CHAPTER 1.

Introducing Mechatornics

1.1 What is mechatronics?

- The term is invented by a Japanese engineer in 1969.

- 'mechatronics' = 'mecha'(mechanics) + 'tronics'(electronics)

- A mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all them in which there is a concurrent approach to the design

- Mechatronics brings together areas of technology involving sensors and measurement systems, drive and actuation systems, and microprocessor systems, together with the analysis of the behavior of systems and control systems.

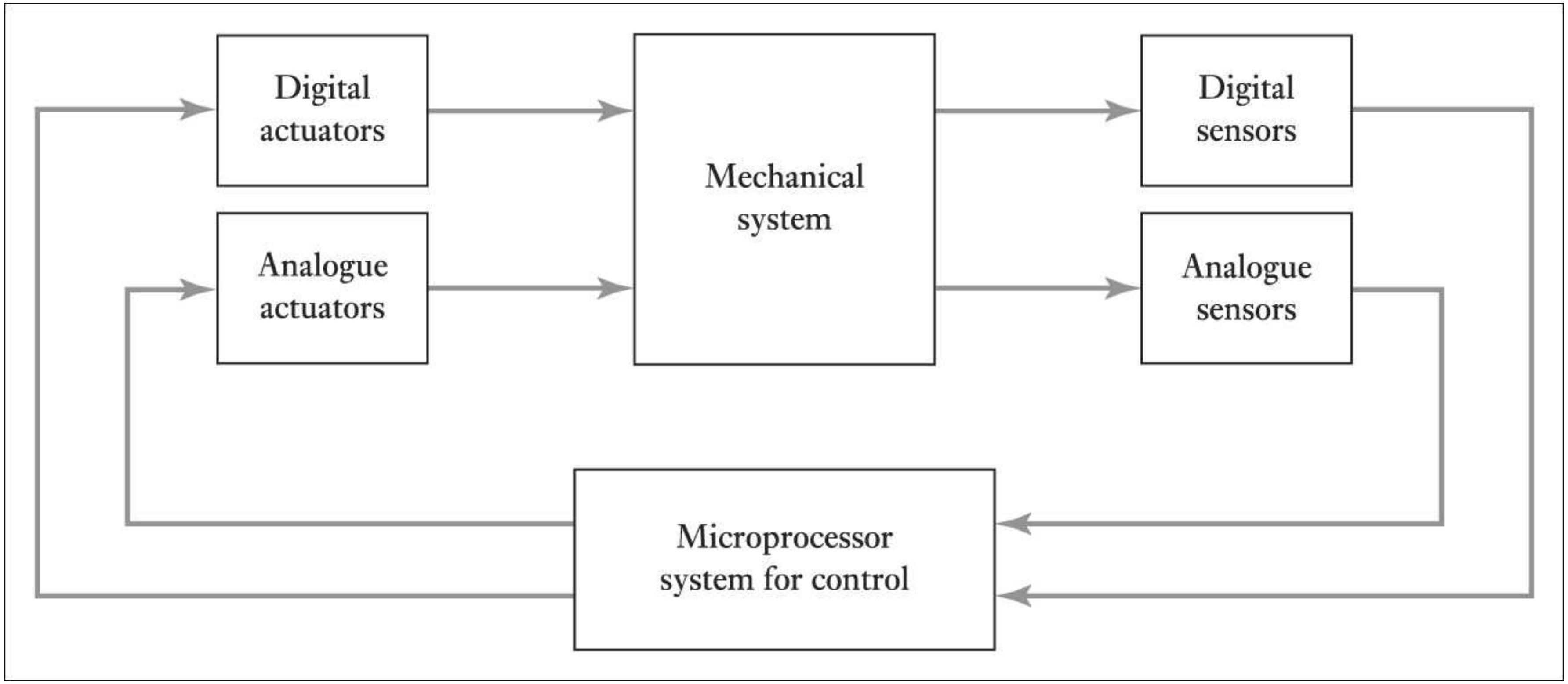

Figure 1.1 The basic elements of a mechatronic system

1.1.1 Example of mechatronic systems

- Camera, Smart suspension, Production process and etc.

1.1.2 Embedded system

- Microprocessors are embedded into systems and it is this type of system we are generally concerned with in mechatronics.

- For a microprocessor to be used in a control system, it needs additional chips to give memory for data storage and for input/output ports to enable it to process signals from and to the outside world.

- Example :
  - Car
    - Anti-lock brake system (ABS)
    - Engine controller
    - Etc.

1.2 The design process

- 1. The need:
  - The design process begins with a need from, perhaps, a customer or client.
  - Market research

- 2. Analysis of the specification:
  - To find out the true nature of the problem, i.e. analyzing it.

- 3. Preparation of specification:
  - Statement of mass, dimensions, types and range of motion required, accuracy, input and output requirements of elements, interfaces, power requirements, operating environment, relevant standards and codes of practice, etc.

- 4. Generation of possible solutions:
  - Conceptual stage
  - Outline solutions are prepared which are worked out in sufficient detail to indicate the means of obtaining each of the required functions, e.g. approximate sizes, shapes, materials and costs.
  - Finding out what has been done before for similar problems.

1.2 The design process

- 5. Selection of suitable solution:
  - The various solutions are evaluated and the most suitable one selected.
  - Evaluation will often involve the representation of a system by a model and then simulation to establish how it might react to inputs.

- 6. Production of a detailed design:
  - The detail of selected design has now to be worked out. This might require the production of prototypes or mock-ups in order to determine the optimum details of a design.

- 7. Production of working drawings:
  - The selected design is then translated into working drawings, circuit diagrams, etc., so that the item can be made.

1.2.1 Traditional and mechatronics designs

- Engineering design is a complex process involving interactions between many skills and disciplines.

- With traditional design, the approach was for the mechanical engineer to design the mechanical elements, then the control engineer to come along and design the control system.

- The basis of the mechatronics approach is considered to lie in the concurrent inclusion of the disciplines of mechanical engineering, electronics, computer technology and control engineering in the approach to design.

- The inherent concurrency of this approach depends very much on system modelling and then simulation of how the model reacts to inputs and hence how the actual system might react to inputs.

1.3 Systems

- Creation of a modes of the system for behavior prediction

- A system ~ box or block diagram having input and output:
  - We are concerned with the relationship between the output and the input.

- Modeling: We represent the behavior of a real system by mathematical equation, such equations representing the relationship between the inputs and outputs from the system.

1.3 Systems

- Example: a spring can be considered as a system to have an input of a force F and an output of an extension x.
  - F=kx
- Example: a temperature measurement system
  - temperature – number on a scale

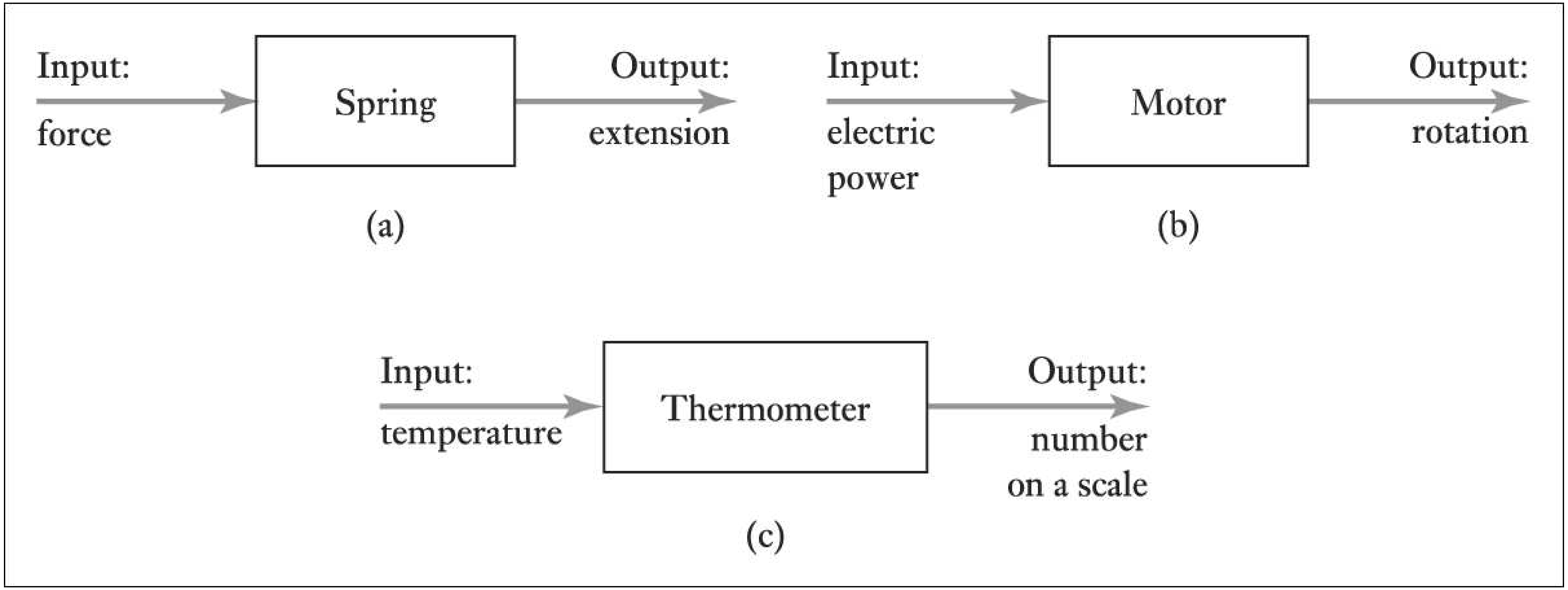

Figure 1.2 Examples of systems: (a) spring, (b) motor, (c) thermometer

1.3.1 Modelling systems

- The response of any system to an input is not instantaneous.
- Ex) spring mass system: F=kx only at the steady state
  - For finding out the behavior, we need the mathematical model of the system.

- Example

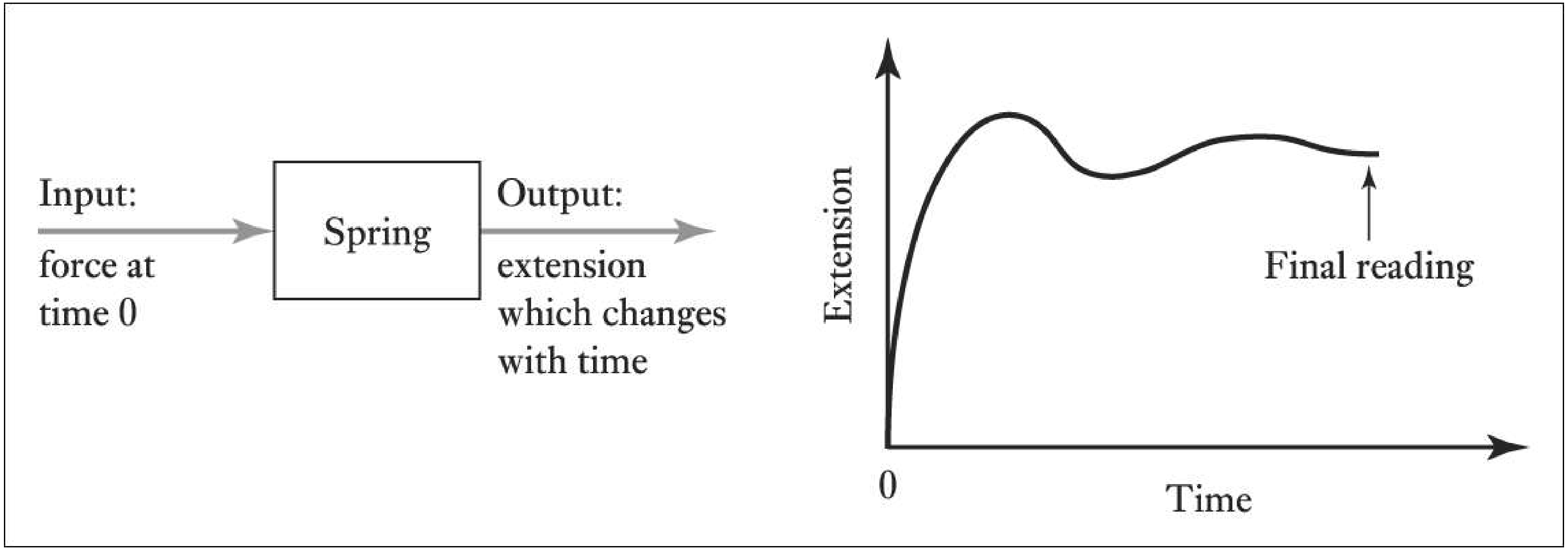

Figure 1.3 The response to an input for a spring

1.3.1 Modelling systems

- Example

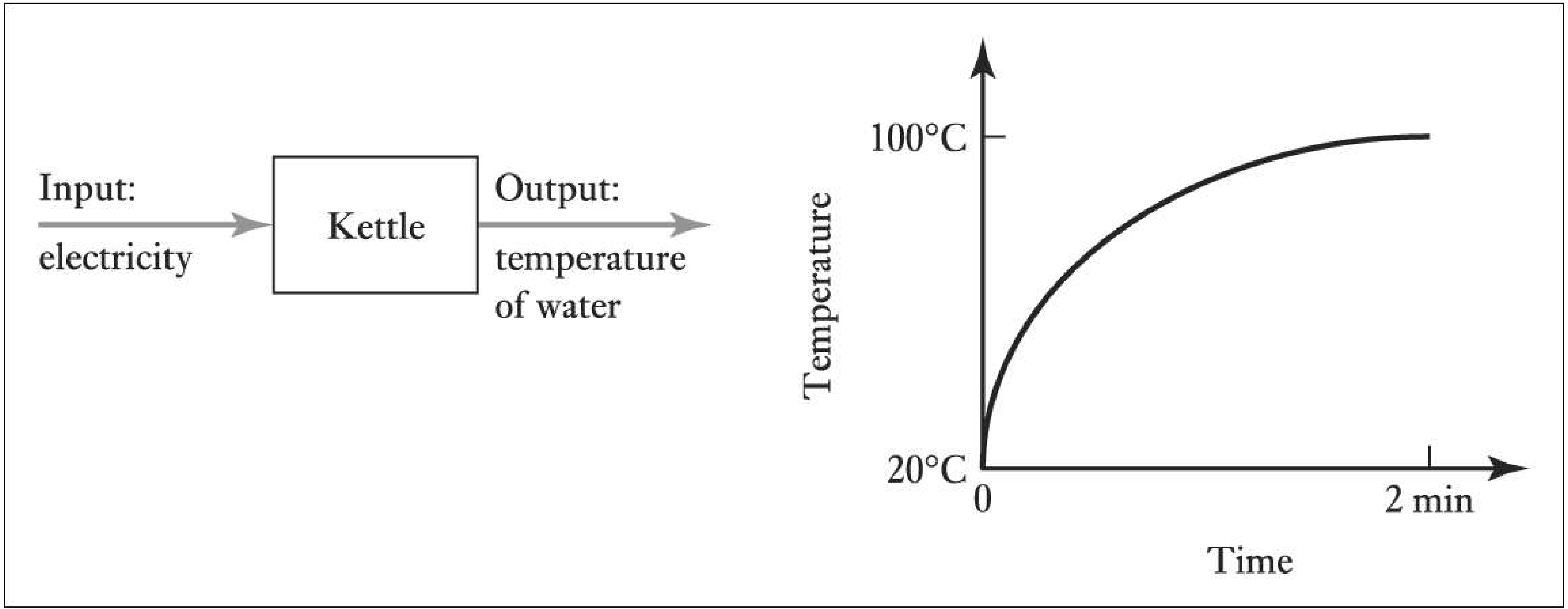

Figure 1.4 The response to an input for a kettle system

1.3.2 Connected systems

- In other than the simplest system, it is generally useful to consider it as a series of interconnected blocks, each such block having a specific function

- Lines drawn to connect boxes indicate a flow of information, not necessarily physical connections.

- Example

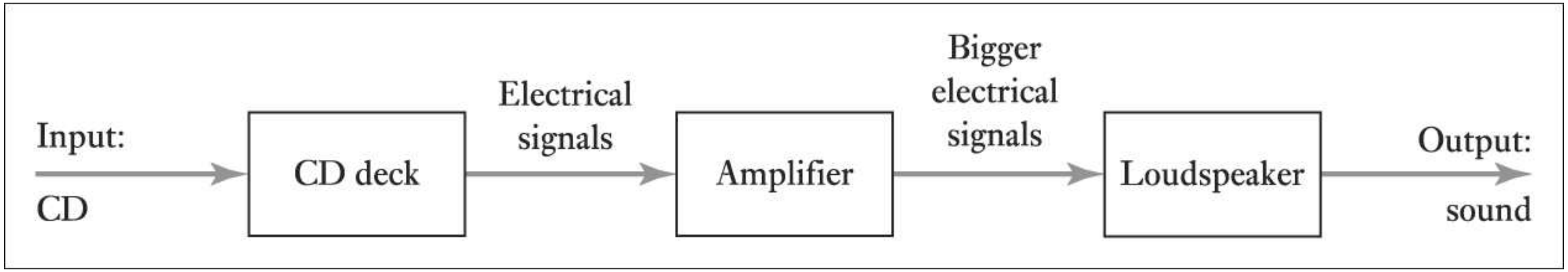

Figure 1.5 A CD player

1.4 Measurement systems

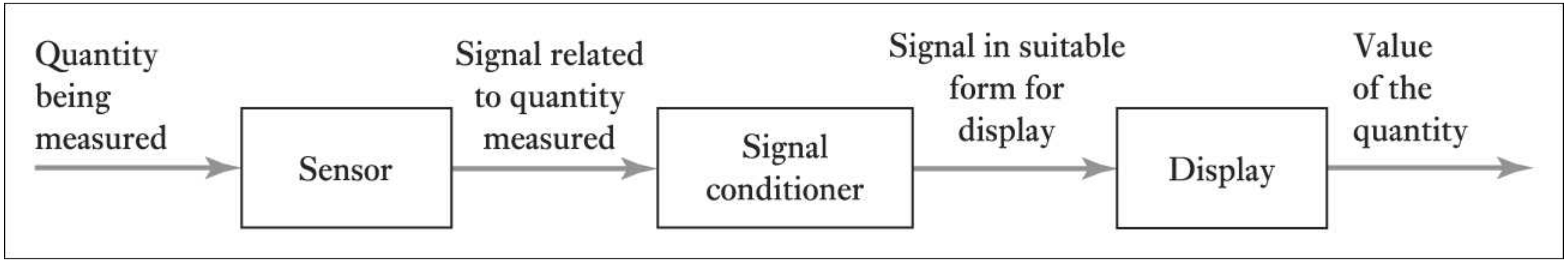

Figure 1.6 A measurement system and its constituent elements

Example:

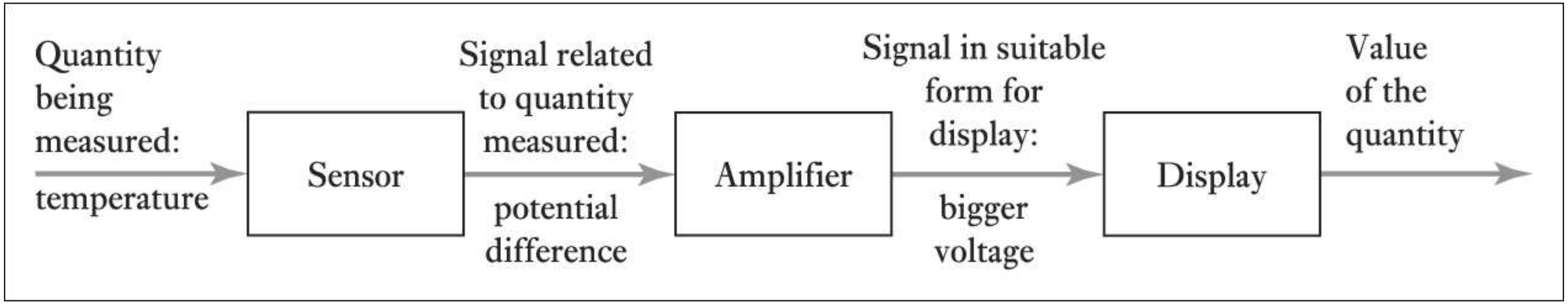

Figure 1.7 A digital thermometer system

1.5 Control systems

- 1. Control some variable to some particular value, e.g. a central heating system where the temperature is controlled to a particular value.

- 2. Control the sequence of events, e.g. a washing machine where when the dials are set to, say, 'white' and the machine is then controlled to a particular washing cycle, i.e. sequence events, appropriate to that type of clothing.

- 3. Control whether an event occurs, or not, e.g. a safety lock on a machine where it cannot be operated until a guard is in position.

1.5.1 Feedback

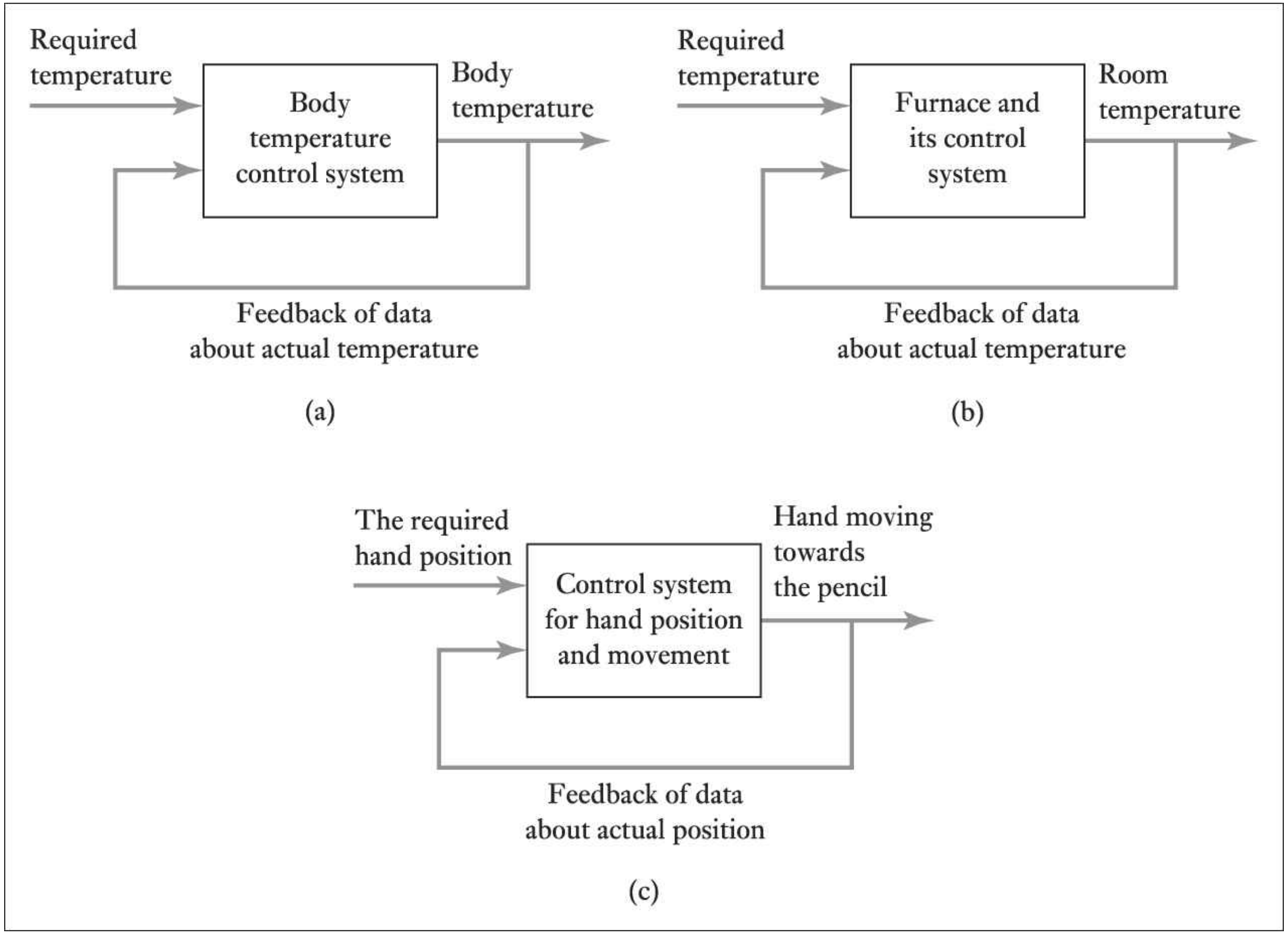

Figure 1.8 Feedback control: (a) human body temperature, (b) room temperature with central heating, (c) picking up a pencil

1.5.2 Open- and closed-loop system

- Open-Loop:
  - Open-loop systems have the advantage of being relatively simple and consequently low cost with generally good reliability.
  - However, they are often inaccurate since there is no correction for error

- Closed-Loop:
  - Closed-Loop systems have the advantage of being relatively accurate in matching the actual to the required values.
  - However, more complex and so more costly with a greater chance of breakdown as a consequence of the greater number of components.

1.5.2 Open- and closed-loop system

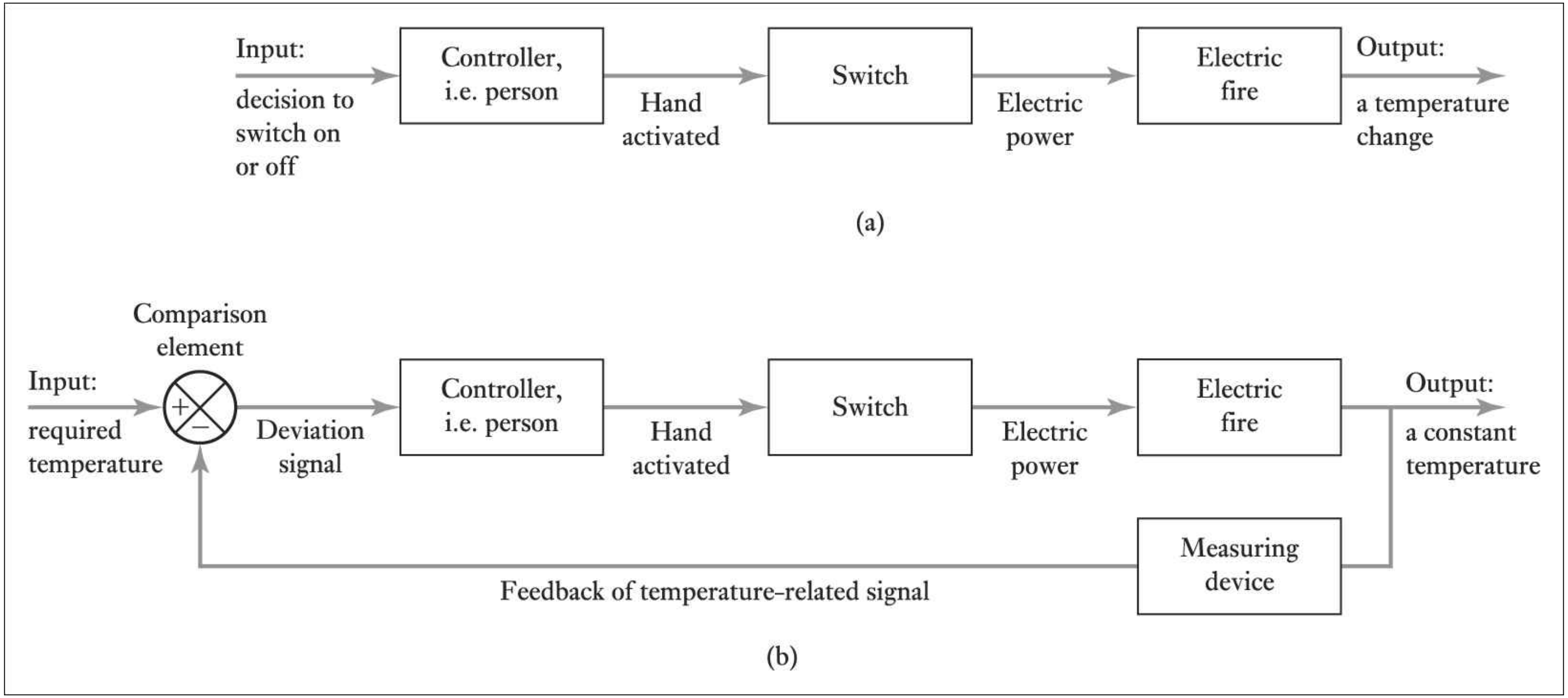

Figure 1.9 Heating a room: (a) an open-loop system, (b) a closed-loop system

1.5.3 Basic elements of a closed-loop system

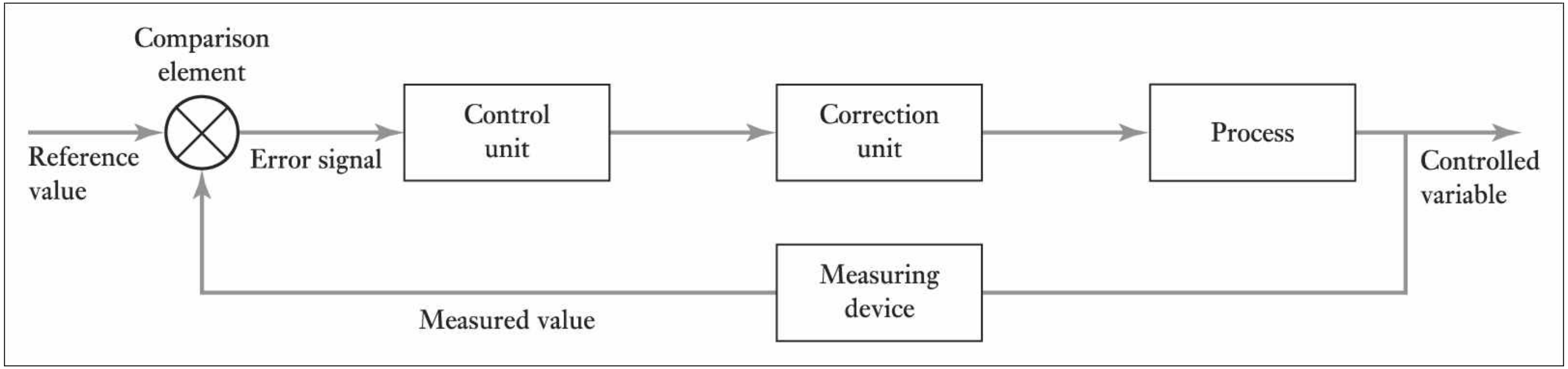

Figure 1.10 The elements of a closed-loop control system

1.5.3 Basic elements of a closed-loop system

- 1. Comparison element:

    error signal = reference value signal – measured value signal

- 2. Control element:

    This decides what action to take when it receives an error signal.

    hard-wired system or programmable system

- 3. Correction element:

    The correction element produces a change in the process to correct or change the controlled condition (ex. Actuator)

- 4. Process element:

    The process is what is being controlled.

- 5. Measurement element:

    The measurement element produces a signal related to the variable condition of the process that is being controlled.

1.5.3 Basic elements of a closed-loop system

- Example:

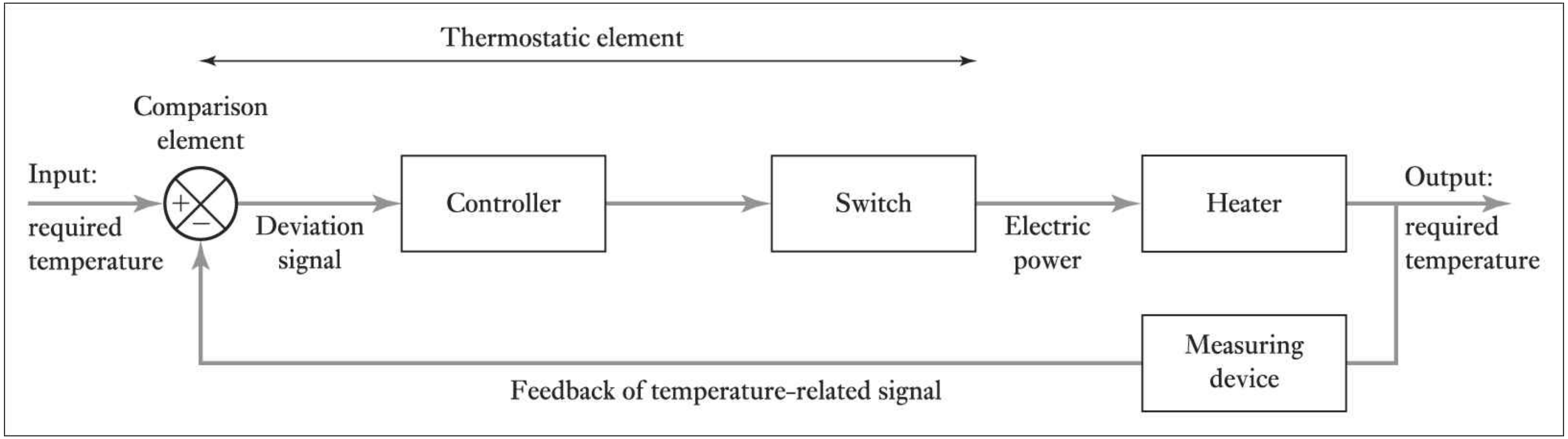

Figure 1.11 Heating a room: a closed-loop system

1.5.3 Basic elements of a closed-loop system

- Example:

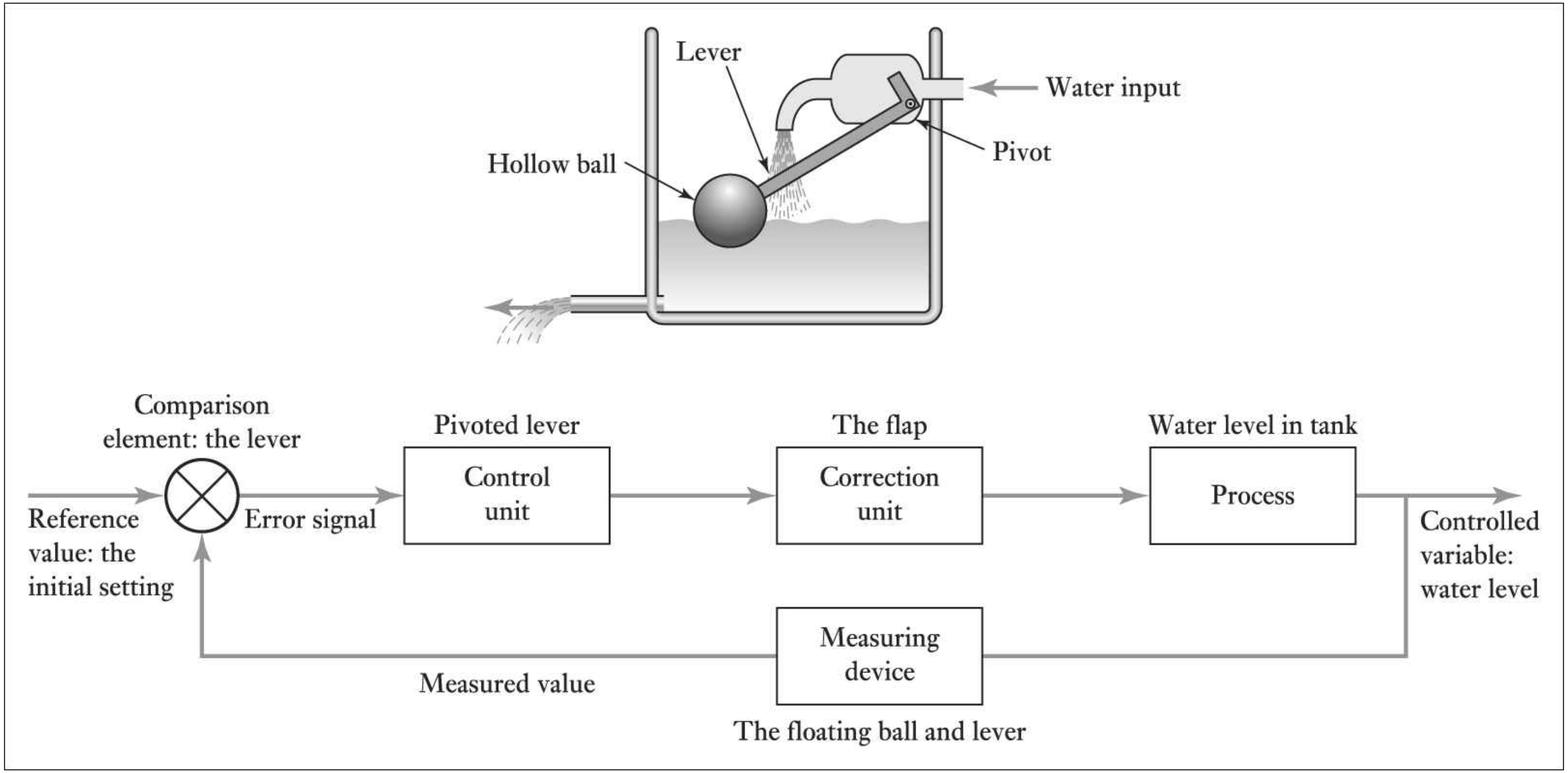

Figure 1.12 The automatic control of water level

1.5.3 Basic elements of a closed-loop system

- Example:

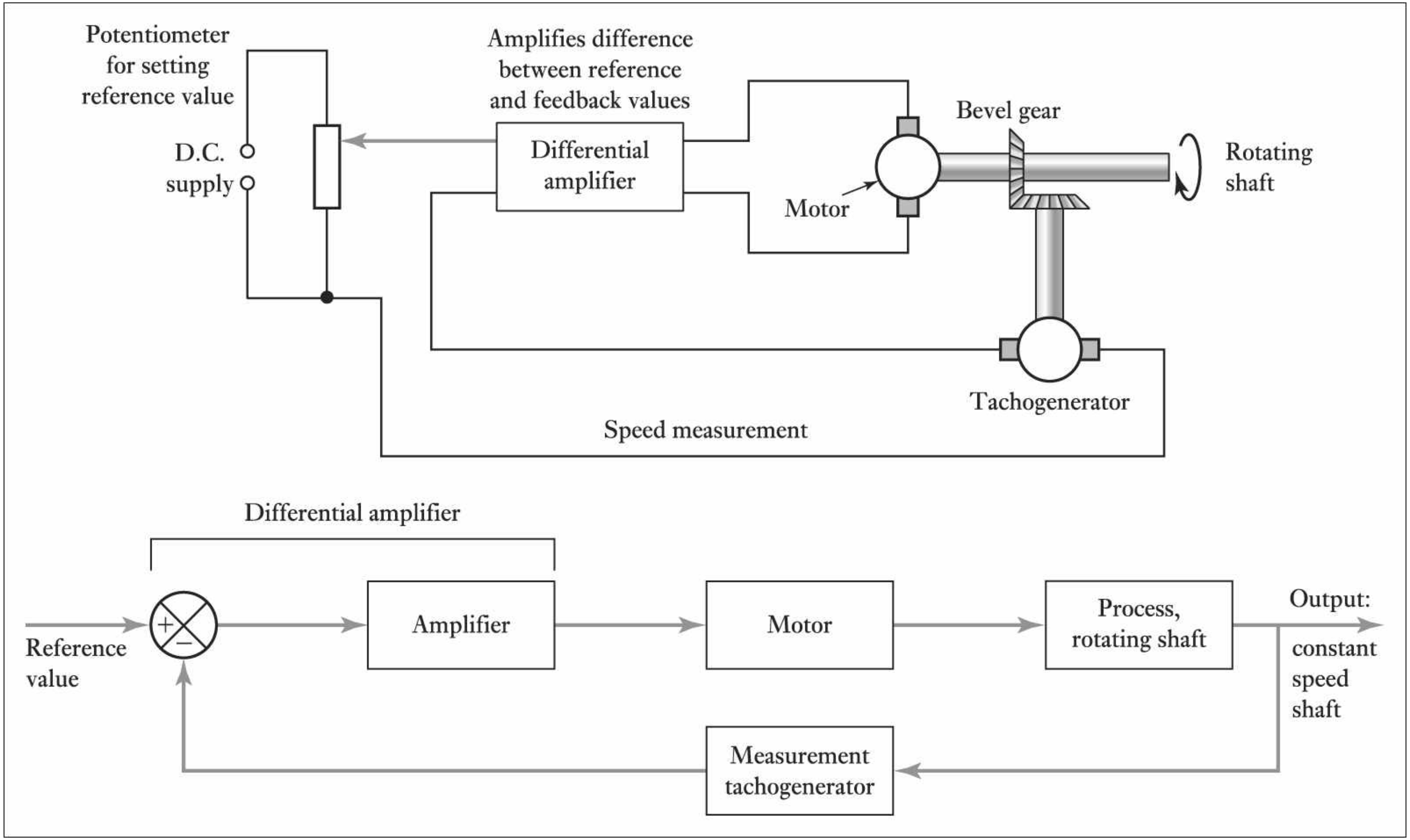

Figure 1.13 Shaft speed control

1.5.4 Analogue and digital control systems

- Analogue system:
  - The signal is continuous with respect to time and measurable.

- Digital system:
  - It can be considered as sequences of on/off signal and it can be represented by the sequence of on/off pulse.

- Analogue-to-Digital Converter, ADC

- Digital-to-Analogue Converter, DAC

1.5.4 Analogue and digital control systems

- Example

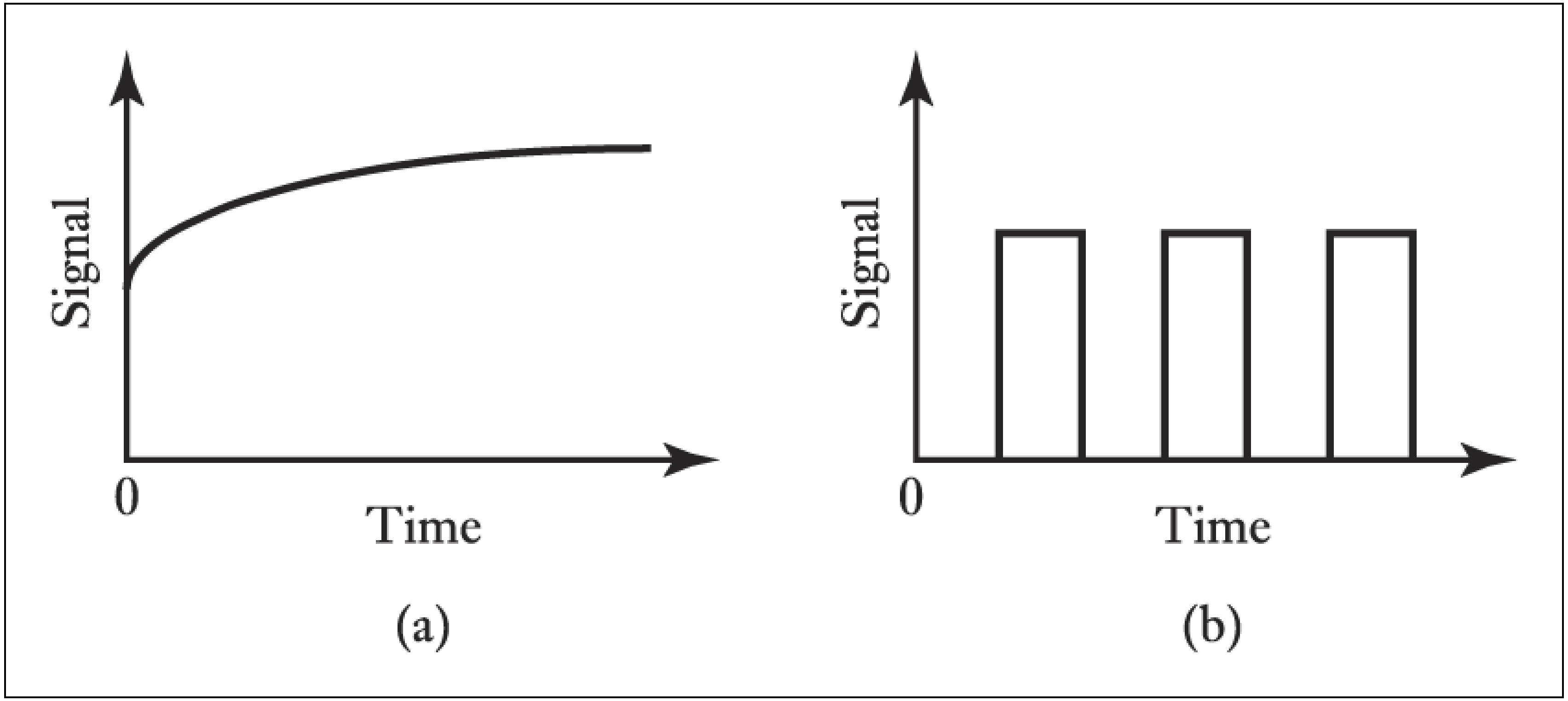

Figure 1.14 Signals: (a) analogue, (b) digital

1.5.4 Analogue and digital control systems

- Example

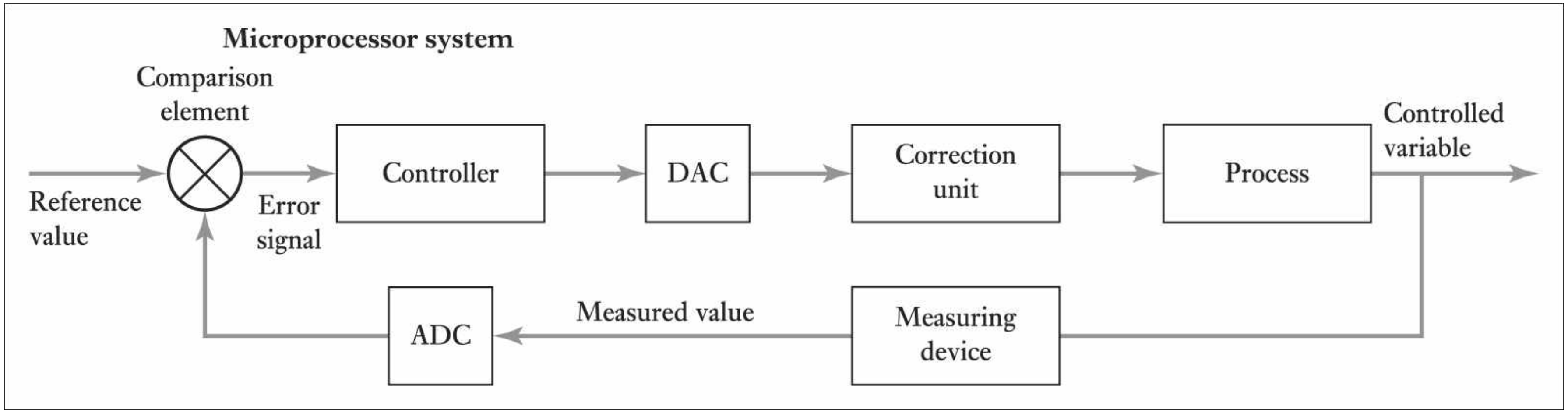

Figure 1.15 The elements of a digital closed-loop control system

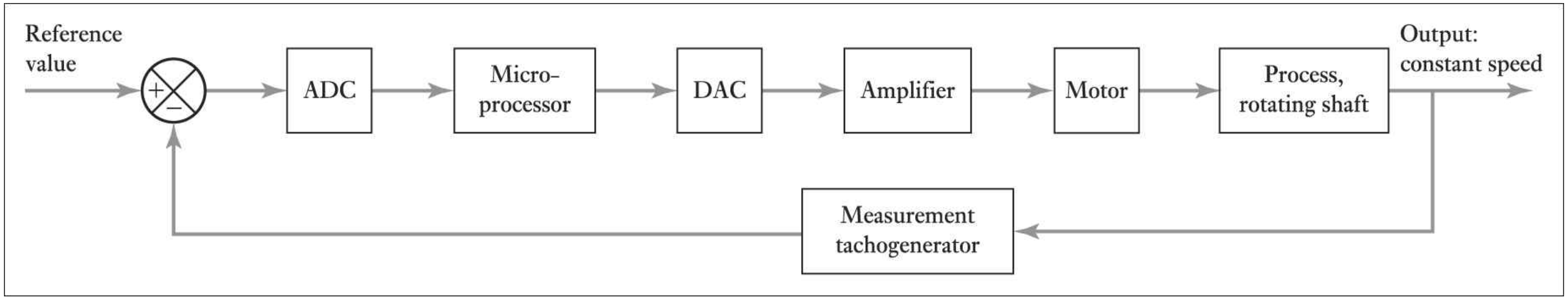

Figure 1.16 Shaft speed control

1.5.5 Sequential controllers

- The term sequential control is used when control is such that actions are strictly ordered in a time- or event-driven sequence.

- The operating sequence is called a program, the sequence of instructions in each program being predefined and ‘built’ into the controller used.

1.5.5 Sequential controllers

- Example

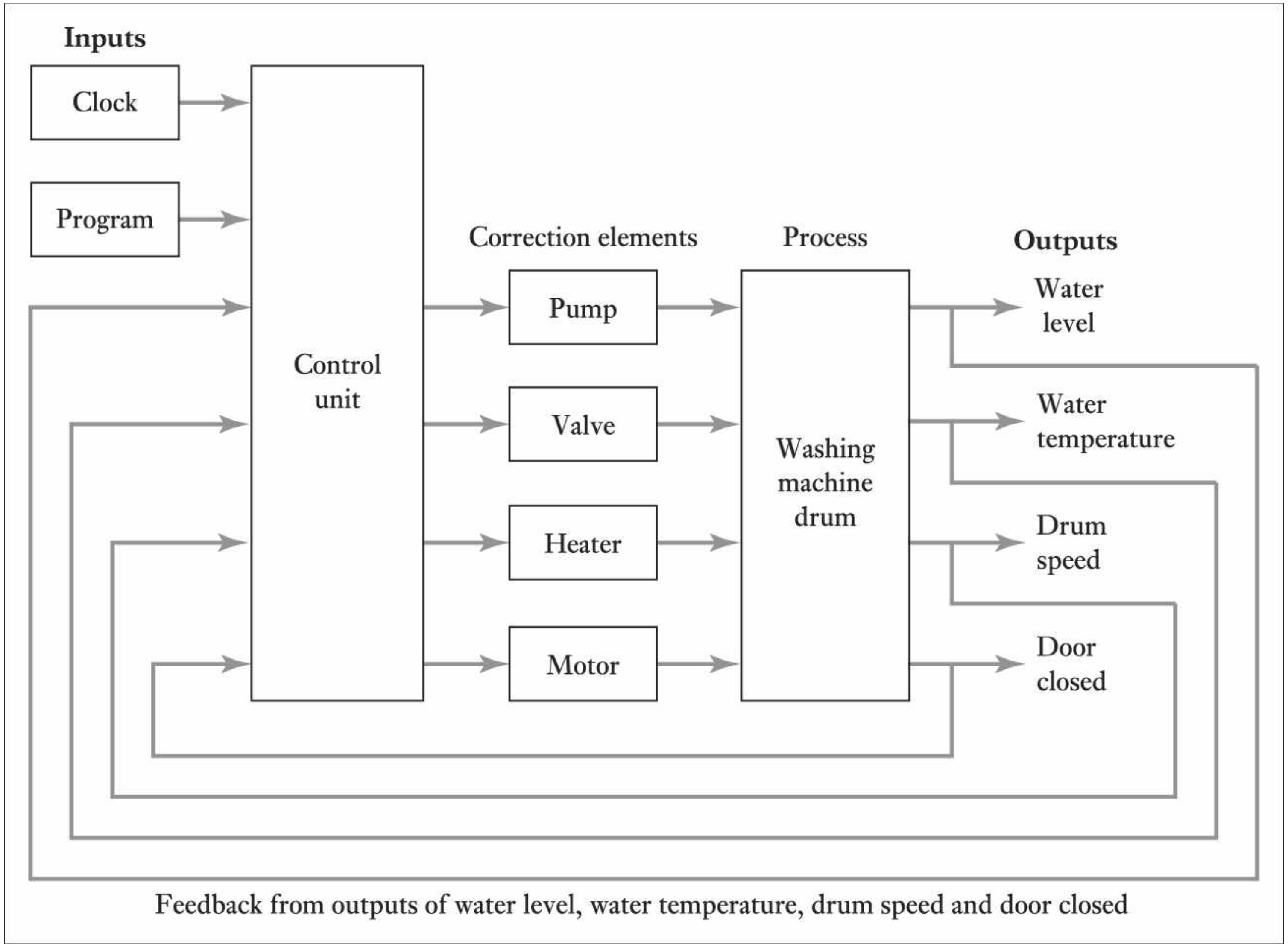

Figure 1.17 Washing machine system

1.5.5 Sequential controllers

- Example

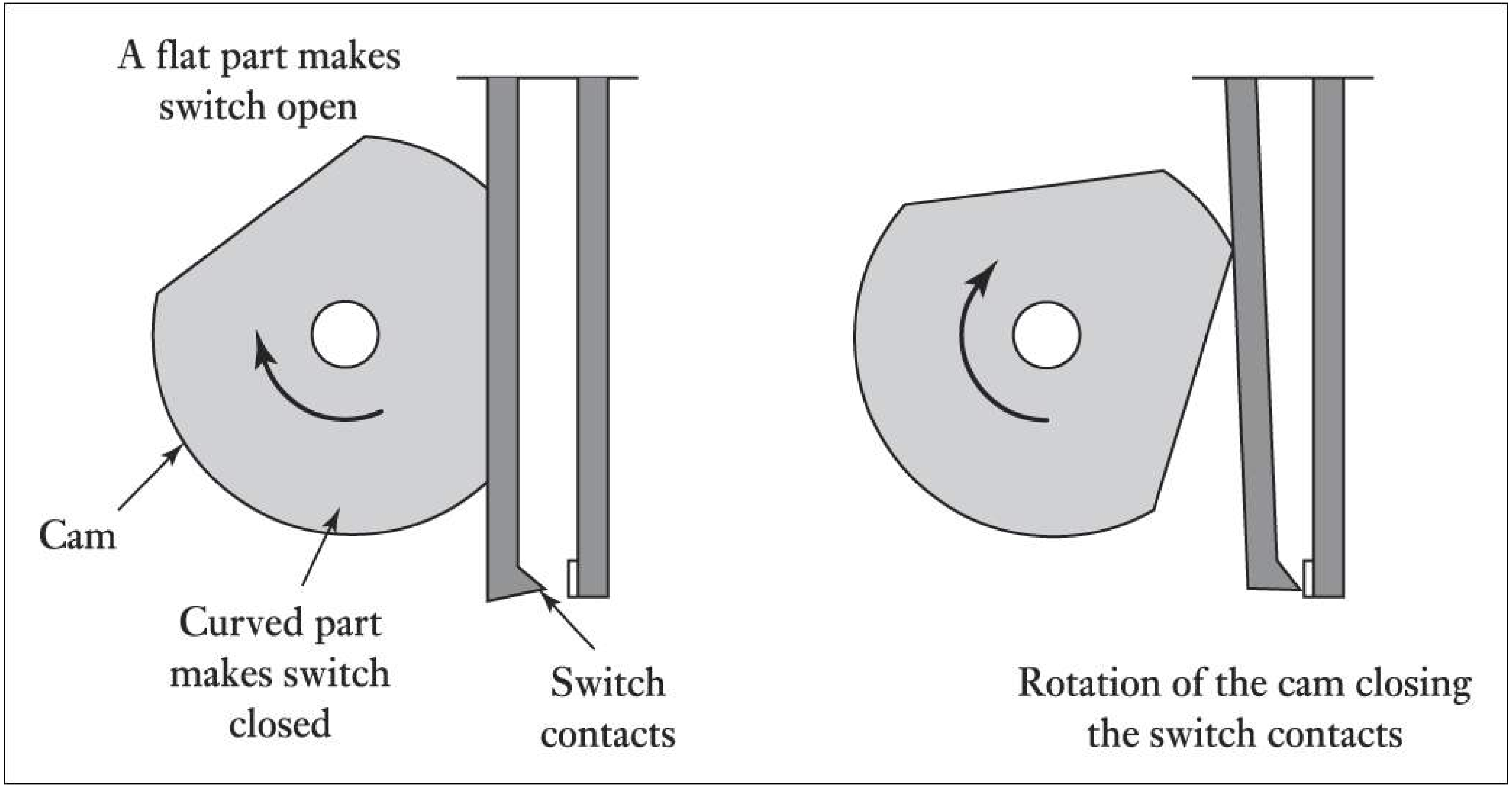

Figure 1.18 Cam-operated switch

1.6 Programmable Logic Controller

- This is a microprocessor based controller which uses programmable memory to store instructions and to implement functions such as logic, sequence, timing counting and arithmetic to control events and can be readily reprogrammed for different tasks.

- Example

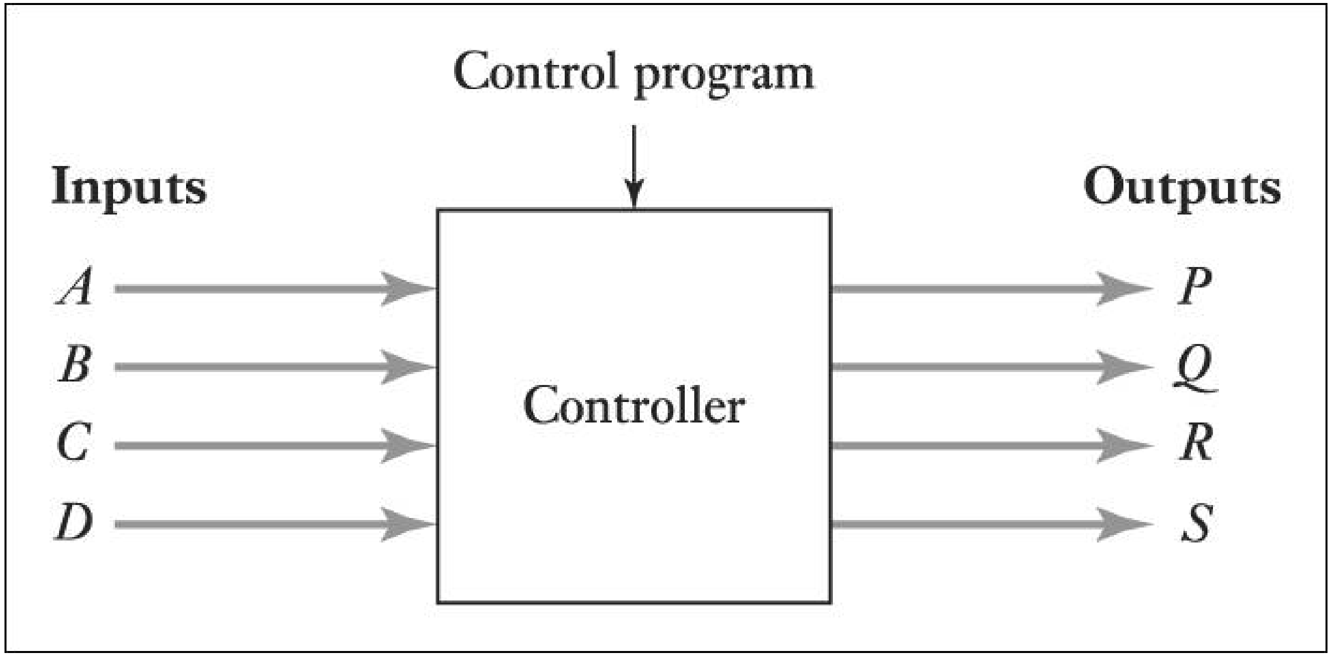

Figure 1.19 Programmable logic controller

1.7 Examples of mechatronic systems

1.7.1 The digital camera and auto focus

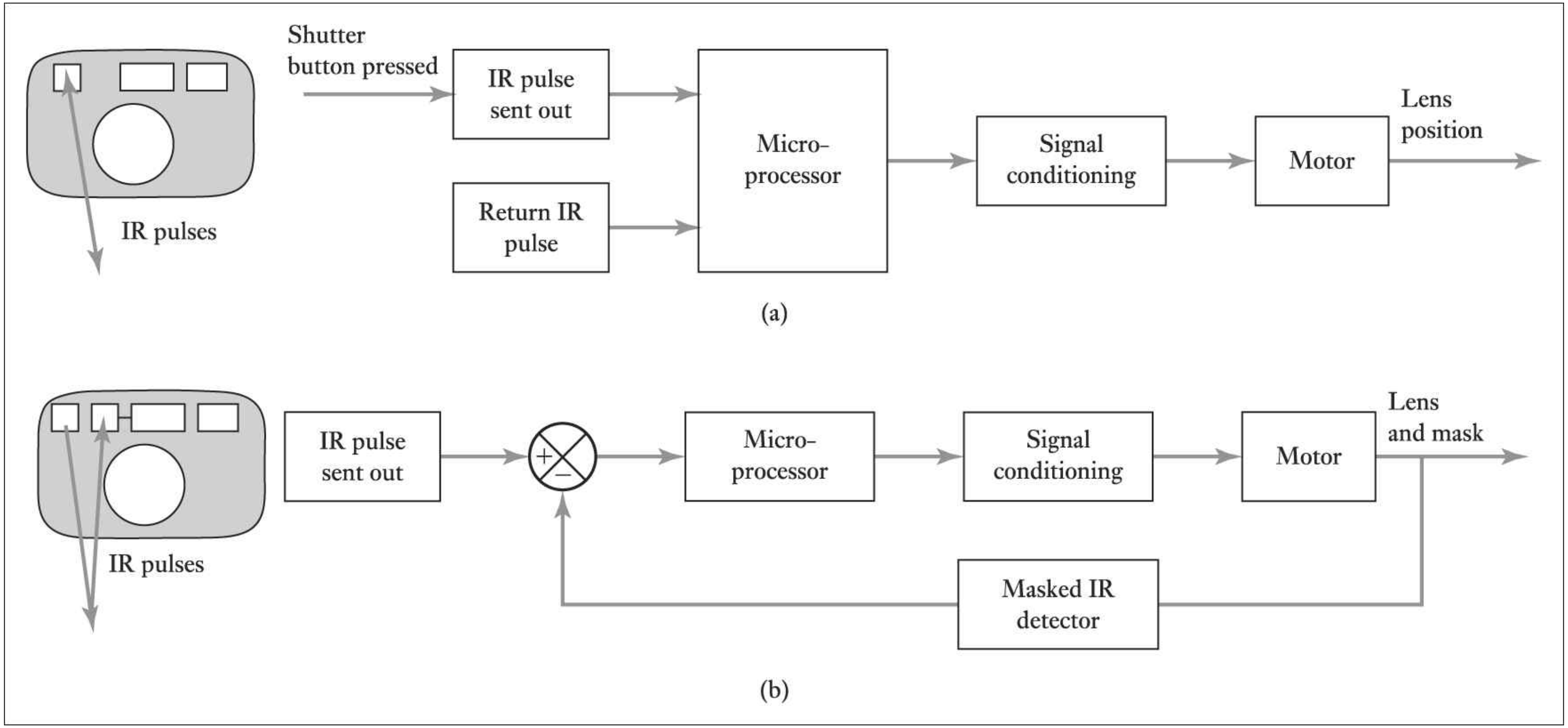

Figure 1.20 Autofocus

1.7.2 The engine management system

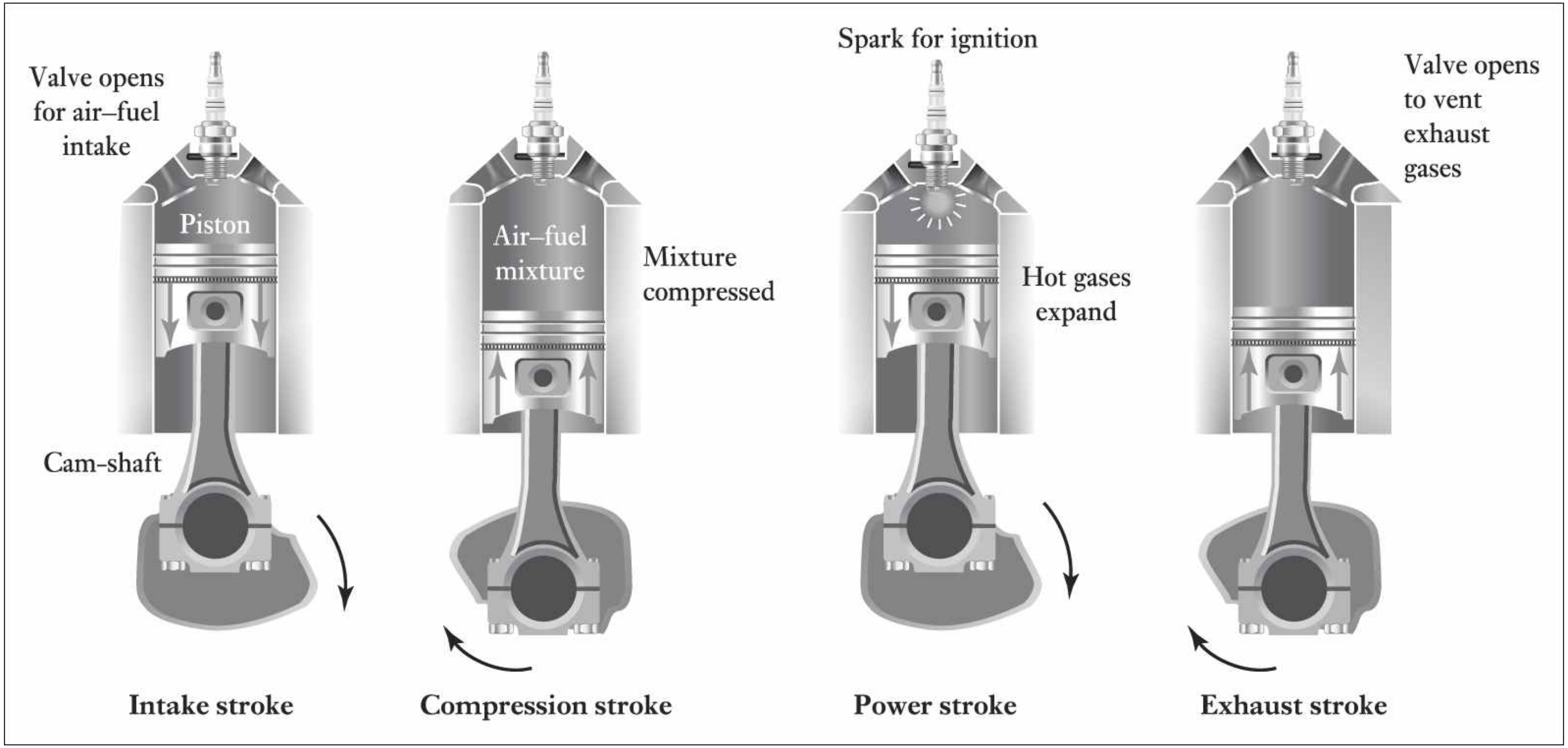

Figure 1.21 Four-stroke sequence

1.7.2 The engine management system

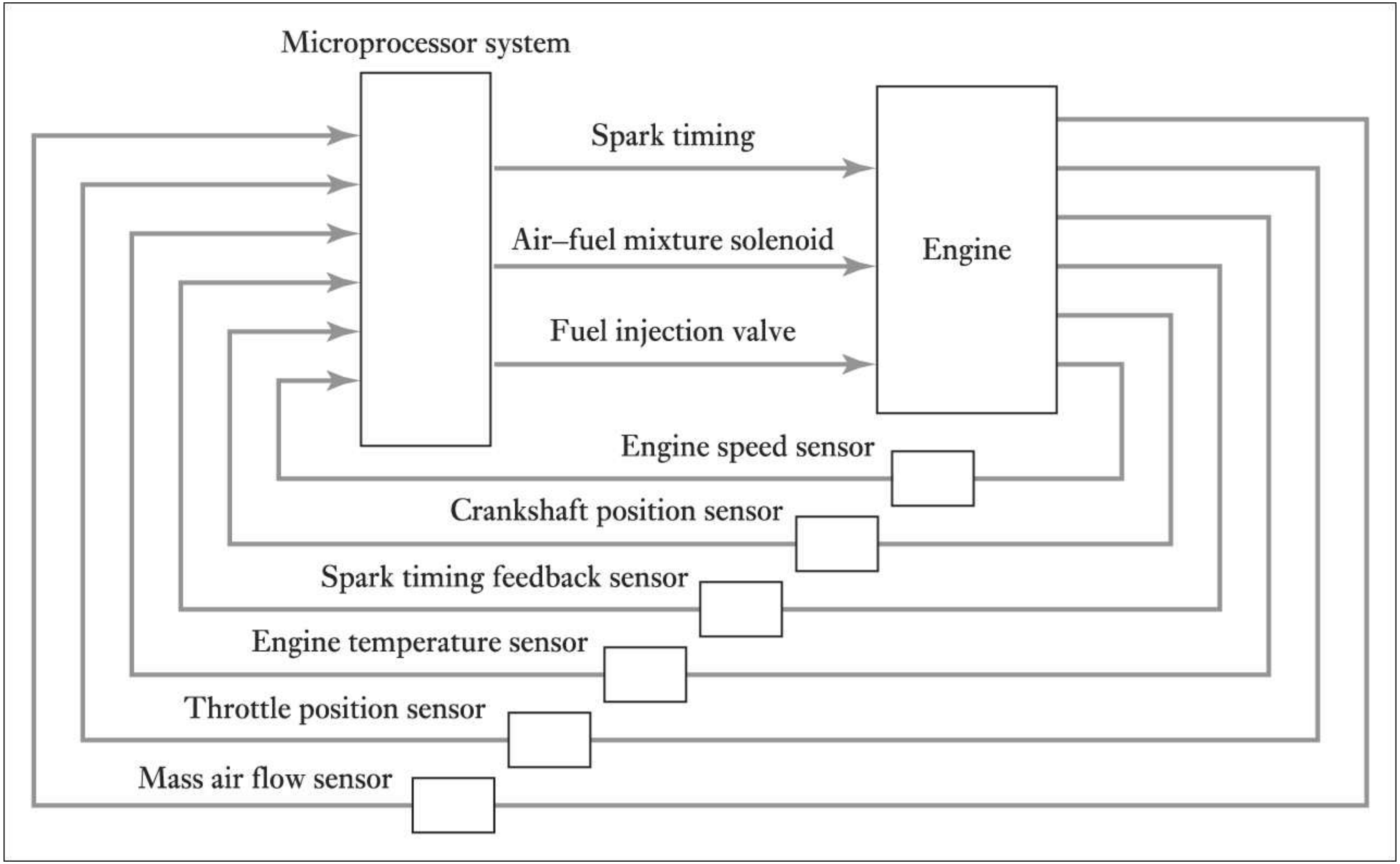

Figure 1.22 Elements of an engine management system