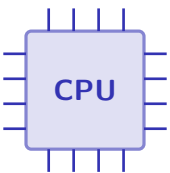
Hardware

AS Computer Science ▪ Topic 3

A-Level Computer Science



What we will cover

3.1 Computers and their components: overview

3.1.1 Primary memory: RAM, ROM and their types

3.1.2 Secondary storage

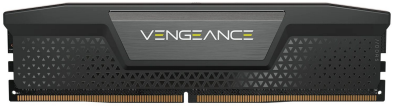
3.1.3 Input and output devices, and buffers

3.1.4 Embedded systems, monitoring and control

3.2 The six logic gates

3.2.1 Reading a logic circuit

3.2.2 Building a logic circuit



Each part of this deck has the number of its exercise sheet and past-paper sheet.

1 Sheet 3.1 – Computers and their components

Sheet 3.1 – what you need to know

You must be able to:

- name the four building blocks and give examples
- say which data belongs in primary and which in secondary storage
- tell a control system from a monitoring system

What the exam asks

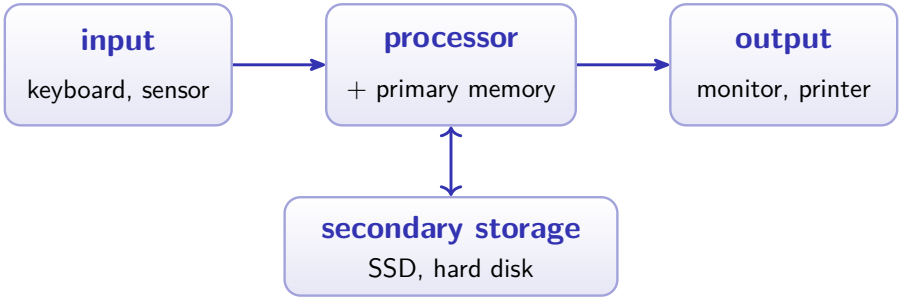
"Identify the data that will be stored in the primary and secondary storage of the car." **[2]**

"Explain why the system in the refrigerator is a control and not a monitoring system." **[2]**

"Describe the drawbacks of embedded systems." **[3]**

Practise on exercise sheet 3.1, then try the real exam questions on past-paper sheet 3.1.

The four building blocks



primary memory 主存储器 (RAM/ROM): **fast**, used directly by the processor.
secondary storage 辅助存储器: **large**, keeps data **without power**.

Input and output devices



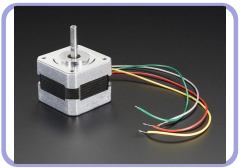
keyboard
input



monitor
output



laser printer
output



motor (actuator)
output

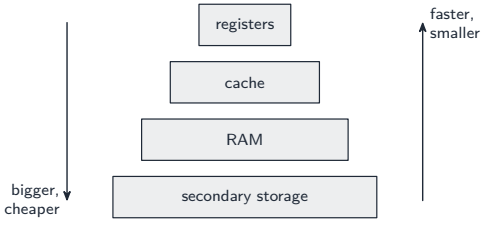
Laser printer 激光打印机: a charged **drum** 感光鼓 attracts **toner** 墨粉, which heat then fuses onto the paper.

Why a computer needs secondary storage

RAM is **volatile** 易失性, small and expensive. **Secondary storage** 辅助存储器 is:

- non-volatile: it keeps the operating system, the programs and the files when the power is off
- large, and cheap for each GB
- not read directly by the processor: data is copied into RAM first

Removable storage (USB drive, memory card, optical disc) moves files between computers and keeps a backup in a different place.



Which memory holds what, and why control?

A car shows the distance of this trip, and the total it has ever travelled. Where is each stored?

Primary (RAM): this trip's distance, updated while the car is running, lost when it is switched off.
Secondary (flash): the total distance, which must survive the engine being switched off.

"Describe the drawbacks of embedded systems." [3]

Hard or impossible to upgrade; usually replaced, not repaired; a limited interface; if connected, open to hacking.

"Explain why the refrigerator is a control and not a monitoring system." [2]

It acts on its readings: when the temperature is too high it switches the compressor on, changing the temperature it measures.
A monitoring system only reports or warns; it changes nothing.

The test: does an actuator change the thing the sensor measures? Then it is control.

2

Sheet 3.1.1 – Primary memory

Sheet 3.1.1 – what you need to know

You must be able to:

- compare RAM with ROM, and SRAM with DRAM
- tell PROM, EPROM and EEPROM apart
- say what a ROM holds, and what survives power loss

What the exam asks

"Describe the contents of the ROM in the central computer." **[2]**

"SRAM uses transistors arranged as ... DRAM uses transistors and ..." **[5]**

"Explain the importance of feedback in a control system." **[3]**

Practise on exercise sheet 3.1.1, then try the real exam questions on past-paper sheet 3.1.1.

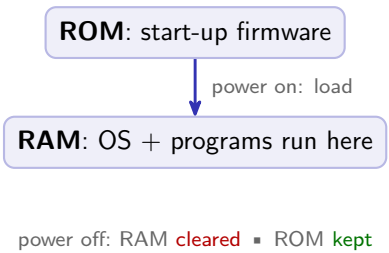
RAM and ROM

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



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.

What is held in RAM, and what in ROM?

Ask one question about each item: does it change while the device is running?

In a microwave oven	**held in**	**because**
the program that runs the cooking cycles	ROM	it never changes, and it must be there at switch-on
the cooking time the user has typed in	RAM	it changes with every use
the time that is left	RAM	it changes every second

ROM: start-up instructions (bootstrap) and **firmware** 固件. **RAM:** the programs and data in use now, and the part of the operating system in use.

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 **refreshed** 刷新 thousands of times a second; dense – main memory

ROM you can program later

PROM
written once: fuses are burned

EPROM
UV light erases the whole chip

EEPROM
erased electrically, in circuit (flash)

SRAM or DRAM? Choose, and justify

	SRAM (static)	**DRAM** (dynamic)
a bit is stored in	a **flip-flop** 触发器 (several transistors)	one transistor and one **capacitor** 电容器
refresh	not needed	needed: the charge leaks away
access speed	faster	slower
bits per chip, cost	fewer bits, dearer per bit	more bits, cheaper per bit
power	lower	higher (because of the refresh)
used for	cache	main memory

A full answer has two parts: a **property**, and **why it suits the use**. "SRAM is faster, and cache must supply data to the processor with as little delay as possible."

PROM, EPROM and EEPROM

	can it be erased?	**how?**	**inside the device?**
PROM	no: programmed once	–	–
EPROM	yes, many times	ultraviolet light; the whole chip	no: the chip is taken out
EEPROM	yes, many times	an electrical signal; part of the contents	yes, in place

A smart TV receives a firmware update over the internet. Nobody opens the TV, so its firmware must be in **EEPROM**: only EEPROM is erased and rewritten electrically, in place.

Power off, ROM contents, and feedback

memory	power lost	why
ROM	kept	non-volatile
SRAM	lost	flip-flops need power
DRAM	lost	capacitors discharge

"Describe the contents of the ROM in the central computer." [2]

The bootstrap (start-up) instructions, the BIOS and firmware that never needs changing.

"Explain the importance of feedback in a control system." [3]

The output of the system affects its next input;

each new reading is compared with the set value, and the actuators are adjusted;

this keeps the value within range automatically, without overshooting.

SRAM: transistors as flip-flops. DRAM: transistors and capacitors, refreshed.

3

Sheet 3.1.2 – Secondary storage

Sheet 3.1.2 – what you need to know

You must be able to:

- describe how magnetic, solid-state and optical storage work
- choose a storage device and justify it
- explain the job of a buffer

What the exam asks

"Describe two reasons why magnetic storage is more appropriate than solid state storage for this computer." **[4]**

"The two types of logic gate used to create solid state devices ... the number of transistors in each cell." **[4]**

"Describe how the video doorbell will use the buffer." **[2]**

Practise on exercise sheet 3.1.2, then try the real exam questions on past-paper sheet 3.1.2.

“Describe the principal operation of ...”

One mark for each correct point, so write short sentences in this order:

1. name the parts;
2. say what happens, step by step, with the technical words;
3. finish with the result: how a 1 or a 0 is stored or read, or what comes out.

> Describing what the device is *for* earns nothing. “A hard disk stores files” is not its operation.

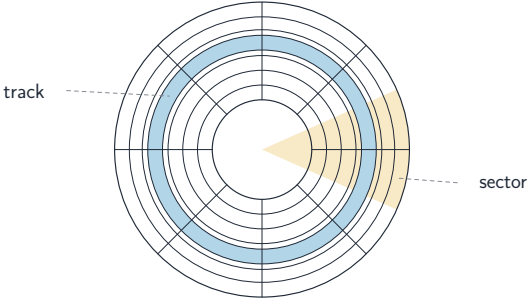
Magnetic hard disk

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

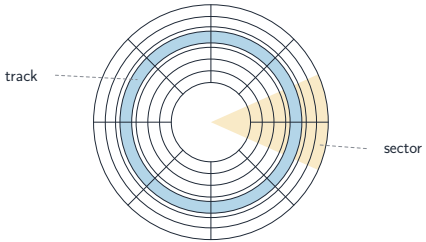


Access time is dominated by seek (moving the head to the track) and latency (waiting for the sector to arrive).

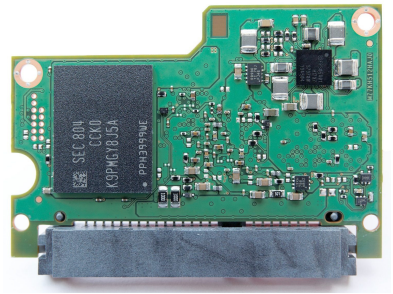
> Data sits in concentric tracks divided into sectors; the head moves in and out while the platter spins, so access time is seek time plus rotational delay.

Magnetic hard disk: the marking points

1. platters with a surface that can be magnetised
2. on a spindle, spinning at high speed
3. surface divided into tracks, tracks into sectors
4. a read/write head on an actuator arm moves to the track
5. **Write:** current in the head magnetises a tiny area one of two ways, for 1 and 0
6. **Read:** magnetised areas passing the head induce a small current



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.

Solid state (flash): how a bit is stored

- a grid of **transistors** 晶体管, using NAND (or NOR) flash technology; no moving parts
- each cell has a control gate and a floating gate
- a voltage pushes electrons onto the floating gate, where an insulating layer traps them
- trapped electrons read as 0, no trapped electrons as 1; they stay without power
- data is erased and rewritten in blocks

Why an SSD in a laptop?
Faster access, robust when dropped, less power, lighter.
Why not everywhere?
Dearer per GB, and a limited number of erase cycles.

An optical disc

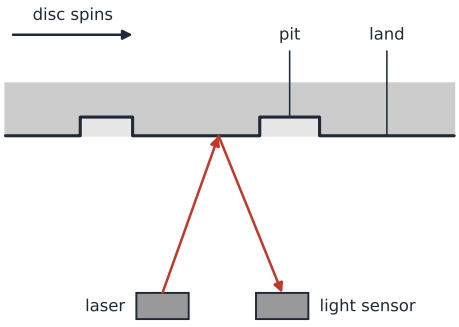


Pits and lands along a spiral track; a weak laser reads the reflections. The same drive writes with a stronger beam that burns the marks – CD, DVD and Blu-ray differ only in laser wavelength, and so in how small a pit can be.

Optical disc: reading and writing

1. A motor spins the disc, which has one spiral track.
2. A laser beam is focused on the track.
3. The track is made of **pits** 凹坑 and **lands** 平台, which reflect the light differently.
4. A light sensor detects the reflected light.
5. A change between pit and land is read as 1; no change as 0.

Writing: a stronger laser heats spots in a dye layer, so that they reflect differently.



Choosing a storage device

	magnetic hard disk	**solid state**	**optical disc**
access speed	slow: moving parts	fast	slowest
capacity	very large	large	small
cost per GB	low	higher	low per disc
robustness	damaged by a knock	robust	scratches
power and noise	more	less	more

Ten years of CCTV video on a server: huge files, never moved, speed not important ⇒ magnetic hard disks. State the point *and* why it matters for this job.

Magnetic or solid state: reasons that score

"Describe two reasons why magnetic storage is more appropriate than solid state for this (CCTV) computer." [4]

Cheaper per gigabyte, so far more video fits for the same cost.

It stands constant rewriting: flash cells wear out after a limited number of writes.

Flash: gates and transistors

Built from NAND or NOR gates; each cell has two transistors, a control gate and a floating gate.

Why not keep everything in RAM?

RAM is volatile: everything is lost when the power goes. It is also smaller and costs more per gigabyte.

What is removable storage for?

Backups kept away from the computer, and moving files to another machine.

> Every reason needs its consequence: "cheaper per GB" so "more video can be kept".

4 Sheet 3.1.3 – Devices and buffers

Sheet 3.1.3 – what you need to know

You must be able to:

- describe the principal operation of each named device
- choose between resistive and capacitive touchscreens
- explain how a buffer is used, step by step

What the exam asks

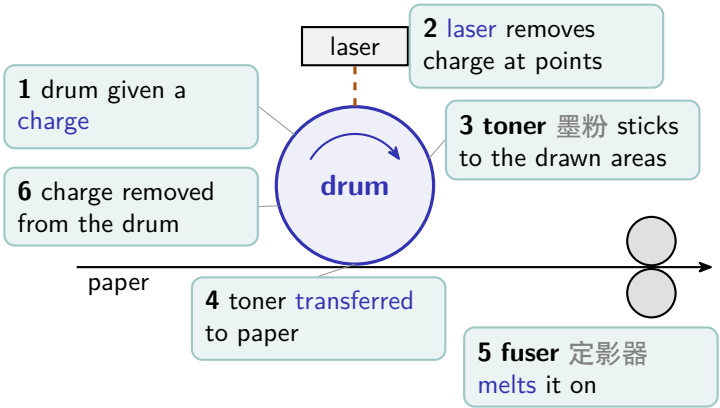
"Describe the principal operation of a microphone." **[3]**

"Complete the description of the principal operation of touchscreens." **[5]**

"Explain how a memory buffer is used when a computer is transferring data to its magnetic hard disk drive." **[4]**

Practise on exercise sheet 3.1.3, then try the real exam questions on past-paper sheet 3.1.3.

Laser printer: six steps



Charge, write, develop, transfer, fuse, clean: the **drum** repeats it every page.

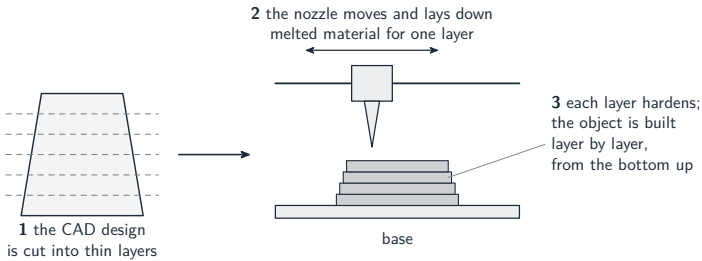
A 3D printer builds an object layer by layer



- **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

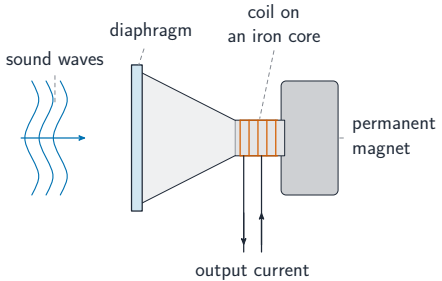
Used for prototypes, custom parts and medical models – anything where one item is wanted, not a thousand.

3D printer: from a design to an object



CAD design → cut into thin layers → the nozzle lays down melted material for one layer → the layer hardens → the next layer: the object is built layer by layer, from the bottom up (**additive manufacturing** 增材制造).

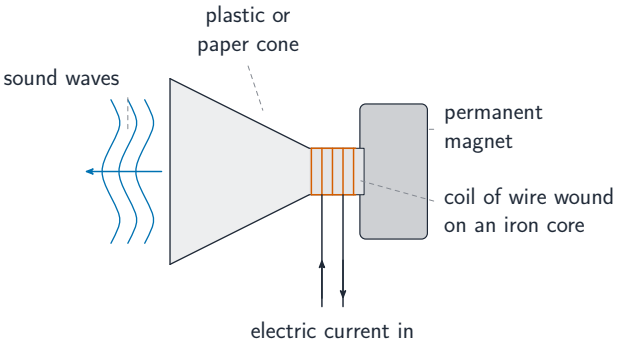
Microphone and loudspeaker



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.

Inside the loudspeaker



1. a changing **current** flows in the coil
2. the coil sits in the **magnet's field**, so it is pushed in and out
3. the **cone** moves with it and pushes the **air**: sound

A microphone is the same parts run backwards.

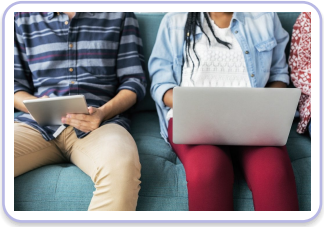
Input devices you should know



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).

Resistive or capacitive touchscreen?

	resistive	**capacitive**
layers	two conductive layers with a small gap	glass over a conductive layer that holds a charge
a touch	pressure pushes the layers together and completes a circuit	the finger takes a little charge, so the electric field changes
the position	calculated from the voltage at the point of contact	sensors at the corners measure the change
in use	works with a glove or a pen; cheaper	needs a bare finger; multi-touch; clearer

Virtual reality headset

- video is sent from the computer to the headset
- two slightly different images, one for each eye, make the scene look 3D
- lenses focus and reshape the images
- sensors such as a **gyroscope** 陀螺仪 and an **accelerometer** 加速度计 detect the movement of the head
- the images are redrawn so that the view follows the head



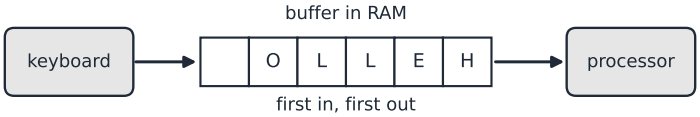
Buffers

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.



Buffers in exam questions

A **buffer** 缓冲 is a temporary storage area that holds data while it passes between two devices that work at different speeds. It is a queue: first in, first out.



printer: the computer sends the document quickly, then carries on **keyboard:** no key press is lost

streaming: video is downloaded ahead, so it plays smoothly

Buffer, speaker and touchscreen: the full answers

"Explain how a buffer is used when transferring data to the hard disk." [4]

The processor sends data to the buffer (in RAM);
it then carries on with other tasks;
the disk takes data from the buffer at its own speed;
when the buffer is empty it sends an interrupt for more, until all is written.

A speaker plays a stored sound

Binary data → a DAC gives an analogue current → the coil's magnetic field pushes against the permanent magnet → the cone vibrates.

A resistive touchscreen

Pressing pushes the top layer onto the bottom one; the circuit is completed; the change in current is measured; the coordinates of the touch are calculated.

5

Sheet 3.1.4 – Embedded systems and control

Sheet 3.1.4 – what you need to know

You must be able to:

- explain why a device is an embedded system
- choose sensors and actuators, and say how each is used
- describe a control loop in full, with feedback

What the exam asks

"Explain why the automatic braking system of the car is a control system." **[3]**

"Explain how the control system will ensure the correct amount of mixture is placed in the cake tins." **[5]**

"Identify two different sensors ... and describe how each sensor is used." **[2]**

Practise on exercise sheet 3.1.4, then try the real exam questions on past-paper sheet 3.1.4.

Embedded systems

An **embedded system** 嵌入式系统 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



“Explain why this is an embedded system”

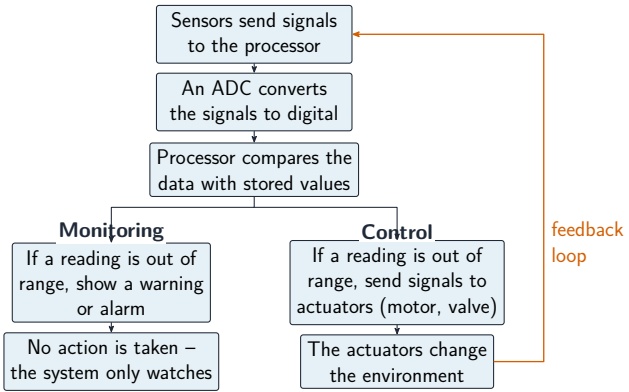
Make three points about this device:

1. it is a microprocessor system inside a larger device;
2. it has one dedicated task;
3. its program is in ROM, and the user cannot install other software.

A laptop is not embedded: it is a general-purpose computer.

benefits	**drawbacks**
small, low power	hard to upgrade
cheap to mass-produce	hard to repair
reliable; starts at once	only one task
	can be hacked if never updated

Monitoring vs control



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

Sensors and actuators

sensor	measures	used in
temperature	how hot or cold something is	an oven, a fridge, a greenhouse
pressure	a force pressing on an area	an alarm mat, a car tyre
infra-red	heat from a body, or a broken beam	an automatic door, a security light
sound	the loudness of a sound	a noise monitor, a glass-break alarm

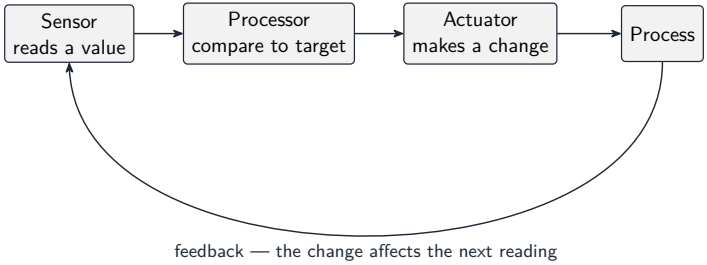
A sensor's signal is analogue, so an ADC converts it first. An **actuator** 执行器 (motor, pump, valve, heater) turns the processor's signal into a physical change. There is no "weight sensor": weight is measured with a pressure sensor.

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.

How a control system works: the answer in six steps



1. the sensor measures the value continuously
2. an ADC converts the reading to digital
3. it is compared with the **preset value** 预设值
4. too low: the actuator switches the heater on
5. high enough: the heater is switched off
6. **feedback** 反馈: the output changes the next reading; repeat

Worked example – filling cake tins

"Explain how the control system will ensure the correct amount of mixture is placed in the cake tins." [5]

1. An infra-red sensor detects that a tin is in place.
2. A weight sensor under the tin sends readings to the microprocessor, through an ADC.
3. The microprocessor compares the weight with the stored target.
4. Below target: the valve (actuator) stays open; at target, it is closed.
5. The conveyor moves the next tin into place.
6. The loop repeats continuously.

An automatic brake is control for the same reason: sensor readings are compared with a limit, and an actuator (the brake) acts, with no human in the loop.

6

Sheet 3.2 – The six logic gates

Sheet 3.2 – what you need to know

You must be able to:

- draw the six gate symbols and give their truth tables
- draw a circuit from an expression, with up to four inputs
- write an expression for each output of a circuit

What the exam asks

"Tick one box in each row to identify the logic gate that each statement describes." **[3]**

"Draw a logic circuit for this logic expression: X = NOT ((A AND B) OR (C AND D))" **[2]**

"Write the logic expressions for the following logic circuit. X = ... Y = ..." **[2]**

Practise on exercise sheet 3.2, then try the real exam questions on past-paper sheet 3.2.

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.

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: $0 \to 1$, $1 \to 0$. AND: all 1. OR: any 1. XOR: inputs differ.

NAND, NOR and XOR: three quick rules

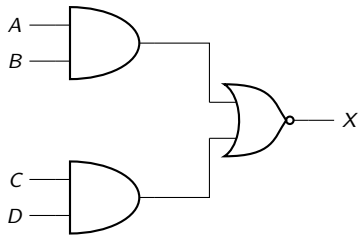
- **NAND**: work out AND, then flip every bit. The output is 0 only when both inputs are 1.
- **NOR**: work out OR, then flip every bit. The output is 1 only when both inputs are 0.
- **XOR**: the output is 1 when the two inputs are different. OR allows "both"; XOR does not.



A truth table for n inputs has 2^n rows, written by counting up in binary.

Four inputs, and a gate built from two

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



NOT of an OR is one NOR gate.

- n inputs need 2^n rows: four inputs give 16
- AND followed by NOT behaves as one NAND; OR then NOT as one NOR
- a circuit can have two outputs: write one expression for each, $X = \ldots$ and $Y = \ldots$

Count the rows before you start: 8 for three inputs, 16 for four.

7

Sheet 3.2.1 – Reading a logic circuit

Sheet 3.2.1 – what you need to know

You must be able to:

- write the expression a circuit computes
- complete a truth table with working columns
- handle NAND, NOR and XOR nested inside a circuit

What the exam asks

"Complete the truth table for the logic expression: X = NOT (A AND (B XOR C))" **[2]**

"Complete the truth table for: X = A XOR (B AND (A NAND B) AND NOT C)" **[2]**

"Identify one logic gate not used in the given logic circuit. Draw its symbol and complete its truth table." **[3]**

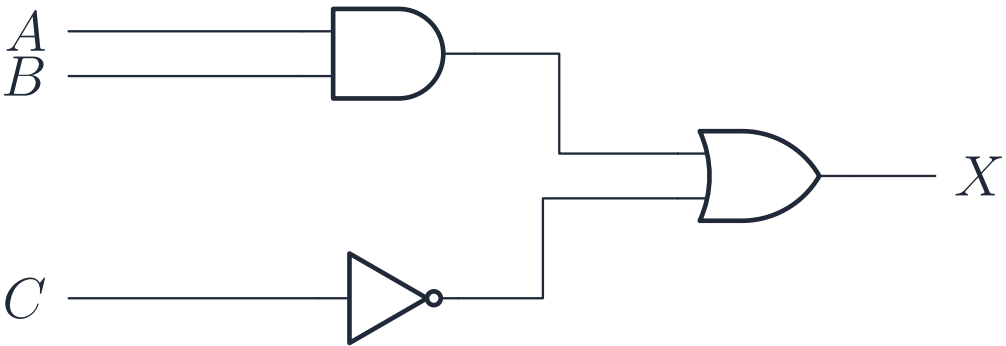
Practise on exercise sheet 3.2.1, then try the real exam questions on past-paper sheet 3.2.1.

Logic circuits

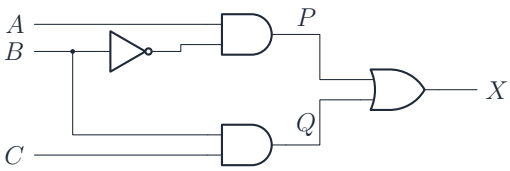
A **logic circuit** 逻辑电路 wires gates to do a Boolean expression – here

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

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



From a circuit to an expression

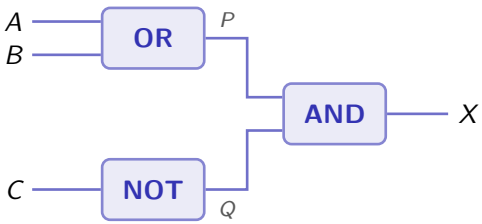


Read from left to right, and name every gate's output:

1. $P = A$ AND NOT B $\quad$ $Q = B$ AND C
2. $X = P$ OR Q
3. replace each name, in brackets:
   $X =$
   (A AND NOT B) OR (B AND C)

The dot on the wire from B is a junction: one input that goes to two gates.

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.

From an expression straight to a truth table

No circuit to look at, so the brackets give the order: one working column for each bracket.

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

A	B	A OR B	A AND B	NOT (A AND B)	X
0	0	0	0	1	0
0	1	1	0	1	**1**
1	0	1	0	1	**1**
1	1	1	1	0	0

Fill one whole column at a time. The result is 1 when the inputs differ: three gates that do the job of one XOR gate.

Worked example – $X = \text{NOT}(A \text{ AND } (B \text{ XOR } C))$

A	B	C	$B \oplus C$	$A \cdot (B \oplus C)$	X
0	0	0	0	0	1
0	0	1	1	0	1
0	1	0	1	0	1
0	1	1	0	0	1
1	0	0	0	0	1
1	0	1	1	1	**0**
1	1	0	1	1	**0**
1	1	1	0	0	1

1. innermost bracket first: B XOR C, 1 when they differ
2. then AND it with A
3. finally NOT: flip every value

Working columns earn the method mark, and catch slips: $X = 0$ only where $A = 1$ and $B \neq C$.

8

Sheet 3.2.2 – Building a logic circuit

Sheet 3.2.2 – what you need to know

You must be able to:

- draw a circuit from an expression, including NOTs and 3-input gates
- turn a problem statement into one expression per output
- write an expression from a truth table

What the exam asks

"Draw a logic circuit for: X = NOT ((NOT A AND NOT B) OR (NOT B AND NOT C))" **[2]**

"Write logic expressions for the security system. X = ... Y = ..." **[2]**

"Draw a logic circuit for: X = NOT (A OR B OR C) OR (B AND C AND D)" **[4]**

Practise on exercise sheet 3.2.2, then try the real exam questions on past-paper sheet 3.2.2.

From an expression to a circuit: three rules

1. One gate for each operator. Count the operators: NOT counts too.
2. Brackets first. The gate for a bracket is drawn on the left, and its output goes into the gate outside the bracket.
3. An input used twice is one input. Draw one wire, with a junction dot where it branches.



$X = (A$ AND $B)$ OR C: two operators, two gates. Draw the correct shape, and the small circle on NOT, NAND and NOR.

From a problem statement

Turn the English into a **Boolean expression** first:

the words	**the gate**
"A and B"	A AND B
"A or B or both"	A OR B
"exactly one of A, B"	A XOR B
"neither A nor B"	A NOR B
"not both"	A NAND B

Worked example

The alarm X sounds when the guard is open ($A = 1$) **and** either the motor is running ($B = 1$) or the temperature is high ($C = 1$).

"either … or" (or both) ⇒ OR; the whole condition needs the guard ⇒ AND.

$$X = A \text{ AND } (B \text{ OR } C)$$

brackets first: the OR is inside the AND

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.

From a truth table to an expression

Look only at the rows where $X = 1$. Each of them becomes one term:

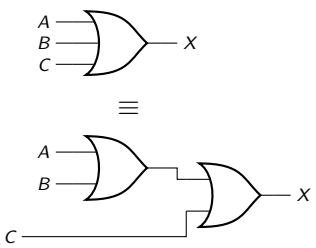
- an input that is 1 is written as itself; an input that is 0 as NOT that input
- the inputs of one row are joined with AND; the terms are joined with OR

$X = 1$ on the rows $ABC = 001$, 010 and 111:

$X =$ (NOT A AND NOT B AND C) OR (NOT A AND B AND NOT C) OR (A AND B AND C)

> One term for each 1-row, and every term has **all three** inputs. The rows where $X = 0$ give nothing.

Three-input gates, and five inputs with two outputs



One 3-input gate, or two 2-input gates in a chain: both score.

A security system. Inputs: A door open, B window open, C alarm set, D motion, E dark. The alarm X sounds if it is set and a door, a window or motion is detected. The light Y comes on if there is motion in the dark.

$$X = C \text{ AND } (A \text{ OR } B \text{ OR } D)$$
$$Y = D \text{ AND } E$$

One expression per output; an input can feed both.

9 Recap

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.

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