

3.1.4 Embedded systems, monitoring and control

Name: _____ Class: _____ Date: _____

Total: 53 marks

KEY WORDS embedded system 嵌入式系统 • sensor 传感器 • actuator 执行器 • feedback 反馈
• preset value 预设值

Objective

Learn to answer exam questions on **embedded systems** 嵌入式系统 and on **monitoring and control systems** 监控与控制系统: what they are, which **sensor** 传感器 and **actuator** 执行器 a system needs, and how **feedback** 反馈 keeps a process steady. This is the last sheet of 3.1; memory, storage and devices were on sheets 3.1.1 to 3.1.3.

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 Worked examples

Study these first. Each one shows a **method** that a question later on this sheet needs.

■ Embedded systems

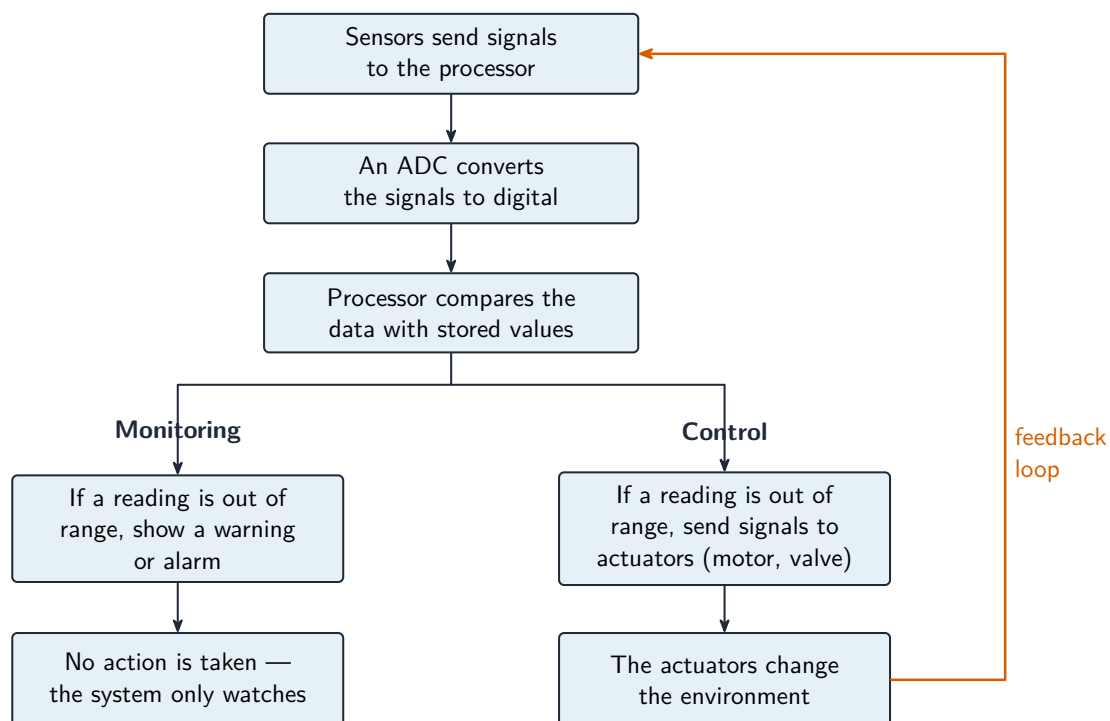
An **embedded system** is a **microprocessor** 微处理器 system **built into a larger device**, with **one dedicated task**.

- 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

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

■ 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 =

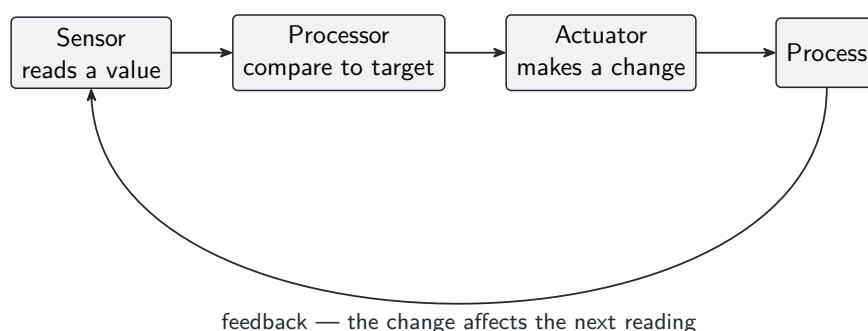
control.

■ 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.

■ How a control system works: six steps



Keeping a fish tank at 25 °C:

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.

2 Practice

Now use the methods above. The first questions need one idea each.

2.1 Tick (✓) **one** box in each row to show whether the system is a monitoring system or a control system. [5]

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.		

2.2 Name the most suitable sensor from the list for each system. [4]

temperature · pressure · infra-red · sound

- (a) a door that opens when a person walks up to it
- (b) a system that warns when a baby is crying in another room
- (c) a system that checks that a freezer stays cold enough
- (d) a mat that detects a person standing on it

2.3 State what is meant by an **actuator**, and give **one** example. [2]

2.4 Explain why an **ADC** is needed between a temperature sensor and a microprocessor. [2]

2.5 State whether each device contains an embedded system. Give a reason for each answer. [4]

(a) a microwave oven

(b) a desktop computer

2.6 Complete the description of a control system. Use words from the list. Each word is used once. [5]

actuator · compares · continuously · preset · sensor

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

3 Exam-style questions

3.1 A modern washing machine is controlled by an embedded system.

- (a) **Explain** why the controller of the washing machine is an embedded system. [3]

- (b) Give **two** benefits of using an embedded system in the washing machine. [2]

- (c) Give **two** drawbacks of using an embedded system in the washing machine. [2]

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

- (a) **State** whether this is a monitoring system or a control system. **Justify** your answer. [2]

- (b) The office wants to be warned when the temperature falls below 0 °C. **Describe** how the system does this. [3]

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

(a) **Describe** how the control system keeps the water in this range. [6]

(b) **Explain** the importance of **feedback** in this system. [3]

3.4 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.

(a) Identify **two** sensors the system needs. For each one, state what it is used to detect. [4]

(b) Identify the **actuator** in this system, and state what it does. [2]

(c) **Explain** why the barrier system is a control system, not a monitoring system. [2]

(d) 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. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

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

2.2

- (a) a person's body heat, or a broken beam → **infra-red**
- (b) crying is a loud sound → **sound**
- (c) how cold it is → **temperature**
- (d) a force pressing on the mat → **pressure**

2.3

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

2.4

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

2.5

- (a) **yes**
 - its microprocessor is built into the oven and only runs the fixed cooking program
- (b) **no**
 - it is a general-purpose computer: the user can install and run many different programs

2.6

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

3.1

- (a) it is a microprocessor system built into a larger device, the washing machine
 - it has one dedicated task: running the wash programs

- its program is stored in ROM and the user cannot install other software

(b) any **two** of:

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

(c) any **two** of:

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

3.2

(a) **monitoring**

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

(b) the sensor's reading is converted by an ADC and sent to the microprocessor

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

3.3

(a) any **six** of:

- the temperature sensor measures the water temperature and sends the reading to the microprocessor
- an ADC converts the analogue reading to digital
- the microprocessor compares the reading with the stored values 26 °C and 28 °C
- if the reading is below 26 °C, it sends a signal to the actuator to switch the heater on
- if the reading is above 28 °C, it sends a signal to switch the heater off
- if the reading is in the range, no action is taken
- the process is repeated continuously

(b) the heater changes the water temperature, so the output of the system affects its next input

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

3.4

(a) one mark for each sensor, and one for its use, for example:

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

(b) a **motor**

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

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

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

(d) any **two** of:

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