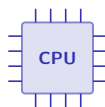


Hardware

AS Computer Science • Topic 3

A-Level Computer Science



Hardware

What we will cover

- 1 Components & embedded systems
- 2 Storage devices
- 3 Memory: RAM, ROM & variants
- 4 Monitoring & control
- 5 Logic gates & circuits
- 6 Recap



1

Components and embedded systems

Hardware

Components and embedded systems

The four building blocks



primary memory 主存儲器 (RAM/ROM) is fast and direct;
secondary storage 輔助存儲器 is large and keeps data without power.



Microphone photo

Hardware

Components and embedded systems

Embedded systems

An **embedded system** 嵌入式系統 is a computer built **into another device** for one fixed job (washing machine, car engine, thermostat).

- + small, cheap, reliable, low power
- – locked to its one task; **firmware** 固件 updates may need special tools
- – often not repairable, and security is sometimes weak



Hardware

Components and embedded systems

A 3D printer builds an object layer by layer



- **FDM** melts plastic filament through a moving nozzle
- **stereolithography** cures liquid resin with a UV laser
- either way the object grows one thin **layer** at a time

Used for prototypes, custom parts and medical models – anything where one item is wanted, not a thousand.

2 Storage devices

Hardware
└ Storage devices

Input and output devices



keyboard
input



monitor
output



laser printer
output



motor (actuator)
output

Laser printer 激光打印机: a charged **drum** 感光鼓 attracts **toner** 墨粉, which heat then fuses onto the paper.

Hardware
└ Storage devices

Input devices you should know



mouse – optical movement



scanner – reflected light

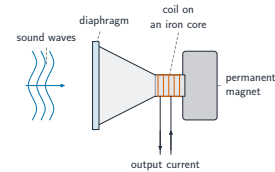


touchscreen – input and output

A **touchscreen** 触摸屏 is both: **resistive** presses two conductive layers together (works with any object, less accurate); **capacitive** senses the change your finger makes to a charge grid (sharper, but needs skin or a special stylus).

Hardware
└ Storage devices

Microphone and loudspeaker

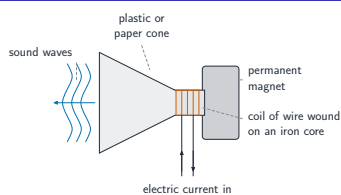


microphone 麦克风: sound → signal

A **diaphragm** 振膜 vibrates, changing a **capacitor** 电容器's charge or a coil's position; an **analogue-to-digital converter** 模数转换器 (ADC) digitises the signal. A loudspeaker runs the same parts backwards.

Hardware
└ Storage devices

Inside the loudspeaker



A current in the coil sits in the magnet's field, so it is pushed in and out – the cone moves with it and pushes the air.

A current in the coil moves it in the magnet's field, the cone pushes the air, and you hear it. A microphone is the same parts run **backwards**.

Hardware
└ Storage devices

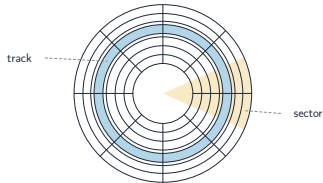
Magnetic hard disk

A **hard disk** 硬盘 stores bits as magnetised regions on spinning platters.

- a **read/write head** flies just above the surface
- data sits in concentric **tracks**, split into sectors
- cheap per GB, but mechanical – slower, and shock can crash the head



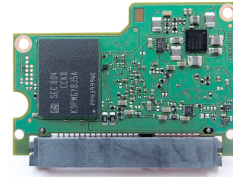
Tracks, sectors and the head



Access time is dominated by **seek** (moving the head to the track) and **latency** (waiting for the sector to arrive).

Data sits in concentric **tracks** divided into **sectors**; the head moves in and out while the platter spins, so access time is seek time plus rotational delay.

Solid-state and optical



solid-state drive 固态硬盘: flash, no moving parts

SSD: faster, tougher, lower power – but dearer per GB and cells wear out.

An optical disc



Pits and lands along a spiral track; a weak laser reads the reflections. The same drive **writes** with a stronger beam that burns the marks – CD, DVD and Blu-ray differ only in laser wavelength, and so in how small a pit can be.

Virtual reality headset

A **virtual reality** 虚拟现实 (VR) headset has two small displays (one per eye) and motion sensors (**accelerometer** 加速度计).

3 Memory

Buffers

A **buffer** 缓冲 holds data temporarily between devices of **different speeds**. The CPU writes to a printer buffer quickly, then works on; the printer prints from it at its own pace.



Hardware

Memory

RAM and ROM

RAM 随机存取存储器

volatile 易失性, read/write

– running programs

ROM 只读存储器

non-volatile 非易失性,

read-only – firmware

ROM: start-up firmware

power on: load

RAM: OS + programs run here

power off: RAM cleared • ROM kept

Hardware

Memory

RAM against ROM

RAM

volatile — lost at power off

read *and* write

holds running programs & data

ROM

non-volatile — kept at power off

read-only

holds start-up instructions

RAM is *volatile* working memory that the processor writes to; ROM holds what must survive a power cut, such as the bootstrap.

RAM 随机存储器 is volatile working memory that loses everything at power-off; ROM 只读存储器 is non-volatile and holds the start-up code.

Hardware

Memory

Memory variants

SRAM 静态 RAM

transistors 晶体管 in flip-flops; fast, costly – CPU cache 高速缓存

DRAM 动态 RAM

capacitors, must be re-freshed 刷新 thousands of times a second; dense – main memory

ROM you can program later

PROM – written once, fuses burned

EPROM – UV light erases the whole chip

EEPROM – erased electrically, a byte at a time, in circuit (flash is its descendant)

4

Monitoring and control

Hardware

Monitoring and control

Monitoring vs control

Sensors send signals to the processor

An ADC converts the signals to digital

Processor compares the data with stored values

Monitoring

If a reading is out of range, show a warning or alarm

No action is taken – the system only watches

Control

If a reading is out of range, send signals to actuators (motor, valve)

The actuators change the environment

feedback loop

Both read **sensors** 传感器:

■ **monitoring** 监控: collects and reports, *takes no action* – a weather station logging readings

■ **control** 控制系统: *acts* via **actuators** 执行器 in a **feedback** 反馈 loop

Hardware

Monitoring and control

A sensor in a control system



A **thermistor** 热敏电阻: its resistance falls as it warms, so a potential divider turns temperature into a voltage the ADC can read.

5 Logic

Hardware
└ Logic

Logic gates



NOT



AND



OR



NAND



NOR



XOR

A **logic gate** 逻辑门 does one **Boolean** 布尔 operation; inputs/outputs are 0 or 1. Know the symbol, function and **truth table** 真值表 of each.

Hardware
└ Logic

Truth tables

A	B	AND	OR	NAND	NOR	XOR
0	0	0	0	1	1	0
0	1	0	1	1	0	1
1	0	0	1	1	0	1
1	1	1	1	0	0	0

NOT: $0 \rightarrow 1, 1 \rightarrow 0$. **AND:** all 1. **OR:** any 1. **XOR:** inputs differ.

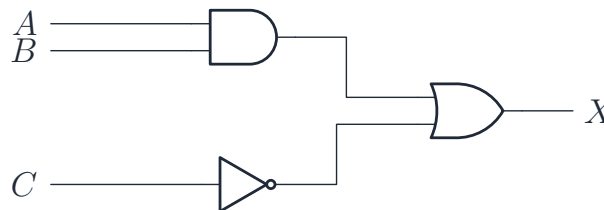
Hardware
└ Logic

Logic circuits

A **logic circuit** 逻辑电路 wires gates to do a Boolean expression – here

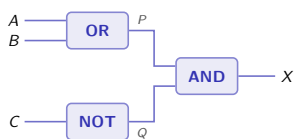
$$X = (A \text{ AND } B) \text{ OR } (\text{NOT } C).$$

Move freely between statement $\leftrightarrow$ expression $\leftrightarrow$ table $\leftrightarrow$ circuit.



Hardware
└ Logic

Worked example: from circuit to truth table



$$P = A \text{ OR } B, \quad Q = \text{NOT } C$$

$$X = P \text{ AND } Q$$

A	B	C	P	Q	X
0	0	0	0	1	0
0	0	1	0	0	0
0	1	0	1	1	1
0	1	1	1	0	0
1	0	0	1	1	1
1	0	1	1	0	0
1	1	0	1	1	1
1	1	1	1	0	0

Work **gate by gate**: add a column for every intermediate signal, then combine.

Hardware
└ Logic

From a problem statement

Turn the English into a Boolean expression first: "A and B" $\rightarrow$ A AND B; "A or B or both" $\rightarrow$ A OR B; "exactly one of A and B" $\rightarrow$ A XOR B; "neither A nor B" $\rightarrow$ A NOR B; "not both" $\rightarrow$ A NAND B.

Worked example. A machine's alarm X sounds when the guard is open ($A = 1$) and either the motor is running ($B = 1$) or the temperature is high ($C = 1$).

Worked example – English into Boolean

An alarm X sounds when the guard is open ($A = 1$) and either the motor runs ($B = 1$) or the temperature is high ($C = 1$). Write the expression and give the rows where $X = 1$.

- One clause at a time: "either B or C " is $B + C$, and "A and that" is $X = A \cdot (B + C)$.
- $X = 1$ needs $A = 1$ and at least one of B , C : (1, 0, 1), (1, 1, 0) and (1, 1, 1) – three rows of eight.
- $A = 0$ can never sound the alarm, whatever B and C do.

Bracket the OR before ANDing it. $X = A \cdot B + C$ is a different circuit – one that sounds on a high temperature with the guard shut.

Exam tips

- Distinguish **RAM (volatile, read/write)** from **ROM (non-volatile, holds the bootstrap)**; SRAM (cache, faster) from DRAM (main memory, needs refreshing).
- For a **logic circuit**, build the Boolean expression gate by gate, then a truth table covering **every** input combination.
- Learn the symbol, expression and truth table for each gate (AND, OR, NOT, NAND, NOR, XOR).
- Explain a **buffer** (a temporary store bridging two different speeds) and the role of an interrupt.

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Recap

Topic 3 – key takeaways

1 Components

input, output, primary memory, secondary storage

2 Storage

HDD magnetic; SSD flash; optical laser

3 Memory

RAM volatile; ROM non-volatile; SRAM vs DRAM

4 Logic

six gates; build circuits from expressions

Check yourself

- 1 Is RAM volatile or non-volatile?
- 2 Which memory is used for CPU cache?
- 3 A gate that outputs 1 only when inputs differ?
- 4 Monitoring or control: which acts on the data?



Answers 1. volatile 2. SRAM 3. XOR 4. control