PrepWithTee

NOTES

Hardware

Cambridge O Level Computer Science (2210)

The full notes for this chapter: the topic taught from the basics, then how it is examined - question types, marking points, keywords and real past-paper questions solved - with practice to finish.

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Each note has two parts. **Part 1** teaches the topic from the basics. **Part 2** shows how it is examined: the types of question, what the examiner gives marks for, the keywords to use, and real past-paper questions solved with the official mark scheme. The answers to every practice question are at the end of each note.

NOTE 1

The CPU and Von Neumann architecture

1 In this note

SYLLABUS 3.1 COMPUTER ARCHITECTURE

- 3.1.1 Understand the **role of the CPU** and what is meant by a **microprocessor**.
- 3.1.2a Understand the purpose of the components in a CPU with a **Von Neumann architecture**: **ALU**, **CU**, the registers **PC**, **MAR**, **MDR**, **CIR**, **ACC**, and the **address**, **data** and **control** buses.

Next: The fetch-decode-execute cycle.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Programs are instructions

A program is a list of instructions. Before it runs it is copied from storage into RAM.

Quick check: where is a program while it is running?

In RAM (main memory).

Everything is binary

Instructions, data and memory addresses are all stored as binary numbers.

Quick check: what is an address?

A number that identifies one location in memory.

3 The CPU and the microprocessor

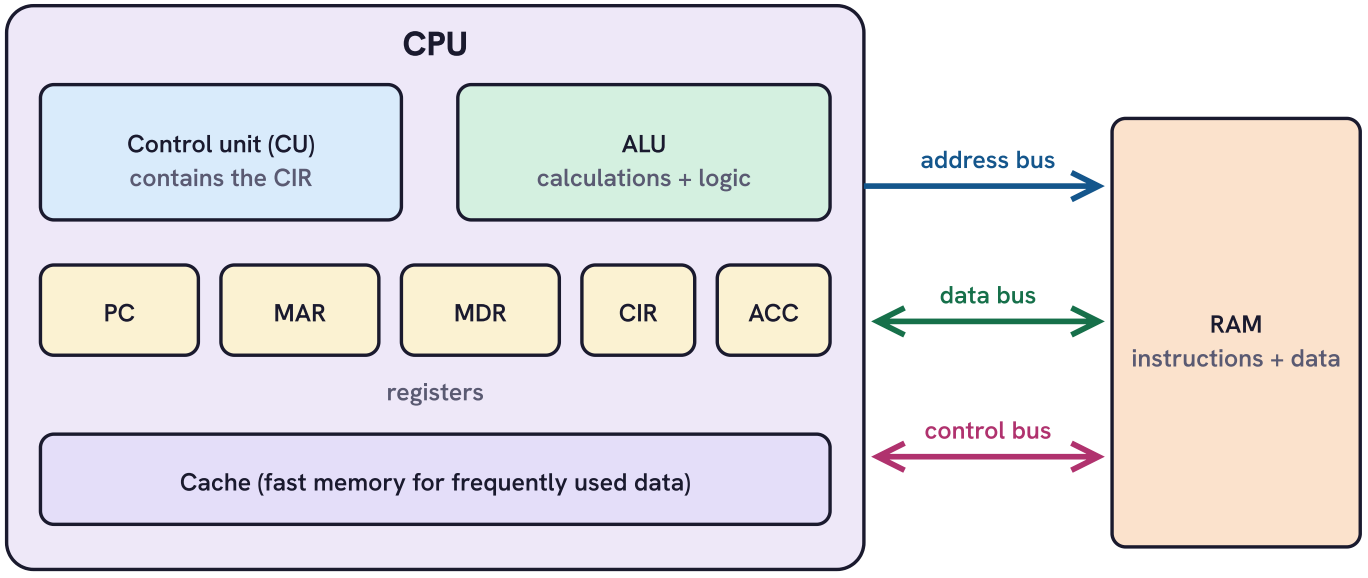
The **central processing unit (CPU)** is the part of the computer that **processes instructions and data**. It takes the data that is input, processes it by running the program's instructions (the **fetch-decode-execute cycle**), so that the result can be output.

A **microprocessor** is a type of **integrated circuit on a single chip**. In most computers the CPU is a microprocessor; simpler devices (a washing machine, a microwave) have a microprocessor that does one job.

> **Role of the CPU**: to process instructions and data (by running the fetch-decode-execute cycle).

4 Von Neumann architecture

Almost every computer uses the **Von Neumann architecture**. Its key idea is that the **program instructions and the data are stored together in the same memory** (RAM), and the CPU fetches them one at a time to process them.



The address bus goes one way (CPU → memory); the data and control buses go both ways.
Instructions and data are stored together in the same memory.

The parts of a Von Neumann CPU and how it connects to RAM.

The two units

Unit	Purpose
Control unit (CU)	**sends control signals** to manage the **flow of data** through the CPU and to **manage the fetch-decode-execute cycle**; it **decodes** the instructions (using the instruction set)
Arithmetic logic unit (ALU)	**carries out the calculations** (e.g. add, subtract) and the **logical operations** (e.g. AND, OR, comparing two values); it **executes** the instructions and stores interim results in the accumulator

The registers

A **register** is a tiny, very fast storage location **inside the CPU**. Each register **temporarily stores** one item: an address, an instruction or some data, so it can be accessed immediately during the cycle.

Register	What it stores
Program counter (PC)	the **address of the next instruction** to be fetched
Memory address register (MAR)	the **address** in memory of the instruction or data that is **about to be fetched** (or the address data is to be written to)
Memory data register (MDR)	the **data or instruction** that has just been **fetched from memory** (or is waiting to be written to memory)
Current instruction register (CIR)	the **instruction currently being decoded and executed**; it is built into the CU
Accumulator (ACC)	the **result of a calculation** by the ALU (interim results)

> A memory hook for which registers hold **addresses**: **PC** and **MAR** ("A" for address). **MDR** holds **data** ("D" for data). **CIR** holds the **instruction**; **ACC** holds **answers**.

The buses

A **bus** is a set of parallel wires that **transmits** data, addresses or signals between the parts of the computer.

Bus	What it carries	Direction
Address bus	**addresses** (e.g. from the MAR to RAM)	one way: CPU → memory
Data bus	**data and instructions** (e.g. from RAM to the MDR)	both ways
Control bus	**control signals** from the control unit (e.g. read, write, clock)	both ways

TRY IT YOURSELF

1. Which register holds the address of the next instruction?
2. Which unit carries out calculations and logical operations?
3. Which bus carries addresses?
4. State the purpose of a register.

5 Summary

- CPU: processes instructions and data (runs the FDE cycle). Microprocessor: integrated circuit on a single chip.
- Von Neumann: instructions and data stored together in the same memory.
- CU: sends control signals, manages the FDE cycle, decodes. ALU: calculations and logical operations.
- PC: address of next instruction. MAR: address about to be fetched. MDR: data / instruction fetched. CIR: current instruction. ACC: results.
- Address bus (one way): addresses. Data bus: data and instructions. Control bus: signals.

IF YOU SEE …

"describe the role of the CPU"	→ processes instructions / data · runs the FDE cycle
"purpose of the ALU"	→ calculations · logical operations · executes instructions · results in the accumulator
"purpose of a register"	→ temporarily stores data / instruction / address · fast access during the FDE cycle

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Role / purpose**

> *"Describe the role of the CPU" [2]; "describe the purpose of the ALU" [3]; "state the purpose of a register" [1]*

Spot it "role", "purpose".

1. Use the definitions in the tables: one mark per separate point.

TYPE 2 **Name a component**

> *"State the name of the component that sends signals ..." [1]; "circle three components built into the CPU" [3]*

Spot it "name", "identify", "circle".

1. Built into the CPU: CU, ALU, registers, cache, clock. NOT RAM, ROM, HDD, motherboard.

TYPE 3 **Register table**

> *a table of register names and descriptions to complete [6]*

Spot it a table.

1. Watch for addresses (PC, MAR) vs data (MDR) vs instruction (CIR) vs results (ACC).

TYPE 4 **Buses**

> *"circle three buses" [3]; "describe the address bus" [2]*

Spot it "bus".

1. Address, data, control: say what each carries.

7 What the examiner looks for

"Describe the purpose of the ALU" [3]

Marking points (one mark each, up to the marks shown)

- To execute instructions
- To perform calculations // e.g. addition, subtraction
- To perform logical operations // e.g. AND, OR, comparisons
- To store interim results of calculations
- Stores / reads / writes data to / from the accumulator

KEYWORDS **calculations** **logical operations** **accumulator**

Wording trap · Components inside the CPU

THE QUESTION **2210/13/O/N/23 Q3** ↗ Paper 1 · Computer systems **3 marks**

Circle three components that are built into the CPU: accumulator (ACC) · control unit (CU) · graphics card · hard disk drive (HDD) · motherboard · program counter (PC) · random access memory (RAM) · read only memory (ROM)

✓ CREDITED

- Accumulator (ACC)
- Control unit (CU)
- Program counter (PC)

✗ NOT CREDITED

- RAM or ROM (primary storage, but outside the CPU)
- motherboard (the CPU sits on it)
- HDD, graphics card

WHY

RAM is directly accessed by the CPU but it is not built into it.

From: 2210/13/O/N/23 Q3(a) mark scheme

8 Past-paper questions, solved

0478/13/M/J/24 Q8 ↗ Paper 1 · Computer systems **9 marks** ⤢ Full size

8 A student has a computer that has a central processing unit (CPU).

(a) Describe the role of the CPU in the computer.

..... [2]

(b) The CPU contains registers.

(i) State the purpose of a register.

..... [1]

(ii) Give **three** registers that are built into the CPU.

[3]

(c) One component in the CPU is the arithmetic logic unit (ALU).

Describe the purpose of the ALU.

..... [3]

Swipe sideways to read the whole question

How to start Each part is a definition from the notes. Count the marks: (c) wants three separate points.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) To process instructions and data, by running the fetch-decode-execute cycle.

(b)(i) To temporarily store data, an instruction or an address. (ii) Program counter, memory address register, accumulator.

(c) To execute instructions: it performs the calculations, such as addition, and the logical operations, such as comparing values, and stores the interim results in the accumulator.

PART	ANSWER / WORKING	MARKS	GUIDANCE
8(a)	process instructions / data · run the FDE cycle	**B2**	
8(b)(i)	temporarily store data / instruction / address // immediate access during FDE	**B1**	
8(b)(ii)	Any three: MAR · MDR · ACC · PC · CIR	**B3**	
8(c)	Any three: execute instructions · calculations · logical operations · interim results · accumulator	**B3**	

Total: 9 marks

6 The table contains names and descriptions of components in a central processing unit (CPU).

Complete the table by giving the missing component names and descriptions.

Component name	Description
.....	sends signals to manage the flow of data through the CPU
program counter	....
.....	stores the address of the data that is about to be fetched from random access memory (RAM) into the CPU
.....	transmits data between the RAM and the CPU
accumulator	....
.....	stores an instruction when it is being decoded

[6]

Swipe sideways to read the whole question

How to start Four rows need a name, two need a description. "Address … about to be fetched" is the MAR; "transmits data" is a bus.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Control unit (CU) · program counter: stores the address of the next instruction to be fetched · memory address register (MAR) · data bus · accumulator: stores the interim result of a calculation · current instruction register (CIR)

PART	ANSWER / WORKING	MARKS	GUIDANCE
6	CU · MAR · data bus · CIR; PC: address of the next instruction; ACC: interim result of a calculation	B6	

Total: 6 marks

9 Common mistakes

✗ "The MAR stores instructions" ✓ "The MAR stores addresses"

✗ "RAM is part of the CPU" ✓ "RAM is primary storage outside the CPU"

✗ "The CPU stores data" ✓ "The CPU processes instructions and data"

Storing is memory's job.

✗ "The ALU controls the CPU" ✓ "The CU sends control signals; the ALU calculates"

10 Practice

Practice: easy, medium, hard

1. What does MDR stand for?
2. Which register holds the result of a calculation?
3. Name the three buses.
1. State what is meant by a microprocessor.
2. Describe the role of the control unit. [2]
3. Explain the key idea of the Von Neumann architecture.
1. Compare what the PC and the MAR store. [2]
2. Which bus is one-way, and why?

11 Can I do this?

0 / 4 ticked

- [ ] I can describe the role of the CPU and define a microprocessor.
- [ ] I can give the purpose of the CU and the ALU.
- [ ] I can say what each of PC, MAR, MDR, CIR, ACC stores.
- [ ] I can describe the three buses.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Program counter (PC)**

2.

ANSWER **Arithmetic logic unit (ALU)**

3.

ANSWER **Address bus**

4.

ANSWER

To temporarily store data / an instruction / an address so it can be accessed immediately

Practice: easy, medium, hard

Easy 1.

ANSWER **Memory data register**

Easy 2.

ANSWER **Accumulator (ACC)**

Easy 3.

ANSWER **Address bus, data bus, control bus**

Medium 1.

ANSWER **An integrated circuit on a single chip**

Medium 2.

ANSWER

Sends control signals to manage the flow of data through the CPU; manages / decodes during the FDE cycle

Medium 3.

ANSWER **Program instructions and data are stored together in the same memory**

Hard 1.

ANSWER

PC: the address of the NEXT instruction to be fetched. MAR: the address of the instruction / data being fetched NOW (or written to)

Hard 2.

ANSWER **The address bus: addresses only go from the CPU to memory**

NOTE 2

The fetch-decode-execute cycle

1 In this note

SYLLABUS 3.1 COMPUTER ARCHITECTURE

- 3.1.2b Describe the **fetch-decode-execute (FDE) cycle**, including the **role of each component** in the process: storing data and addresses in registers, using **buses** to transmit them, using the **units** to fetch, decode and execute.

Before this: The CPU and Von Neumann architecture. Next: CPU performance and embedded systems.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

The registers

PC: address of the next instruction. MAR: address being fetched. MDR: data fetched. CIR: current instruction. ACC: results.

Quick check: which register holds the address of the next instruction?

The program counter (PC).

The buses

Address bus: addresses. Data bus: data and instructions. Control bus: signals.

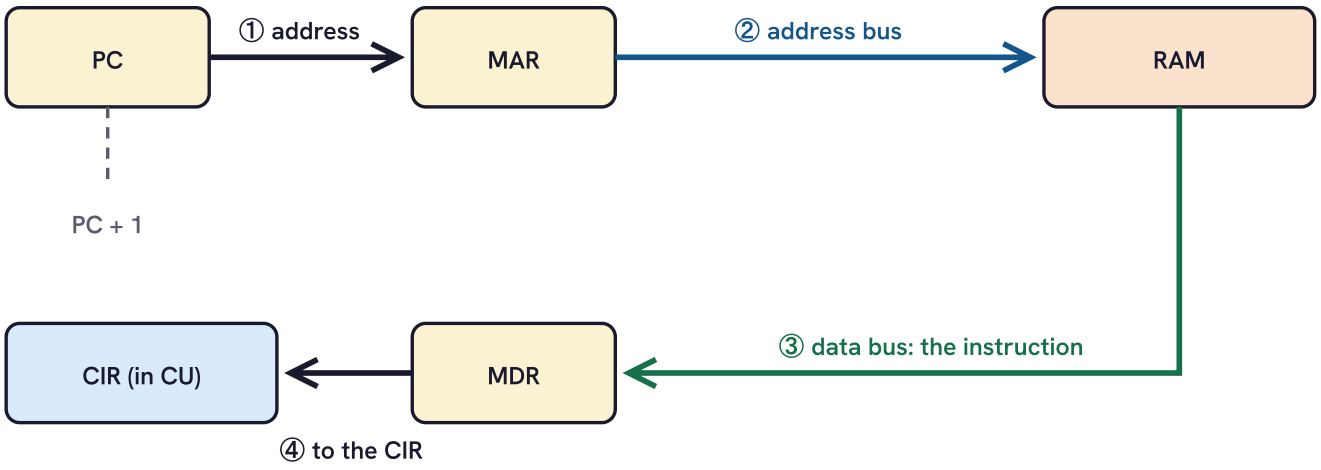
Quick check: which bus brings the instruction from RAM?

The data bus.

3 The cycle

The CPU runs every program by repeating three stages over and over, billions of times a second: **fetch** the next instruction from RAM, **decode** it to work out what it means, then **execute** it. This is the **fetch-decode-execute (FDE) cycle**.

1 Fetch



The fetch stage, in order ① to ④. The PC is increased by 1 so it points to the next instruction.

GENERAL METHOD

The fetch stage

1. The **program counter (PC)** holds the address of the next instruction. This address is **copied to the MAR**.
2. The **PC is incremented** (increased by 1) so it holds the address of the instruction after this one.
3. The address in the MAR is sent to **RAM** along the **address bus**.
4. The control unit sends a **read signal** along the **control bus**.
5. The instruction stored at that address is sent from RAM to the **MDR** along the **data bus**.
6. The instruction is copied from the MDR to the **CIR** (in the control unit).

2 Decode

GENERAL METHOD **The decode stage**

1. The instruction is in the **CIR**, in the **control unit**.
2. The control unit **decodes** the instruction using the **instruction set** (the list of machine code commands the CPU understands).
3. The instruction is split into the **opcode** (what to do, e.g. ADD) and the **operand** (what to do it to: data or an address).

3 Execute

GENERAL METHOD **The execute stage**

1. The control unit sends **control signals** to the parts that are needed to carry out the instruction.
2. If the instruction needs data from memory, its address goes to the MAR and the data comes back into the MDR.
3. If it is a calculation or comparison, the **ALU** carries it out and the result goes to the **accumulator (ACC)**.
4. The cycle then **starts again** with the next fetch.

Stage	Registers used	Buses used
Fetch	PC, MAR, MDR, CIR	address bus (MAR → RAM), data bus (RAM → MDR), control bus (read signal)
Decode	CIR (in the CU)	data bus (MDR → CIR)
Execute	ACC, MAR, MDR (if more data is needed)	any, depending on the instruction

TRY IT YOURSELF

1. Which register is incremented during the fetch stage?

2 Along which bus is the address sent from the MAR to RAM?

3 What does the control unit use to decode an instruction?

4 Summary

- Fetch: PC → MAR; PC + 1; MAR → RAM (address bus); instruction RAM → MDR (data bus); MDR → CIR.
- Decode: the CU decodes the instruction in the CIR using the instruction set (opcode + operand).
- Execute: the CU sends signals; the ALU calculates; results in the ACC. Then the cycle repeats.

IF YOU SEE …

"registers used in the fetch stage"	→ PC · MAR · MDR · CIR
"describe the decode stage"	→ MDR → CIR / CU · data bus · split into opcode and operand · CU decodes · instruction set

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

5 Ways they test it

TYPE 1 **Fetch paragraph**

> *"Complete the paragraph about fetching an instruction" [7]*

Spot it a word list.

1 Follow the fetch method in order: address · MAR · RAM · MDR · data · CIR · CU.

TYPE 2 **Registers per stage**

> *"Give two registers used in the fetch stage" [2]; "one register used in the execute stage" [1]*

Spot it "stage".

1. Fetch: PC, MAR, MDR, CIR. Execute: ACC (also MAR, MDR).

TYPE 3 **Describe a stage**

> *"Describe what happens at the decode stage" [3]*

Spot it "decode".

1. MDR → CIR on the data bus; split into opcode and operand; CU decodes using the instruction set.

TYPE 4 **Diagram**

> *"Complete and annotate the diagram to show how the data is decoded" [4]; draw the fetch stage [4]*

Spot it "annotate".

1. Boxes for each register, arrows in order, and label each arrow with the bus.

TYPE 5 **Correct the statement**

> *"Two statements are not correct. Suggest a corrected statement" [4]*

Spot it "incorrect".

1. Typical traps: "MAR stores instructions" (addresses), "MDR gets data from the PC" (from RAM via the data bus).

6 What the examiner looks for

"Describe what happens at the decode stage of the cycle" [3]

Marking points (one mark each, up to the marks shown)

- The CIR / CU receives the instruction from the MDR …
- … using the data bus
- The instruction is separated into opcode and operand
- The control unit decodes the instruction …
- … using an instruction set

KEYWORDS **CIR** **control unit** **opcode** **operand** **instruction set**

The fetch stage drawn as a diagram [4]

Marking points (one mark each, up to the marks shown)

- The registers MAR, MDR and PC shown
- Address sent from PC to MAR; PC is incremented
- Address sent from MAR to RAM … using the address bus
- Data / instruction sent from RAM to MDR … using the data bus
- Data / instruction sent from MDR to CIR / CU
- Control unit sending a control signal … using the control bus

KEYWORDS **PC** **MAR** **address bus** **MDR** **data bus** **CIR**

7 Past-paper questions, solved

2210/12/M/J/24 Q5 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

5 Instructions are processed by a central processing unit (CPU) in a computer.

(a) Complete the paragraph about fetching an instruction into the CPU to be processed.

Use the terms from the list.

Some of the terms in the list will **not** be used. You should only use a term once.

address arithmetic logic unit (ALU) binary control unit (CU)

current instruction register (CIR) data denary driver

fetch interrupt memory address register (MAR)

memory data register (MDR) random access memory (RAM)

read only memory (ROM) secondary storage signal

The program counter contains the ……

of the next instruction to be processed; this is then sent to the

…… using the address bus. The address is then

sent to the …… .

Once the address is received, the instruction stored at the location is

sent to the ……, using the

…… bus. The instruction is then

sent to the …… that is built into the

…… .

[7]

(b) The CPU uses an instruction set to decode the instruction.

State what is meant by an instruction set.

……

…… [1]

Swipe sideways to read the whole question

How to start Walk through the fetch method: what does the PC hold, where does it go, which bus, where does the instruction land?

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) address · memory address register (MAR) · random access memory (RAM) · memory data register (MDR) · data · current instruction register (CIR) · control unit (CU)

(b) A list of all the machine code commands that can be processed by the CPU.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	address · MAR · RAM · MDR · data · CIR · CU, one mark each in the correct place	B7	
5(b)	a list of (machine code) commands that can be processed by the CPU	B1	

Total: 8 marks

0478/11/O/N/24 Q5 ↗ Paper 1 · Computer systems **9 marks** ⤢ Full size

5 A central processing unit (CPU) performs the fetch–decode–execute (FDE) cycle.

(a) Give the name of **two** registers that are used in the fetch stage of the cycle.

[2]

(b) Describe what happens at the decode stage of the cycle.

..... [3]

(c) Give **one** register in the CPU that is used in the execute stage of the cycle.

..... [1]

(d) Buses are used in the CPU to transmit data through the FDE cycle.

Circle **three** buses that are used in the CPU.

fetch	address	register	execute
data	decode	calculation	
central	value	binary	control

[3]

Swipe sideways to read the whole question

How to start (b) is the decode method: three points. (d) circle the three real bus names.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Program counter (PC); memory address register (MAR).

(b) The instruction is sent from the MDR to the CIR in the control unit along the data bus. It is split into the opcode and the operand, and the control unit decodes it using the instruction set.

(c) Accumulator (ACC).

(d) address · data · control

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Any two: PC · MAR · MDR · CIR	B2	
5(b)	Any three: MDR → CIR / CU · data bus · opcode and operand · CU decodes · instruction set	B3	
5(c)	Any one: ACC · MAR · MDR	B1	
5(d)	data · address · control	B3	
			Total: 9 marks

2 A computer has a central processing unit (CPU).

The CPU includes the registers:
- Program counter (PC)
- Memory address register (MAR)
- Memory data register (MDR)
- Accumulator (ACC)
- Current instruction register (CIR).

(a) The table contains **five** statements about the role of registers in the fetch–decode–execute cycle of a CPU.

Letter	Statement
A	PC stores the address of the next instruction to be accessed
B	MAR stores the instructions of the program that is running
C	MDR stores the data passed to it from the PC
D	ACC stores the result of each calculation
E	CIR stores the instruction currently being executed

Two of the statements are **not** correct.

Identify the letter of each incorrect statement.

Suggest a corrected statement for each.

Incorrect statement 1 .....

Corrected statement .....

Incorrect statement 2 .....

Corrected statement .....

[4]

Swipe sideways to read the whole question

How to start Check each statement against the register table: who holds addresses, who holds data, where does data come from?

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Incorrect statement 1: **B**. Corrected: the MAR stores the address of the instruction / data to be fetched, not the instructions.

Incorrect statement 2: **C**. Corrected: the MDR stores data passed to it from RAM along the data bus (from the address in the MAR), not from the PC.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	B … MAR stores addresses, not instructions · C … data comes from RAM / the address in the MAR (data bus), not the PC	B4	

Total: 4 marks

8 Common mistakes

✗ "The PC sends the instruction to the MAR" ✓ "The PC's ADDRESS is copied to the MAR"

The PC never holds an instruction.

✗ "The address goes on the data bus" ✓ "Addresses go on the address bus"

✗ Forgetting the PC is incremented ✓ "PC + 1" in the fetch stage

It earns a mark in diagrams.

✗ "The ALU decodes the instruction" ✓ "The control unit decodes it using the instruction set"

9 Practice

Practice: easy, medium, hard

1. Name the three stages of the cycle, in order.
2. Which register receives the instruction from RAM?
3. Which register holds the instruction while it is decoded?
1. Describe the fetch stage. [4]
2. What are the two parts an instruction is split into when it is decoded?
1. An instruction says ADD the value at address 50 to the accumulator. Describe what happens in the execute stage. [3]
2. Explain why the PC is incremented during the fetch stage.

10 Can I do this?

0 / 3 ticked

- [ ] I can describe the fetch stage step by step with registers and buses.
- [ ] I can describe the decode and execute stages.
- [ ] I can draw and annotate the fetch stage.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Program counter (PC)

2.

ANSWER Address bus

3.

ANSWER The instruction set

Practice: easy, medium, hard

Easy 1.

ANSWER Fetch, decode, execute

Easy 2.

ANSWER MDR (memory data register)

Easy 3.

ANSWER CIR (current instruction register)

Medium 1.

ANSWER

PC address copied to MAR; PC incremented; address sent to RAM on the address bus; instruction returned to MDR on the data bus; copied to CIR

Medium 2.

ANSWER Opcode and operand

Hard 1.

ANSWER

CU sends signals; address 50 goes to the MAR → RAM; the value returns to the MDR on the data bus; the ALU adds it to the ACC; result stored in the ACC

Hard 2.

ANSWER **So it holds the address of the next instruction, ready for the next cycle**

NOTE 3

CPU performance and embedded systems

1 In this note

SYLLABUS 3.1 COMPUTER ARCHITECTURE

- 3.1.3 Understand what is meant by a **core**, **cache** and **clock** in a CPU and explain how they can **affect the performance** of a CPU.
- 3.1.4 Understand the purpose and use of an **instruction set** for a CPU.
- 3.1.5 Describe the purpose and characteristics of an **embedded system** and identify devices in which they are commonly used.

Before this: The fetch-decode-execute cycle. Next: Input and output devices.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

The FDE cycle

The CPU fetches, decodes and executes one instruction, then repeats.

Quick check: what does a faster CPU let you do?

Run more fetch-decode-execute cycles every second.

3 What makes a CPU faster

Three features of a CPU decide how many instructions it can process per second. For each one, learn **what it is** and **how it affects performance**: the examiner almost always wants the link to **FDE cycles**.

Feature	What it is	Effect on performance
Clock	sends out **timing signals** (clock pulses) that keep the parts of the CPU in step. Clock speed is measured in **hertz**: 3.5 GHz = 3.5 billion cycles per second	**higher clock speed** → **more FDE cycles per second** → instructions processed faster
Core	a complete **processing unit** (with its own ALU, CU and registers). A quad-core CPU has four	**more cores** → **more instructions processed at the same time** (each core runs its own FDE cycle simultaneously)
Cache	small, **very fast memory** inside / next to the CPU that stores **frequently used data and instructions** (levels L1, L2, L3)	**bigger cache** → frequently used data is **accessed faster than from RAM** → less waiting

✗ COMMON MISTAKE

Not always. Doubling the cores does not always double the speed: the program must be able to split its work between cores, and the cores have to communicate. Very high clock speeds also make the CPU hot. If the question says "explain", one sentence on a limit can earn the extra mark.

EXAMPLE **Comparing two CPUs**

CPU A: 4 cores, 3.2 GHz, 8 MB cache. CPU B: 2 cores, 3.6 GHz, 4 MB cache. Which is likely to perform better on a program that can use many cores, and why?

> CPU A has twice as many cores, so it can run twice as many FDE cycles at the same time.
>
> CPU A also has a bigger cache, so more frequently used data is stored close to the CPU and accessed faster than from RAM.
>
> CPU B has the faster clock (more cycles per second per core), but 3.6 is only 12.5% more than 3.2.

ANSWER **CPU A: more cores and more cache outweigh the slightly lower clock speed.**

4 Instruction sets

An **instruction set** is the **list of all the commands (machine code instructions)** that a particular CPU can **process**. Each command is made of an **opcode** (the operation, e.g. ADD, LOAD, JUMP) and usually an **operand** (the data or address it works on).

The control unit uses the instruction set to **decode** each instruction in the FDE cycle. A program written in a high-level language must be translated into instructions from the CPU's instruction set before it can run, which is why machine code made for one type of CPU will not run on another.

> **Instruction set**: a list of all the commands that can be processed by a CPU, used to decode instructions.

5 Embedded systems

An **embedded system** is a computer system **built into a larger device** to perform **one dedicated function**. It has a **microprocessor** (or microcontroller), and its program is stored as **firmware** in ROM, so it usually **cannot be reprogrammed** by the user.

Characteristic	Why
performs a **single, dedicated function**	it only controls one device: e.g. keeping a freezer cold
built into a larger device	it is part of the machine, not a separate computer
has **dedicated hardware** + a microprocessor	only the parts needed for its job
runs **firmware** / cannot (easily) be **reprogrammed**	the program is fixed in ROM
small, **cheap**, **low power**	easy to mass-produce; can run on batteries
often **real-time** and **automatic**	reacts to sensor input without a user

Devices that commonly contain embedded systems:

Domestic	Transport / other
washing machine, microwave oven, fridge / freezer, central heating, security alarm, smart TV	car engine management, ABS brakes, traffic lights, vending machine, digital camera, lift (elevator), set-top box

A **general-purpose computer** (a laptop) can run any program you install. An **embedded system** does one job inside another device. If the question asks you to "identify" embedded systems from a list, cross out the laptops, PCs and servers.

TRY IT YOURSELF

1. What is the effect of a higher clock speed?
2. Where is the program of an embedded system stored?
3. Is a smartphone an embedded system?

6 Summary

- Clock: timing signals; higher clock speed = more FDE cycles per second.
- Core: a processing unit; more cores = more instructions processed at the same time.
- Cache: fast memory for frequently used data; bigger cache = faster access than RAM.
- Instruction set: list of all the machine code commands a CPU can process; used to decode.
- Embedded system: one dedicated function, built into a larger device, microprocessor, firmware, cannot be reprogrammed.

IF YOU SEE …

"explain how the cores affect performance"	→ more cores · more FDE cycles at the same time · simultaneously
"characteristics of an embedded system"	→ dedicated function · built into a device · firmware · cannot be reprogrammed · small / low power

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 Effect on performance

> *"Explain how the number of cores / cache / clock speed can affect performance" [2] each*

Spot it "explain".

1 Two marks: what it is + the effect, linked to FDE cycles.

TYPE 2 Interpret a spec

> *"The CPU has a clock speed of 3.5 GHz. Explain what this means" [1]*

Spot it a number.

1 3.5 billion FDE cycles (clock pulses) per second.

TYPE 3 Instruction set

> *"State what is meant by an instruction set" [1]*

Spot it "instruction set".

1 A list of all the commands that can be processed by the CPU.

TYPE 4 Embedded system

> *"Describe two characteristics of an embedded system" [4]; "circle three embedded systems" [3]*

Spot it a device scenario.

1 Two marks per characteristic: state it, then expand it.

8 What the examiner looks for

"Explain how these three components can affect the performance of the CPU" (cores, clock, cache) [6]

Marking points (one mark each, up to the marks shown)

- More cores … more FDE cycles can be performed at the same time / simultaneously
- Higher clock speed … more FDE cycles can be performed per second
- Bigger cache … more frequently used data / instructions can be stored … and accessed faster than from RAM

KEYWORDS **FDE cycles** **simultaneously** **per second** **frequently used** **faster than RAM**

TOO VAGUE "more cores make the computer faster" with no reason; "cache stores data" (all memory does: say which data and why it helps)

9 Past-paper questions, solved

0478/12/F/M/24 Q2 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

2 A computer has a central processing unit (CPU).

The CPU includes the registers:
- Program counter (PC)
- Memory address register (MAR)
- Memory data register (MDR)
- Accumulator (ACC)
- Current instruction register (CIR).

(b) The computer has a single core 3.5 GHz processor and an 8 kB cache.

(i) State what is meant by a 3.5 GHz processor.

..... [1]

(ii) The CPU is changed to a dual-core 3.5 GHz processor.

Explain how the number of cores affects the performance of a CPU.

..... [2]

(iii) The amount of cache is increased to 64 kB.

Explain how the amount of cache affects the performance of a computer.

..... [2]

Swipe sideways to read the whole question

How to start One point per mark: what the number means, then the effect of each feature, linked to FDE cycles.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(i) The CPU can perform 3.5 billion fetch-decode-execute cycles every second.

(ii) Each core can perform its own FDE cycle, so several instructions are processed at the same time.

(iii) The cache stores frequently used data and instructions, which can be accessed faster than from RAM.

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(b)(i)	3.5 billion FDE cycles / clock pulses per second	B1	
2(b)(ii)	each core performs an FDE cycle · simultaneously / more instructions at once	B2	
2(b)(iii)	stores frequently used data / instructions · accessed faster than RAM	B2	

Total: 5 marks

2210/12/O/N/23 Q4 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

4 A washing machine is an example of an embedded system.

(a) Give **two** characteristics of an embedded system.

[2]

(b) Circle **three** other examples of an embedded system.

freezer laptop

personal computer (PC) security light system smartphone

vending machine web server

[3]

Swipe sideways to read the whole question

How to start Pick characteristics from the list and expand each one with a reason or example.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

It performs a single, dedicated function, for example only controlling the security light. It is built into a larger device and its program is stored as firmware, so it cannot be reprogrammed by the user. It uses little power and is small and cheap to make.

PART	ANSWER / WORKING	MARKS	GUIDANCE
4	Any two characteristics, two marks each: dedicated function · microprocessor · dedicated hardware · firmware · built into a larger device · cannot be reprogrammed · low power · small / cheap · real-time	B4	

Total: 4 marks

10 Common mistakes

✗	✓
"Cache is extra storage"	"Cache is fast memory for frequently used data, accessed faster than RAM"
"More cores = computer goes faster"	"More cores = more FDE cycles at the same time"
"Clock speed is the time of the computer"	"Clock speed = number of FDE cycles per second"
"An embedded system can be reprogrammed by the user"	"Its firmware is fixed; it usually cannot be reprogrammed"

Say the reason.

11 Practice

Practice: easy, medium, hard

1. A CPU has a clock speed of 2 GHz. How many cycles is that per second?
2. Give two devices that contain an embedded system.
3. What is a core?
1. Explain how increasing the cache size can improve performance. [2]
2. State what is meant by an instruction set.
1. A quad-core CPU is replaced by an eight-core CPU but a program does not run faster. Suggest why. [2]
2. Explain why an embedded system usually cannot be reprogrammed. [2]

12 Can I do this?

0 / 3 ticked

- [ ] I can explain the effect of clock speed, cores and cache on performance.
- [ ] I can define an instruction set.
- [ ] I can describe characteristics of an embedded system and give examples.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER More FDE cycles per second, so instructions are processed faster

2.

ANSWER In ROM, as firmware

3.

ANSWER No: it is general purpose (it runs many apps)

Practice: easy, medium, hard

Easy 1.

ANSWER 2 billion

Easy 2.

ANSWER e.g. washing machine, microwave

Easy 3.

ANSWER A processing unit inside the CPU that can run its own FDE cycle

Medium 1.

ANSWER

More frequently used data / instructions stored in cache; accessed faster than from RAM

Medium 2.

ANSWER A list of all the commands a CPU can process

Hard 1.

ANSWER

The program may not be able to split its work across more cores / it uses one core; cores must communicate

Hard 2.

ANSWER **Its program is firmware stored in ROM; it is designed for one dedicated function**

NOTE 4

Input and output devices

1 In this note

SYLLABUS 3.2 INPUT AND OUTPUT DEVICES

- 3.2.1 Understand what is meant by an **input device** and why it is required.
- 3.2.2 Understand what is meant by an **output device** and why it is required.

Before this: CPU performance and embedded systems. Next: Sensors.

> The syllabus only asks **what** each device is, **why** it is needed and **where** it is used. You do not need to describe how a device works inside.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Input → process → output

A computer takes data in, processes it, and gives results out.

Quick check: which part does the processing?

The CPU.

3 Input devices

An **input device** **captures data** from the user or the surroundings and **sends it to the computer** to be processed. Input devices are needed because the computer can only process

data it has been given, and most data starts outside the computer (a key press, a sound, a picture).

Input device	Typical use
Keyboard	typing text and commands into a word processor or a form
Mouse	pointing, clicking and selecting on a desktop computer
Touch screen	selecting options on a smartphone, a ticket machine or a self-service checkout
Microphone	recording speech, voice commands to a smart speaker, video calls
Digital camera	taking photos and videos, video calls, scanning documents with a phone
Barcode scanner	reading the product code at a shop checkout or in a library
QR code scanner	opening a web link or a payment from a QR code (often the phone camera)
2D / 3D scanner	copying a printed document (2D); copying the shape of an object for 3D printing (3D)
Sensor	measuring a physical quantity automatically, e.g. temperature (next note)

4 Output devices

An **output device** **receives data from the computer** and **presents it** in a form the user can understand (a picture, sound, printout) or **uses it to make something happen** (an actuator

moves a valve). Output devices are needed so the results of processing can be seen, heard or acted on.

Output device	Typical use
Screen / monitor	displaying documents, games, video
Speaker / headphones	playing music, alarms and the sound of a video call
Printer (inkjet, laser)	printing documents and photos on paper
3D printer	making a solid object, layer by layer, e.g. a prototype or a spare part
Projector	showing a presentation on a large screen in a classroom
LED / LCD light	an indicator light (charging, on/off), a digital display
Actuator	making a physical movement in a control system: opening a valve, turning a motor, switching a heater

> **Not input or output:** HDD, SSD, USB flash drive, CD/DVD are **storage**; RAM, ROM, registers are memory. A touch screen is both input and output. An **actuator is an output device**; a **sensor is an input device**.

TRY IT YOURSELF

1. Is a printer an input or output device?
2. Is a microphone an input or output device?
3. Which output device moves a valve in a control system?

5 Summary

- Input device: captures data and sends it to the computer to be processed.
- Output device: receives data from the computer and presents it / makes something happen.
- Inputs: keyboard, mouse, touch screen, microphone, camera, barcode / QR scanner, 2D/3D scanner, sensor.
- Outputs: screen, speaker, printer, 3D printer, projector, LED, actuator.

IF YOU SEE …

"circle three output devices"	→ speaker · printer · actuator (not DVD, SSD, sensor)
"identify two input devices built into a smartphone"	→ touch screen · microphone · camera · sensor

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **Circle the devices**

> *"Circle three devices that are output devices" [3]*

Spot it a list.

1. Cross out storage and memory first: they are distractors.

TYPE 2 **Devices in a gadget**

> *"Identify two input devices that can be built into the smartwatch" [2]*

Spot it a device scenario.

1. Choose devices that make sense for that gadget: a smartwatch has a touch screen, microphone, sensors.

TYPE 3 **Input / output / storage**

> *"Tick to show whether a barcode scanner is input, output, process or storage" [1]*

Spot it a tick box.

1. Ask: does data go IN to the computer or OUT of it?

7 What the examiner looks for

Wording trap · Output devices

THE QUESTION **2210/12/M/J/23 Q1** ↗ Paper 1 · Computer systems — **3 marks**

Circle three devices that are output devices: actuator · DVD · keyboard · microphone · mouse · printer · scanner · sensor · SSD · speaker

✓ CREDITED

- Actuator
- Printer
- Speaker

✗ NOT CREDITED

- DVD, SSD (storage)
- keyboard, microphone, mouse, scanner, sensor (input)

WHY

Remember that the actuator is an output: it moves something in response to the computer's signal.

From: 2210/12/M/J/23 Q1 mark scheme

8 Past-paper questions, solved

2210/12/O/N/24 Q4 ↗ Paper 1 · Computer systems **3 marks** ⤢ Full size

4 A student has a smartwatch.

(a) The smartwatch has built-in input and output devices.

Identify **two** input devices that can be built into the smartwatch.

[2]

(b) Identify **one** output device that can be built into the smartwatch.

..... [1]

Swipe sideways to read the whole question

How to start Picture a smartwatch: what do you touch, speak into, and what does it show or play?

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) Touch screen; microphone (also accepted: button, camera, a sensor such as a heart-rate sensor).

(b) Screen (also: speaker, LED).

PART	ANSWER / WORKING	MARKS	GUIDANCE
4(a)	Any two: touchscreen · microphone · button · camera · sensor	B2	
4(b)	Any one: screen · speaker · LED · actuator	B1	
			Total: 3 marks

9 Common mistakes

✗ "An SSD is an output device"

✓ "An SSD is secondary storage"

✗	✓
"An actuator is an input"	"An actuator is an output: it moves something"
"Keyboard" for a smartwatch	"Touch screen"

Pick devices that suit the gadget.

10 Practice

Practice: easy, medium, hard

1. Is a 3D printer an input or output device?
2. Name an input device used at a shop checkout.
1. Explain why a computer needs input devices.
2. Give one use of a projector.
1. A touch screen is described as both input and output. Explain why.

11 Can I do this?

0 / 2 ticked

- [ ] I can define an input device and give examples and uses.
- [ ] I can define an output device and give examples and uses.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **Output**

2.

ANSWER **Input**

3.

ANSWER **Actuator**

Practice: easy, medium, hard

Easy 1.

ANSWER **Output**

Easy 2.

ANSWER **Barcode scanner**

Medium 1.

ANSWER **To capture data and send it to the computer so it can be processed**

Medium 2.

ANSWER **Showing a presentation on a large screen to a class**

Hard 1.

ANSWER **It displays output (screen) and captures input when the user touches it**

NOTE 5

Sensors

1 In this note

SYLLABUS 3.2 INPUT AND OUTPUT DEVICES

- 3.2.3 Understand what is meant by a **sensor** and its purposes; identify the **type of data** captured by each sensor and where each is used: **acoustic, accelerometer, flow, gas, humidity, infra-red, level, light, magnetic field, moisture, pH, pressure, proximity, temperature**.

Before this: Input and output devices. Next: Primary and secondary storage.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Input devices

An input device captures data and sends it to the computer.

Quick check: is a sensor input or output?

Input.

3 What a sensor is

A **sensor** is an **input device** that **measures a physical quantity** from its surroundings (temperature, light, sound ...) and sends the reading to a computer or microprocessor. It

captures data automatically, with no person entering it. If the reading is analogue it is converted to digital before the microprocessor can process it.

Why use sensors?	
data is collected **without human intervention**	nobody has to stand and watch
readings are taken **continuously** (24/7)	the system reacts the moment something changes
readings are **accurate** and taken **faster** than a human	no human error
they work in **dangerous** places	e.g. inside a chemical plant or a nuclear reactor

4 The fourteen sensors you must know

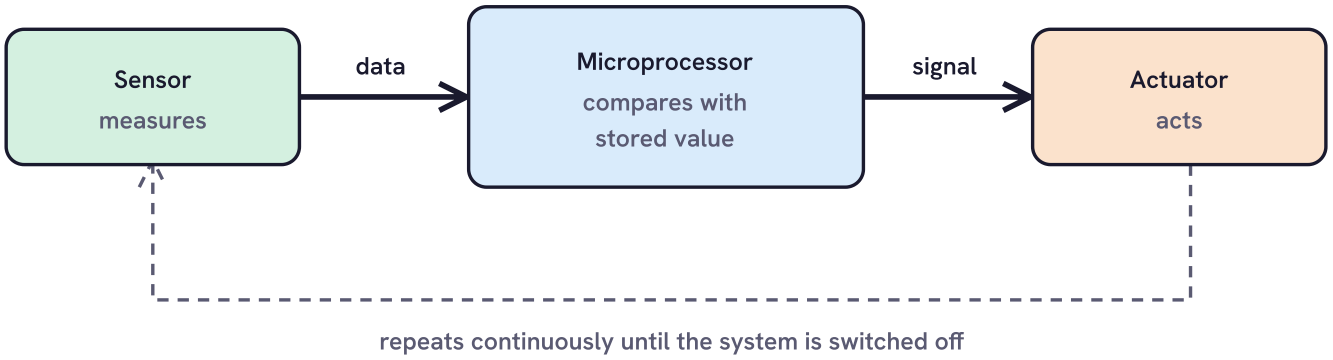
For each sensor, learn **what it measures** and **one use**. Exam questions give a scenario and ask for "the most appropriate sensor", so match the quantity that changes.

Sensor	Measures	Example use
Acoustic	sound	detecting breaking glass in a burglar alarm; a dripping, leaking pipe
Accelerometer	acceleration / movement and tilt	rotating a phone screen; fitness trackers; air-bag deployment in a crash
Flow	rate of flow of a liquid or gas	monitoring water through a pipe; fuel flow in an engine
Gas	presence / level of a gas (e.g. CO_2, carbon monoxide)	carbon monoxide alarm; gas leak detector
Humidity	water vapour in the air	greenhouse; spray-painting room; museum display case
Infra-red	infra-red radiation (heat / a broken beam)	motion detection in a security system; automatic doors
Level	how full a container is	fuel tank gauge; refilling a water tank or an animal's water bowl
Light	light intensity	street lights switching on at dusk; phone screen brightness; barcode scanner
Magnetic field	changes in a magnetic field	counting vehicles over a bridge / into a car park; phone compass
Moisture	water in a substance (e.g. soil)	automatic watering of plants
pH	acidity / alkalinity	soil in a greenhouse; water in a swimming pool or a fish tank
Pressure	force applied / pressure	a car on a car-park barrier; weighing; burglar alarm pad under a carpet
Proximity	how close an object is	parking sensors on a car; phone screen turning off at your ear
Temperature	temperature	central heating; a kettle; a freezer; a climate-controlled room

Moisture vs humidity: **moisture** is water in a solid (soil); **humidity** is water vapour in the air. Level vs pressure vs moisture can all detect an empty water bowl, and the mark scheme accepts any of them.

5 Sensor + microprocessor: how a system reacts

In an automated system the sensor and a **microprocessor** work in a loop. Questions often ask for this as a 6-mark description, so learn the steps.



The control loop used by almost every automated system.

GENERAL METHOD **Describing a sensor-controlled system**

1. The **sensor** continually takes readings and sends the (digitised) data to the **microprocessor**.
2. The microprocessor **compares** the reading with a **stored value** (or range).
3. If the reading is outside the range, the microprocessor sends a **signal** to an **actuator** (e.g. to open a valve, switch on a heater).
4. If the reading is within the range, **no action** is taken.
5. The process **repeats continuously** until the system is switched off.

EXAMPLE **A greenhouse that keeps the soil damp**

Describe how a moisture sensor and a microprocessor keep the soil damp.

The moisture sensor continually sends readings of the soil moisture to the microprocessor.

The microprocessor compares each reading with the stored minimum moisture level.

If the reading is below it, the microprocessor sends a signal to an actuator to open the water valve.

When the reading reaches the stored level, the microprocessor signals the actuator to close the valve.

This repeats continuously.

ANSWER **Five marking points: sensor · compare · actuator opens · stops · repeats.**

TRY IT YOURSELF

1. Which sensor counts cars entering a car park?
2. Which sensor measures the acidity of soil?
3. Which sensor turns a phone's screen sideways?

6 Summary

- A sensor is an input device that measures a physical quantity and sends the data to a microprocessor.
- Benefits: no human needed, continuous, accurate, fast, works in dangerous places.
- 14 sensors: acoustic, accelerometer, flow, gas, humidity, infra-red, level, light, magnetic field, moisture, pH, pressure, proximity, temperature.
- Control loop: sensor → microprocessor compares with stored value → signal to actuator → repeat.

IF YOU SEE …

"identify the most appropriate sensor"	→ name the quantity that changes
"describe how the sensor and microprocessor are used" [6]	→ continually · digital data · compare · stored value · signal · actuator · repeats

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

7 Ways they test it

TYPE 1 **Which sensor?**

> *"Identify the most appropriate sensor for this system" [1]*

Spot it a scenario.

1. One word: the sensor's name from the list of 14.

TYPE 2

Sensor uses table

> *"Complete the table by giving a suitable use for each type of sensor" [4]*

Spot it a table.

1. A specific use: "monitoring the temperature in a greenhouse", not just "measures temperature".

TYPE 3

Benefits

> *"Give two benefits of using sensors in this type of system" [2]*

Spot it "benefits".

1. no human needed · continuous · accurate · fast · dangerous places

TYPE 4

Control loop

> *"Describe how the sensor and the microprocessor are used to ..." [6]*

Spot it "describe how".

1. Follow the five-step method, using the scenario's own words (water bowl, valve).

8 What the examiner looks for

"Describe how the sensor and the microprocessor are used to automatically refill the water bowl" [6]

Marking points (one mark each, up to the marks shown)

- Sensor continually sends digitised data to the microprocessor
- Microprocessor compares the data to stored value(s)
- If the value is outside the range / matches, the microprocessor sends a signal to release water
- … bowl filled by a set amount // for a certain time
- Actuator used to release the water
- Whole process repeats until turned off

KEYWORDS **continually** **compares** **stored value** **signal** **actuator** **repeats**

TOO VAGUE "the sensor decides to refill the bowl" (the microprocessor decides); "the sensor sends a signal to the actuator"

9 Past-paper questions, solved

0478/13/M/J/24 Q6 ↗ Paper 1 · Computer systems **9 marks** ⤢ Full size

6 A sensor is an input device that is used to capture data from its surrounding environment.

(a) Circle **three** other input devices.

touch screen hard disk drive (HDD) headphones

speaker microphone actuator

universal serial bus (USB) drive printer keyboard

[3]

(b) Sensors can be used in an automated system.

Give **two** benefits of using sensors in this type of system.

[2]

(c) The table contains different types of sensors and a use for each.

Complete the table by giving a suitable use for each type of sensor. The first one has been done for you.

type of sensor	use
acoustic	to monitor whether a water pipe has cracked and is leaking and dripping onto the floor
temperature	
humidity	
infra-red	
magnetic field	

[4]

Swipe sideways to read the whole question

How to start (a) cross out storage and outputs. (c) give a specific situation for each sensor.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a) touch screen · microphone · keyboard

(b) Data can be collected without human intervention; readings can be taken continuously, 24/7.

(c) Temperature: monitoring the temperature in a climate-controlled room. Humidity: checking the air in a greenhouse is moist enough. Infra-red: detecting a person approaching automatic doors. Magnetic field: counting vehicles that cross a bridge.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	touch screen · microphone · keyboard	B3	
6(b)	Any two: no human intervention · faster · accurate · continuous · dangerous environments	B2	
6(c)	One suitable use per sensor (temperature, humidity, infra-red, magnetic field)	B4	

Total: 9 marks

2210/11/M/J/23 Q5 ↗ Paper 1 · Computer systems **7 marks** ⤢ Full size

5 A farm has an automated drinking system for its animals. The drinking system has a water bowl that contains the water. When the water bowl is empty, it is automatically refilled.

The system uses a sensor and a microprocessor.

(a) Identify the most appropriate sensor for this system.

..... [1]

(b) Describe how the sensor and the microprocessor are used to automatically refill the water bowl.

..... [6]

Swipe sideways to read the whole question

How to start (a) What changes when the bowl empties? (b) Use the control-loop method.

▾ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) A level sensor.

(b) The level sensor continually sends digitised readings to the microprocessor. The microprocessor compares each reading with the stored value for an empty bowl. If they match, the microprocessor sends a signal to an actuator to open a valve and release water. The bowl is filled for a set time or until the stored full level is reached, then the valve is closed. The whole process repeats until the system is turned off.

PART	ANSWER / WORKING	MARKS	GUIDANCE
5(a)	Any one: level · pressure · moisture	**B1**	
5(b)	Any six: continually sends digitised data · compares to stored value · if outside range / matches sends signal · filled by set amount / for a set time · actuator releases water · repeats until stopped	**B6**	

Total: 7 marks

10 Common mistakes

✗ "Heat sensor"

✓ "Temperature sensor"

Use the syllabus names.

✗ "Motion sensor"

✓ "Infra-red sensor" (or accelerometer if the device itself moves)

✗ "The sensor turns on the heater"

✓ "The microprocessor sends a signal to the actuator"

Sensors only measure.

✗ Forgetting the loop repeats

✓ "The process repeats continuously"

It is a mark every time.

11 Practice

Practice: easy, medium, hard

1. Which sensor detects carbon monoxide?
2. Which sensor would switch on street lights at night?
3. Which sensor helps a driver park without hitting a wall?
1. Give two benefits of using sensors instead of people to monitor a chemical tank.
2. Give a use for a flow sensor.
1. Describe how a temperature sensor and a microprocessor keep a freezer below −18 °C. [5]

12 Can I do this?

0 / 3 ticked

- [ ] I can name all 14 sensors, what each measures and a use.
- [ ] I can give benefits of using sensors.
- [ ] I can describe a sensor + microprocessor control system.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Magnetic field (or pressure)

2.

ANSWER pH

3.

ANSWER Accelerometer

Practice: easy, medium, hard

Easy 1.

ANSWER Gas

Easy 2.

ANSWER Light

Easy 3.

ANSWER Proximity

Medium 1.

ANSWER Works continuously; no human in a dangerous place (also: accurate, fast)

Medium 2.

ANSWER e.g. monitoring the rate of water through a pipe

Hard 1.

ANSWER

Sensor continually sends readings; microprocessor compares with −18 °C; if above, signal to actuator to switch on the compressor; when below, switch off; repeats

NOTE 6

Primary and secondary storage

1 In this note

SYLLABUS 3.3 DATA STORAGE

- 3.3.1 Understand what is meant by **primary storage**, including the role of **RAM** and **ROM**, why a computer needs both and the difference between them.
- 3.3.2 Understand what is meant by **secondary storage**.
- 3.3.3 Describe the operation of **magnetic**, **optical** and **solid-state (flash memory)** storage and give examples of each.

Before this: Sensors. Next: Virtual memory and cloud storage.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Volatile

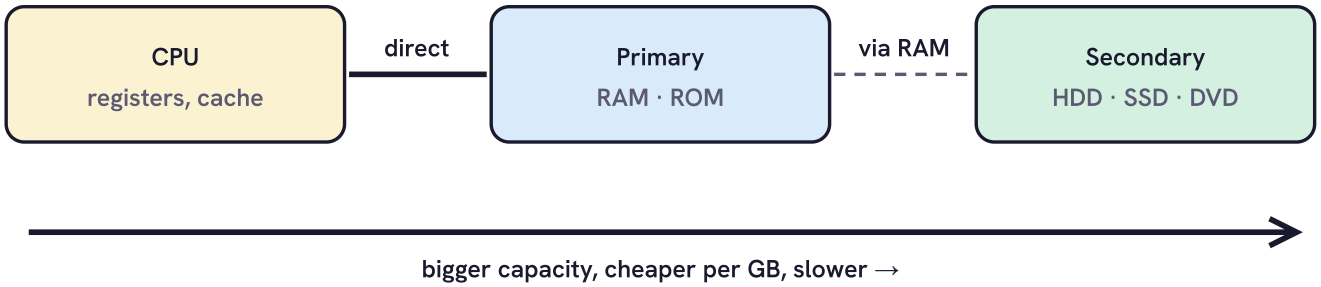
Volatile memory loses its contents when the power is turned off. **Non-volatile** keeps them.

Quick check: is a USB flash drive volatile?

No: it is non-volatile.

3 Primary storage: RAM and ROM

Primary storage is memory that is **directly accessed by the CPU**. There are two types: RAM and ROM.



Primary storage is directly accessed by the CPU. Secondary storage is not: its data is copied into RAM first.

Where primary and secondary storage sit.

	RAM (random access memory)	ROM (read only memory)
volatile?	**volatile**: contents lost when power is off	**non-volatile**: contents kept
can it be changed?	read and **written to**	**read only**: contents cannot (normally) be changed
what it stores	the **data and programs currently in use**, including parts of the operating system	the **start-up instructions**: the **BIOS / bootstrap** and **firmware**
size	large (e.g. 8-32 GB)	small

A computer needs **both**. ROM holds the instructions to **start the computer** (they must survive with the power off, and must not be changed by accident). RAM holds **whatever is running now**: it is much faster than secondary storage, so the CPU can fetch instructions quickly, and it can be written to as the data changes.

4 Secondary storage

Secondary storage is **not directly accessed by the CPU** and is **non-volatile**. It is needed to store data, files and software **permanently**: otherwise everything would have to be re-installed or re-entered every time the computer was switched on. It also provides the space for virtual memory.

Magnetic storage (hard disk drive, HDD)

GENERAL METHOD **How a hard disk drive works**

1. Data is stored on **platters**, round disks coated in a magnetic material, which **spin** at high speed.
2. Each platter is divided into concentric **tracks**, and each track into **sectors**.
3. A **read/write head** on an arm moves across the platter to the correct track.
4. The head uses an **electromagnet** to magnetise tiny areas (writing) or to sense their magnetisation (reading).
5. The direction of the magnetisation of each area represents **1 or 0**.

Optical storage (CD, DVD, Blu-ray)

GENERAL METHOD **How optical storage works**

1. The disk **spins**.
2. To write, a **laser** burns **pits** into the reflective surface; the unburnt areas are **lands**. The pits are laid in a **spiral track**.
3. To read, a laser is shone onto the surface: pits and lands **reflect the light differently**, which a sensor detects.
4. The pits and lands represent the **binary values**.
5. CD and DVD use a **red laser**; **Blu-ray** uses a **blue laser** with a shorter wavelength, so the pits are smaller and more data fits.

Solid-state storage (SSD, SD card, USB flash drive)

GENERAL METHOD **How solid-state (flash memory) storage works**

1. It has **no moving parts**: data is stored in **transistors** on silicon chips, laid out in a **grid**.
2. It uses **NAND or NOR** technology.
3. Each transistor has a **control gate** and a **floating gate**.
4. The gates control the **flow of electrons**: when electrons are trapped in the floating gate the value changes between 1 and 0.
5. The electrons stay trapped with the power off, so it is **non-volatile**.

	Magnetic (HDD)	Optical	Solid state (SSD)
moving parts	yes	yes	**none**
access speed	medium	slowest	**fastest**
capacity	very large	small (≈ 0.7-100 GB)	large
cost per GB	**cheap**	cheapest (disks)	more expensive
durability	can be damaged if dropped	scratches easily	**robust** (no moving parts)
power / noise / heat	more power, some noise	noisy drive	**low power**, silent, cool
good for	servers, cheap large storage	distributing films / software, archive	laptops, phones, portable use

TRY IT YOURSELF

1. Which storage type uses pits and lands?
2. Which storage type uses floating gates?
3. Which type of memory stores the bootstrap?

4 State the characteristic that makes RAM primary storage.

5 Summary

- Primary = directly accessed by the CPU: RAM (volatile, data in use) and ROM (non-volatile, read only, bootstrap / BIOS / firmware).
- Secondary = not directly accessed, non-volatile, permanent storage.
- Magnetic: spinning platters, tracks and sectors, read/write head with electromagnets.
- Optical: laser, pits and lands, spiral track; red laser CD/DVD, blue laser Blu-ray.
- Solid state: NAND/NOR, transistors with control and floating gates, electrons trapped; no moving parts.

IF YOU SEE …

"why does a computer need RAM?"	→ store data / software currently in use · temporarily · faster than secondary storage
"why does it need ROM?"	→ store the BIOS / bootstrap / firmware · non-volatile · should not change
"describe how optical storage works"	→ disk spun · laser · pits burnt · spiral track · pits and lands = binary

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 Which storage type?

> *"Complete the table by writing the type of storage for each statement" [6]*

Spot it operation keywords.

1. pits/lands/laser = optical; platters/tracks/electromagnets = magnetic; NAND/NOR/gates/transistors = solid state.

TYPE 2 Why RAM / ROM

> *"Explain why a computer needs RAM" [3]; "why the smartwatch needs ROM" [2]*

Spot it "why".

1. Use the RAM vs ROM table: role + one characteristic.

TYPE 3 Describe operation

> *"Describe how the data is stored on the optical disk" [4]*

Spot it "describe how".

1. Follow the method boxes in order.

TYPE 4 Compare / choose

> *"Describe three differences between solid-state and optical storage" [6]; "most suitable storage for a smartphone; explain" [4]*

Spot it "differences", "suitable".

1. Compare the SAME property for both types. For a choice, link each property to the scenario.

7 What the examiner looks for

"Identify the most suitable type of secondary storage for the smartphone. Explain your choice" [4]

Marking points (one mark each, up to the marks shown)

- Solid state (1 mark), then any three:
- small / thin … so it fits easily into the smartphone
- no moving parts … so it is durable; data less likely to be lost if the phone is dropped
- fast read/write … so files and apps load quickly
- low power … so it does not drain the battery
- runs cool and quietly

KEYWORDS **no moving parts** **durable** **low power** **battery** **fast**

TOO VAGUE listing features without linking them to the smartphone

8 Past-paper questions, solved

0478/13/M/J/24 Q4 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

4 The table contains statements about types of secondary storage.

Complete the table by writing the correct type of secondary storage for each statement.

type of secondary storage	statement
.....	Pits and lands are created on a reflective surface.
.....	NAND or NOR technology is used.
.....	Platters are spun that are divided into tracks and sectors.
.....	Electromagnets are used to read and write data.
.....	Transistors are used as control gates and floating gates.
.....	A red or blue laser is used to read and write data.

[6]

Swipe sideways to read the whole question

How to start Look for the keyword in each statement and map it with the operation methods.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

optical · solid state · magnetic · magnetic · solid state · optical

PART	ANSWER / WORKING	MARKS	GUIDANCE
4	optical (pits and lands) · solid-state (NAND/NOR) · magnetic (platters) · magnetic (electromagnets) · solid-state (control and floating gates) · optical (red or blue laser)	B6	

Total: 6 marks

2210/12/M/J/24 Q9 ↗ Paper 1 · Computer systems **8 marks** ⤢ Full size

9 A company uses both solid-state and optical secondary storage.

(a) Explain why a computer needs secondary storage.

..... [2]

(b) Describe **three** differences between solid-state and optical storage.

[6]

Swipe sideways to read the whole question

How to start (b) is six marks: three properties, each stated for BOTH types.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) To store data and files permanently, otherwise programs would need to be installed again every time the computer was used.

(b) Solid-state has no moving parts, whereas optical has moving parts (the disk spins). Solid-state is faster to access data, whereas optical is slower. Solid-state stores data in transistors using NAND/NOR gates, whereas optical uses a laser to burn pits and lands onto a disk.

PART	ANSWER / WORKING	MARKS	GUIDANCE
9(a)	Any two: store permanently · otherwise reinstall each time · allow software to be installed · virtual memory	B2	
9(b)	Any six (max 3 for one type): moving parts · access speed · power · noise · durability · capacity · cost per GB · how data is stored	B6	

Total: 8 marks

2210/12/O/N/25 Q1 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

1 A toy store gives each of the toys it sells a unique code. The codes are 3-digit hexadecimal codes, for example A4B.

A computer is used to store a database of the codes. The computer has 12-bit registers.

(e) The hexadecimal code for each toy is stored in a barcode that is displayed on each toy.

Each time a customer buys a toy, the barcode is scanned and the amount of stock stored in the database for that toy is reduced by 1.

An item of hardware is used in this system to receive the hexadecimal code from the barcode scanner and find it in the database. The item of hardware is built into a single chip.

(iv) A backup of the database is made at the end of each day using optical storage.

Describe how the database is written to the optical storage.

..... [4]

Swipe sideways to read the whole question

How to start Follow the optical method: four marking points.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

The disk is spun. A laser is shone onto the disk and burns pits into its surface in a spiral track. The pits and the unburnt lands represent the binary values.

PART	ANSWER / WORKING	MARKS	GUIDANCE
1(e)(iv)	Any four: disk spun · laser shone · pits burnt · in a spiral track · pits and lands represent binary	B4	

Total: 4 marks

9 Common mistakes

✗ "ROM stores the operating system"

✓ "ROM stores the BIOS / bootstrap"

The OS is on secondary storage and loaded into RAM.

✗ "RAM is permanent storage"

✓ "RAM is volatile: data in use, lost when power is off"

✗ "An SSD uses lasers"

✓ "An SSD uses transistors with control and floating gates"

✗ "Solid state is faster" (only one side)

✓ "Solid state is faster … optical is slower"

Differences need both sides.

10 Practice

Practice: easy, medium, hard

1. Is RAM volatile or non-volatile?
2. Name two examples of optical storage.
3. What are platters divided into?
1. State two differences between RAM and ROM.
2. Why does a Blu-ray disk hold more data than a DVD?
1. A video editor needs fast, large storage in a laptop that is carried every day. Recommend a storage type and justify it. [3]

11 Can I do this?

0 / 4 ticked

- [ ] I can explain primary storage, and why a computer needs both RAM and ROM.
- [ ] I can explain why secondary storage is needed.
- [ ] I can describe how magnetic, optical and solid-state storage work.
- [ ] I can compare storage types and choose one for a scenario.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER Optical

2.

ANSWER Solid state

3.

ANSWER ROM

4.

ANSWER It is directly accessed by the CPU

Practice: easy, medium, hard

Easy 1.

ANSWER Volatile

Easy 2.

ANSWER e.g. CD, DVD (also Blu-ray)

Easy 3.

ANSWER Tracks and sectors

Medium 1.

ANSWER

RAM volatile / ROM non-volatile; RAM can be written to / ROM read only (also contents)

Medium 2.

ANSWER A blue laser has a shorter wavelength, so pits are smaller and closer together

Hard 1.

ANSWER

Solid state: no moving parts so durable when carried; fast access for large video files; low power for battery

NOTE 7

Virtual memory and cloud storage

1 In this note

SYLLABUS 3.3 DATA STORAGE

- 3.3.4 Describe what is meant by **virtual memory**, how it is created and used and why it is necessary.
- 3.3.5 Understand what is meant by **cloud storage**.
- 3.3.6 Explain the **advantages and disadvantages** of storing data on the cloud in comparison to storing it **locally**.

Before this: Primary and secondary storage. Next: Network hardware.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

RAM

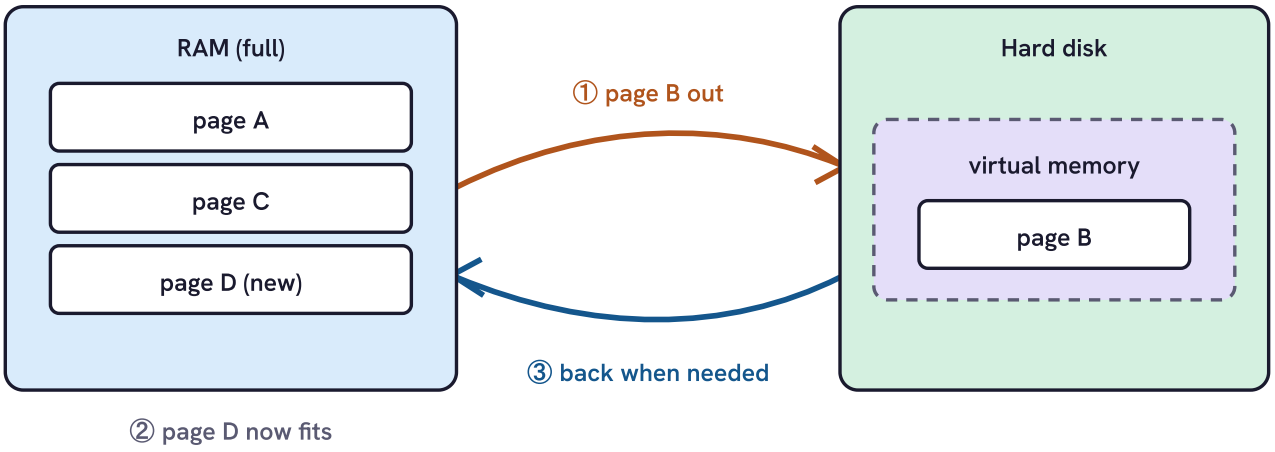
RAM holds the data and programs currently in use. It is fast but limited in size.

Quick check: what happens if you open more programs than RAM can hold?

Without virtual memory, the computer could crash or refuse to open them.

3 Virtual memory

Virtual memory is an area of **secondary storage** (usually the hard disk or SSD) that is used **as if it were RAM** when RAM is full. It is created by **partitioning** part of the secondary storage. Data is moved in blocks called **pages**.



Pages are swapped between RAM and virtual memory.

GENERAL METHOD **How virtual memory is used**

1. RAM becomes **full**.
2. Pages of data that are **not needed immediately** are **transferred from RAM to virtual memory**.
3. This **frees space in RAM** for the new data or program that is needed now.
4. When a page in virtual memory is **needed again**, it is **transferred back into RAM** (another page may be moved out to make room).

Why it is necessary	Its drawback
stops the computer **crashing** when RAM is full; lets **more / larger programs** run than RAM alone allows	secondary storage is **much slower** than RAM, so heavy use slows the computer ("disk thrashing" when pages keep swapping)

4 Cloud storage

Cloud storage is storage that is **accessed remotely**, usually over the **internet**, on a **collection of servers** owned and maintained by a **third party** (e.g. Google Drive, iCloud, OneDrive). The cloud still needs **physical servers and storage**: the data is just not on your own device. Storing data on your own device or your own server is **storing it locally**.

Advantages of the cloud (vs local)	Disadvantages of the cloud (vs local)
data can be **accessed from any location** and any device with an internet connection	needs an **internet connection**: no or unstable connection = no access
the **third party maintains** the hardware and its security; you do not	you **rely on the third party**: its security, and whether it stays in business
storage can be **increased easily** without buying new hardware	an **ongoing fee** (subscription) is often charged
no need to buy, house and power your own storage hardware	data may be **less secure** / stored in another country
the provider **backs up** the data	uploading / downloading large files can be **slow**
easy to **share** and collaborate on files	

TRY IT YOURSELF

1. Where is virtual memory created?
2. What are the blocks of data moved by virtual memory called?
3. Give one disadvantage of cloud storage.

5 Summary

- Virtual memory: a partition of secondary storage used as RAM when RAM is full.
- Pages not needed now move RAM → virtual memory; moved back when needed.
- Necessary: prevents crashing, more programs run. Drawback: slower than RAM.
- Cloud: remote collection of servers, third party, accessed over the internet; still physical servers.
- Cloud vs local: anywhere access, no maintenance, scalable, backed up · needs internet, third party, fees, security.

IF YOU SEE …

"explain how virtual memory can be used in this scenario"	→ partition · page B to VM · space for D · B back when needed
"explain two advantages of cloud storage"	→ point + consequence for the scenario ("… so employees can work from home")

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

6 Ways they test it

TYPE 1 **VM scenario**

> *"Pages A, B, C in RAM; page D needs to be sent; explain how virtual memory can be used" [4]*

Spot it named pages.

1. Use the letters given: page B to VM, D into RAM, B back later.

TYPE 2 **Name it**

> *"Give the name of the partitioned section of the secondary storage" [1]*

Spot it "partitioned".

1. Virtual memory.

TYPE 3 **Cloud definition**

> *"Describe what is meant by cloud storage" [2]*

Spot it "cloud".

1. collection of servers · remote · accessed over the internet · third party

TYPE 4 **Cloud pros / cons**

> *"Explain two advantages for the owners ..." [4]; "one disadvantage to employees" [2]*

Spot it "explain".

1. Two marks each: the point, then "... meaning that" for the people in the question.

7 What the examiner looks for

"Explain two advantages for the owners of the company of storing its data in cloud storage" [4]

Marking points (one mark each, up to the marks shown)

- Data can be accessed from any location ... meaning employees can work from anywhere with a connection
- Hardware is owned/maintained by a third party ... so the company is not responsible for maintenance / security
- Storage can be increased easily ... without buying new hardware
- No need to house the hardware ... saving the cost of the space
- The cloud system backs up the data ... so the company does not need to

KEYWORDS **any location** **third party** **maintain** **increase** **back up**

8 Past-paper questions, solved

0478/13/M/J/23 Q10 ↗ Paper 1 · Computer systems **4 marks** ⤢ Full size

10 A computer has pages A, B and C that are stored in RAM. Page D needs to be sent to the RAM but the RAM is full.

Page B is **not** needed immediately.

Explain how virtual memory can be used in this scenario.

..... [4]

Swipe sideways to read the whole question

How to start Follow the method with the question's letters.

▼ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

Part of the secondary storage is partitioned to create virtual memory. Page B, which is not needed immediately, is sent from RAM to virtual memory. This makes space in RAM for page D. When page B is needed again (once another page has been processed), it is sent back from virtual memory to RAM.

PART	ANSWER / WORKING	MARKS	GUIDANCE
10	Any four: secondary storage partitioned · page B sent to VM · makes space for page D · once another page not required · page B sent back to RAM when required	B4	

Total: 4 marks

2 A company employee is editing a video for the company's website.

Data is stored in the random access memory (RAM) when the video is edited.

The RAM becomes full and pages of data are transmitted to a partitioned section of the secondary storage to stop the computer from crashing.

(a) Give the name of the partitioned section of the secondary storage that is used in this process.

..... [1]

(b) The secondary storage is a hard disk drive (HDD). An HDD is an example of magnetic storage.

One feature of magnetic storage is that it uses platters.

Give **three** other features of magnetic storage.

[3]

(c) Give the reasons why an HDD is an example of secondary storage.

..... [2]

Swipe sideways to read the whole question

How to start (b) the question already gives platters, so give three other features. (c) two reasons from the definition of secondary storage.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Virtual memory.

(b) The platters are divided into tracks and sectors. The platters rotate (it has moving parts). It uses a read/write head with an electromagnet.

(c) It is not directly accessed by the CPU, and it stores data permanently until the user deletes it (non-volatile).

PART	ANSWER / WORKING	MARKS	GUIDANCE
2(a)	Virtual memory	**B1**	
2(b)	Any three: tracks / sectors · platters rotate / moving parts · read/write head · electromagnet · magnetised dots	**B3**	
2(c)	not directly accessed by the CPU · stores data permanently / non-volatile	**B2**	

Total: 6 marks

6 A company uses cloud storage to store its data.

(a) Tick (✓) **one** box to show which is **not** a characteristic of cloud storage.

A Data is accessed through a network ☐

B Data is stored locally ☐

C Data is stored remotely ☐

D Physical servers are used to store the data ☐

[1]

(b) Explain **two** advantages for the owners of the company of storing its data in cloud storage.

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

(c) Explain **one** disadvantage to employees of the company storing data in the cloud.

.....

.....

.....

..... [2]

Swipe sideways to read the whole question

How to start (b) and (c) are point + expansion: say what happens for the owners / the employees.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) B (data is stored locally).

(b) 1: The data can be accessed from any location, meaning employees can work from anywhere with an internet connection. 2: The hardware is maintained by a third party, meaning the company is not responsible for maintaining it or its security.

(c) An internet connection is needed, and if it is unavailable or unstable the employees cannot access the data.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)	B	B1	
6(b)	Two advantages with expansion: any location ... work anywhere · third party ... not responsible · increase storage ... no new hardware · no need to house hardware ... saves cost · backs up ... company need not	B4	
6(c)	internet connection needed ... if unavailable, no access // pressured to work out of hours ... access from anywhere	B2	

Total: 7 marks

9 Common mistakes

✗ "Virtual memory is extra RAM"

✓ "Virtual memory is part of secondary storage used as RAM"

✗ "Virtual memory makes the computer faster"

✓ "It stops it crashing; it is slower than RAM"

✗ "The cloud has no hardware"

✓ "Cloud data is on physical servers owned by a third party"

✗ "You can access it anywhere" with no expansion

✓ "... so employees can work from home"

Explain = point + effect.

10 Practice

Practice: easy, medium, hard

1. Is cloud storage accessed locally or remotely?
2. What is virtual memory used for?
1. Explain why virtual memory is necessary. [2]
2. Give two advantages of storing photos on the cloud instead of a phone.
1. Explain one disadvantage of a computer relying heavily on virtual memory. [2]

11 Can I do this?

0 / 3 ticked

- [ ] I can describe how virtual memory is created and used, and why it is necessary.
- [ ] I can describe cloud storage.
- [ ] I can explain advantages and disadvantages of cloud storage vs local storage.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER On secondary storage (a partition of the hard disk / SSD)

2.

ANSWER Pages

3.

ANSWER Needs an internet connection (also: relies on third party, fee, security)

Practice: easy, medium, hard

Easy 1.

ANSWER Remotely

Easy 2.

ANSWER As extra RAM when RAM is full

Medium 1.

ANSWER

When RAM is full, pages can be moved out so new data fits; stops the computer crashing

Medium 2.

ANSWER

Access from any device / location; frees phone storage; backed up if the phone is lost

Hard 1.

ANSWER

Secondary storage is slower than RAM, so moving pages back and forth slows the computer

NOTE 8

Network hardware

1 In this note

SYLLABUS 3.4 NETWORK HARDWARE

- 3.4.1 Understand that a computer needs a **network interface card (NIC)** to access a network.
- 3.4.2 Understand what is meant by, and the purpose of, a **media access control (MAC) address**, including its structure.
- 3.4.3 Understand what is meant by, and the purpose of, an **internet protocol (IP) address**, and that there are different types: **static / dynamic**, **IPv4 / IPv6**.
- 3.4.4 Describe the role of a **router** in a network.

Before this: Virtual memory and cloud storage.

PART 1

Learn the topic

The notes: every idea from the start, with our own examples.

2 What you should already know

Hexadecimal

One hex digit = 4 bits; two hex digits = 1 byte.

Quick check: how many bits in 12 hex digits?

48 bits.

Packets

Data on a network is sent in packets, each with the destination address in its header.

Quick check: why does a packet need an address?

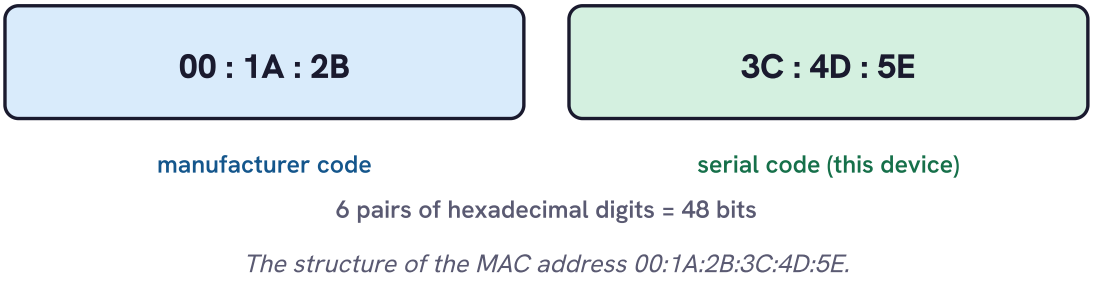
So routers can send it to the right device.

3 Network interface card (NIC)

A **network interface card (NIC)** is the component in a device that **allows it to connect to a network**. It can be wired (an Ethernet port) or wireless (a **WNIC**). Every NIC is given a **MAC address** when it is **manufactured**.

4 MAC address

A **media access control (MAC) address** is a **unique** address **assigned by the manufacturer** that identifies a device on a network. It is **usually written in hexadecimal** (12 hex digits, 48 bits), in pairs separated by colons or dashes. Because it is set at manufacture it normally **does not change**.



The structure of the MAC address 00:1A:2B:3C:4D:5E.

It has two parts: the **manufacturer code** (identifies who made the device) and the **serial code** (identifies this particular device from that manufacturer).

5 IP address

An **internet protocol (IP) address** is an address **allocated by the network** (normally by the **router**) that is used to **identify a device on a network** so data can be sent to it. Unlike a MAC address it can change, for example when the device joins a different network.

Static IP address	Dynamic IP address
does not change: the same every time the device connects	**can change** each time the device connects to the network
set manually / reserved	allocated **automatically** by the router (from a pool)
used for servers (a web server must always be found at the same address)	used for most home devices; addresses are reused, so fewer are needed

	IPv4	IPv6
size	**32 bits**	**128 bits**
written as	**denary**, **4 groups** of numbers **0-255**, separated by **dots**	**hexadecimal**, **8 groups** of 4 hex digits (0000-FFFF), separated by **colons**
example	192.168.1.25	2001:0db8:85a3:0000:0000:8a2e:0370:7334 shortened: 2001:db8:85a3::8a2e:370:7334
number of addresses	about 4.3 billion (2^{32}): **running out**	**far more** (2^{128})
shortening	all digits shown	leading zeros dropped; **a double colon** :: can replace consecutive groups of zeros (once only)

> Similarities to remember: both IPv4 and IPv6 identify a device on a network, both are unique on that network, both can be static or dynamic, both can be assigned by a router, both can be public or private.

6 Router

A **router** **sends data to a specific destination** on a network: it reads the destination IP address in each packet's header and **forwards the packet** towards it. A router can **assign IP addresses** to the devices connected to it, and it **connects a local network to the internet** (a home router joins every device in the house to the internet).

Term	One-line meaning
NIC	component that lets a device connect to a network
MAC address	unique hex address set by the manufacturer: manufacturer code + serial code
IP address	address allocated by the network to identify a device; static or dynamic; IPv4 or IPv6
Router	forwards packets to their destination; assigns IP addresses; connects a LAN to the internet

TRY IT YOURSELF

1. Which address is assigned by the manufacturer?

2 How many bits is an IPv6 address?

3 Which device assigns dynamic IP addresses on a home network?

4 Is 192.168.1.300 a valid IPv4 address?

7 Summary

- NIC: needed to connect to a network; given a MAC address at manufacture.
- MAC: unique, set by the manufacturer, hex, 48 bits; manufacturer code + serial code.
- IP: allocated by the network to identify a device; static (same) or dynamic (can change each time).
- IPv4: 32-bit, 4 denary groups 0-255, dots. IPv6: 128-bit, 8 hex groups, colons, :: shortening, more addresses.
- Router: forwards packets to the destination, assigns IP addresses, connects a LAN to the internet.

IF YOU SEE …

"describe the characteristics of an IPv4 address"	→ denary · 0-255 · 32 bits · 4 groups · dots · unique · static or dynamic
"describe two differences between IPv4 and IPv6"	→ state each property for BOTH: bits · denary vs hex · dots vs colons · groups

PART 2

How it is examined

Question types, what the examiner gives marks for, and real past-paper questions solved.

8 Ways they test it

TYPE 1 Identify

> *"Identify the component needed to access a network" [1]; "the type of address allocated by the manufacturer" [1]*

Spot it "identify".

1. NIC · MAC address · router.

TYPE 2 Terms table

> *"Complete the table by giving the missing term or definition" [5]*

Spot it a table.

1. Use the one-line meanings; firewall also appears (chapter 5).

TYPE 3 IPv4 / IPv6

> *"Describe the characteristics of an IPv4 address" [4]; "two differences" [4]; "give an example" [1]*

Spot it "IPv4", "IPv6".

1. Comparisons need both sides. An example must follow the format exactly.

TYPE 4 Dynamic

> *"Describe what is meant by a dynamic IP address" [3]*

Spot it "dynamic".

1. identifies a device · can change · each time it connects

9 What the examiner looks for

"Describe the characteristics of an IPv4 address" [4]

Marking points (one mark each, up to the marks shown)

- It is denary based … with numbers between 0 and 255
- It is 32 bits
- 4 sets / groups of numbers … separated by dots
- Any two: unique · can be static or dynamic · can be public or private · contains the network prefix and host number

KEYWORDS **denary** **0-255** **32 bits** **4 groups** **dots**

10 Past-paper questions, solved

2210/11/M/J/23 Q6 ↗ Paper 1 · Computer systems **6 marks** ⤢ Full size

6 A user wants to connect their computer to a network.

(a) (i) Identify the component in the computer that is needed to access a network.

..... [1]

(ii) Identify the type of address that is allocated to the component by the manufacturer, which is used to uniquely identify the device.

..... [1]

(b) A dynamic internet protocol (IP) address is allocated to the computer when it is connected to the network.

(i) Identify the device on the network that can connect multiple devices and automatically assign them an IP address.

..... [1]

(ii) Describe what is meant by a dynamic IP address.

..... [3]

Swipe sideways to read the whole question

How to start Four short identify answers and one 3-mark description.

▾ Show a full-mark answer and the mark scheme · official marking

WHAT TO WRITE

(a)(i) Network interface card (NIC). (ii) MAC address.

(b)(i) Router. (ii) An IP address that uniquely identifies the device on the network, but it can change: a new one may be allocated each time the device connects to the network.

PART	ANSWER / WORKING	MARKS	GUIDANCE
6(a)(i)	NIC // WNIC	B1	
6(a)(ii)	MAC address	B1	
6(b)(i)	Router	B1	
6(b)(ii)	uniquely identifies a device · can change · each time it is connected	B3	

Total: 6 marks

0478/13/M/J/23 Q9 ↗ Paper 1 · Computer systems **5 marks** ⤢ Full size

9 A device can be given an internet protocol (IP) address. This can be an IPv4 or IPv6.

(a) Give **one** similarity between IPv4 and IPv6.

..... [1]

(b) Describe **two** differences between IPv4 and IPv6.

[4]

Swipe sideways to read the whole question

How to start (b) each difference = 2 marks: the IPv4 side and the IPv6 side.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

(a) Both are used to identify a device on a network.

(b) 1: IPv4 is 32 bits, whereas IPv6 is 128 bits. 2: IPv4 is written in denary separated by dots, whereas IPv6 is written in hexadecimal separated by colons.

PART	ANSWER / WORKING	MARKS	GUIDANCE
9(a)	Any one: identify a device · static / dynamic · unique · assigned by a router · public / private	B1	
9(b)	Two differences, both sides each: denary / hex · dots / colons · 32 / 128 bit · 4 / 8 groups · 0-255 / 0000-FFFF · IPv6 :: shortening · fewer / more addresses	B4	

Total: 5 marks

3 **Five** network terms or definitions are given in the table.

Complete the table by giving the missing term or definition.

Term	Definition
router	....
.....	This address is assigned by the network and used to identify a device on a network.
network interface card (NIC)	....
.....	This address is assigned by the manufacturer and is used to uniquely identify the device.
.....	This can be hardware or software based and filters traffic coming into and out of a network.

[5]

Swipe sideways to read the whole question

How to start Three definitions and two terms. "Assigned by the network" = IP; "assigned by the manufacturer" = MAC.

▼ **Show a full-mark answer and the mark scheme** · official marking

WHAT TO WRITE

Router: a device that forwards packets to their correct destination on a network. IP address. NIC: a component in a device that enables it to connect to a network. MAC address. Firewall.

PART	ANSWER / WORKING	MARKS	GUIDANCE
3	router definition · IP address · NIC definition · MAC address · firewall // proxy server	B5	

Total: 5 marks

11 Common mistakes

✗ "A MAC address is assigned by the router"	✓ "MAC: by the manufacturer. IP: by the network / router"
✗ "IPv6 uses dots"	✓ "IPv6 uses colons and hexadecimal"
✗ IPv4 example 256.1.1.1	✓ every group 0-255, e.g. 10.245.3.99
✗ "A dynamic IP address changes all the time"	✓ "It can change each time the device connects"

12 Practice

Practice: easy, medium, hard

1 How many groups of numbers are in an IPv4 address?

2 What number base is a MAC address usually written in?

3 What does NIC stand for?

1 Name the two parts of a MAC address.

2 Give one reason why IPv6 was introduced.

1 Explain why a web server should have a static IP address. [2]

2 Shorten 2001:0db8:0000:0000:0000:0000:0000:0001.

13 Can I do this?

0 / 4 ticked

- [ ] I know a device needs a NIC to access a network.
- [ ] I can describe a MAC address and its structure.
- [ ] I can describe IP addresses: static vs dynamic, IPv4 vs IPv6.
- [ ] I can describe the role of a router.

Anything unticked: revise that section first (each line links to it). All ticked: take the quiz.

Answers

Answers to the "Try it yourself" and practice questions on this page. Try every question first.

Try it yourself 1

1.

ANSWER **MAC address**

2.

ANSWER **128**

3.

ANSWER **Router**

4.

ANSWER **No: 300 is greater than 255**

Practice: easy, medium, hard

Easy 1.

ANSWER **4**

Easy 2.

ANSWER **Hexadecimal**

Easy 3.

ANSWER **Network interface card**

Medium 1.

ANSWER **Manufacturer code and serial code**

Medium 2.

ANSWER **IPv4 addresses are running out; IPv6 has far more addresses**

Hard 1.

ANSWER **Its address must not change so users / DNS can always find it at the same IP**

Hard 2.

ANSWER **2001:db8::1**