Exercise walk-through

3.1.4 Embedded systems, monitoring and control

A-Level Computer Science

You must be able to

- explain what an embedded system is, and give its benefits and drawbacks
- explain the difference between a monitoring system and a control system
- choose suitable sensors (temperature, pressure, infra-red, sound) and actuators for a system
- describe, step by step, how a control system works
- explain the importance of feedback

1 The method

Method — Embedded systems

An **embedded system** is a **microprocessor** 微处理器 system **built into a larger device**, with **one dedicated task**.

- Its program is in **ROM**; the user cannot install other programs.
- Examples: a washing machine, a microwave oven, a car's engine unit. **Not** a laptop: that is a general-purpose computer.

benefits	**drawbacks**
small, so it fits inside the device	hard to **upgrade**
low **power**; **cheap** to mass-produce	hard to **repair**
reliable; starts at once	only **one task**
	can be **hacked** if it is connected and never updated

Method — Embedded systems

"Explain why this is an embedded system" = three points about **this** device: inside a larger device, one fixed task, program in ROM.

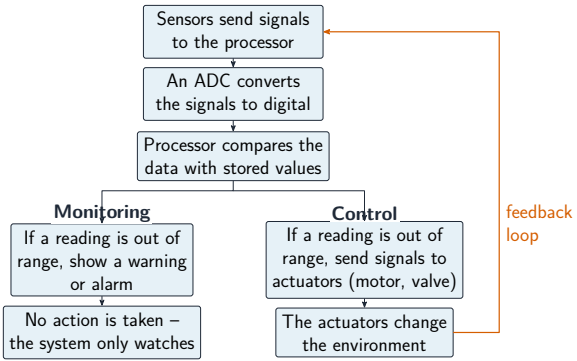
Method — Monitoring or control?

	monitoring system	**control system**
what it does with a reading	**records**, **displays** or **warns** a person	**acts**: it changes the process **itself**
output devices	screen, alarm, light	**actuators**: motor, pump, heater, valve
does the output change the next reading?	no	**yes**: feedback
examples	burglar alarm, heart monitor, weather station	central heating, greenhouse, automatic braking

Ask: *does the computer itself change the thing it measures?* No = monitoring. Yes = control.

Method — Monitoring or control?

center Ask: does the computer itself change the thing it measures?



Monitoring reports data; a control system acts through a feedback loop

Method — Sensors and actuators

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

- A sensor's signal is **analogue**, so an **ADC** converts it to binary first.
- An **actuator** turns the processor's signal into **movement** or another physical change.
- There is no "weight sensor": weight is measured with a **pressure** sensor.

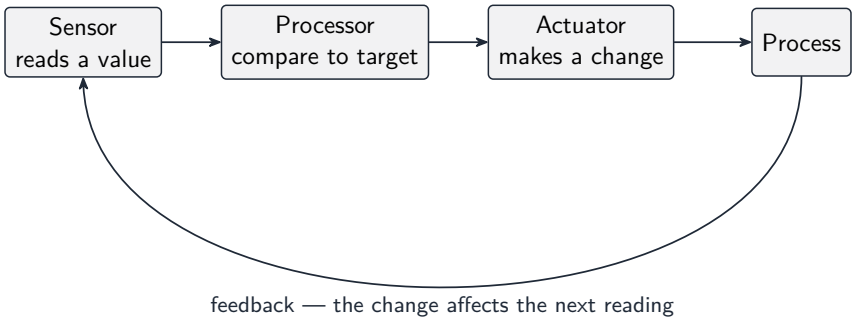
Method — How a control system works: six steps

1. The **sensor** measures the temperature continuously.
2. The **ADC** converts the reading to digital.
3. The microprocessor **compares** it with the stored **preset value** 预设值 (25 °C).
4. Below 25 °C: a signal to the **actuator** switches the heater **on**.
5. 25 °C or above: a signal switches the heater **off**.
6. The heater changes the next reading, and the process **repeats continuously**.

Step 6 is **feedback**: the output of the system changes its own next input, so the system **corrects itself automatically**, with no person involved.

Method — How a control system works: six steps

Step 6 is feedback : the output of the system changes its own next input, so the system corrects itself...



2 Practice

Practice 2.1 ▪ 5 marks

Tick (✓) **one** box in each row to show whether the system is a monitoring system or a control system.

System	monitoring	control
A display in a car shows the temperature outside.		
An air conditioner keeps a room at 22 °C.		
An alarm sounds when a window is broken.		
A street light switches itself on when it gets dark.		
A machine in a hospital records a patient's heart rate.		

Solution 2.1

Method: Monitoring or control? — p.6

Worked steps

- a display only tells the driver → **monitoring** B1
- the air conditioner changes the room temperature itself → **control** B1
- an alarm only warns a person → **monitoring** B1
- the light is switched on by the system itself → **control** B1
- recording only → **monitoring** B1

Practice 2.2 ▪ 4 marks

Name the most suitable sensor from the list for each system.

Practice 2.2 (a)

a door that opens when a person walks up to it

Solution 2.2 (a)

Method: Sensors and actuators — p.8

Worked steps

a person's body heat, or a broken beam → **infra-red** B1

Practice 2.2 (b)

a system that warns when a baby is crying in another room

Solution 2.2 (b)

Worked steps

crying is a loud sound $\rightarrow$ **sound** B1

Practice 2.2 (c)

a system that checks that a freezer stays cold enough

Solution 2.2 (c)

Worked steps

how cold it is $\rightarrow$ **temperature** B1

Practice 2.2 (d)

a mat that detects a person standing on it

Solution 2.2 (d)

Worked steps

a force pressing on the mat $\rightarrow$ **pressure** B1

Practice 2.3 ▪ 2 marks

State what is meant by an **actuator**, and give **one** example.

Solution 2.3

Worked steps

- a device that turns a signal from the processor into movement or another physical change B1
- for example a motor, a pump, a valve or a heater B1

Practice 2.4 ▪ 2 marks

Explain why an **ADC** is needed between a temperature sensor and a microprocessor.

Solution 2.4

Method: How a control system works: six steps — p.9

Worked steps

- the sensor produces an **analogue** signal (a continuously changing voltage) B1
- the microprocessor can process only **digital** (binary) data, so the signal must be converted B1

Practice 2.5 ▪ 4 marks

State whether each device contains an embedded system. Give a reason for each answer.

Practice 2.5 (a)

a microwave oven

Solution 2.5 (a)

Method: Embedded systems — p.4

Worked steps

yes B1

- its microprocessor is built into the oven and only runs the fixed cooking program B1

Practice 2.5 (b)

a desktop computer

Solution 2.5 (b)

Worked steps

no B1

- it is a general-purpose computer: the user can install and run many different programs B1

Practice 2.6 ▪ 5 marks

Complete the description of a control system. Use words from the list. Each word is used once.
The ..... measures the temperature and sends the reading to the microprocessor. The microprocessor ..... the reading with a ..... value. If the reading is too low, the microprocessor sends a signal to an ..... to switch on a heater. The process is repeated .....
.

Solution 2.6

Method: How a control system works: six steps — p.9

Worked steps

- the device that measures → **sensor** B1
- the microprocessor **compares** the reading with a **preset** value B1 B1
- the heater is switched by an **actuator** B1
- the loop never stops → **continuously** B1

3 Exam-style

Exam-style 3.1 ▪ 7 marks

A modern washing machine is controlled by an embedded system.

Exam-style 3.1 (a) ▪ 3 marks

Explain why the controller of the washing machine is an embedded system.

Solution 3.1 (a)

Method: Embedded systems — p.4

Worked steps

it is a microprocessor system built into a larger device, the washing machine B1

- it has one dedicated task: running the wash programs B1
- its program is stored in ROM and the user cannot install other software B1

Exam-style 3.1 (b) ▪ 2 marks

Give **two** benefits of using an embedded system in the washing machine.

Solution 3.1 (b)

Worked steps

any **two** of:

- it is small, so it fits inside the machine B1
- it is cheap to mass-produce B1
- it uses little power B1
- it is reliable, and it is ready as soon as the machine is switched on B1

Exam-style 3.1 (c) ▪ 2 marks

Give **two** drawbacks of using an embedded system in the washing machine.

Solution 3.1 (c)

Worked steps

any **two** of:

- it is hard to upgrade or to add new wash programs B1
- it is hard to repair, so a fault often means replacing the whole unit B1
- it can only do this one task B1
- if the machine is connected to the internet and is never updated, it can be hacked B1

Exam-style 3.2 ▪ 5 marks

A weather station on a mountain measures the temperature and the wind speed every minute and sends the readings to an office.

Exam-style 3.2 (a) ▪ 2 marks

State whether this is a monitoring system or a control system.
Justify your answer.

Solution 3.2 (a)

Method: Monitoring or control? — p.6

Worked steps

monitoring B1

- the system only measures and reports the readings; it does nothing to change the temperature or the wind B1

Exam-style 3.2 (b) ▪ 3 marks

The office wants to be warned when the temperature falls below 0 °C. **Describe** how the system does this.

Solution 3.2 (b)

Worked steps

the sensor's reading is converted by an ADC and sent to the microprocessor B1

- the microprocessor compares each reading with the stored value 0 °C B1
- if the reading is below 0 °C, it sends a warning (a message or an alarm) to the office B1

Exam-style 3.3 ▪ 9 marks

A swimming pool must stay between 26 °C and 28 °C. A control system uses a temperature sensor, a microprocessor and a heater.

Exam-style 3.3 (a) ▪ 6 marks

Describe how the control system keeps the water in this range.

Solution 3.3 (a)

> Method: How a control system works: six steps — p.9

Worked steps

any **six** of:

- the temperature sensor measures the water temperature and sends the reading to the microprocessor B1
- an ADC converts the analogue reading to digital B1
- the microprocessor compares the reading with the stored values 26 °C and 28 °C B1
- if the reading is below 26 °C, it sends a signal to the actuator to switch the heater on B1

Solution 3.3 (a)

- if the reading is above 28 °C, it sends a signal to switch the heater off **B1**
- if the reading is in the range, no action is taken **B1**
- the process is repeated continuously **B1**

Exam-style 3.3 (b) ▪ 3 marks

Explain the importance of **feedback** in this system.

Solution 3.3 (b)

Worked steps

the heater changes the water temperature, so the output of the system affects its next input B1

- the sensor measures the effect of each change, so the system knows whether to keep heating or to stop B1
- so the system corrects itself automatically and keeps the water in the range, without a person B1

Exam-style 3.4 ▪ 10 marks

A car park has an automatic barrier. The barrier rises when a car arrives and the driver has paid. It comes down again after the car has passed. If a second car follows too closely, the barrier must not come down on it.

Exam-style 3.4 (a) ▪ 4 marks

Identify **two** sensors the system needs. For each one, state what it is used to detect.

Solution 3.4 (a)

Method: Monitoring or control? — p.6

Worked steps

one mark for each sensor, and one for its use, for example:

- an **infra-red** sensor B1 detects a car arriving at, or still under, the barrier, because the car breaks the beam B1
- a **pressure** sensor in the road B1 detects a car waiting at the barrier or passing over it B1

Exam-style 3.4 (b) ▪ 2 marks

Identify the **actuator** in this system, and state what it does.

Solution 3.4 (b)

Worked steps

a **motor** B1

- it raises and lowers the barrier when the microprocessor sends it a signal B1

Exam-style 3.4 (c) ▪ 2 marks

Explain why the barrier system is a control system, not a monitoring system.

Solution 3.4 (c)

Worked steps

the system does not only report what the sensors detect: it **acts** by moving the barrier itself B1

- and the position of the barrier depends on the next sensor readings (whether a car is still under it), so there is feedback B1

Exam-style 3.4 (d) ▪ 2 marks

The car park owner could replace the embedded controller with a desktop computer running the same program. Give **two** reasons why the embedded controller is the better choice.

Solution 3.4 (d)

Worked steps

any **two** of:

- it is smaller and cheaper B1
- it uses less power B1
- it is more reliable: it runs only this one program, with no other software to fail or be changed B1
- it starts at once after a power cut B1