patterns
- 1.5 The binary system
- 1.6 Storing integers
- 1.7 Storing fractions
- 1.8 Data and programming
- 1.9 Data compression
- 1.10 Communication errors

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1.1 Bits and their storage

Basic operations for binary data and the physical devices to implement them

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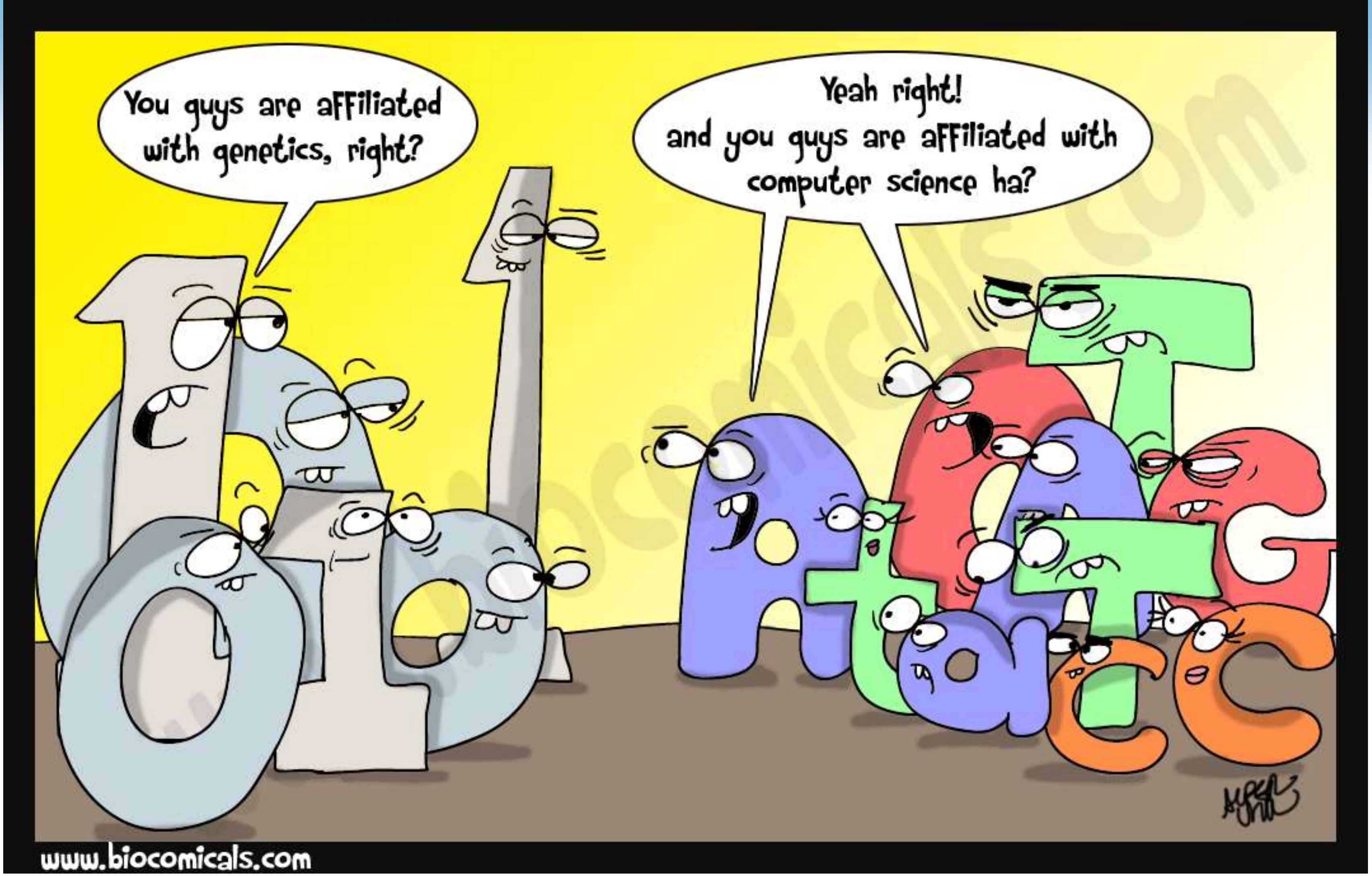
You guys are affiliated with genetics, right?
Yeah right! and you guys are affiliated with computer science ha?
www.biocomicals.com

1 / 0 bit位 （Binary：二进制数）

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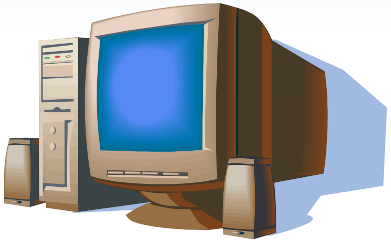
Two Different Worlds



What we see/hear		Inside computers
Text	a,b,c	01100001,01100010,01100011
Number	1,2,3	00000001,00000010,00000011
Sound	🔈	01001100010101000110100…
Image		10001001010100000100111...
Video		00110000001001101011001…

Discrete/digital and binary

数字化的二进制的

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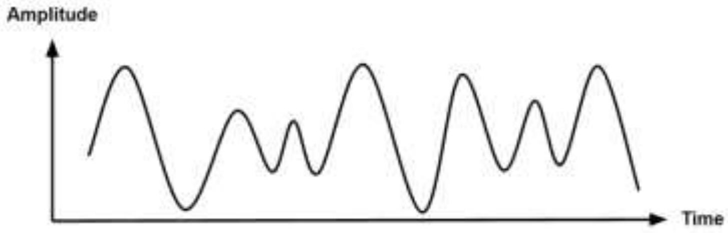
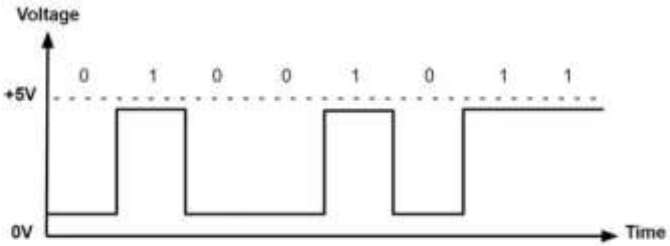
模拟信号与数字信号

- 模拟信号
  - 用连续变化的物理量（时间、幅度、频率、相位等）表示的信息。
  - 如每天的气温，汽车在行驶过程中的速度，电路中某节点的电压幅度等
- 数字信号
  - 是人为抽象出来的不连续信号，通常可由模拟信号获得。数字信号的取值是不连续的、取值的个数是有限的。
- 模拟信号数字化
  - 将模拟信号转换成可以用有限个数值来表示的离散序列。

模拟信号



数字信号



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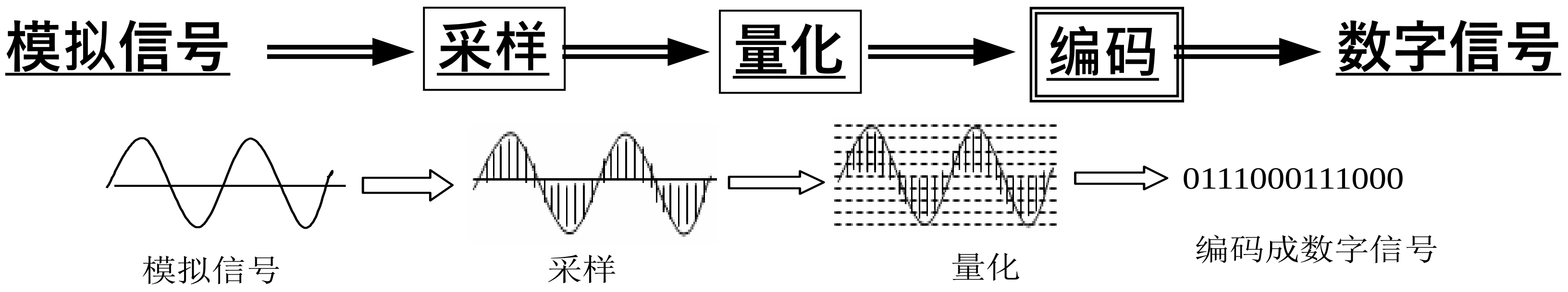
模拟信号的数字化



模拟信号 → 采样 → 量化 → 编码 → 数字信号

模拟信号 ⇨ 采样 ⇨ 量化 ⇨ 0111000111000

编码成数字信号

采样 每隔一定时间间隔对模拟波形上取一个幅度值。

可以保证不失去原始信号的原始信息的最小采样率是多少？

在进行模拟/数字信号的转换过程中，当采样频率fs大于信号中最高频率fmax的2倍时(fs>2fmax)，采样之后的数字信号完整地保留了原始信号中的信息，采样定理又称奈奎斯特定理

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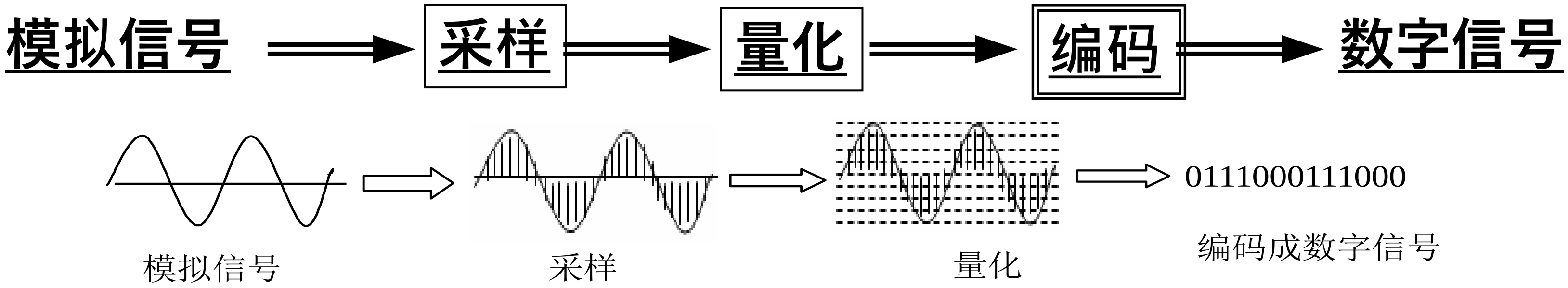
模拟信号的数字化



模拟信号 → 采样 → 量化 → 编码 → 数字信号

量化 将每个采样点得到的幅度值以数字存储。

编码 将采样和量化后的数字数据以一定的格式记录下来

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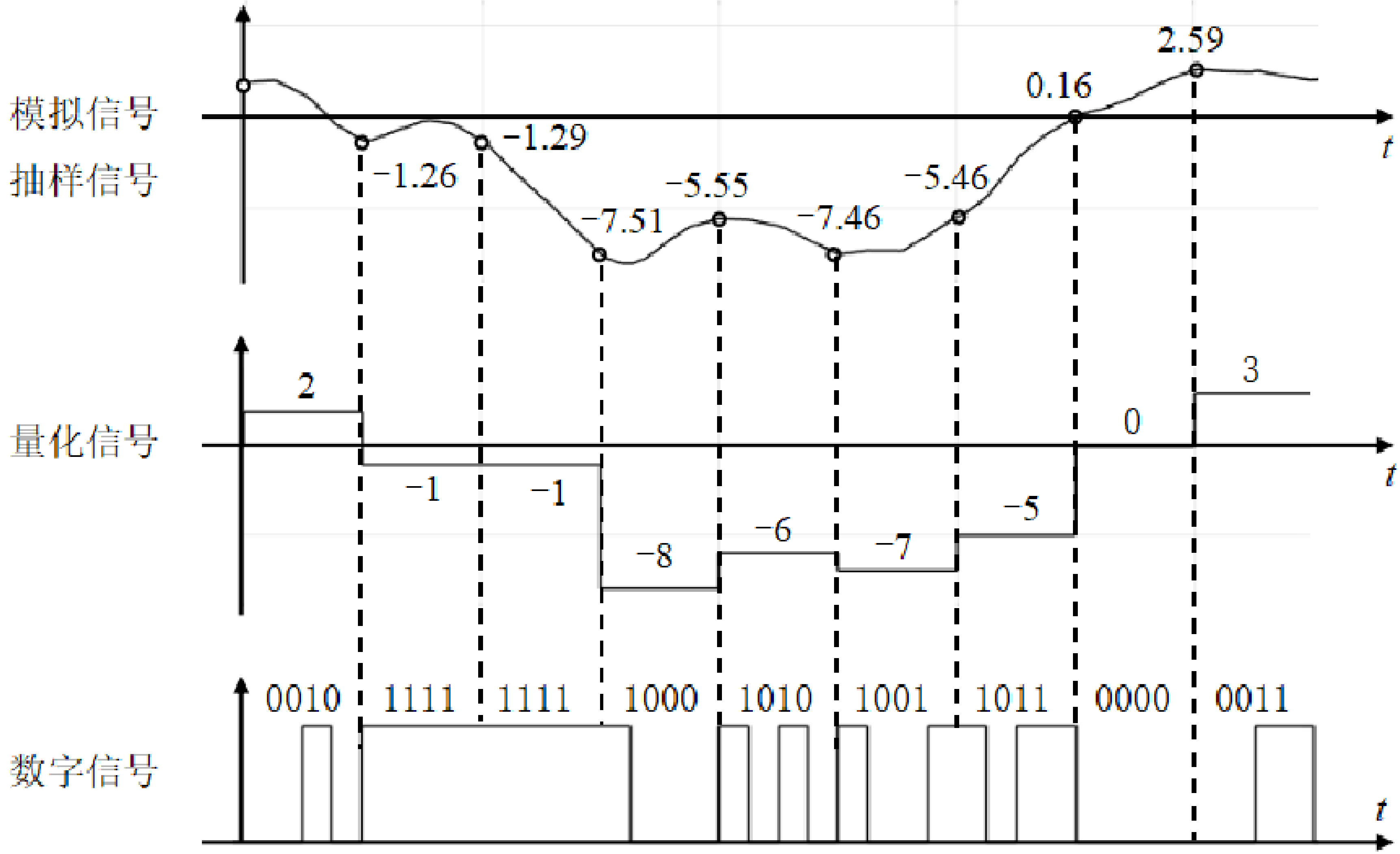

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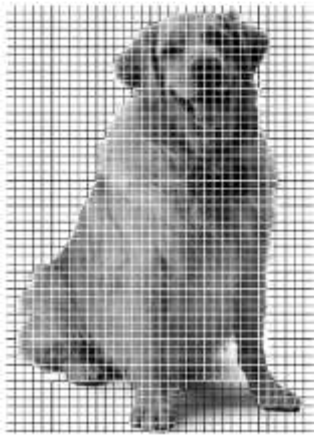
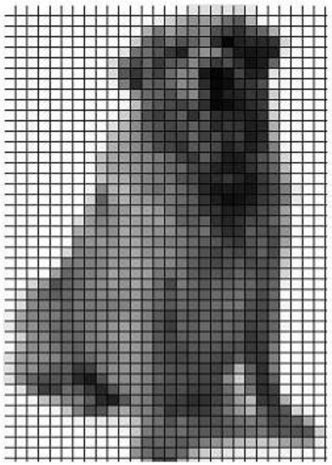
图像的数字化

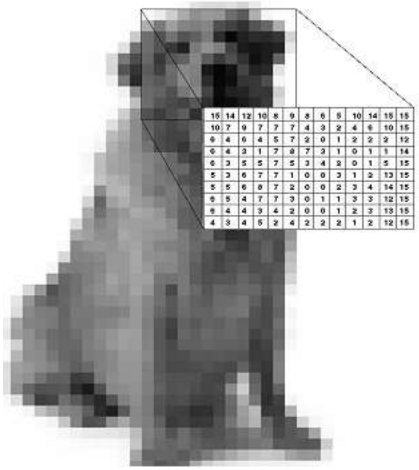
图像



采样



量化



15	14	12	10	8	9	8	6	5	10	14	15	15
10	7	9	7	7	7	4	3	2	4	6	10	15
6	4	6	4	5	7	2	0	1	2	2	2	12
6	4	3	1	7	8	7	3	1	0	1	1	14
6	3	5	5	7	5	3	4	2	0	1	5	15
5	3	6	7	7	1	0	0	3	1	2	13	15
5	5	6	8	7	2	0	0	2	3	4	14	15
6	5	4	7	7	3	0	1	1	3	3	12	15
6	4	4	3	4	2	0	0	1	2	3	13	15
4	3	4	5	2	4	2	2	2	1	2	12	15

数字图像

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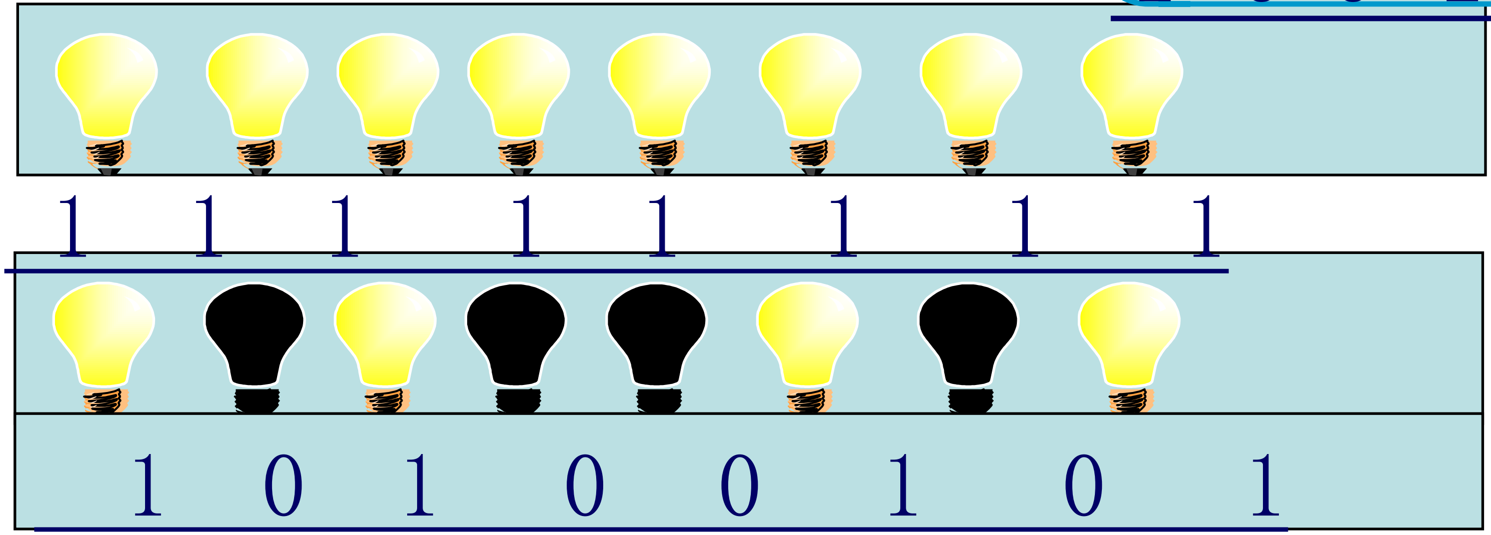
Binary representation

- Why is binary representation used by computer?
  - Easy to implement
  - Simple computation rules

$1 \times 1 = 1$

$0 \times 0 = 0$

$1 \times 0 = 0 \times 1 = 0$



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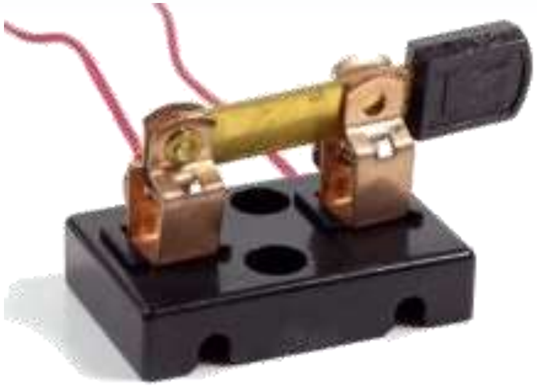
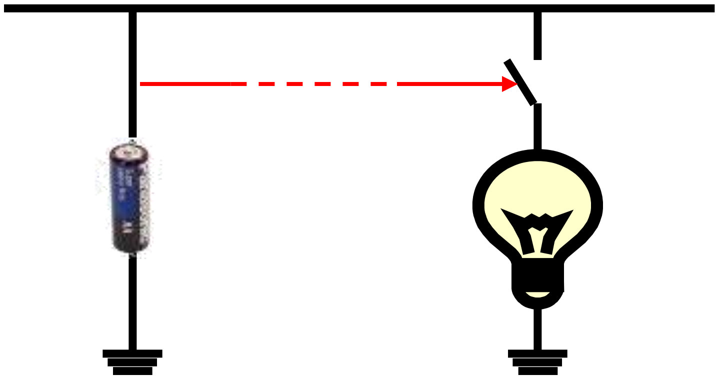
How to Turn on a Switch?

- By hand



- Electric Switch?
  - Why do we want to do that?



✓1 0

✓bit

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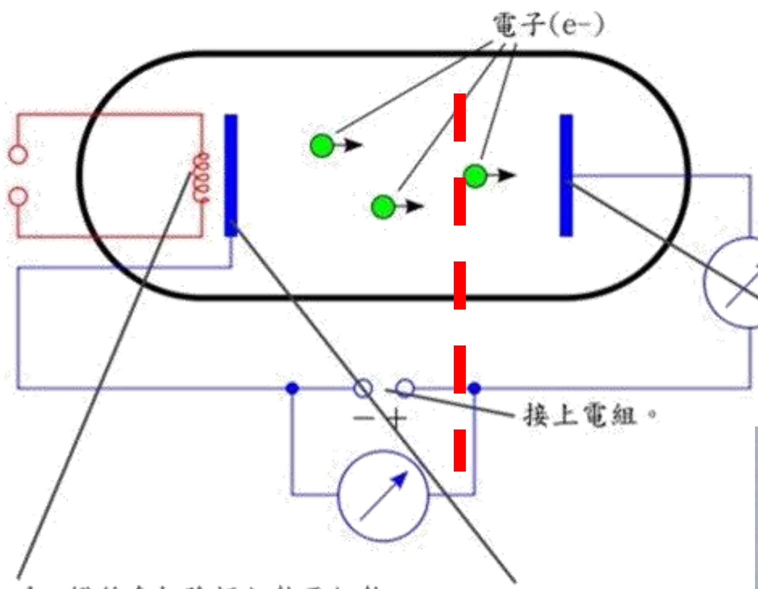
Electronic Switch: vacuum tube

- The earliest one is the *vacuum tube*真空管



I 4. 電流:電流是指電子的流動因為有電子從陰極從走向陽極，所以形成了電流。

*電子是傾向由電池組的負極流向同一電池組之正極。

3. 由於陽極被接到正極，所以就形成了電勢差(電壓的差
)。所以，帶負電荷的電子

1. 燈絲會把陰極加熱至紅熱，把陰極之原子激態。

2. 陰極是接上電
負極，而負極是傾
電子。由於陰極之
至激態(所以發出
當被接出高的負電

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The 1946 ENIAC computer used 17,468 vacuum tubes and consumed 150 kW of power

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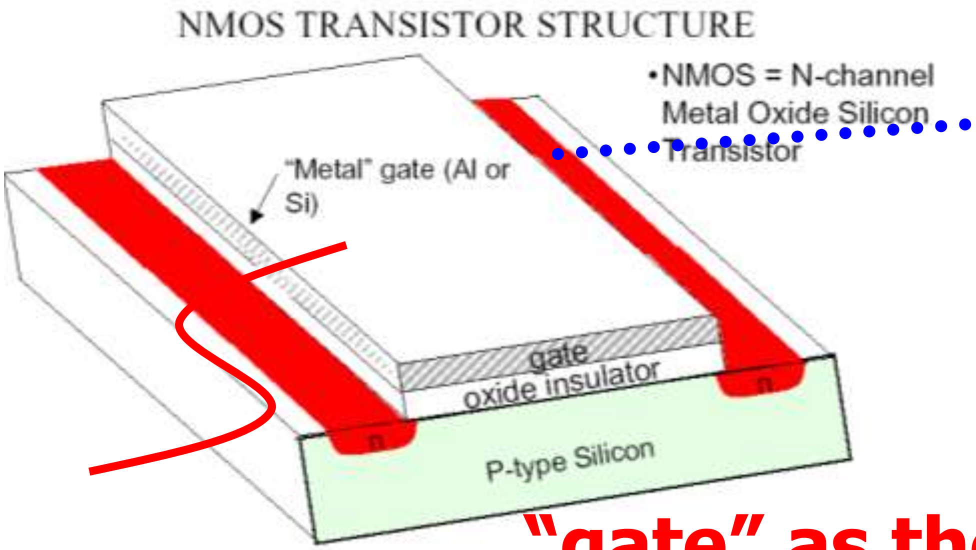
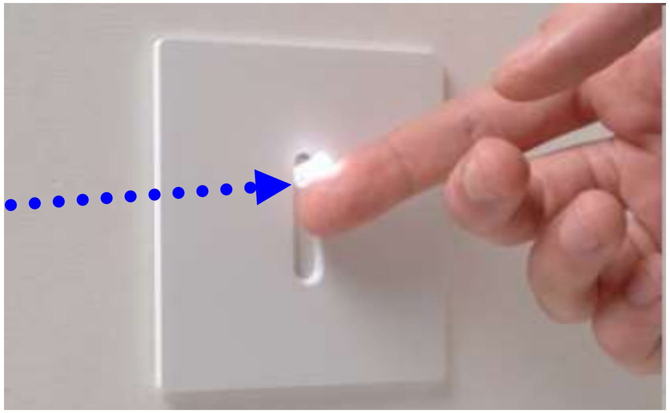
Electronic Switch: Transistor晶体管

- The problems of vacuum tubes are slow, large, expensive, easy to break
- Transistor can be faster, smaller, and more robust


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



"gate" as the switch

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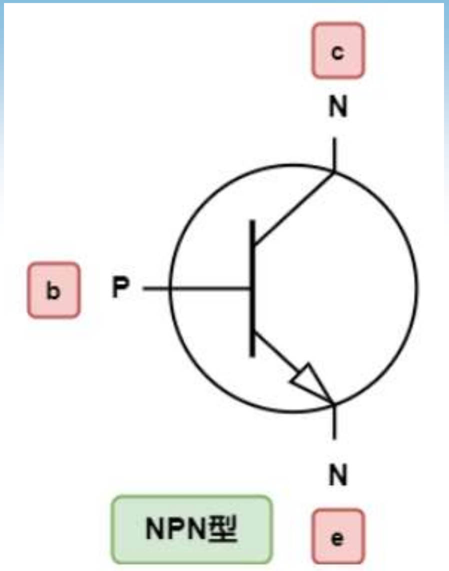
晶体管开关

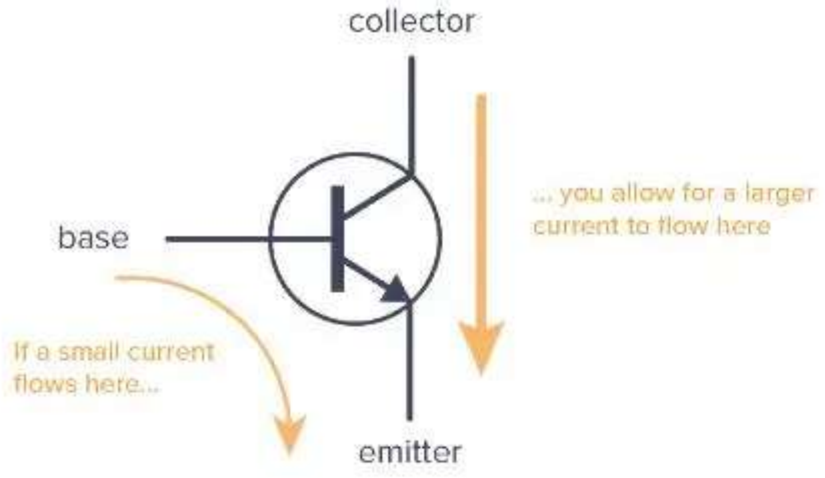
基极（b）

集电极（c）

发射极（e）



当电流从基极流向发射极时，晶体管打开，使更大的电流可以从集电极流向发射极。


collector
base
... you allow for a larger current to flow here
If a small current flows here...
emitter

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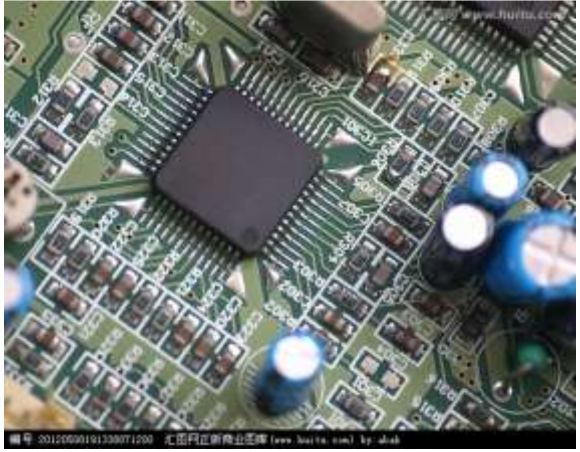
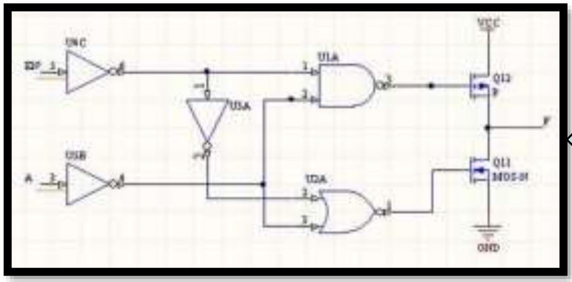
LCD Monitor
Hard Disk Drive
DVD/CD-ROM
Floppy Drive
Motherboard
Keyboard
Mouse

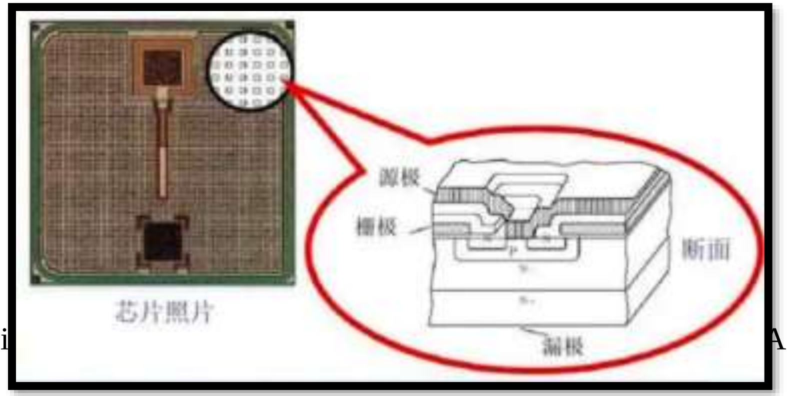


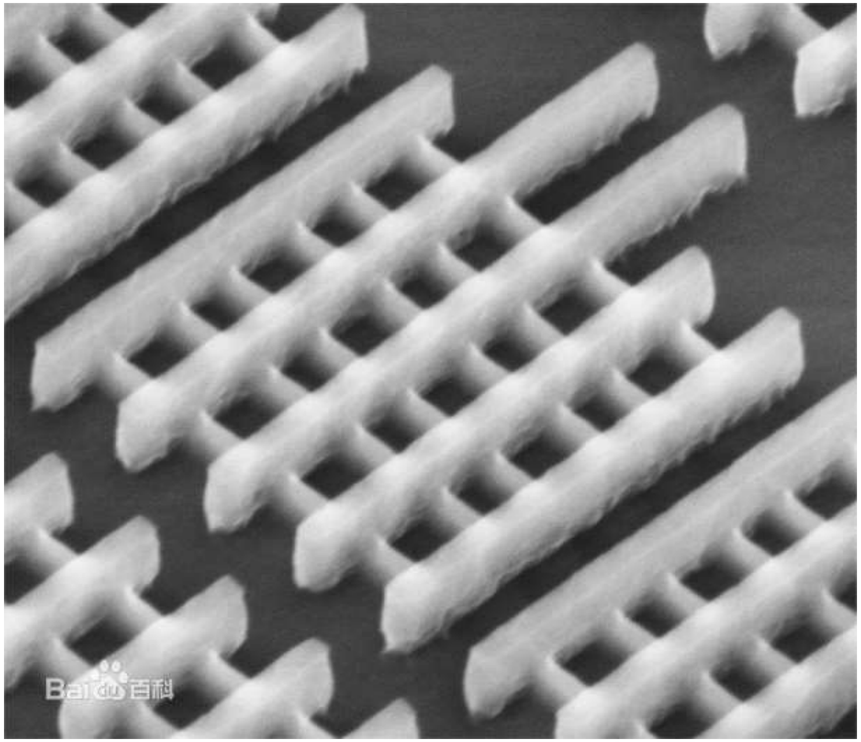

VCC
U1A
Q12
Q11
A
GND

门电路

晶体管

0/1


源极
栅极
断面
漏极
芯片照片



Intel Core i7

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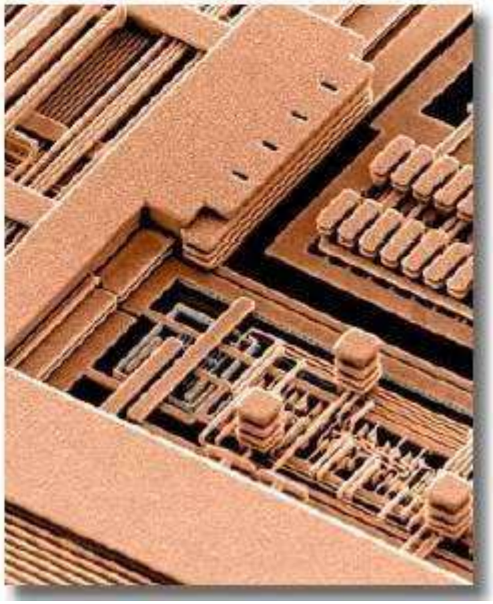

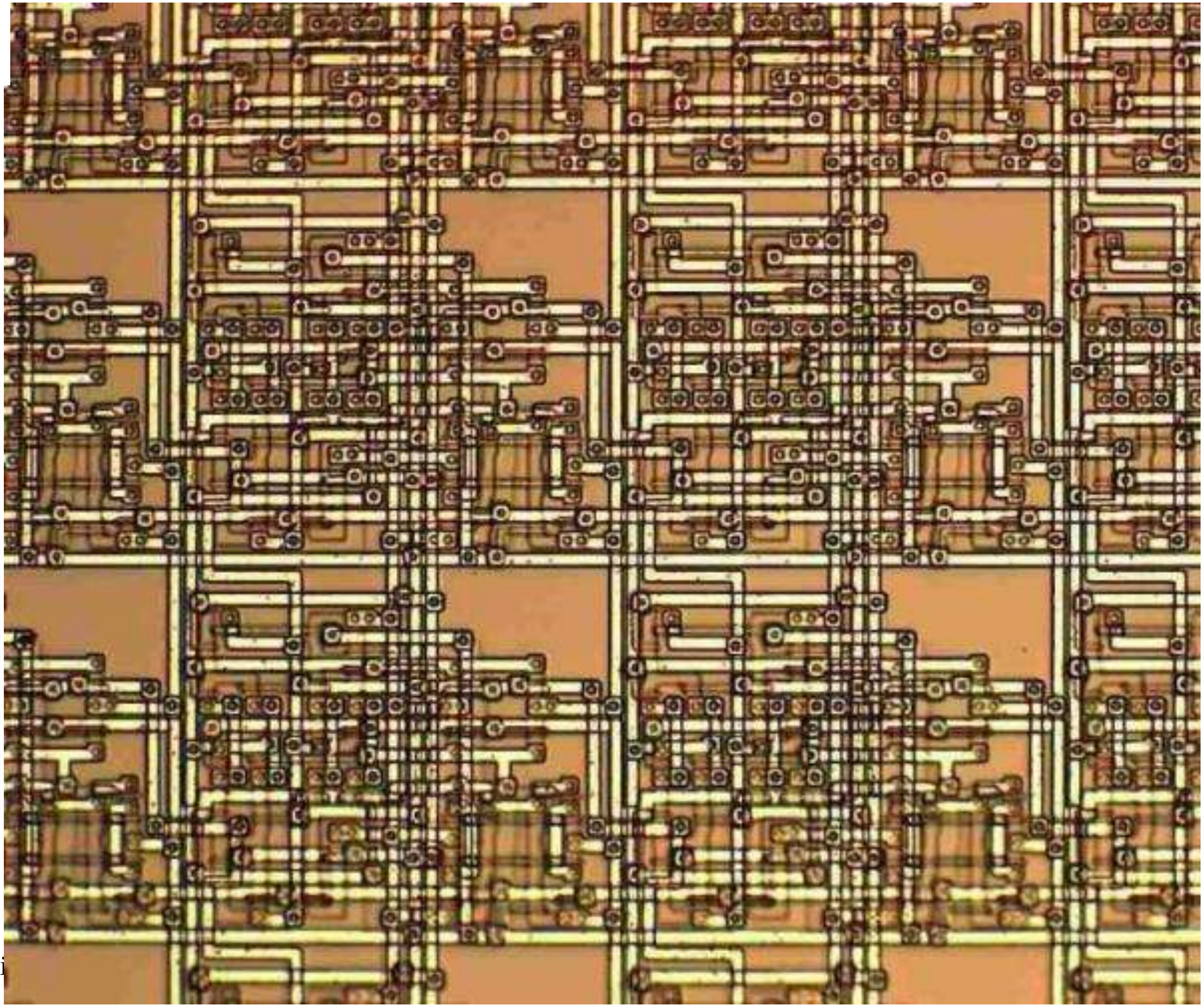

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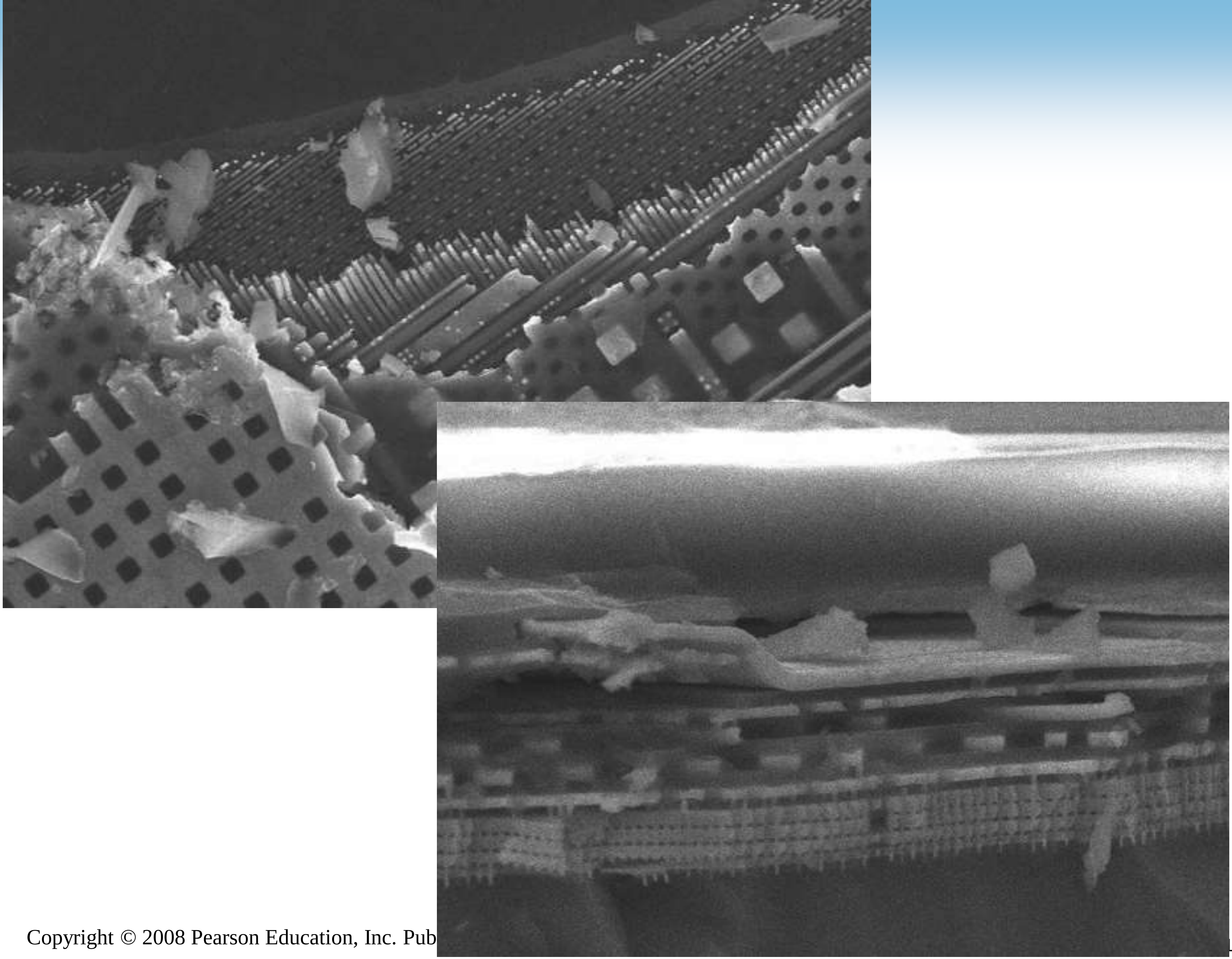

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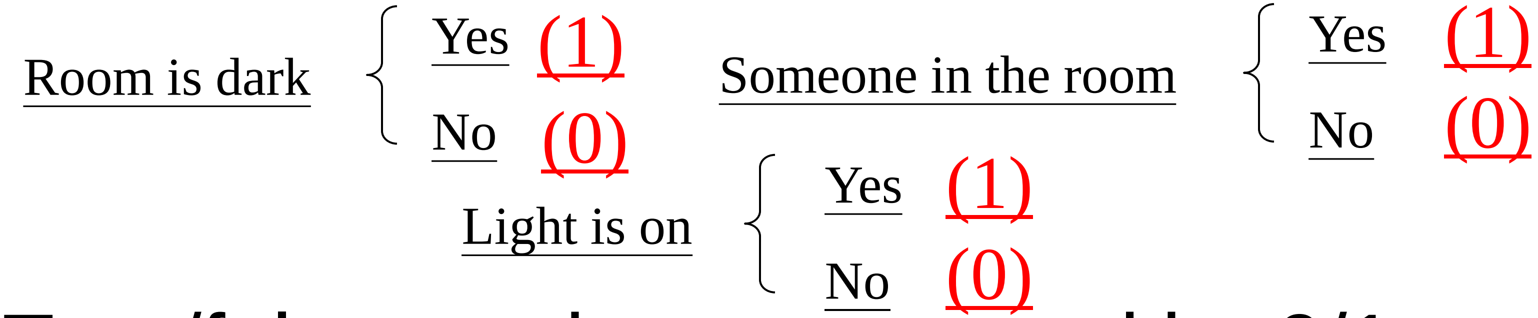
Binary and Logic逻辑

- Logic: concerns about true or false
- Logic operation:
  - If the room is dark and someone is in the room, turn on the light.



Room is dark
- Yes (1)
- No (0)

Someone in the room
- Yes (1)
- No (0)

Light is on
- Yes (1)
- No (0)

- True/false can be represented by 0/1

Binary number system in computer ←→ logic

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The AND Function

- We can use the AND function to represent the statement

Room is dark A	Someone in the room B	Light is on A .AND. B
0	0	0
0	1	0
1	0	0
1	1	1

Input Output

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Boolean Operations （布尔运算）

- **Boolean Operation:** An operation that manipulates one or more true/false values
- Specific operations
  - AND
  - OR
  - XOR (exclusive or) 异或
  - NOT

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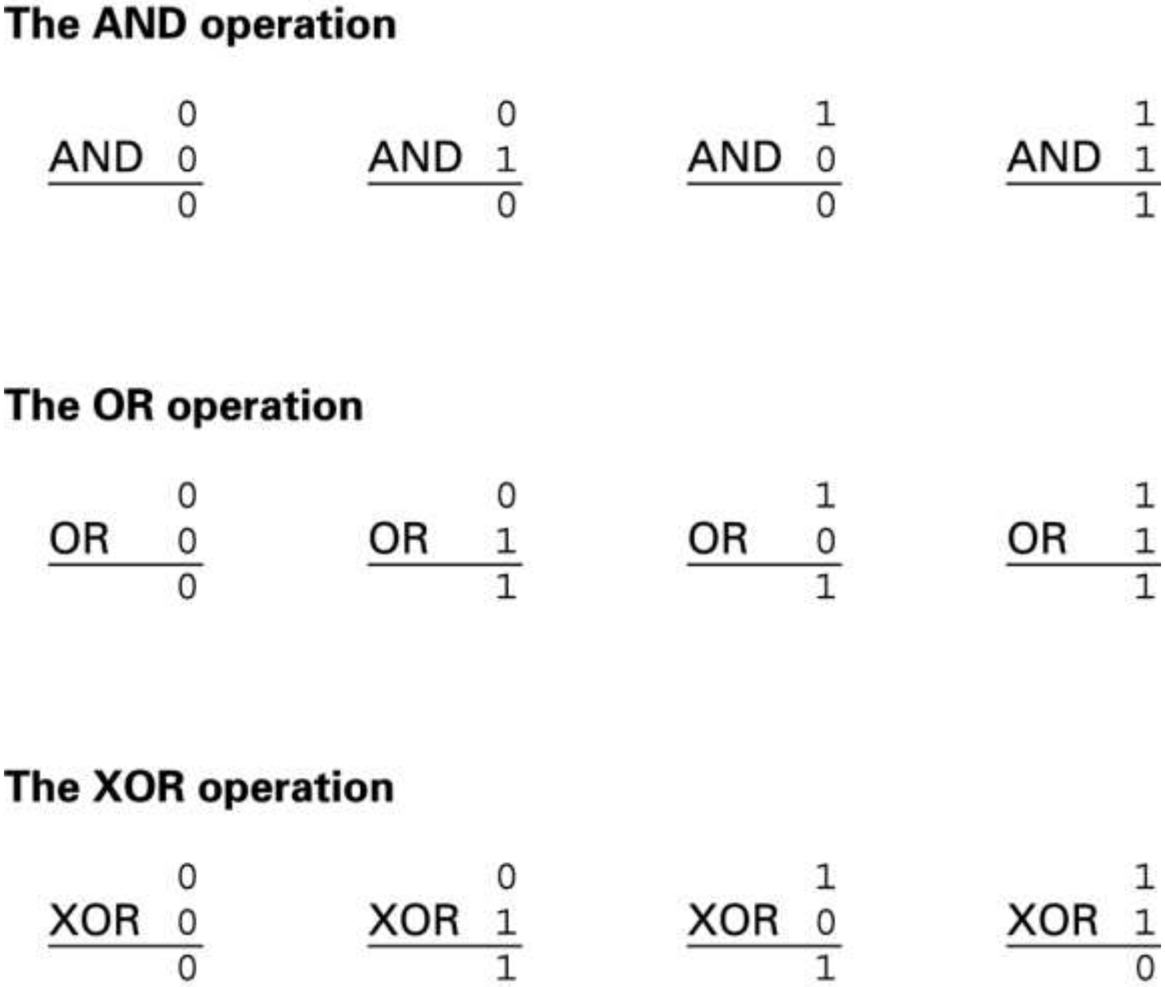
Figure 1.1 **The Boolean operations AND, OR, and XOR (exclusive or)**



The AND operation

$$\begin{array}{r} 0 \\ \text{AND}\quad 0 \\ \hline 0 \end{array} \qquad \begin{array}{r} 0 \\ \text{AND}\quad 1 \\ \hline 0 \end{array} \qquad \begin{array}{r} 1 \\ \text{AND}\quad 0 \\ \hline 0 \end{array} \qquad \begin{array}{r} 1 \\ \text{AND}\quad 1 \\ \hline 1 \end{array}$$

The OR operation

$$\begin{array}{r} 0 \\ \text{OR}\quad 0 \\ \hline 0 \end{array} \qquad \begin{array}{r} 0 \\ \text{OR}\quad 1 \\ \hline 1 \end{array} \qquad \begin{array}{r} 1 \\ \text{OR}\quad 0 \\ \hline 1 \end{array} \qquad \begin{array}{r} 1 \\ \text{OR}\quad 1 \\ \hline 1 \end{array}$$

The XOR operation

$$\begin{array}{r} 0 \\ \text{XOR}\quad 0 \\ \hline 0 \end{array} \qquad \begin{array}{r} 0 \\ \text{XOR}\quad 1 \\ \hline 1 \end{array} \qquad \begin{array}{r} 1 \\ \text{XOR}\quad 0 \\ \hline 1 \end{array} \qquad \begin{array}{r} 1 \\ \text{XOR}\quad 1 \\ \hline 0 \end{array}$$

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Gates门（器件）

抽象工具

- **Gate:** A device that computes a Boolean operation
  - Often implemented as (small) electronic circuits
  - Provide the building blocks from which computers are constructed
  - VLSI (Very Large Scale Integration)

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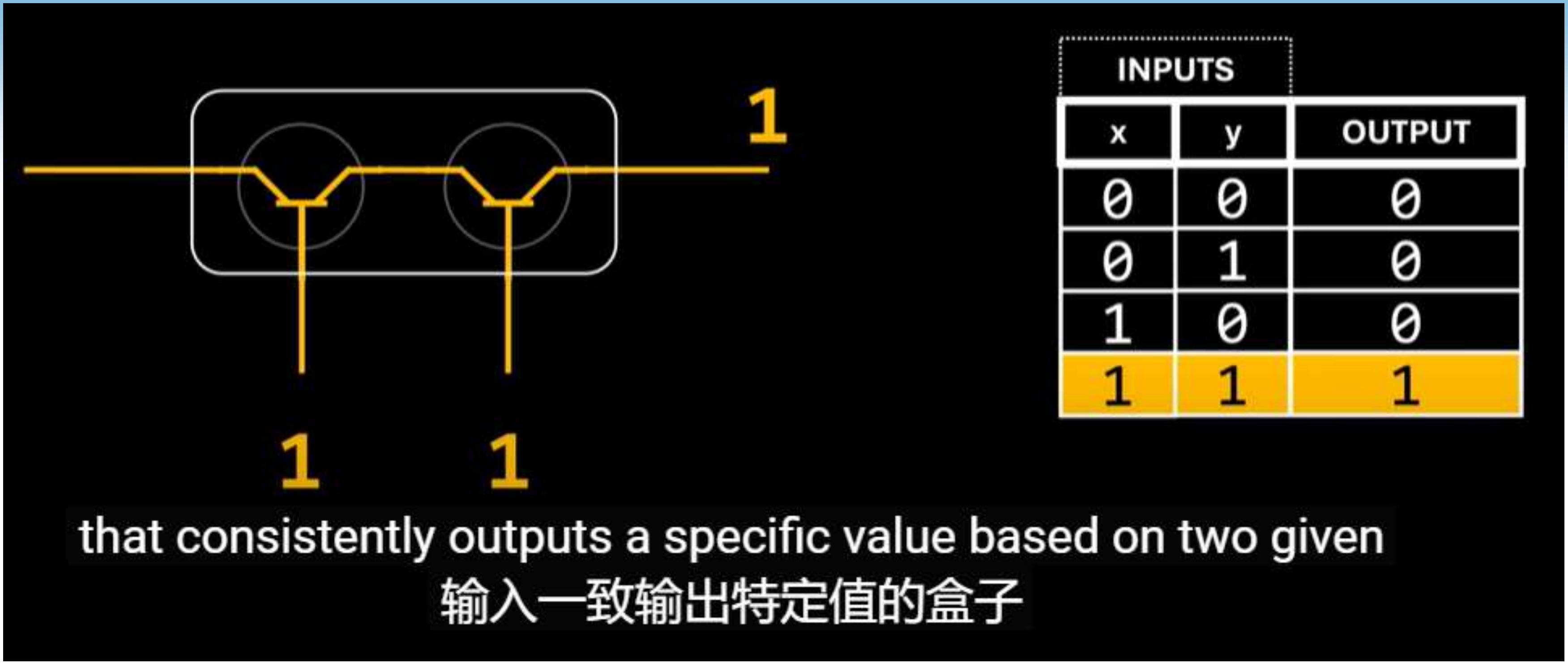
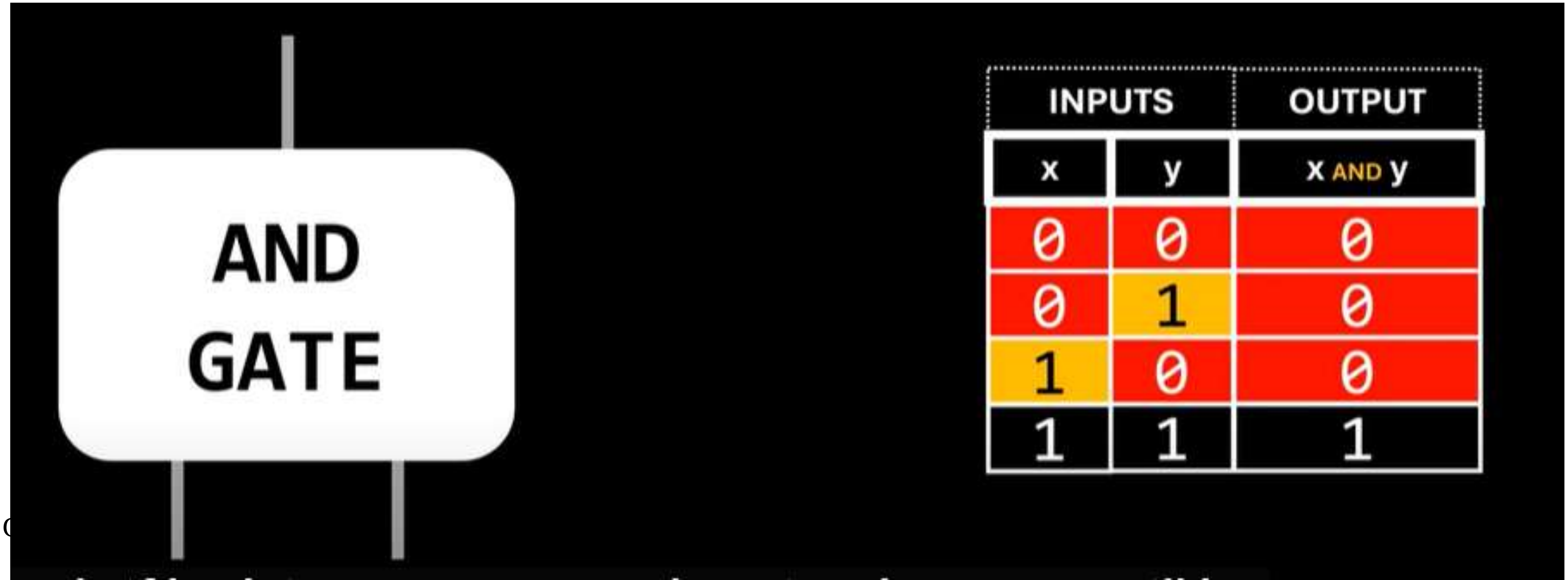


INPUTS		
x	y	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

that consistently outputs a specific value based on two given

输入一致输出特定值的盒子

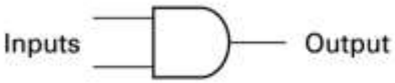


INPUTS		OUTPUT
x	y	x AND y
0	0	0
0	1	0
1	0	0
1	1	1

A pictorial representation of AND, OR, XOR, and NOT gates as well as their input and output values

AND

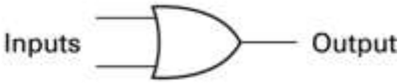
与门



Inputs	Output
0 0	0
0 1	0
1 0	0
1 1	1

OR

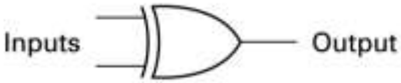
或门



Inputs	Output
0 0	0
0 1	1
1 0	1
1 1	1

XOR

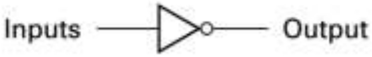
异或门



Inputs	Output
0 0	0
0 1	1
1 0	1
1 1	0

NOT

非门



Inputs	Output
0	1
1	0

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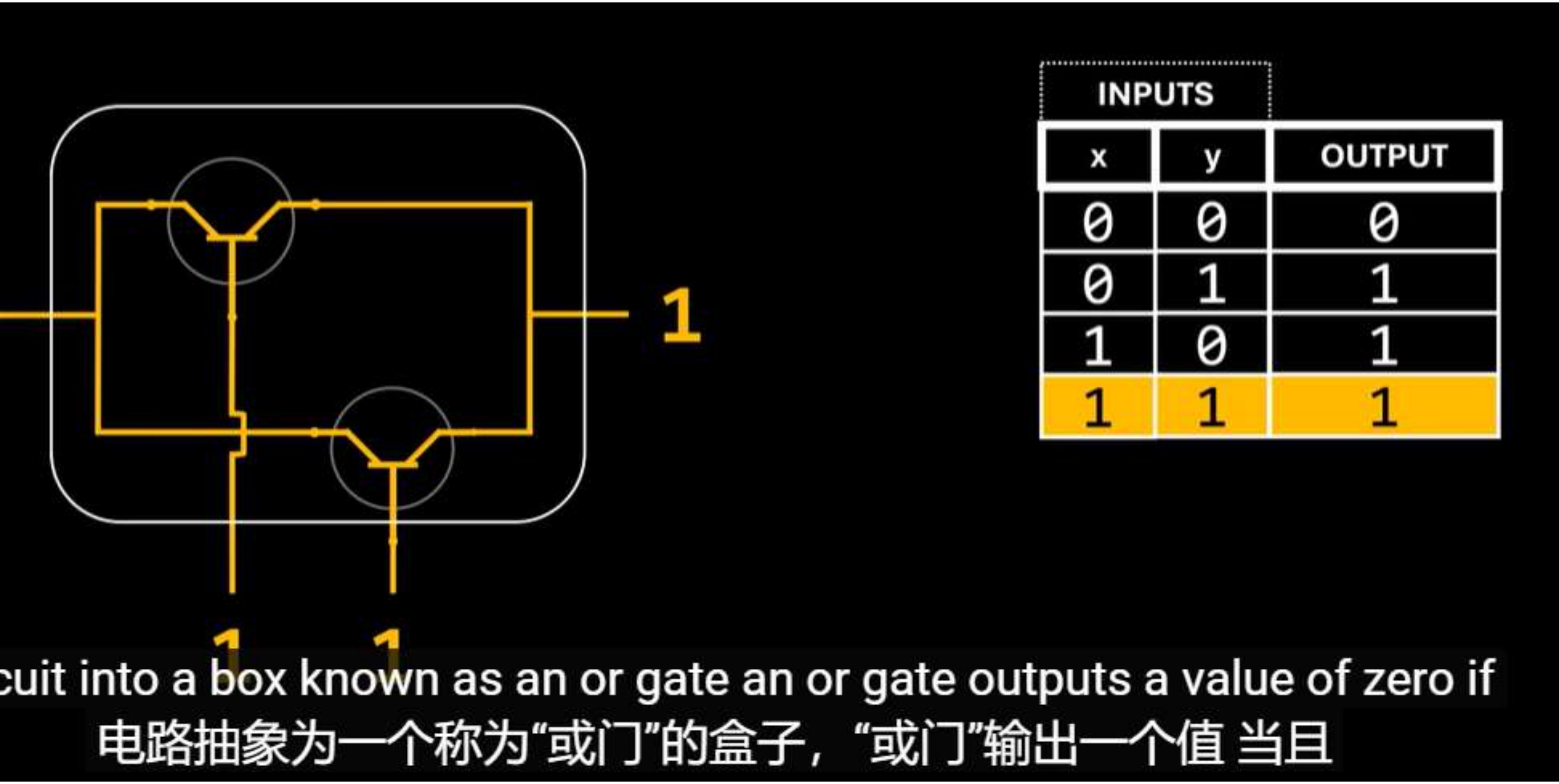

INPUTS		
x	y	OUTPUT
0	0	0
0	1	1
1	0	1
1	1	1

cuit into a box known as an or gate an or gate outputs a value of zero if

电路抽象为一个称为“或门”的盒子，“或门”输出一个值 当且

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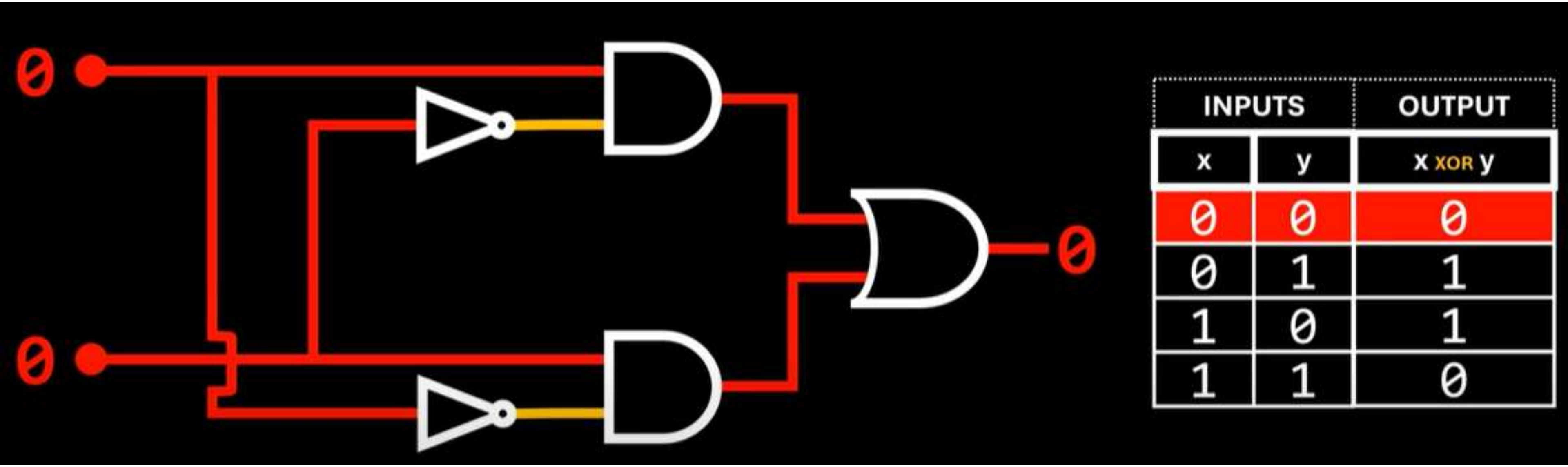

INPUTS		OUTPUT
x	y	x XOR y
0	0	0
0	1	1
1	0	1
1	1	0

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- Arithmetic

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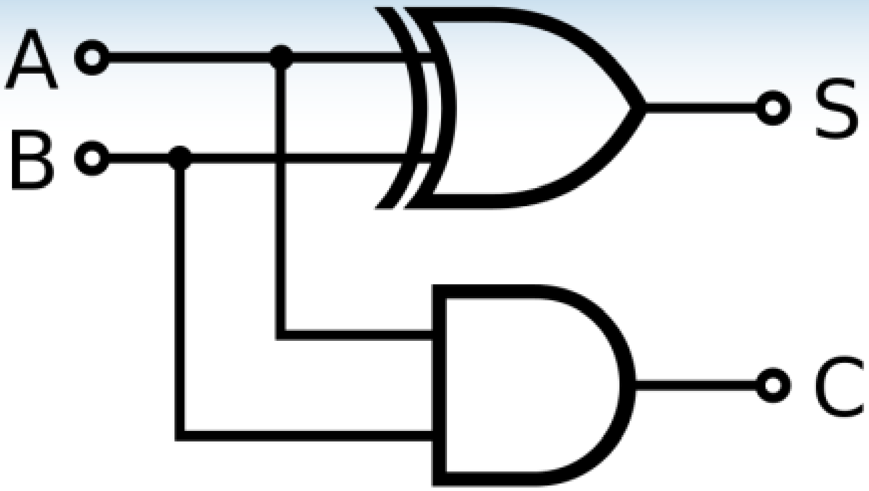
Adder

- Half adder半加器



半加器

Inputs		Outputs	
A	*B*	*C*	*S*
0	0	0	0
1	0	0	1
0	1	0	1
1	1	1	0

将两个一位二进制数相加，输出和（sum）及进位（carry）

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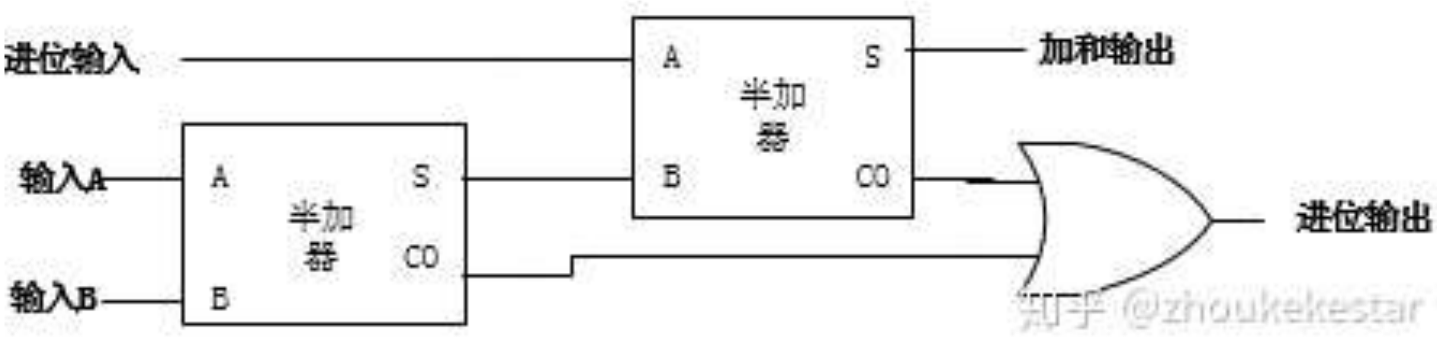
Adder

- Full adder全加器
  - 将两个一位二进制数相加，并根据接收到的低位进位信号，输出和、进位输出。全加器的三个输入信号为两个加数A、B和低位进位Cin。



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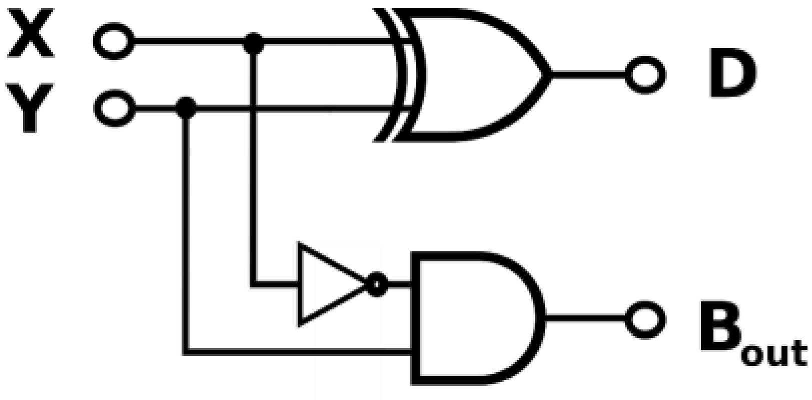
Subtractor

- Half subtractor
- Full subtractor

X	Y	D	Bor
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0



Half subtractor

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BIG Idea

- Computers store and process binary
- Logic true and false can be used to represent binary 1 and 0
- Logic operations can be implemented by logic gates
  - and in turn by ON/OFF switches
- Computers can be implemented using logic gates → for storing and processing

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How is the bit information stored by the computer?

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Storage: Flip-flops （触发器）

- **Flip-flop:** A circuit built from gates that can store one bit.
  - One input line is used to set its stored value to 1
  - One input line is used to set its stored value to 0
  - While both input lines are 0, the most recently stored value is preserved

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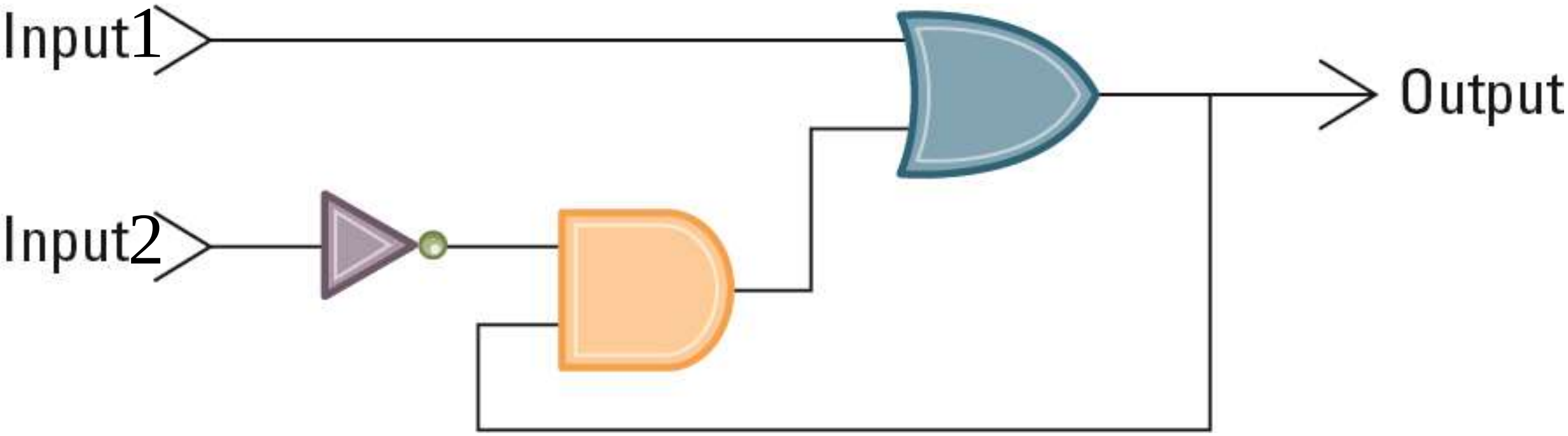
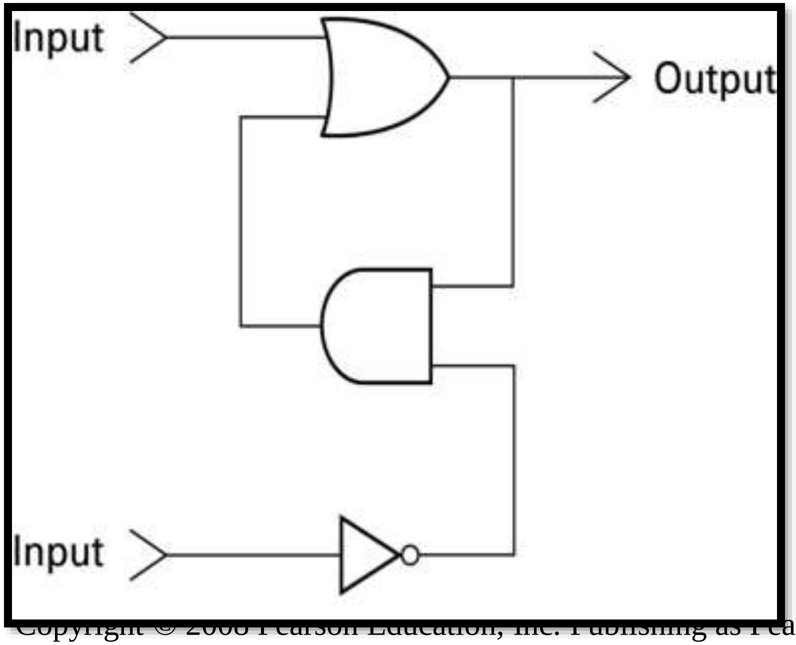
A simple flip-flop circuit





Input 1	Input 2	Output
1	0	1
0	1	0
1	1	1
0	0	保持不变

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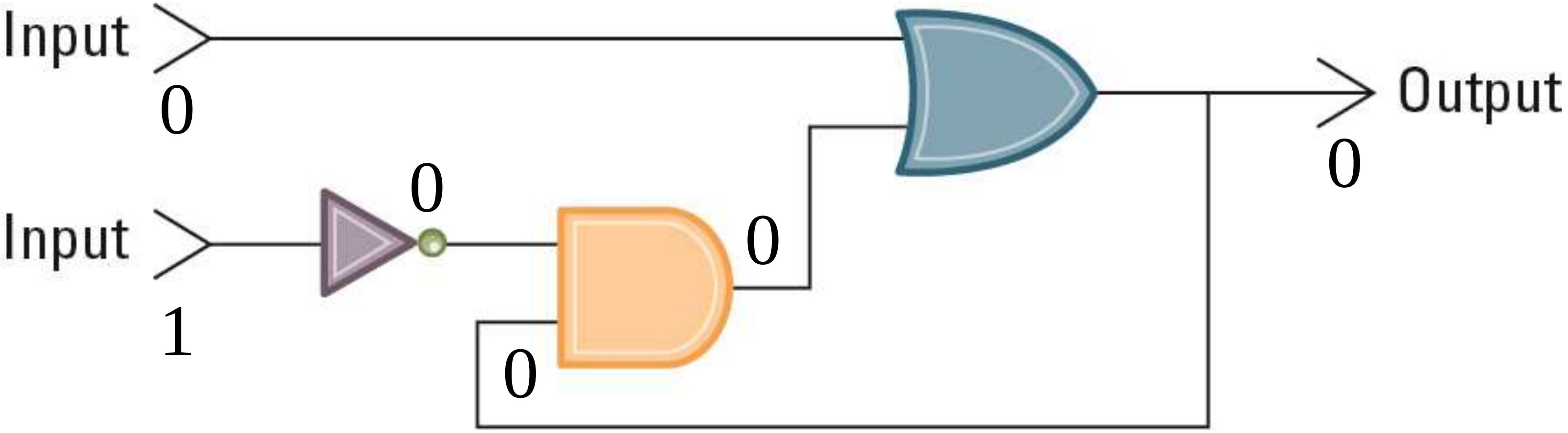
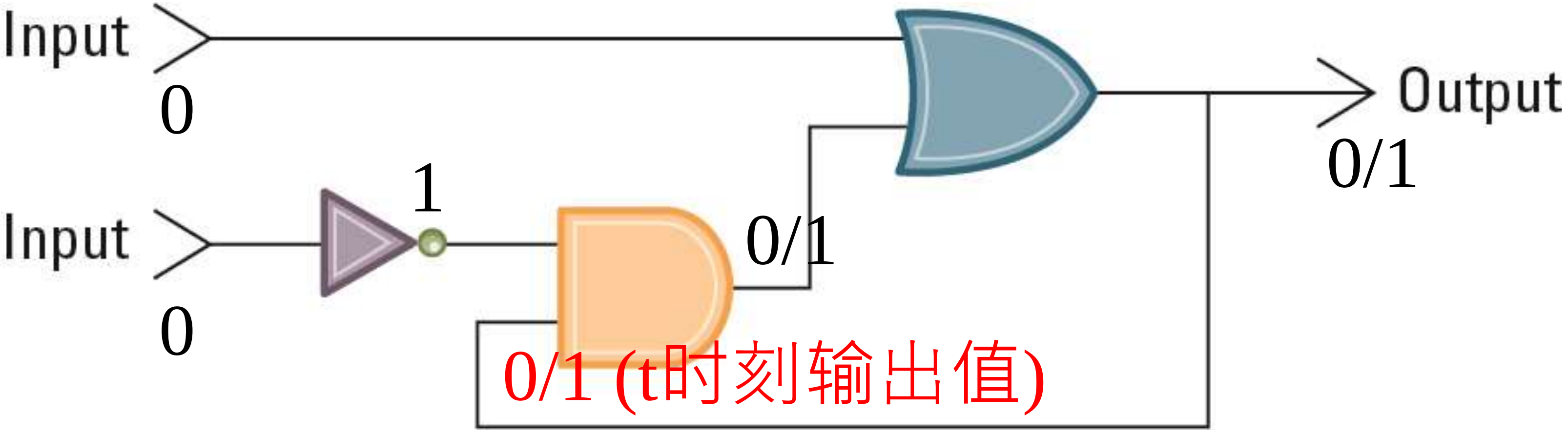
在t时刻



在t+1时刻



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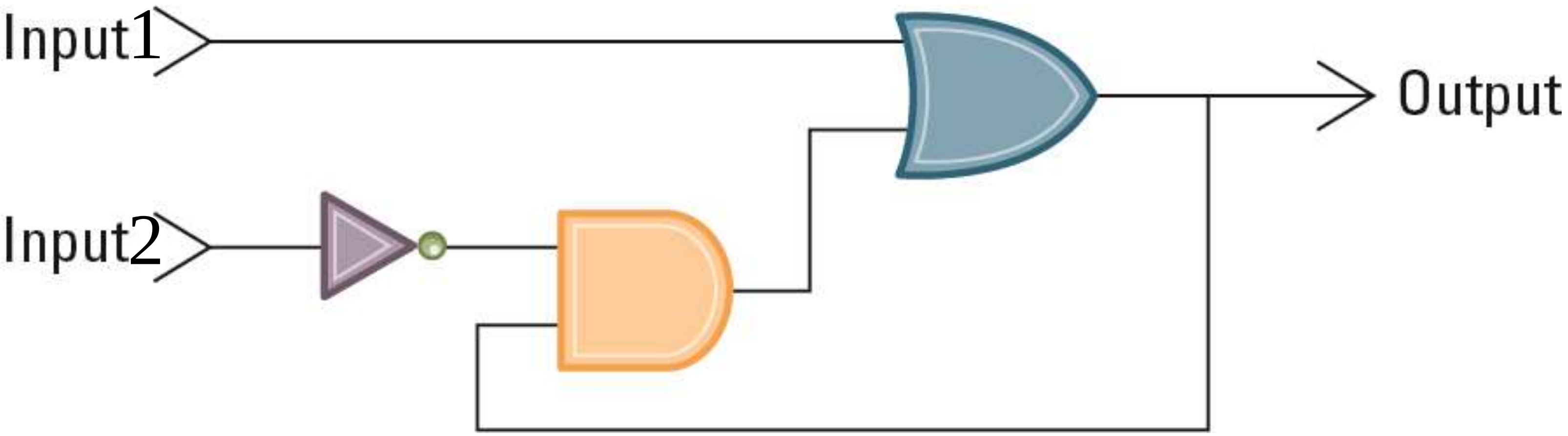
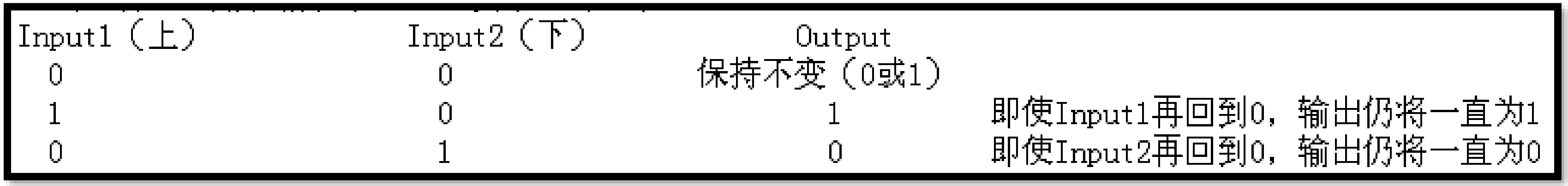
A simple flip-flop circuit



Input 1	Input 2	Output
1	0	1
0	1	0
1	1	1
0	0	保持不变



Input1（上）	Input2（下）	Output	
0	0	保持不变（0或1）	
1	0	1	即使Input1再回到0，输出仍将一直为1
0	1	0	即使Input2再回到0，输出仍将一直为0

Flip-flop

- Shows how a device can be constructed from gates
- Example of abstraction
- Store a bit

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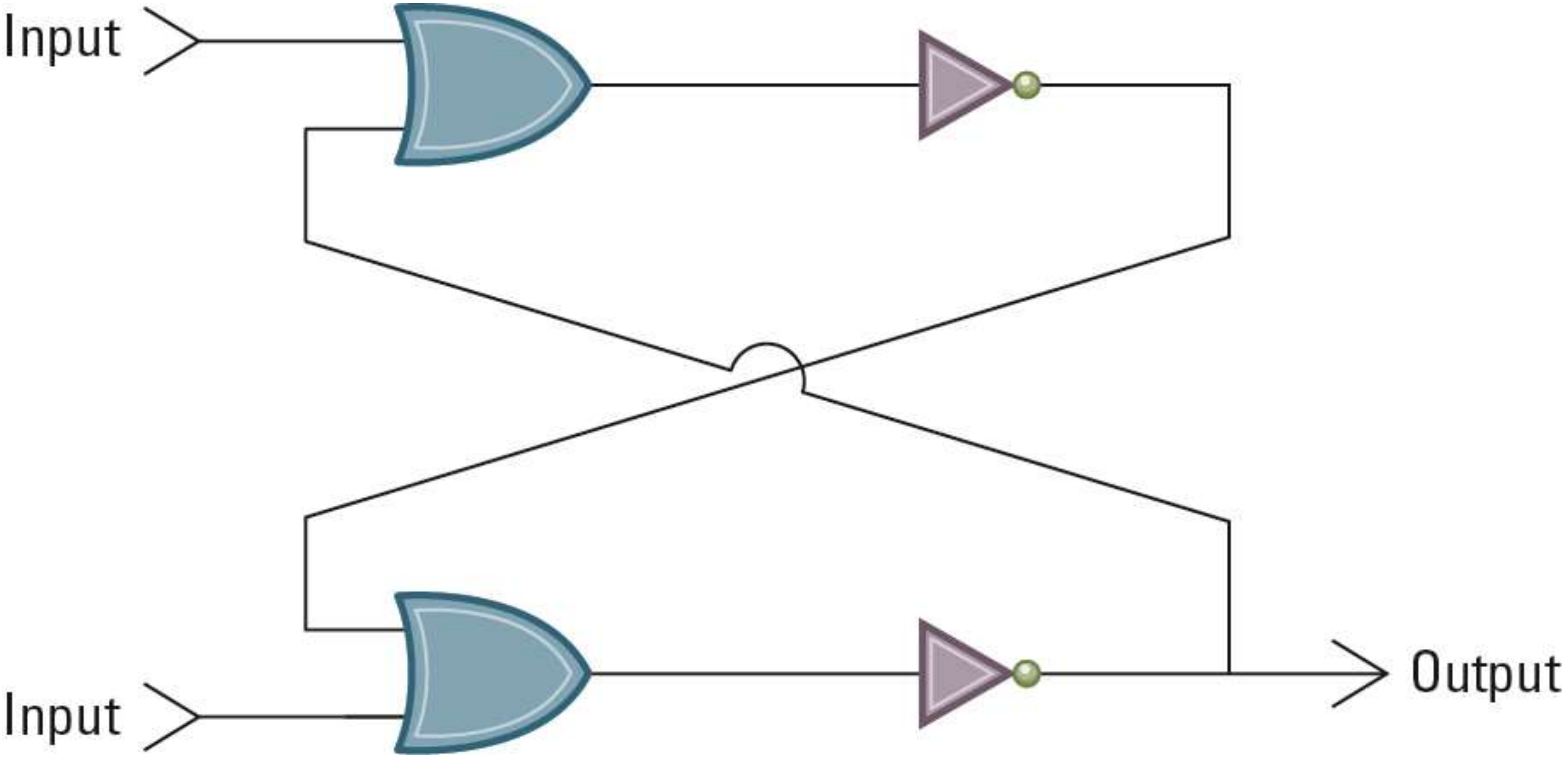
Another way of constructing a flip-flop



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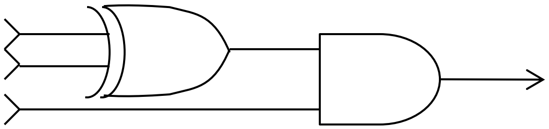
Exercises

- What input bit patterns will cause the following circuit to output 1? And output 0?



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- **How are patterns of bits stored in computer?**

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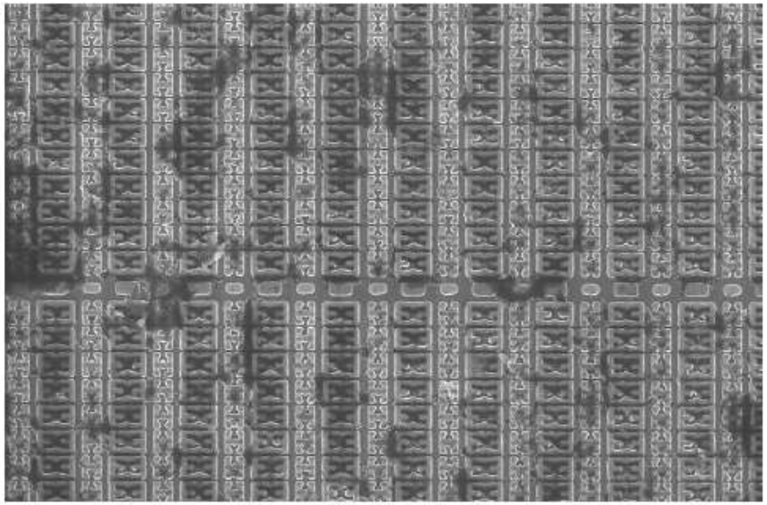
SRAM

- SRAM（Static Random-Access Memory）采用双稳态触发器（Flip-Flop）作为存储单元，能够保持数据的稳定状态而无需定期刷新。因此，SRAM的存取速度非常快，功耗相对较低，但制造成本较高，存储密度也相对较低。



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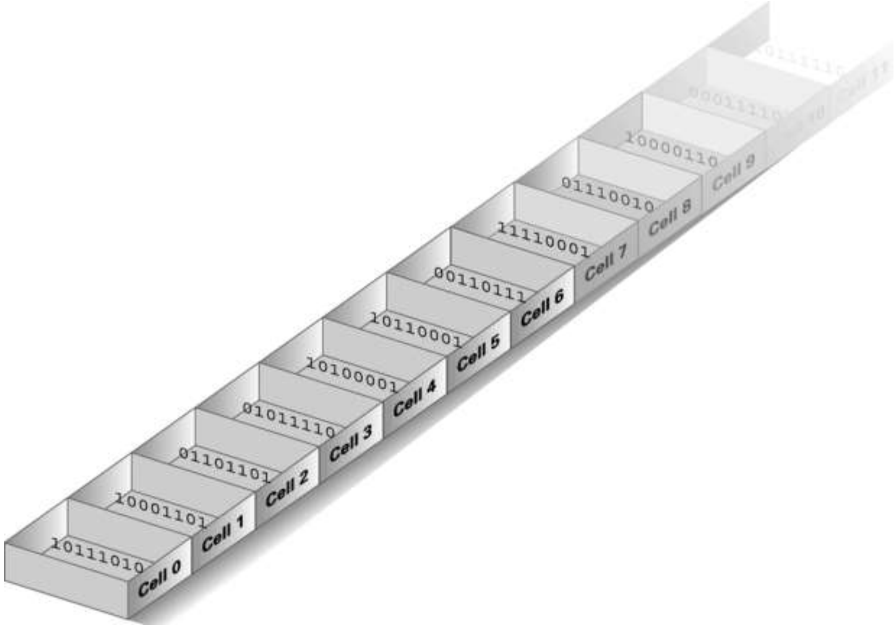
1.2 Main memory

Main Memory Cells

- **Cell:** A unit of main memory (typically 8 bits which is one **byte**)



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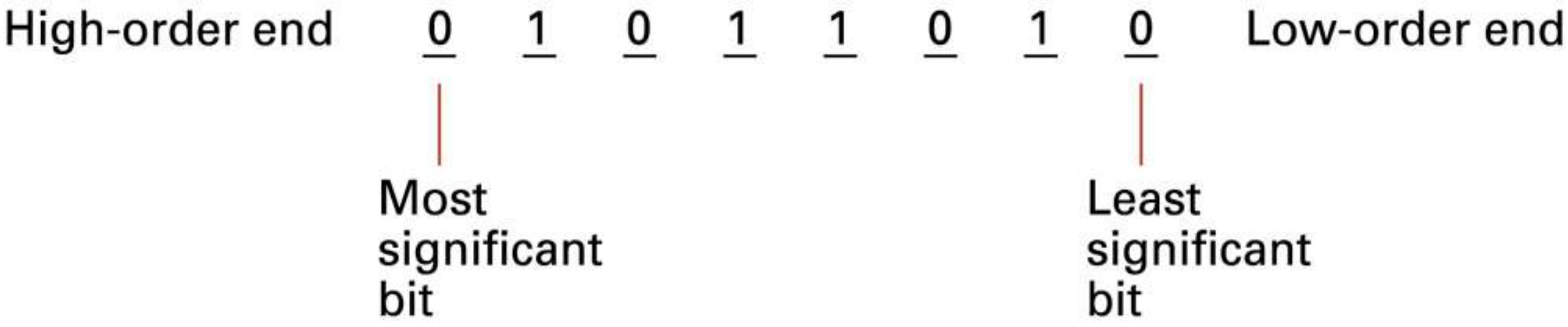
The organization of a byte-size memory cell



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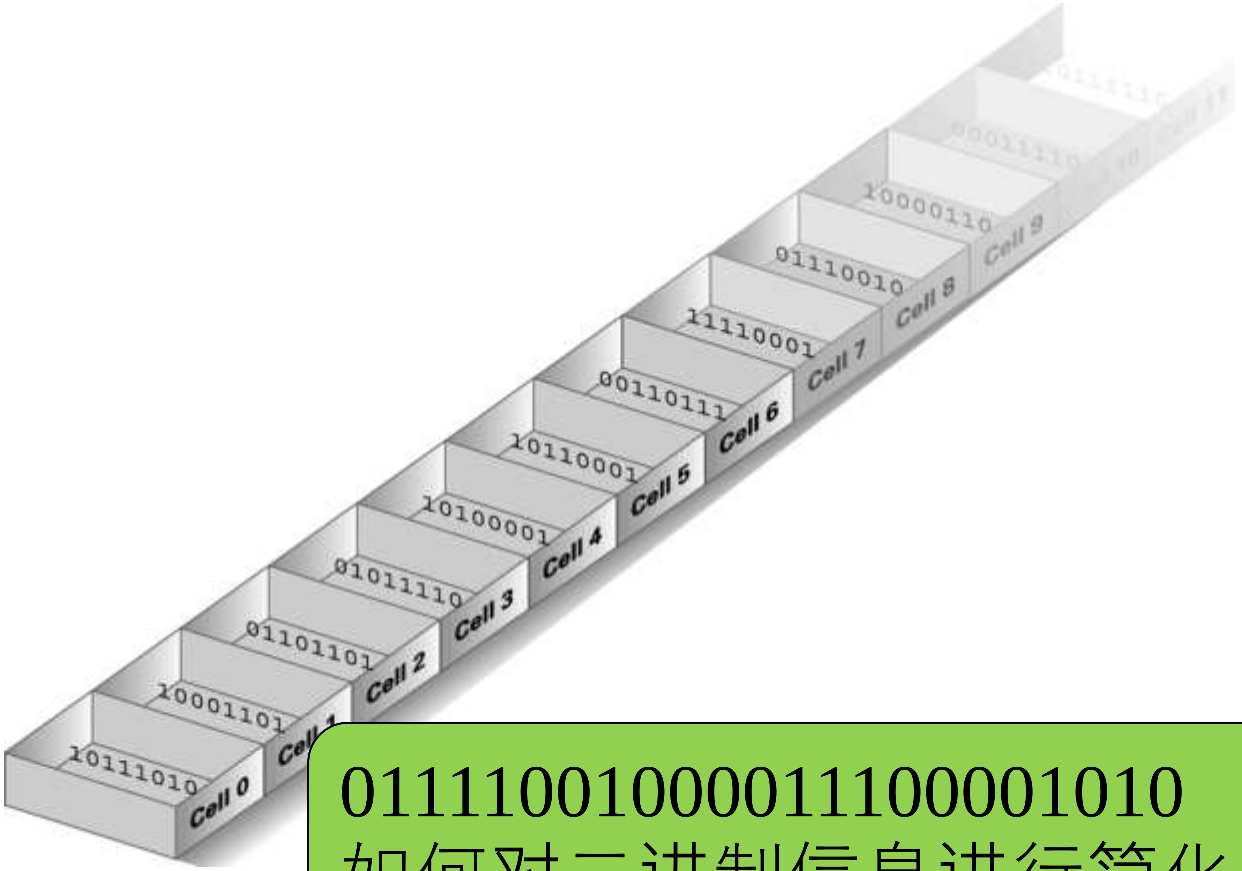
Memory cells arranged by address



01111001000011100001010
如何对二进制信息进行简化表示？

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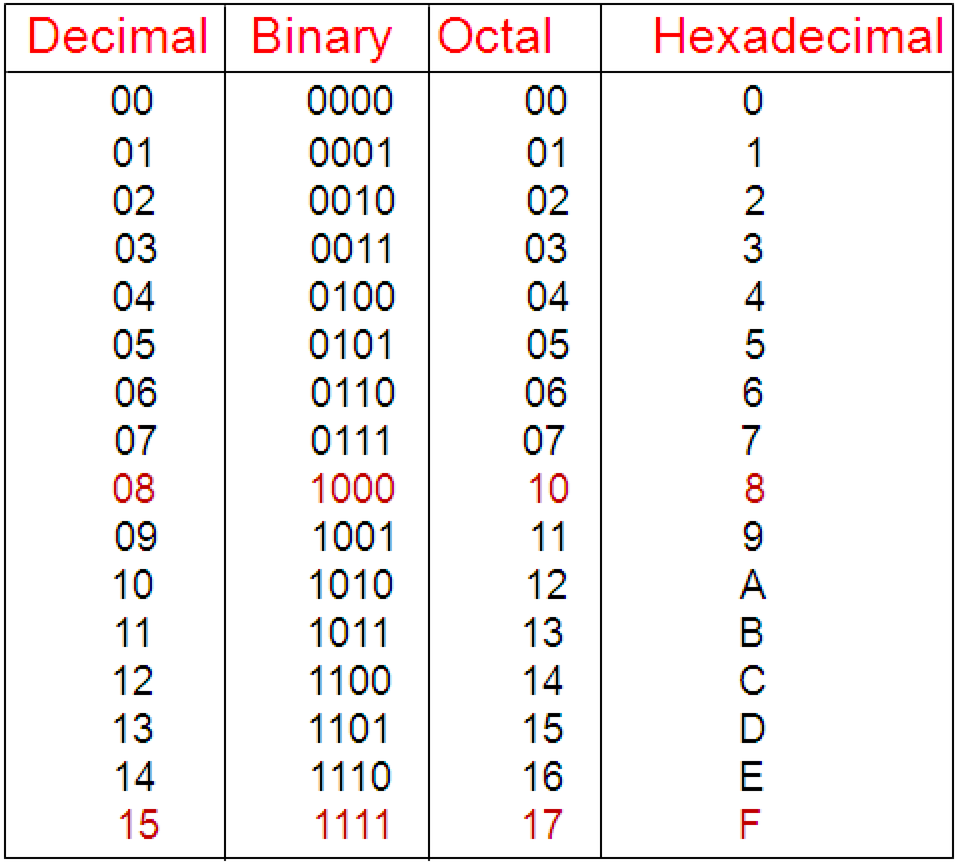
Hexadecimal Notation 十六进制表示



Decimal	Binary	Octal	Hexadecimal
00	0000	00	0
01	0001	01	1
02	0010	02	2
03	0011	03	3
04	0100	04	4
05	0101	05	5
06	0110	06	6
07	0111	07	7
08	1000	10	8
09	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

10001000B
88H

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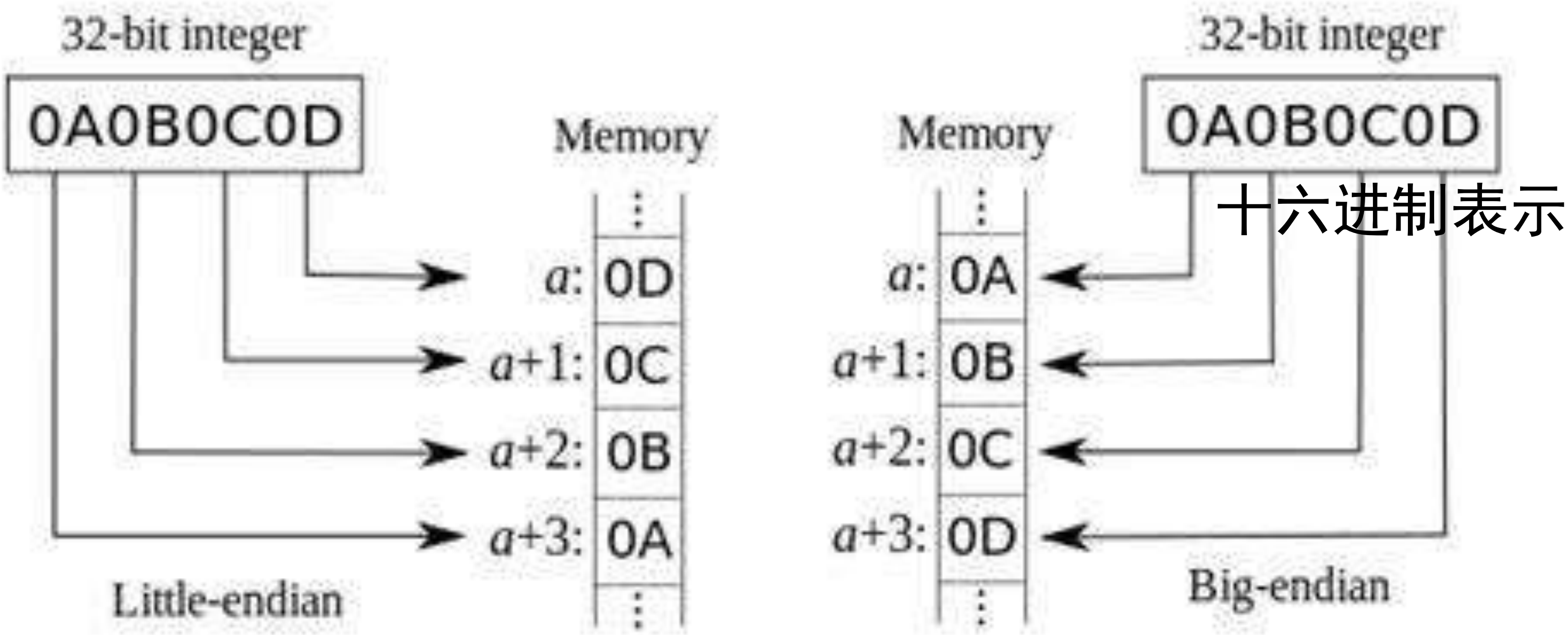
Main Memory Addresses（主存储器地址）

- **Address:** A “name” that uniquely identifies one cell in the computer’s main memory



十六进制表示

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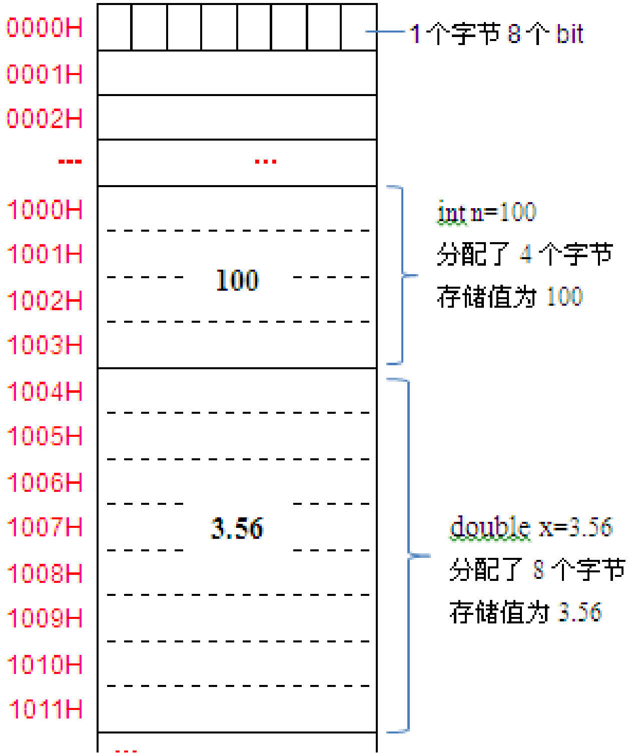
内存地址和数据存放

内存：以字节Byte为单位，每个字节有唯一的地址，就可方便地存取数据。

数据存放：不同的数据类型占据的字节数不同。

```
int    n=100;     //占4个字节
double  x=3.56;  //占8个字节
```



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Memory Categories

- Volatile memory易失性存储
  - Random Access Memory (RAM)随机存取器

- Non-volatile memory非易失性存储
  - For example?

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Memory Terminology

- **Random Access Memory (RAM):**随机存取器
  - Memory in which individual cells can be easily accessed in any order
  - Static Random Access Memory (SRAM)
    - 只要保持通电，储存的数据就可以恒常保持
  - Dynamic Random Access Memory (DRAM)
    - 需要附加的刷新电路，数据需要周期性地更新

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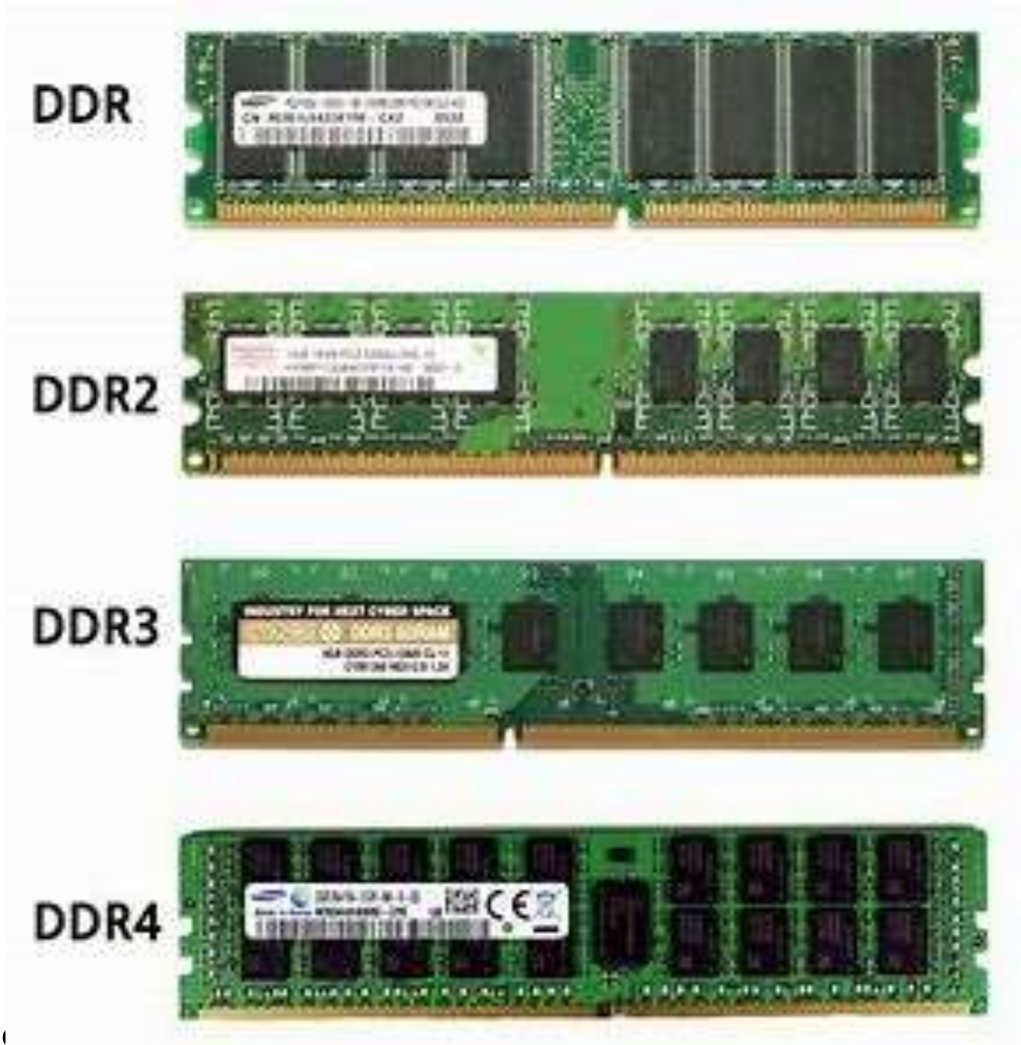
DDR SDRAM (Double Data Rate Synchronous Dynamic Random Access Memory)



双倍速率同步动态随机存储器

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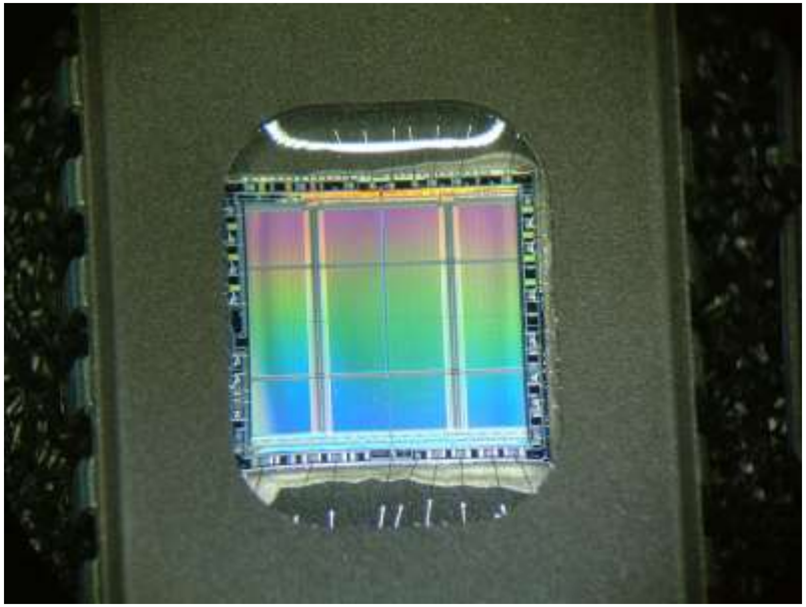
Memory categories

- Volatile memory易失存储器
- Non-volatile memory非易失存储器
  - Read only memory (ROM)
  - Magnetic disk
  - Flash
    - NAND Flash (SSD solid state drive)

Nand-flash存储器是flash存储器的一种，具有容量较大，改写速度快等优点

Electrically

- Read only (mostly) memory (ROM)



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Electrically

- Flash

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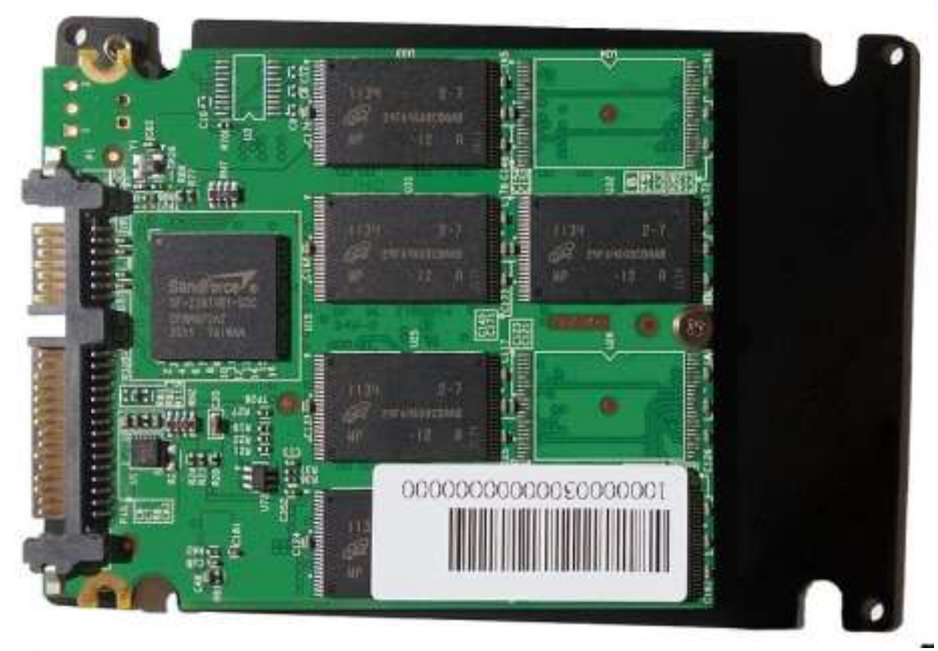
SSD solid-state drive

- NAND Flash



- ✓ 固态硬盘（SSD）是一种基于非易失性存储技术的数据存储设备
- ✓ 是用固态电子存储芯片阵列制成的硬盘
- ✓ SSD更小更轻，速度更快，能耗更低，耐用性更高

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Measuring Memory Capacity

- **Kilobyte:** 2^{10} bytes = 1024 bytes
  - – Example: 3 KB = 3 times1024 bytes
  - – Sometimes “kibi” rather than “kilo”
- **Megabyte:** 2^{20} bytes = 1,048,576 bytes
  - – Example: 3 MB = 3 times 1,048,576 bytes
  - – Sometimes “megi” rather than “mega”
- **Gigabyte:** 2^{30} bytes = 1,073,741,824 bytes
  - – Example: 3 GB = 3 times 1,073,741,824 bytes
  - – Sometimes “gigi” rather than “giga”

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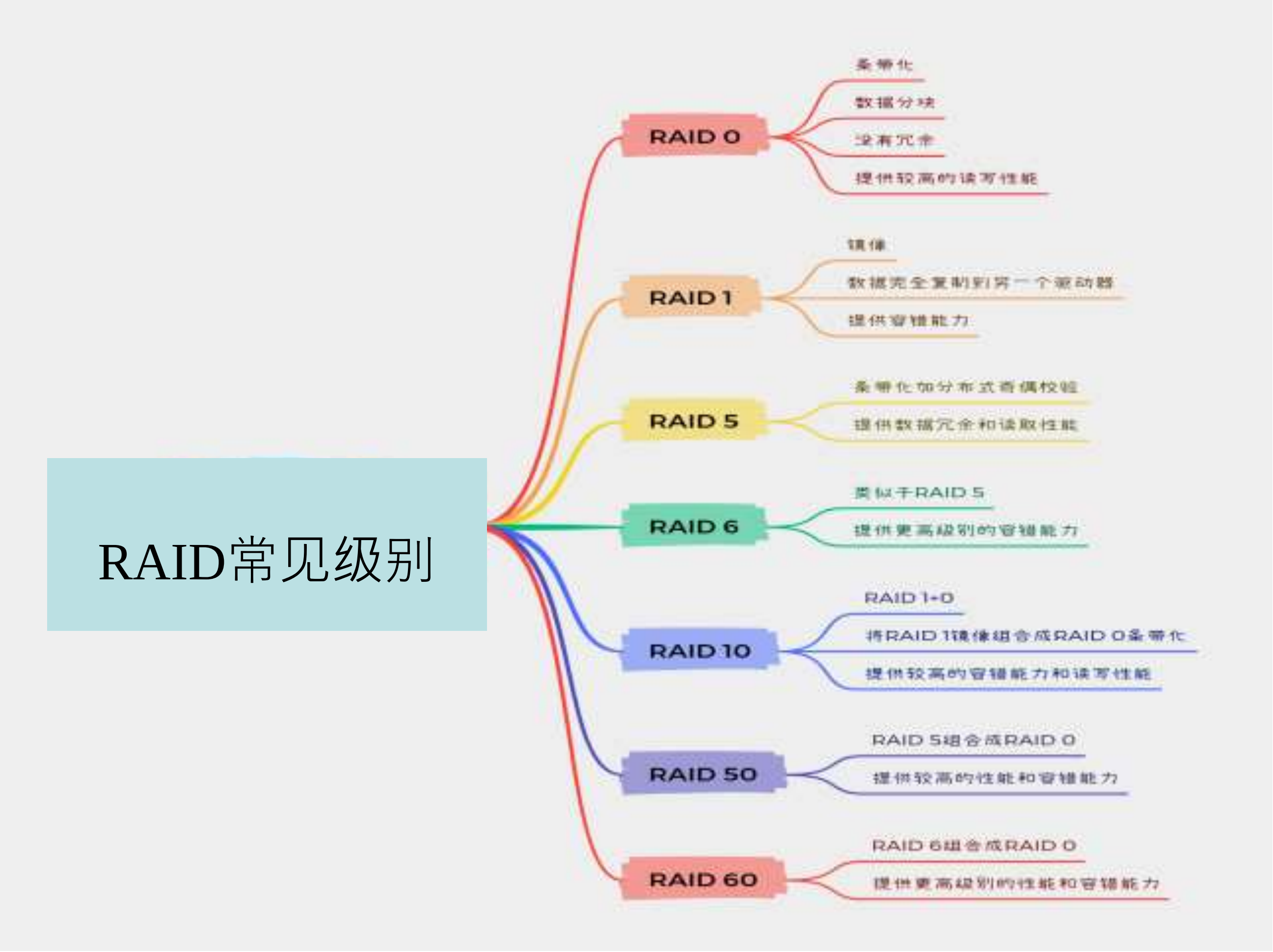
RAID存储

RAID（Redundant Array of Independent Disks，独立磁盘冗余阵列）是一种数据存储虚拟化技术，它将多个物理硬盘组合成一个或多个逻辑单元，以提高存储性能、容量和数据冗余。



RAID常见级别

- RAID 0
  - 条带化
  - 数据分块
  - 没有冗余
  - 提供较高的读写性能
- RAID 1
  - 镜像
  - 数据完全复制到另一个驱动器
  - 提供容错能力
- RAID 5
  - 条带化加分布式奇偶校验
  - 提供数据冗余和读取性能
- RAID 6
  - 类似于RAID 5
  - 提供更高级别的容错能力
- RAID 10
  - RAID 1+0
  - 将RAID 1镜像组合成RAID 0条带化
  - 提供较高的容错能力和读写性能
- RAID 50
  - RAID 5组合成RAID 0
  - 提供较高的性能和容错能力
- RAID 60
  - RAID 6组合成RAID 0
  - 提供更高级别的性能和容错能力

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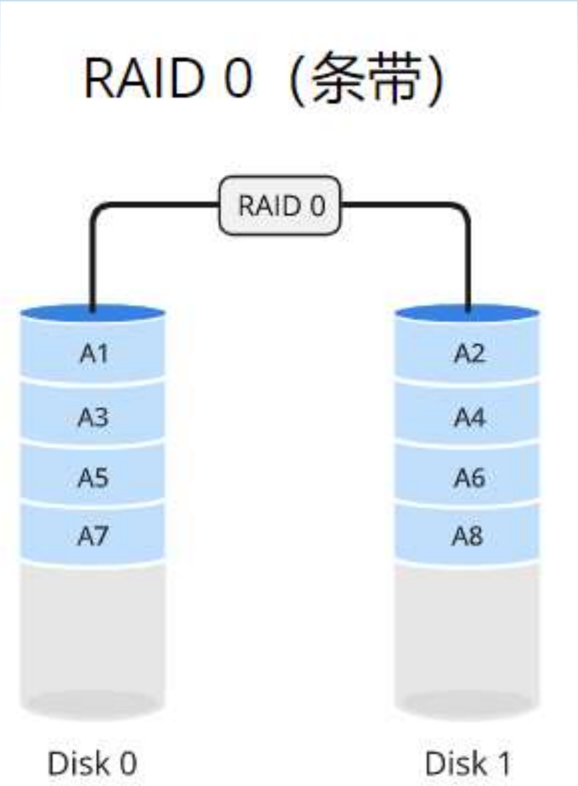

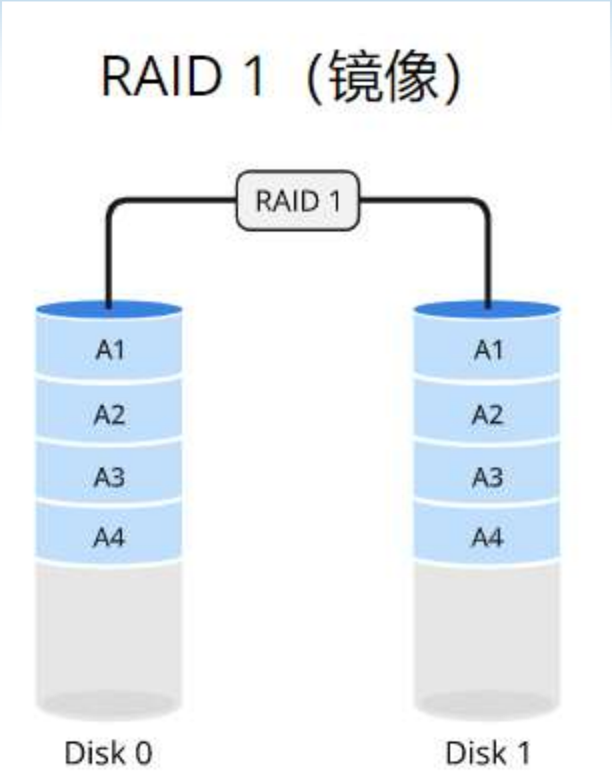

数据被分成块，并依次存储在两个驱动器上。每个块的一部分存储在驱动器A上，另一部分存储在驱动器B上

数据被完全复制到两个驱动器上。每个块的数据都同时存储在两个驱动器上，以实现数据的冗余备份

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云存储

网上在线存储的模式，把数据存放在通常由第三方托管的多台虚拟服务器

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数据中心

- 复杂的设施，用于存储、管理和传输海量数据。
- 通常包含服务器、存储系统、网络设备及确保系统稳定运行所需的电源和冷却系统。
- 数据中心是促进5G、人工智能、云计算等新一代数字技术发展的数据中枢和算力载体。

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