Embedded systems

3.1.3 · Computers · revision notes

An embedded system is a computer system built into a larger device to carry out a dedicated task, such as controlling a washing machine. You need to know what embedded systems are, what they are used for, their typical features and how they differ from general-purpose computers. Paper 1 usually asks short recall questions and 2 to 4 mark 'Explain' questions set in a context.

Key facts

- Embedded system: a computer system inside a larger device, dedicated to a specific task
- Inputs: sensors and buttons. Outputs: motors, heaters, valves, displays, buzzers
- Real time: must respond within a strict time limit
- Its program (firmware) is kept in non-volatile memory, e.g. flash memory
- Features: dedicated, small, cheap, low power, reliable, simple interface
- General-purpose computer: many tasks, and the user can install software

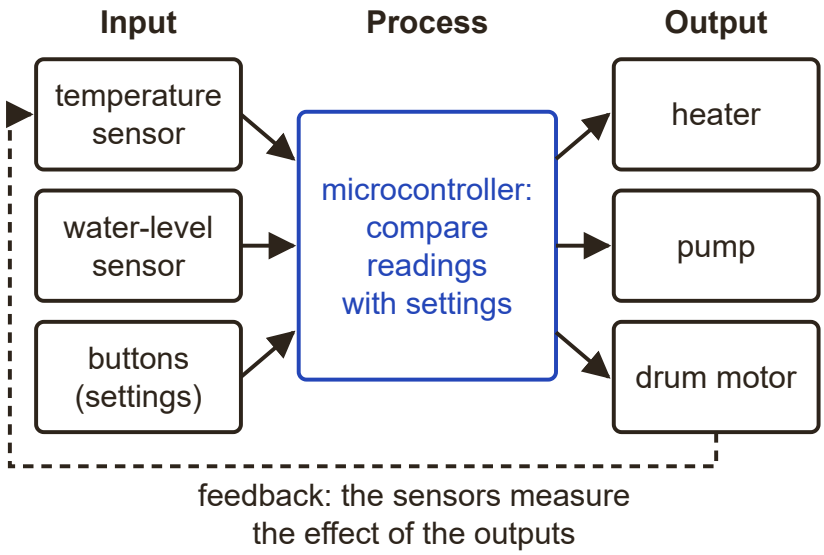
Notes

What an embedded system is

- An **embedded system** is a computer system built into a larger device to carry out a **dedicated** (specific) task, or a small set of tasks.
- Like any computer it has a processor, memory, and inputs and outputs. These are often combined on a single chip called a **microcontroller**.
- Its program (often called **firmware**) is stored in **non-volatile** memory, such as flash memory, so it is not lost when the power is off and it runs as soon as the device is switched on.
- Users cannot install other programs. The firmware is rarely changed, although some devices can receive updates.

What embedded systems are used for

- Embedded systems **monitor** and **control** devices and automate tasks.
- Examples: washing machines, dishwashers, microwave ovens, central heating thermostats, car engine management and anti-lock brakes, traffic lights, digital cameras, fitness trackers and pacemakers.
- They follow input → process → output. Inputs come from **sensors** (temperature, pressure, light, movement) and buttons. The processor compares the readings with stored settings and decides what to do. Outputs drive motors, heaters, pumps, valves, displays, lights and buzzers.
- Example: in a washing machine, a water-level sensor and a temperature sensor are inputs; the heater, pump and drum motor are outputs.



Input → process → output, repeated continuously: the processor keeps checking the sensors and adjusting the outputs

Typical features

- **Dedicated**: it does one job, so it is simpler, easier to test and very reliable.
- **Small and cheap**: embedded systems are mass-produced to fit inside everyday products.
- **Low power**: many run on batteries or are left switched on all the time.
- **Simple user interface**: a few buttons and a small display, or none at all.
- Many must respond in **real time**: within a fraction of a second, e.g. an airbag or anti-lock brakes.

Embedded systems and general-purpose computers

- A general-purpose computer, such as a laptop, runs many different programs chosen by the user, has a full operating system and interface, and lets the user install software.
- An embedded system does one task with a fixed program, has a minimal interface, and usually has a much less powerful processor and far less memory.

How to answer each type of question

Define and give examples

1 to 2 marks | Grade 3

1. A definition needs both ideas: built into a larger device, and a dedicated task.
2. Name real devices for examples, and check you have not repeated one given in the question.

Example. (a) Define the term 'embedded system'. (1)
(b) Give **two** examples of devices, other than a washing machine, that contain an embedded system. (2)

Model answer.

(a) A computer system built into a larger device to carry out a dedicated (specific) task (1)

(b) Any two, e.g. microwave oven (1), car engine management system (1). Also accept dishwasher, thermostat, traffic lights, digital camera, fitness tracker.

Describe how an embedded system controls a device

2 to 3 marks | Grade 5

1. Name the input (usually a sensor) and what it measures.
2. Say that the processor compares the reading with a stored or chosen value.
3. Say what output is switched on or off as a result, and that this repeats.

Example. A dishwasher contains an embedded system.
Describe how the embedded system keeps the water at the temperature chosen by the user. (3)

Model answer. Any three from: a temperature sensor measures the temperature of the water (1); the processor compares the reading with the temperature the user chose (1); if the water is too cool it switches the heater on, and it switches the heater off when the chosen temperature is reached (1); this is repeated continuously during the wash (1).

Explain differences from a general-purpose computer

4 marks | Grade 6

1. Give a feature of the embedded system.
2. Contrast it with the general-purpose computer, using 'whereas'.
3. Repeat for a second difference.

Example. Explain **two** differences between the embedded system in a microwave oven and a desktop computer. (4)

Model answer.

The microwave's embedded system carries out one dedicated task, controlling the cooking (1), whereas a desktop computer can run many different programs chosen by the user (1). The microwave's program is fixed in non-volatile memory (1), whereas the user of a desktop computer can install and remove software (1).
Also accept: a few buttons and a small display, whereas a desktop has a keyboard, mouse and full screen; smaller, cheaper and lower power, whereas a desktop is larger and uses more power.

Explain why a feature matters in a context

2 marks | Grade 7

1. Identify the fact about this device that makes the feature important.
2. Explain the consequence for the user if the feature were missing.

Example. A heart pacemaker contains an embedded system. The pacemaker is fitted inside the patient's chest.
Explain why the embedded system must use very little power. (2)

Model answer. The pacemaker runs on a battery that is sealed inside the patient's body (1). Replacing the battery needs an operation, so using very little power makes the battery last for many years (1).

Don’t lose marks

- Calling a laptop, tablet or smartphone an embedded system. They are general-purpose computers.
- Saying an embedded system has no processor or no memory.
- Saying the program is stored in RAM. It is kept in non-volatile memory so that it survives power cuts.
- Giving vague examples such as 'a machine' instead of a named device.
- Describing what the device does instead of what its embedded system does (reads sensors, makes decisions, controls outputs).

More tips

Memory tricks

- Embedded = inside something else, doing one job.
- Quick test: can the user install any app they like on it? If not, it is probably an embedded system.
- Think sensor → processor → output, and name the real parts of the device in the question.

Exam technique

- A definition must include both ideas: built into a larger device, and a dedicated task.
- For differences, write both sides in one sentence using 'whereas'.
- Use the device in the question: name its real sensors and outputs.
- If you are asked about an internet-connected device, weigh the benefits (remote control, updates) against the risks (hacking, privacy).

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Define an embedded system**
A computer system inside a larger device that carries out a dedicated function.

Grade 3 — **Give examples of embedded systems**
For example a washing machine, microwave oven, central heating thermostat, car engine management system or traffic lights.

Grade 4 — **Identify inputs and outputs of an embedded system**
Inputs are usually sensors and buttons; outputs are motors, heaters, valves, displays and buzzers.

Grade 5 — **Describe the typical features of embedded systems**
Dedicated, small, cheap, low power, reliable, with a simple interface and a program kept in non-volatile memory.

Grade 6 — **Compare embedded and general-purpose computers**
One task with a fixed program, compared with many tasks and software the user can install.

Grade 7 — **Explain why a feature matters in context**
For example, a pacemaker must use very little power because its battery is inside the patient's body.

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