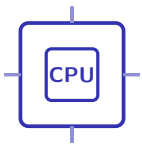
Hardware

IGCSE Computer Science ▪ Topic 3

IGCSE Computer Science



What we will cover

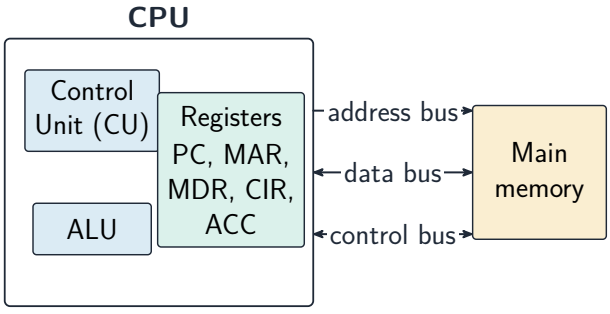
1. The CPU & buses
2. The fetch–execute cycle
3. Input & output devices
4. RAM, ROM & storage
5. Virtual memory
6. Network hardware

1 The CPU

Inside the CPU

Von Neumann 冯 · 诺依曼: one memory holds data *and* instructions, reached over shared buses.

- **ALU** 算术逻辑单元 – arithmetic and logic
- **control unit** 控制器 – decodes and directs
- registers, stepped by the clock



Three buses link the CPU to main memory

Inside the CPU: the units and the three buses

control unit 控制单元	decodes each instruction and sends the signals that carry it out
arithmetic logic unit 算术逻辑单元	the ALU – does calculations (add, subtract) and logical operations (compare)
address bus 地址总线	carries memory addresses – one direction only, CPU to memory
data bus 数据总线	carries data and instructions – both directions
control bus 控制总线	carries control signals, such as read and write

> The width of the address bus fixes how much memory can be addressed; the width of the data bus fixes how much moves per transfer. That asymmetry is why only one is bidirectional.

The special registers

PC 程序计数器 – address of the *next* instruction

MAR 内存地址寄存器 – the address to read/write

MDR 内存数据寄存器 – the data just fetched

CIR 当前指令寄存器 – the instruction now running

ACC 累加器 – the ALU's result

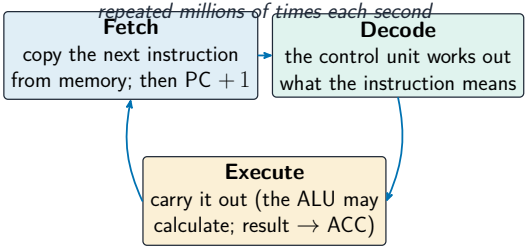
The registers, and what each holds

MAR	The **memory address register** 存储器地址寄存器 holds the *address* being read from or written to.
MDR	The **memory data register** 存储器数据寄存器 holds the *data* that just came from, or is going to, that address.
CIR	The **current instruction register** 当前指令寄存器 holds the instruction being decoded and executed right now.
PC	The program counter holds the address of the *next* instruction – which is what a jump changes.

Address, data, instruction, next: four **registers** 寄存器 inside the **central processing unit** 中央处理器, and the **fetch–execute cycle** 取指执行周期 is just them passing values to each other.

The fetch–execute cycle

- **Fetch**: PC → MAR, memory → MDR, copy to CIR, PC +1
- **Decode** the opcode
- **Execute** (ALU, load, store, jump) – then repeat



The processor does nothing else, billions of times a second

What makes a CPU faster

cores 核心
each runs instructions on its own – more do more at once

cache size
more data kept ready, so the CPU waits less

clock speed 时钟速度
cycles per second – more instructions per second

Faster CPU: more cores, more cache, higher clock speed. An **embedded system** 嵌入式系统 is a small computer built into a device to do one fixed job.

Worked example – which computer is faster?

A: 3.0 GHz single-core, 2 MB cache. B: 2.4 GHz quad-core, 8 MB cache. Which is faster?

- it depends on the task
- one program that cannot be split: A wins on clock speed
- several programs, or one written for many **cores** 核心: B wins – each core runs instructions on its own
- and B's larger **cache** 高速缓存 means fewer slow trips to RAM

"Higher GHz is faster" is only true holding cores and cache equal. The exam sets this comparison precisely to see whether you say so.

2 Devices and storage

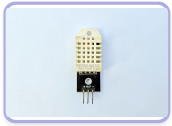
Input devices

keyboard

mouse

touch screen

microphone


sensor

barcode scanner

An input device sends data *into* the computer. A **sensor** 传感器 is the one that needs no person: it measures a physical quantity and sends it as data.

The three kinds of touch screen

touch screen 触摸屏	detects where your finger touches the screen
resistive 电阻式	two layers are pressed together where you touch – cheap, works with a glove or stylus, but less durable and no multi-touch
capacitive 电容式	senses the tiny electric charge of your finger – bright, durable, multi-touch, but bare skin only
infrared 红外线	your finger breaks a grid of light beams – works with any object and at large sizes, but sunlight interferes

Match the type to the use: capacitive for a phone, resistive for a factory where operators wear gloves, infrared for a large interactive whiteboard.

Inside a digital camera

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

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

Output devices

monitor

laser printer

inkjet printer

3D printer

speaker

actuator

An output device sends data *out*. An **actuator** 执行器 turns the signal into movement – which is how a computer acts on the world.

The output devices, by how each makes its image

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 – cheap to buy, good photos, slow for long runs
laser printer 激光打印机	a laser and powder (toner) fixed onto the paper by heat – fast and cheap per page in bulk
3D printer	builds a solid object layer by layer
speaker and actuator	turn a signal into sound, or into movement in a control system

Choose the printer by volume: inkjet for a few high-quality pages, laser for many. That is the comparison the exam asks for.

A pair of blue over-ear headphones

Headphones turn an electrical signal into sound for one listener

RAM vs ROM

	RAM	**ROM**
access	read & write	read only
power off	loses data (volatile)	keeps data (non-volatile)
holds	programs in use	start-up code

RAM 随机存储器 is volatile working memory; **ROM** 只读存储器 keeps the start-up code with the power off.

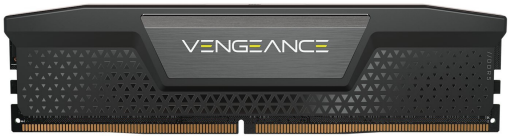
RAM, ROM, and the two kinds of RAM

RAM	Volatile: it loses its contents when the power goes. It holds whatever is running now.
Read only memory	**Read only memory** 只读存储器 (ROM) is non-volatile and holds the start-up instructions – the BIOS – that the machine needs before any disk is read.
Dynamic RAM	**Dynamic** 动态 RAM stores each bit in a capacitor that leaks, so it must be refreshed thousands of times a second. Cheap and dense – this is main memory.
Static RAM	**Static** 静态 RAM holds each bit in a flip-flop, needs no refresh and is much faster – and much dearer, so it is used for cache.

Volatile or not is the first question; refreshed or not is what separates the cache from the main memory.

Primary storage: RAM and ROM

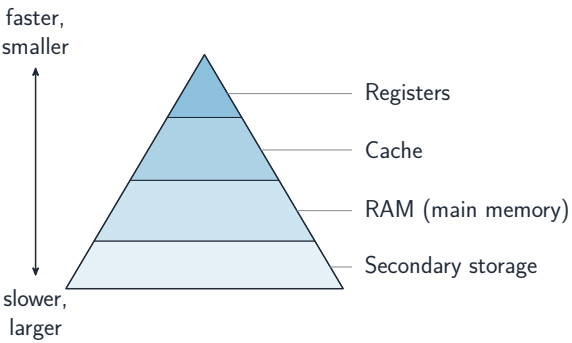
RAM	ROM
volatile	non-volatile
can change	cannot change
running programs	startup (BIOS)



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

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

The memory hierarchy



- Registers and **cache** 高速缓存: fastest, smallest, closest to the ALU.
- **RAM** 随机存储器: the programs and data in use now.
- Secondary storage: slowest but by far the largest, and non-volatile.

Faster memory costs more per byte, so a computer has a little of the fast kind and a lot of the slow kind.

Secondary storage

magnetic 磁存储
magnetised spots
on spinning disks
HDD, tape

optical 光存储
marks read by a laser
CD, DVD, Blu-ray

solid state 固态
flash memory,
no moving parts
SSD, USB drive

Secondary storage is non-volatile – it keeps data with the power off, unlike RAM.

Inside an HDD: the disk spins, the arm reads

Storage media, in the flesh

hard disk
(magnetic)

tape (magnetic)

CD

SSD (solid state)

USB drive
(solid state)

> Magnetic and optical media have moving parts; solid state has none, so it is faster and survives being dropped.

Three kinds of secondary storage

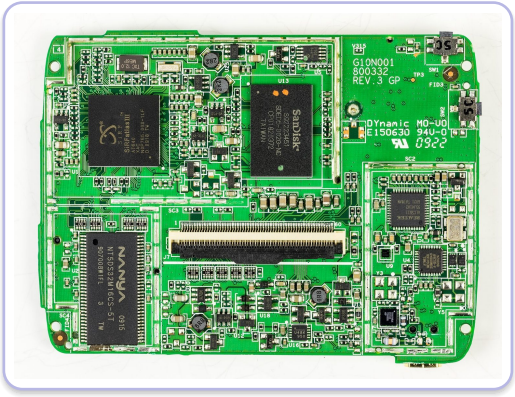
Magnetic storage	**Magnetic storage** 磁存储: a spinning platter magnetised in tiny regions. Cheap per gigabyte, large, and it has moving parts that fail.
Optical storage	**Optical storage** 光存储: pits burned into a disc surface and read by a laser – CD, DVD, Blu-ray. Cheap and slow.
Solid state storage	**Solid state storage** 固态存储: no moving parts, flash memory holding charge in cells. Fast, silent, robust, dearer per gigabyte.
Cloud storage	**Cloud storage** 云存储 is someone else's secondary storage, reached over a network – so it needs a connection, and it raises the security question.

Compare on the same four axes: capacity, speed, durability and cost per gigabyte. That is what the exam question is really asking for.

Embedded systems

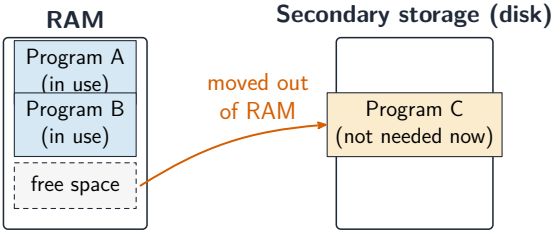
An **embedded system** 嵌入式系统 is a small computer built *inside* a larger device to do one fixed job.

- dedicated to that task, small and low-cost
- no general operating system
- a washing machine, a microwave, a set-top box



The mainboard from inside a satnav

Virtual memory



This frees RAM, so more programs can run than RAM alone could hold — but it is slower, because the disk is much slower than RAM.

- **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.

Virtual memory, and the two kinds of address

virtual memory 虚拟内存	when RAM fills, the computer uses part of secondary storage as extra, pretend RAM
the cost	secondary storage is far slower, so heavy use makes the machine crawl
MAC address MAC 地址	a permanent hardware address, set by the manufacturer, unique to the network card
IP address IP 地址	assigned by the network, and it changes when the device moves
IPv4	32-bit, four denary numbers 0–255, for example 192.168.0.1
IPv6	128-bit, eight groups of hexadecimal – far more addresses, because IPv4 ran out

MAC identifies the device; IP identifies where it is on the network. A letter needs both the person and the address.

3 Networks

Network hardware

- **NIC** 网络接口卡: the card that joins a device to a network
- **MAC address** 介质访问控制地址: identifies one physical device – fixed
- **IP address** 网际协议地址: identifies a device on a network – depends on the network
- **router** 路由器: connects networks (home → internet)

A Wi-Fi router forwards packets between networks

Two more devices, and where they sit

Network interface card	A **network interface card** 网络接口卡 (NIC) gives a device its physical connection and its MAC address – wired or wireless.
Sensors	**Sensors** 传感器 are input devices that read a physical quantity continuously – temperature, light, pressure, motion – and feed an embedded system.
QR code scanner	A **QR code scanner** 二维码扫描器 photographs the pattern and decodes the data stored in it – a camera plus software, not a new kind of hardware.

Sort any device by what it does to data: brings it in, sends it out, stores it, or moves it between machines.

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.

4 Recap

Topic 3 – key takeaways

1 CPU

ALU + CU + registers, joined by buses

2 Cycle

fetch → decode → execute, PC +1

3 Memory

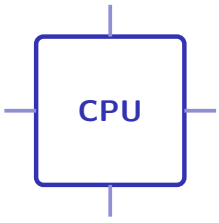
RAM volatile, ROM non-volatile; disk is secondary

4 Network

MAC fixed to device; IP set by the network

Check yourself

1. Which register holds the next instruction's address?
2. Is RAM volatile or non-volatile?
3. Which memory holds the start-up instructions?
4. Which address is fixed to the physical device?



Answers **1.** the PC **2.** volatile **3.** ROM **4.** the MAC address