Hardware

IGCSE Computer Science

The central processing unit (CPU)

The **central processing unit** 中央处理器 (CPU) is the part of the computer that processes data and carries out **instructions** 指令. It runs programs by repeating a cycle, millions of times each second.

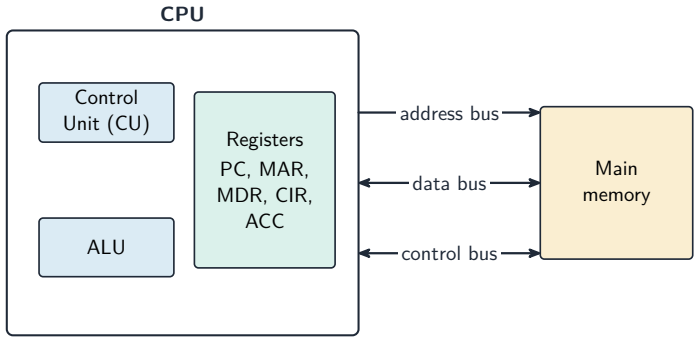
A central processing unit (CPU): the chip that processes data and runs the instructions

Parts of the CPU

Part	What it does
arithmetic logic unit 算术逻辑单元 (ALU)	does calculations (add, subtract) and logical operations (compare)
control unit 控制单元 (CU)	sends control signals to manage all the parts and tell them what to do
registers 寄存器	very small, very fast stores that hold one piece of data at a time

The parts are joined by **buses** 总线 — sets of wires that carry information:

- the **address bus** 地址总线 carries memory addresses (one direction);
- the **data bus** 数据总线 carries data and instructions (both directions);
- the **control bus** 控制总线 carries control signals.



The CPU holds the control unit, the ALU and the registers; three buses link it to main memory

Special registers

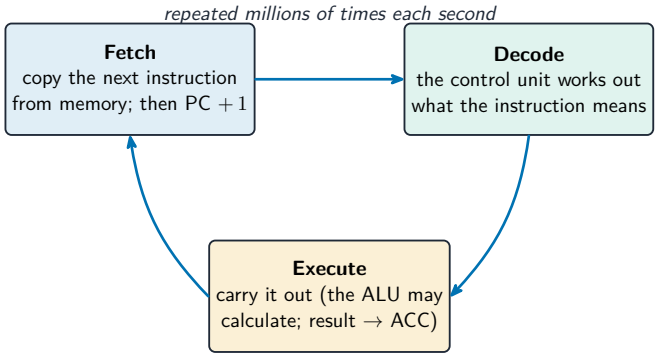
These registers are used during the fetch–execute cycle.

Register	Purpose
program counter 程序计数器 (PC)	holds the address of the next instruction
memory address register 内存地址寄存器 (MAR)	holds the address to read from or write to
memory data register 内存数据寄存器 (MDR)	holds the data or instruction just fetched
current instruction register 当前指令寄存器 (CIR)	holds the instruction now being carried out
accumulator 累加器 (ACC)	holds the result of the ALU's calculations

The fetch–execute cycle

The **fetch–execute cycle** 取指执行周期 has three stages, repeated again and again:

1. **Fetch** — the instruction is copied from memory 内存 into the CPU (using the PC, MAR and MDR). The PC then increases by 1.
2. **Decode** — the control unit works out what the instruction means.
3. **Execute** — the instruction is carried out (the ALU may do a calculation, with the result going to the accumulator).



The processor repeats three stages: fetch the instruction, decode it, then execute it

Cache memory

Cache 高速缓存 is a small amount of very fast memory inside or close to the CPU. It stores data and instructions that the CPU uses often. The CPU can read from cache much faster than from main memory, so the computer runs faster.

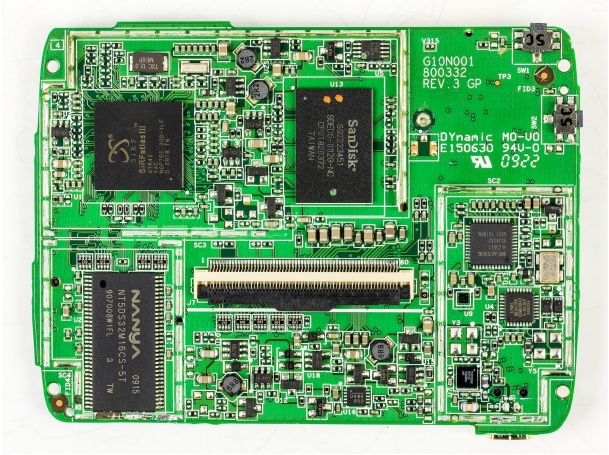
What affects CPU performance

Feature	Effect
number of **cores** 核心	each core can run instructions on its own, so more cores can do more work at the same time
cache size	a larger cache holds more data ready for the CPU, so it waits less
clock speed 时钟速度	the number of cycles per second; a higher clock speed runs more instructions per second

Worked example. Two computers are identical except that A has a 3.0 GHz single-core CPU with 2 MB of cache, and B has a 2.4 GHz quad-core CPU with 8 MB of cache. Which is better for video editing, and why? Video editing splits into many tasks that can run at the same time, so B's **four cores** can process several streams in parallel while A can only work on one at a time. B's larger **cache** also keeps more frequently used data close to the CPU, so it has to fetch from RAM less often. B is the better choice, even though A has the higher clock speed. Never answer on clock speed alone: weigh **cores, cache and clock speed** together, and tie each one to the job being done.

Embedded systems

An **embedded system** 嵌入式系统 is a small computer built inside a larger device to do one fixed job. It is dedicated to that task, is usually small and low-cost, and has no general operating system. Examples: a washing machine, a microwave, a set-top box.



The mainboard from inside a satnav: an embedded system is a small dedicated computer like this, built into a device to do one fixed job

Input devices

An input device sends data *into* the computer.

Device	How it works
barcode scanner 条形码扫描器	shines light at the bars and reads the pattern reflected back
QR code scanner 二维码扫描器	a camera reads a square pattern of black-and-white blocks
keyboard	pressing a key sends a code for that character
optical mouse 光电鼠标	a light and a sensor track movement across a surface
microphone	turns sound waves into an electrical signal
digital camera	a lens focuses light onto a sensor that records pixels
sensors 传感器	measure a physical quantity (such as temperature or light) and send it as data
touch screen 触摸屏	detects where your finger touches the screen

A keyboard: each key press sends a code for that character

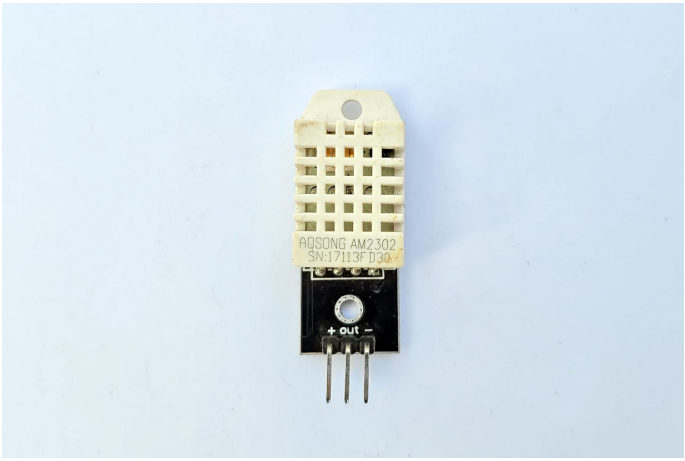
An optical mouse: a light and a sensor track its movement on the desk

A flatbed scanner: it shines light across a page to copy it into the computer

A barcode scanner reads the pattern of bars and sends it to the computer

A digital camera: a lens focuses light onto a sensor that records the pixels

A microphone turns sound waves into an electrical signal



A sensor measures a physical quantity (here, temperature) and sends it as data

A touch screen can work in three ways:

- **resistive** 电阻式 — two layers are pressed together where you touch;
- **capacitive** 电容式 — it senses the tiny electric charge of your finger;
- **infrared** 红外线 — your finger breaks a grid of light beams.

A touch screen senses where your finger touches it

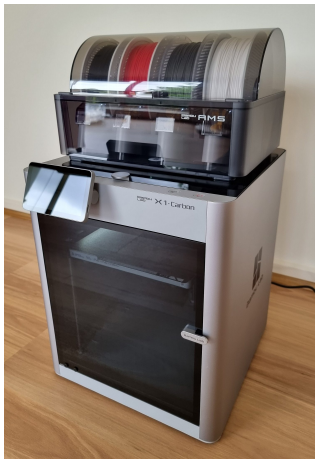
Output devices

An output device sends data *out* of the computer to the user.

Device	How it works
actuator 执行器	turns an electrical signal into movement (e.g. a motor or valve)
LCD/LED screen	shows images using a grid of tiny coloured dots
projector 投影仪	shines an enlarged image onto a wall or screen
inkjet printer 喷墨打印机	sprays tiny drops of ink onto paper
laser printer 激光打印机	uses a laser and powder (toner) fixed onto paper by heat
3D printer	builds a solid object layer by layer
speaker 扬声器	turns an electrical signal into sound

An inkjet printer sprays tiny drops of ink onto the paper

A laser printer uses a laser and powder (toner) fixed onto paper by heat



A 3D printer builds a solid object layer by layer

An LCD/LED monitor shows images using a grid of tiny coloured dots

A speaker turns an electrical signal into sound

Headphones turn an electrical signal into sound for one listener

An actuator such as a motor turns an electrical signal into movement

Primary storage: RAM and ROM

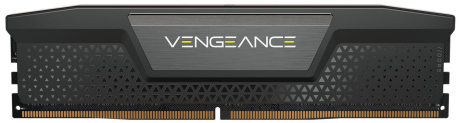
Primary storage 主存储器 is memory the CPU can use directly. There are two kinds.

RAM	ROM
volatile	non-volatile
can change	cannot change
running programs	startup (BIOS)

RAM is volatile and holds running programs; ROM is non-volatile and read-only

	RAM	ROM
Full name	**random access memory** 随机存取存储器	**read only memory** 只读存储器
Read/write	read and write	read only
Keeps data without power?	no — it is **volatile** 易失性	yes — it is **non-volatile** 非易失性
Holds	programs and data in use now	start-up instructions (how to boot the computer)

Both are needed: ROM tells the computer how to start, then RAM holds the programs you run.



A stick of RAM (random access memory): it holds the programs and data in use now

Secondary storage

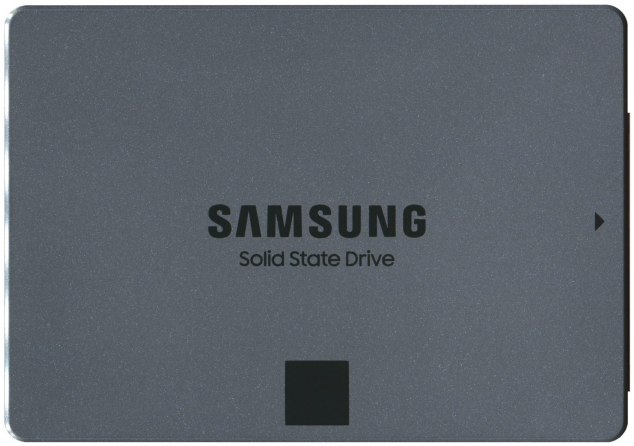
Secondary storage 辅助存储器 keeps data permanently, even when the power is off. It is non-volatile and is used for long-term storage. There are three types.

Type	How it stores data	Examples
magnetic storage 磁存储	data is stored as magnetised spots on spinning disks	hard disk drive (HDD), magnetic tape
optical storage 光存储	data is stored as marks read by a laser	CD, DVD, Blu-ray
solid state storage 固态存储	data is stored in **flash memory** 闪存, with no moving parts	SSD, USB flash drive, memory card

Inside a hard disk drive (HDD): the shiny disk spins and the arm reads the magnetised data

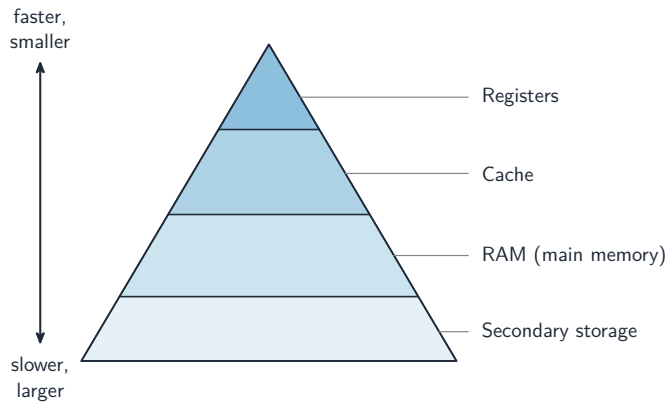
Magnetic tape stores data on a long magnetic strip; it is cheap for large backups

An optical disc such as a CD or DVD: a laser reads the marks on its shiny surface



A solid state drive (SSD) stores data in flash memory chips and has no moving parts

A USB flash drive stores data in flash memory and has no moving parts

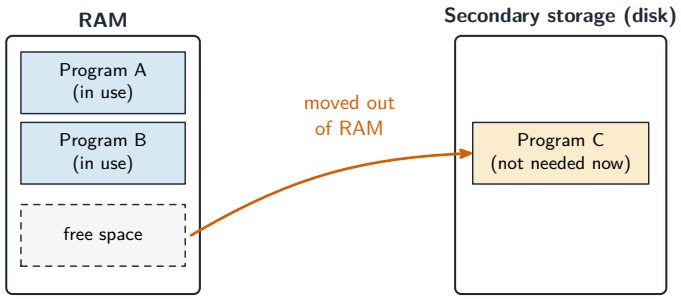


Storage forms a hierarchy: registers and cache are fastest but smallest; secondary storage is slowest but largest

Virtual memory

When the RAM becomes full, the computer can use part of the secondary storage as extra, pretend RAM. This is called **virtual memory** 虚拟内存.

Data that is not needed right now is moved out of RAM onto the disk, which frees space in RAM for other programs. This lets you run more programs than the RAM alone could hold. It is slower, because secondary storage is much slower than RAM.



When RAM is full, data not in use is moved to the disk to free RAM — slower, but it lets more programs run

Cloud storage

Cloud storage 云存储 keeps your data on remote physical servers, reached over the internet, instead of on your own device.

- **Advantages**: reach it from anywhere on any device; no local storage hardware to buy or maintain; easy to share files and to back up automatically.
- **Disadvantages**: needs a working internet connection; an ongoing subscription cost; security and privacy depend on the provider; you rely on that provider staying available and in business.

Data-centre server racks: cloud storage keeps your files on remote servers you reach over the network

Network hardware

Network interface card (NIC)

A **network interface card** 网络接口卡 (NIC) is the hardware that lets a device join a network and send and receive data. Each NIC has a built-in MAC address.

MAC address and IP address

- A **MAC address** (media access control 介质访问控制 address) is a number that identifies one physical device. The maker sets it, and it does not normally change. It is written in hexadecimal.
- An **IP address** (internet protocol 网际协议 address) is a number that identifies a device on a network. It is given by the network and can change.

So a MAC address stays with the device, while an IP address depends on the network the device is using.

There are two versions of IP address. **IPv4** is 32-bit, written as four denary numbers 0–255 (for example `192.168.0.1`); the newer **IPv6** is 128-bit, written as eight groups of hexadecimal separated by colons, giving vastly more addresses. An address is also either **static** 静态 (fixed, set by hand and never changing) or **dynamic** 动态 (handed out by the router/network each time the device connects, so it can change).

Router

A **router** 路由器 connects different networks together — for example, your home network to the internet. It reads the IP address in each packet and forwards it towards the right network.

A Wi-Fi router: network hardware forwards packets between devices and the wider Internet

Exam tips

- Learn the **fetch–decode–execute** cycle and the special registers: the **program counter** holds the address of the *next* instruction, the MAR/MDR carry the address/data, and the **accumulator** holds the ALU's result.
- CPU performance improves with more **cores**, a larger **cache**, and a higher **clock speed**.
- **RAM** is volatile (it loses its data with no power) and holds programs in use; **ROM** is non-volatile and read-only (the start-up instructions).

- Match the secondary-storage types: **magnetic** (HDD, tape), **optical** (CD/DVD, read by a laser), **solid state** (SSD, USB, flash — no moving parts).
- A **MAC address** identifies the physical device and does not normally change; an **IP address** is given by the network and can change.