

Data Representation

IGCSE Computer Science • Topic 1

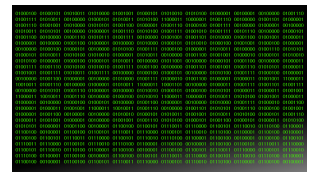
IGCSE Computer Science

1 0 0 1 0 1 1 0

Data Representation

What we will cover

- 1 Binary & number systems
- 2 Binary addition & overflow
- 3 Shifts & two's complement
- 4 Text, sound & images
- 5 Storage & file size
- 6 Compression



1 Number systems

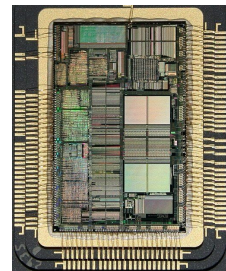
Data Representation

Number systems

Why binary?

A computer has only two states: **on** and **off**, written 1 and 0. A system of two digits is **binary** 二进制 (base 2).

Every kind of data – numbers, text, sound, images – must become binary before the computer can process it.



Data Representation

Number systems

Three number systems

denary 十进制
base 10
digits 0–9

binary 二进制
base 2
digits 0 and 1

hexadecimal 十六进制
base 16
0–9 then A–F



Hard disk storage

The **base** 基数 is how many different digits a system uses. Hex A–F stand for 10–15.

Data Representation

Number systems

Place value

Binary place values **double** from right to left. For 8 bits:

128 64 32 16 8 4 2 1

place value	128	64	32	16	8	4	2	1
bits	1	0	0	1	0	1	1	0

$$150 = 128 + 16 + 4 + 2 \Rightarrow 10010110$$

- 1 **bit** 位 = a single 0 or 1
- 8 bits = 1 **byte** 字节
- 4 bits = 1 **nibble** 半字节

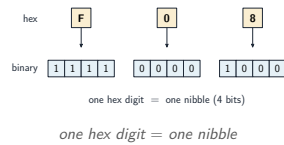
Denary → binary: **subtract** the place values that fit. $150 = 128 + 16 + 4 + 2$.

Worked example – denary to binary and hex

Convert denary 150 to binary, and 100 to hexadecimal.

$150 = 128 + 16 + 4 + 2$, so
128 64 32 16 8 4 2 1
1 0 0 1 0 1 1 0
 $= 10010110$

$100 = 64 + 32 + 4 = 01100100$
nibbles = 6 and 4, so hex = 64



Why hexadecimal?

Hex is **shorter** than binary and easier to read
– one hex digit replaces **four** binary digits, so you make fewer mistakes. Used for:

- MAC and IPv6 addresses
- HTML colours (#FF0000 is red)
- **memory addresses** 内存地址, error codes, memory dumps

Group binary into **nibbles** of 4 from the right; each nibble is exactly one hex digit. The **value** is unchanged – only the notation is shorter.

2 Addition and shifts

Binary addition

Add column by column from the right, carrying like denary:

carries	1	1	1							
	0	1	1	1	0	1	1	0	118	
+	0	0	1	1	0	0	0	0	48	
	1	0	1	0	0	1	1	0	166	

A	B	bit	carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

$1 + 1 + 1 = 1$ carry 1. Example:
 $118 + 48 = 166$.

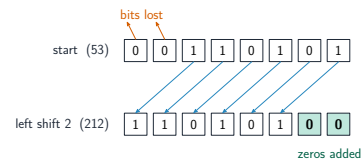
Overflow

$200 + 72 = 272$, but 272 needs **9 bits**:
1 0 0 0 0 1 0 0 0 0
the 9th bit will not fit – it is **lost**
the 8-bit register keeps only these
stored answer = 00010000 = 16, not 272 – this is **overflow**

An 8-bit register holds only 0–255. A bigger result needs a **9th bit** that will not fit. $200 + 72 = 272 = 100010000$ – 9 bits.

The leading 1 is **lost**, so the register shows the wrong answer. That lost carry is **overflow** 溢出.

Logical binary shift



A **logical shift** 逻辑二进制移位 moves every bit left or right:

- bits off the end are **lost**
- **zeros** fill the empty end
- left $\times 2$ per place; right $\div 2$ per place

Left-shift 00110101 (53) by 2 = 11010100 (212 = 53×4). Push a 1 off the end and you lose value.

Two's complement

	sign bit (negative)							
place value	-128	64	32	16	8	4	2	1
bits	1	1	0	1	1	0	0	0

$-128 + 64 + 16 + 8 = -40$

Two's complement 补码 stores negatives by making the **MSB** 最高有效位 **negative**:

-128 64 32 16 8 4 2 1

MSB 0 = positive, MSB 1 = negative.

Make -40: +40 = 00101000,
flip = 11010111, add 1
= 11011000. Check: $-128 + 64 + 16 + 8 = -40$.

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Text, sound and images

Representing text

ASCII - 7 bits per character

□ □ □ □ □ □ □

$2^7 = 128$ characters
English letters, digits
and common symbols

Unicode - more bits per character

□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □

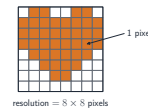
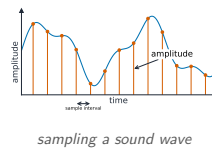
for more characters
many languages, symbols
and emoji - but more storage

Every character gets a number, stored in binary – a **character set** 字符集:

- **ASCII** ASCII 码: 7 bits = 128 characters (English)
- **Unicode** 统一码: more bits = far more, many languages plus emoji

More characters needs more bits, so the same text in Unicode takes **more storage** than in ASCII.

Sound and images



Sound: sample rate 采样率 (samples/s) and **sample resolution** 采样分辨率 (bits/sample).

Image: resolution 分辨率 (pixels) and **colour depth** 颜色深度 (bits/pixel).

Higher rate/resolution/depth $\Rightarrow$ better quality **but a larger file**. Always the same trade-off.

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Storage and file size

Measuring storage

Unit	Equals
byte	8 bits
kibibyte (KiB)	1024 bytes
mebibyte (MiB)	1024 KiB
gibibyte (GiB)	1024 MiB
tebibyte (TiB)	1024 GiB

Each unit is **1024x** the one before, because $1024 = 2^{10}$ fits binary.

Divide by **1024** (not 1000) to step up a unit. This is why a "1 TB" drive shows fewer TiB in the operating system.

Worked example – file size

An image is 1024×1024 pixels, colour depth 2 bytes (16 bits). Find its size in MiB.

bits = $1024 \times 1024 \times 16 = 16\,777\,216$

bytes = $\div 8 = 2\,097\,152$

KiB = $\div 1024 = 2048$

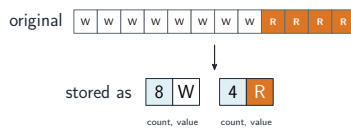
MiB = $\div 1024 = 2$

Image bits = width $\times$ height $\times$ depth; sound bits = rate $\times$ resolution $\times$ seconds. Then $\div 8$, $\div 1024$, $\div 1024$ – in the unit asked for.

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Compression

Compression



Smaller files use less storage, less bandwidth 带宽 and send faster.

- **lossless** 无损: keep every bit – e.g. **RLE** 行程编码
- **lossy** 有损: permanently drop data for a much smaller file

Lossless for text and programs (every bit matters).
Lossy for photos, music, video – a small quality loss is worth the size.

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Recap

Topic 1 – key takeaways

1 Convert

subtract place values; group nibbles for hex

2 Overflow

result needs a 9th bit an 8-bit register loses

3 File size

bits $\rightarrow \div 8 \rightarrow \div 1024$; image/sound formulas

4 Compress

lossless keeps every bit; lossy drops it

Check yourself

- 1 How many bits in a nibble?
- 2 Convert binary 1010 to hex.
- 3 What happens on overflow?
- 4 Lossless or lossy for a text file?

1	0	1	0
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Answers 1. 4 2. A 3. the extra bit is lost (wrong answer) 4. lossless