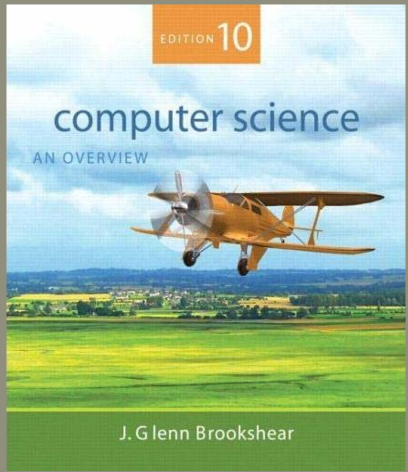
# Chapter 1

## Data Storage




## Chapter 1: Data Storage

- 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



## Chapter 1: Data Storage (continued)

- 1.6 Storing Integers
- 1.7 Storing Fractions
- 1.8 Data Compression
- 1.9 Communications Errors



## Bits and Bit Patterns

- **Bit (位元):** Binary Digit (二進位數字0 or 1)
- Bit Patterns are used to represent information.
  – Numbers
  – Text characters
  – Images
  – Sound
  – And others

## Boolean Operations

- **Boolean Operation(布林運算):** An operation that manipulates one or more true/false values
- Specific operations
  – AND（且）
  – OR（或）
  – XOR (exclusive or)（互斥或）
  – NOT（非）



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

**The AND operation**

| | | | |
|---|---|---|---|
| 0 AND 0 = 0 | 0 AND 1 = 0 | 1 AND 0 = 0 | 1 AND 1 = 1 |

**The OR operation**

| | | | |
|---|---|---|---|
| 0 OR 0 = 0 | 0 OR 1 = 1 | 1 OR 0 = 1 | 1 OR 1 = 1 |

**The XOR operation**

| | | | |
|---|---|---|---|
| 0 XOR 0 = 0 | 0 XOR 1 = 1 | 1 XOR 0 = 1 | 1 XOR 1 = 0 |

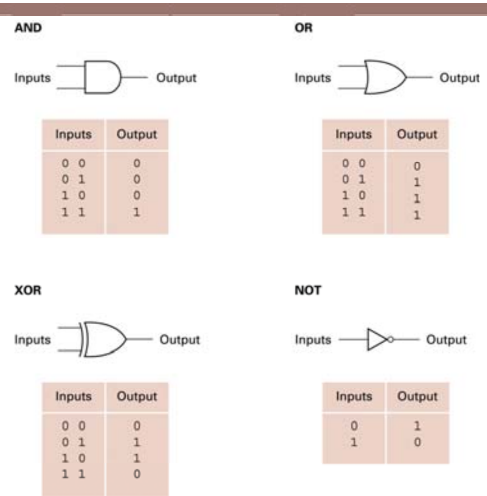


## Gates

- **Gate（邏輯閘）:** A device that computes a Boolean operation
  – Often implemented as (small) electronic circuits
  – Provide the building blocks from which computers are constructed



## **Figure 1.2** A pictorial representation of AND, OR, XOR, and NOT gates as well as their input and output values




AND

| Inputs | Output |
|---|---|
| 0 0 | 0 |
| 0 1 | 0 |
| 1 0 | 0 |
| 1 1 | 1 |

OR

| Inputs | Output |
|---|---|
| 0 0 | 0 |
| 0 1 | 1 |
| 1 0 | 1 |
| 1 1 | 1 |

XOR

| Inputs | Output |
|---|---|
| 0 0 | 0 |
| 0 1 | 1 |
| 1 0 | 1 |
| 1 1 | 0 |

NOT

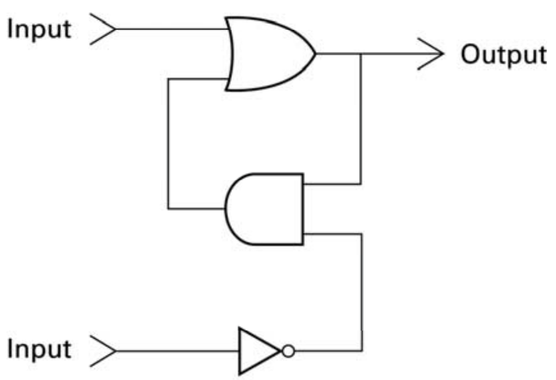
| Inputs | Output |
|---|---|
| 0 | 1 |
| 1 | 0 |

## Flip-flops

- **Flip-flop (正反器):** A circuit built from gates that can store one bit.
  - Has an input line which sets its stored value to 1
  - Has an input line which sets its stored value to 0
  - While both input lines are 0, the most recently stored value is preserved

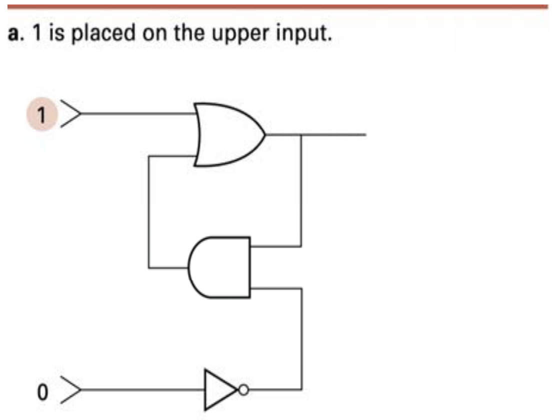


## **Figure 1.3** A simple flip-flop circuit



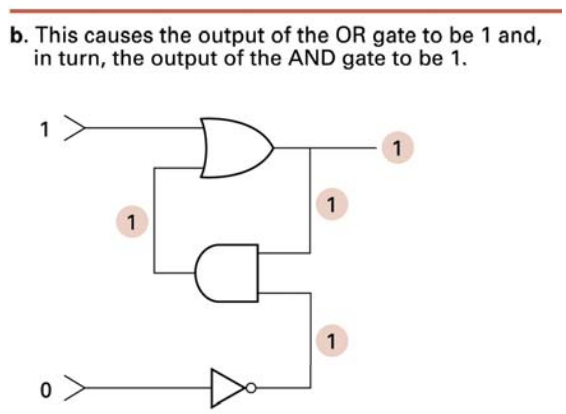



## **Figure 1.4** Setting the output of a flip-flop to 1



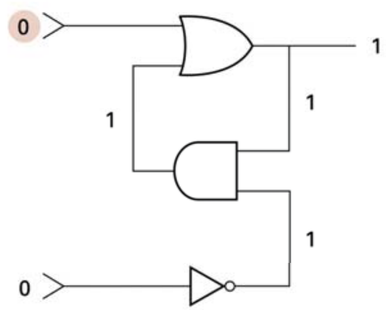



## **Figure 1.4** Setting the output of a flip-flop to 1 (continued)



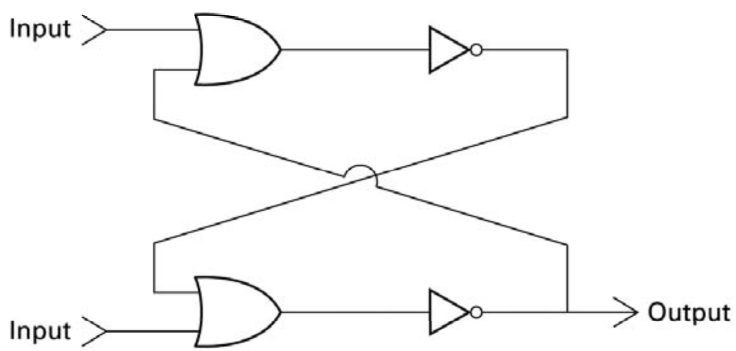
## **Figure 1.4** Setting the output of a flip-flop to 1 (continued)

c. The 1 from the AND gate keeps the OR gate from changing after the upper input returns to 0.






## **Figure 1.5** Another way of constructing a flip-flop






## Hexadecimal Notation

- **Hexadecimal notation(16進位表示法):** A shorthand notation for long bit patterns
  - Divides a pattern into groups of four bits each
  - Represents each group by a single symbol
- Example: 10100011 becomes A3



## **Figure 1.6** The hexadecimal coding system

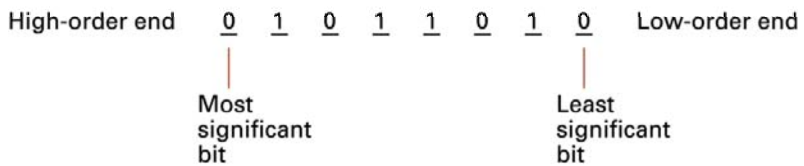
| Bit pattern | Hexadecimal representation |
|---|---|
| 0000 | 0 |
| 0001 | 1 |
| 0010 | 2 |
| 0011 | 3 |
| 0100 | 4 |
| 0101 | 5 |
| 0110 | 6 |
| 0111 | 7 |
| 1000 | 8 |
| 1001 | 9 |
| 1010 | A |
| 1011 | B |
| 1100 | C |
| 1101 | D |
| 1110 | E |
| 1111 | F |

## Main Memory Cells

- **Cell (記憶單元):** A unit of main memory (typically 8 bits which is one **byte (位元組)**)
  - **Most significant bit:** the bit at the left (high-order) end of the conceptual row of bits in a memory cell
  - **Least significant bit:** the bit at the right (low-order) end of the conceptual row of bits in a memory cell



## **Figure 1.7** The organization of a byte-size memory cell



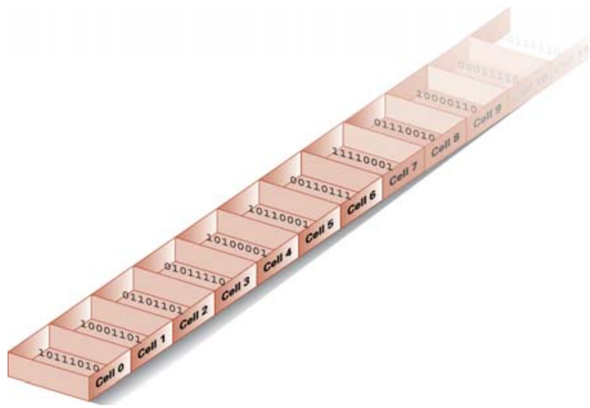



## Main Memory Addresses

- **Address(位址):** A “name” that uniquely identifies one cell in the computer’s main memory
  - The names are actually numbers.
  - These numbers are assigned consecutively starting at zero.
  - Numbering the cells in this manner associates an order with the memory cells.



## **Figure 1.8** Memory cells arranged by address



## Memory Terminology

- **Random Access Memory (RAM):** Memory in which individual cells can be easily accessed in any order（隨機存取記憶體）
- **Dynamic Memory (DRAM):** RAM composed of volatile memory（動態記憶體）



## Measuring Memory Capacity

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



## Mass Storage

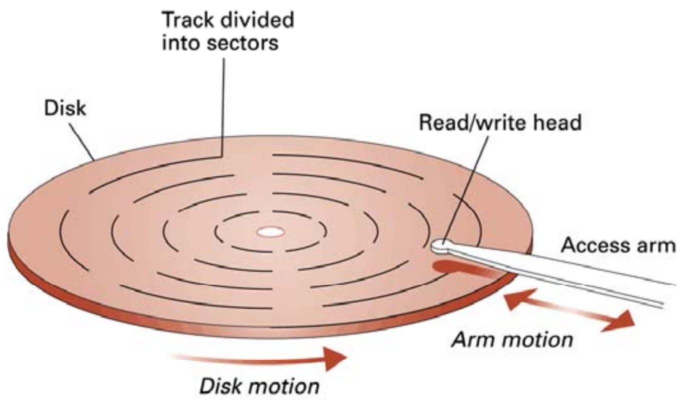
- On-line versus off-line
- Typically larger than main memory
- Typically less volatile than main memory
- Typically slower than main memory



## Mass Storage Systems

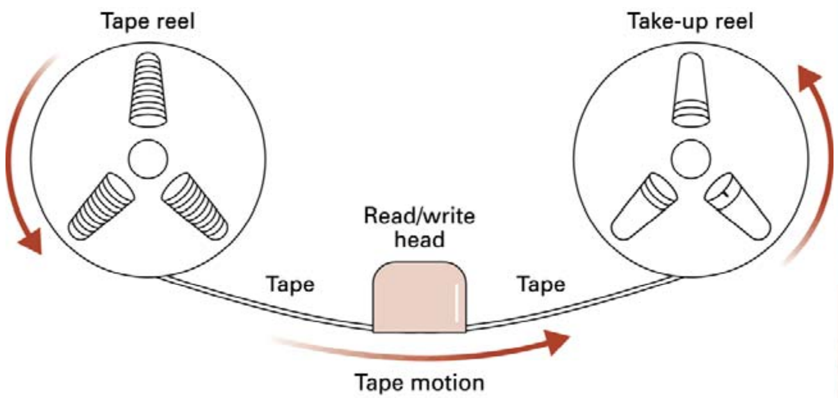
- Magnetic Systems
  - Disk
  - Tape
- Optical Systems
  - CD
  - DVD
- Flash Drives

# Figure 1.9 A magnetic disk storage system



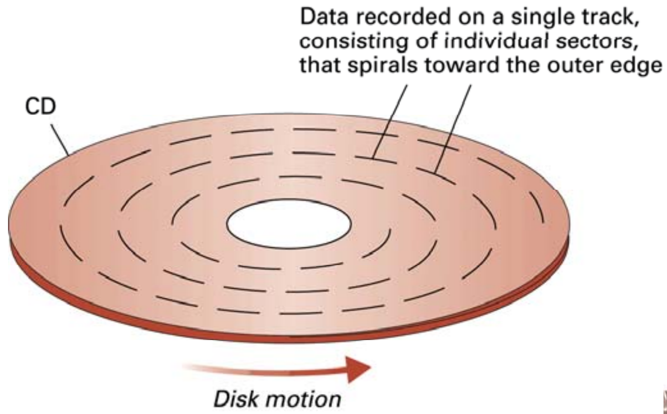



# Figure 1.10 Magnetic tape storage






# Figure 1.11 CD storage

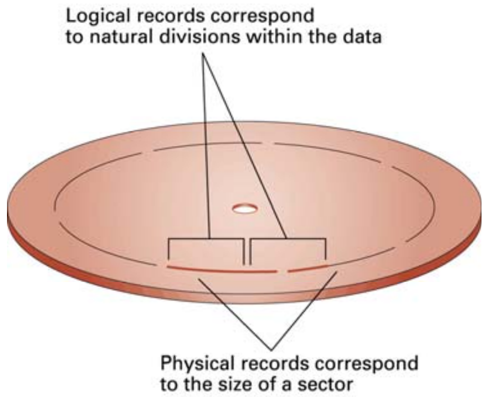





# Files

- **File(檔案):** A unit of data stored in mass storage system
  - **Fields** and **keyfields**
- Physical record versus Logical record
  (See the figure on the next page)
- **Buffer(緩衝記憶區):** A memory area used for the temporary storage of data (usually as a step in transferring the data)

## Figure 1.12 Logical records versus physical records on a disk






## Figure 1.13 The message "Hello." in ASCII

| | | | | | |
|---|---|---|---|---|---|
| 01001000 | 01100101 | 01101100 | 01101100 | 01101111 | 00101110 |
| H | e | l | l | o | . |



## Representing Text

- Each character (letter, punctuation, etc.) is assigned a unique bit pattern.
  - ASCII: Uses patterns of 7-bits to represent most symbols used in written English text
  - Unicode: Uses patterns of 16-bits to represent the major symbols used in languages world side
  - ISO standard: Uses patterns of 32-bits to represent most symbols used in languages world wide



## Representing Numeric Values

- Binary notation(二進位表示法): Uses bits to represent a number in base two
- Limitations of computer representations of numeric values
  - Overflow – happens when a value is too big to be represented
  - Truncation – happens when a value is between two representable values

# Representing Images

- Bit map techniques
  - Pixel: short for “picture element”
  - RGB
  - Luminance and chrominance
- Vector techniques
  - Scalable
  - TrueType and PostScript

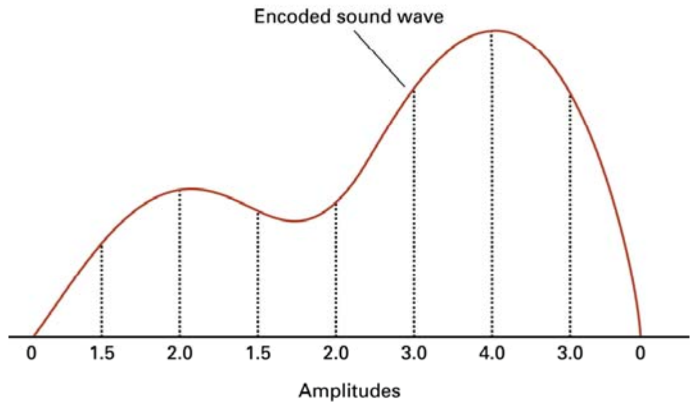


# Representing Sound

- Sampling techniques
  - Used for high quality recordings
  - Records actual audio
- MIDI
  - Used in music synthesizers
  - Records “musical score”



## **Figure 1.14** The sound wave represented by the sequence 0, 1.5, 2.0, 1.5, 2.0, 3.0, 4.0, 3.0, 0



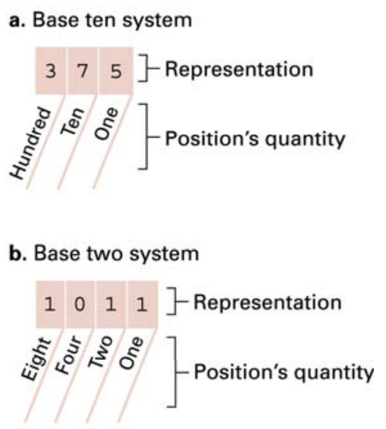



# The Binary System

The traditional decimal system is based on powers of ten.

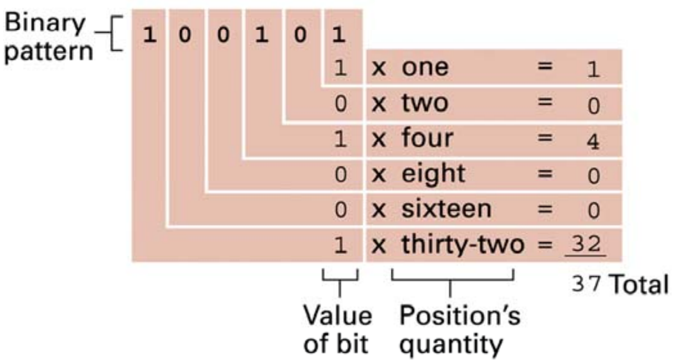
The Binary system is based on powers of two.

## **Figure 1.15** The base ten and binary systems






## **Figure 1.16** Decoding the binary representation 100101






## **Figure 1.17** An algorithm for finding the binary representation of a positive integer

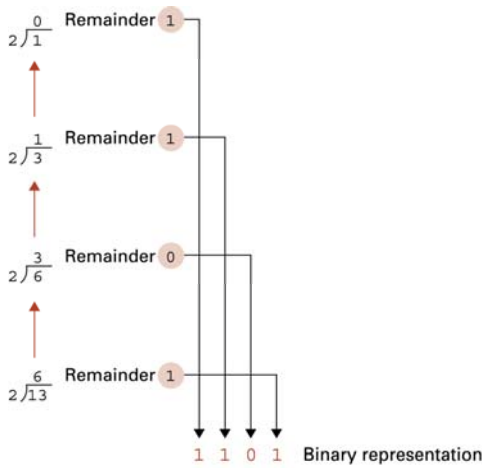
**Step 1.** Divide the value by two and record the remainder.

**Step 2.** As long as the quotient obtained is not zero, continue to divide the newest quotient by two and record the remainder.

**Step 3.** Now that a quotient of zero has been obtained, the binary representation of the original value consists of the remainders listed from right to left in the order they were recorded.



## **Figure 1.18** Applying the algorithm in Figure 1.15 to obtain the binary representation of thirteen

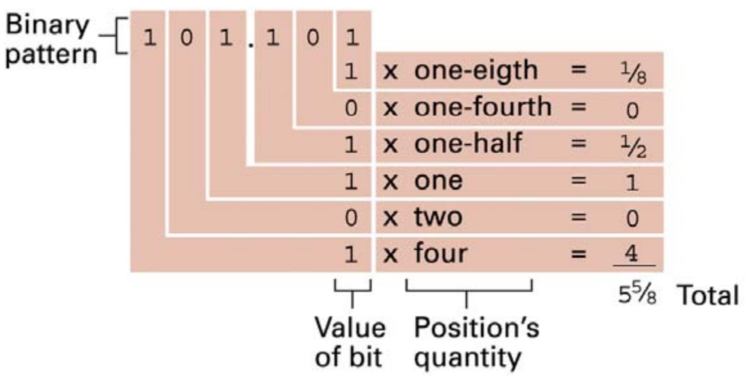


## Figure 1.19 The binary addition facts

$$\begin{array}{r} 0 \\ +\,0 \\ \hline 0 \end{array} \qquad \begin{array}{r} 1 \\ +\,0 \\ \hline 1 \end{array} \qquad \begin{array}{r} 0 \\ +\,1 \\ \hline 1 \end{array} \qquad \begin{array}{r} 1 \\ +\,1 \\ \hline 10 \end{array}$$



## Figure 1.20 Decoding the binary representation 101.101






## Storing Integers

- **Two's complement notation**（二的補數表示法）**:** The most popular means of representing integer values
- **Excess notation**（超額表示法）**:** Another means of representing integer values
- Both can suffer from overflow errors.



## Figure 1.21 Two's complement notation systems

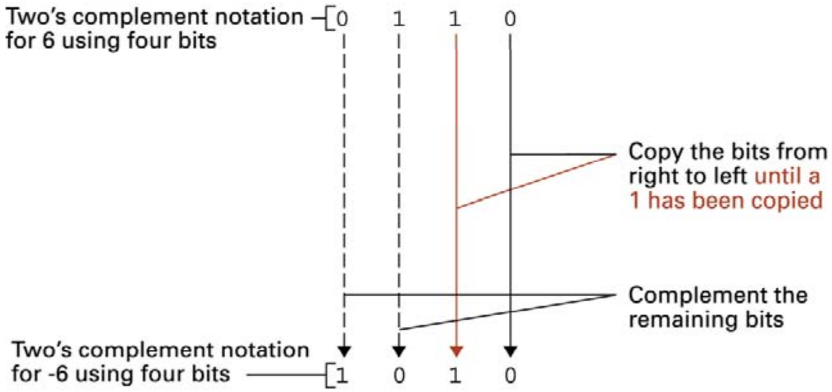
a. Using patterns of length three

| Bit pattern | Value represented |
|---|---|
| 011 | 3 |
| 010 | 2 |
| 001 | 1 |
| 000 | 0 |
| 111 | −1 |
| 110 | −2 |
| 101 | −3 |
| 100 | −4 |

b. Using patterns of length four

| Bit pattern | Value represented |
|---|---|
| 0111 | 7 |
| 0110 | 6 |
| 0101 | 5 |
| 0100 | 4 |
| 0011 | 3 |
| 0010 | 2 |
| 0001 | 1 |
| 0000 | 0 |
| 1111 | −1 |
| 1110 | −2 |
| 1101 | −3 |
| 1100 | −4 |
| 1011 | −5 |
| 1010 | −6 |
| 1001 | −7 |
| 1000 | −8 |

## Figure 1.22 Coding the value -6 in two's complement notation using four bits






## Figure 1.23 Addition problems converted to two's complement notation

| Problem in base ten | Problem in two's complement | Answer in base ten |
|---|---|---|
| 3 + 2 | 0011 + 0010 = 0101 | 5 |
| -3 + -2 | 1101 + 1110 = 1011 | -5 |
| 7 + -5 | 0111 + 1011 = 0010 | 2 |



## Figure 1.24 An excess eight conversion table

| Bit pattern | Value represented |
|---|---|
| 1111 | 7 |
| 1110 | 6 |
| 1101 | 5 |
| 1100 | 4 |
| 1011 | 3 |
| 1010 | 2 |
| 1001 | 1 |
| 1000 | 0 |
| 0111 | -1 |
| 0110 | -2 |
| 0101 | -3 |
| 0100 | -4 |
| 0011 | -5 |
| 0010 | -6 |
| 0001 | -7 |
| 0000 | -8 |



## Figure 1.25 An excess notation system using bit patterns of length three

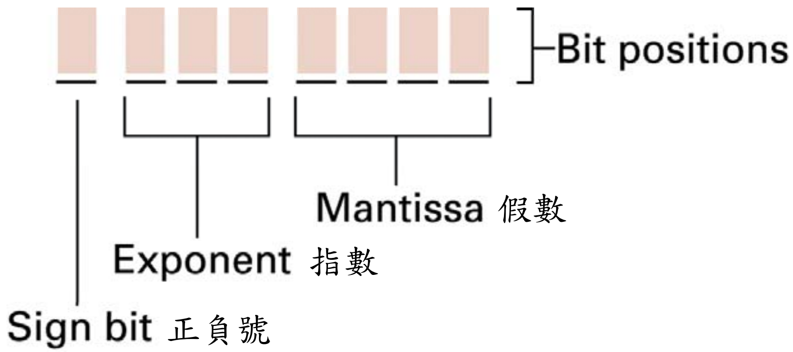
| Bit pattern | Value represented |
|---|---|
| 111 | 3 |
| 110 | 2 |
| 101 | 1 |
| 100 | 0 |
| 011 | -1 |
| 010 | -2 |
| 001 | -3 |
| 000 | -4 |

## Storing Fractions

- **Floating-point Notation:** Consists of a sign bit, a mantissa field, and an exponent field.
- Related topics include
  - Normalized form
  - Truncation errors

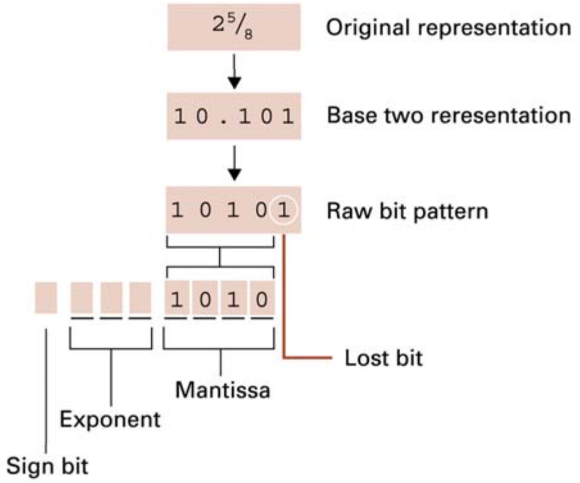


## Figure 1.26 Floating-point notation components






## Figure 1.27 Encoding the value 2 5/8






## Data Compression

- Lossy versus lossless
- Run-length encoding
- Frequency-dependent encoding
  (Huffman codes)
- Relative encoding
- Dictionary encoding (Includes adaptive dictionary encoding such as LZW encoding.)

## Compressing Images

- GIF: Good for cartoons
- JPEG: Good for photographs
- TIFF: Good for image archiving



## Compressing Audio and Video

- MPEG
  - High definition television broadcast
  - Video conferencing
- MP3
  - Temporal masking
  - Frequency masking

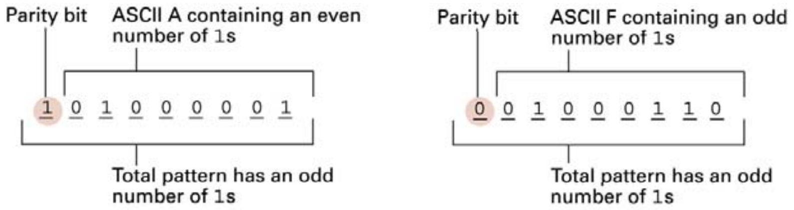


## Communication Errors

- Parity bits (even versus odd)
- Checkbytes
- Error correcting codes



## **Figure 1.28** The ASCII codes for the letters A and F adjusted for odd parity



## Figure 1.29 An error-correcting code

| Symbol | Code |
|---|---|
| A | 000000 |
| B | 001111 |
| C | 010011 |
| D | 011100 |
| E | 100110 |
| F | 101001 |
| G | 110101 |
| H | 111010 |



## Figure 1.30 Decoding the pattern 010100 using the code in Figure 1.30

| Character | Distance between the received pattern and the character being considered |
|---|---|
| A | 2 |
| B | 4 |
| C | 3 |
| D | 1 *Smallest distance* |
| E | 3 |
| F | 5 |
| G | 2 |
| H | 4 |



## 補充
## Hamming code 漢明碼，錯誤更正碼

於原資料的資料位元中插入同位元，若有n個資料位元，則須插入k個同位元，形成n+k個位元，n與k應滿足：

$$2^k \geq n+k+1$$

插入之同位元應置於$2^0$，$2^1$，$2^2$，...的位元位置，若原始資料為$D_0D_1D_2D_3$，插入同位元後的漢明碼為：

$$D_3D_2D_1P_4D_0P_2P_1$$
$$P_7P_6P_5P_4P_3P_2P_1$$



## 編碼規則與錯誤校正方式

插入之同位元（$P_1$、$P_2$、$P_4$）須滿足下列偶同位公式：

$$P_1 \oplus P_3 \oplus P_5 \oplus P_7 = 0$$
$$P_2 \oplus P_3 \oplus P_6 \oplus P_7 = 0$$
$$P_4 \oplus P_5 \oplus P_6 \oplus P_7 = 0$$

錯誤校正方式：當接收到$P_7P_6P_5P_4P_3P_2P_1$時，以下列公式求出$C_1C_2C_3$：

$$C_1 = P_1 \oplus P_3 \oplus P_5 \oplus P_7$$
$$C_2 = P_2 \oplus P_3 \oplus P_6 \oplus P_7$$
$$C_3 = P_4 \oplus P_5 \oplus P_6 \oplus P_7$$

# 錯誤校正方式

若$C_1$＝1，則在位元$P_1$、$P_3$、$P_5$、$P_7$中，有一位元錯誤
若$C_2$＝1，則在位元$P_2$、$P_3$，$P_6$、$P_7$中，有一位元錯誤
若$C_3$＝1，則在位元$P_4$、$P_5$、$P_6$、$P_7$中，有一位元錯誤

| $C_3C_2C_1$ | | 代表意義 |
|---|---|---|
| 0 0 0 | 0 | 所接收到的$P_7P_6P_5P_4P_3P_2P_1$資料正確無誤 |
| 0 0 1 | 1 | $P_1$位元錯誤 |
| 0 1 0 | 2 | $P_2$位元錯誤 |
| 0 1 1 | 3 | $P_3$位元錯誤 |
| 1 0 0 | 4 | $P_4$位元錯誤 |
| 1 0 1 | 5 | $P_5$位元錯誤 |
| 1 1 0 | 6 | $P_6$位元錯誤 |
| 1 1 1 | 7 | $P_7$位元錯誤 |



# 漢明距離（Hamming distance）

兩組位元串中，相對應位置之資料（位元值0或1）有多少個不一樣

示例：0100101　　　　11001
　　　0010101　　　　01110
　　　　↑↑　　　　　↑ ↑↑↑
　　漢明距離為2　　　漢明距離為4

代碼（碼集合）之漢明距離：算出各碼值彼此間之漢明距離，取其最小者為整個代碼之漢明距離

| 整個代碼之漢明距離： | 可偵查錯誤之位元數目 | 可校正之位元數目 |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 1 | 0 |
| 3 | 2 | 1 |
| 4 | 3 | 1 |
| 5 | 4 | 2 |