University of Dhaka
Department of Computer Science and Engineering
CSE-2205: Introduction to Mechatronics

Lec-1: Fundamentals of Mechatronics

Mechatronics: Electronic Control Systems in Mechanical Engineering by W. Bolton

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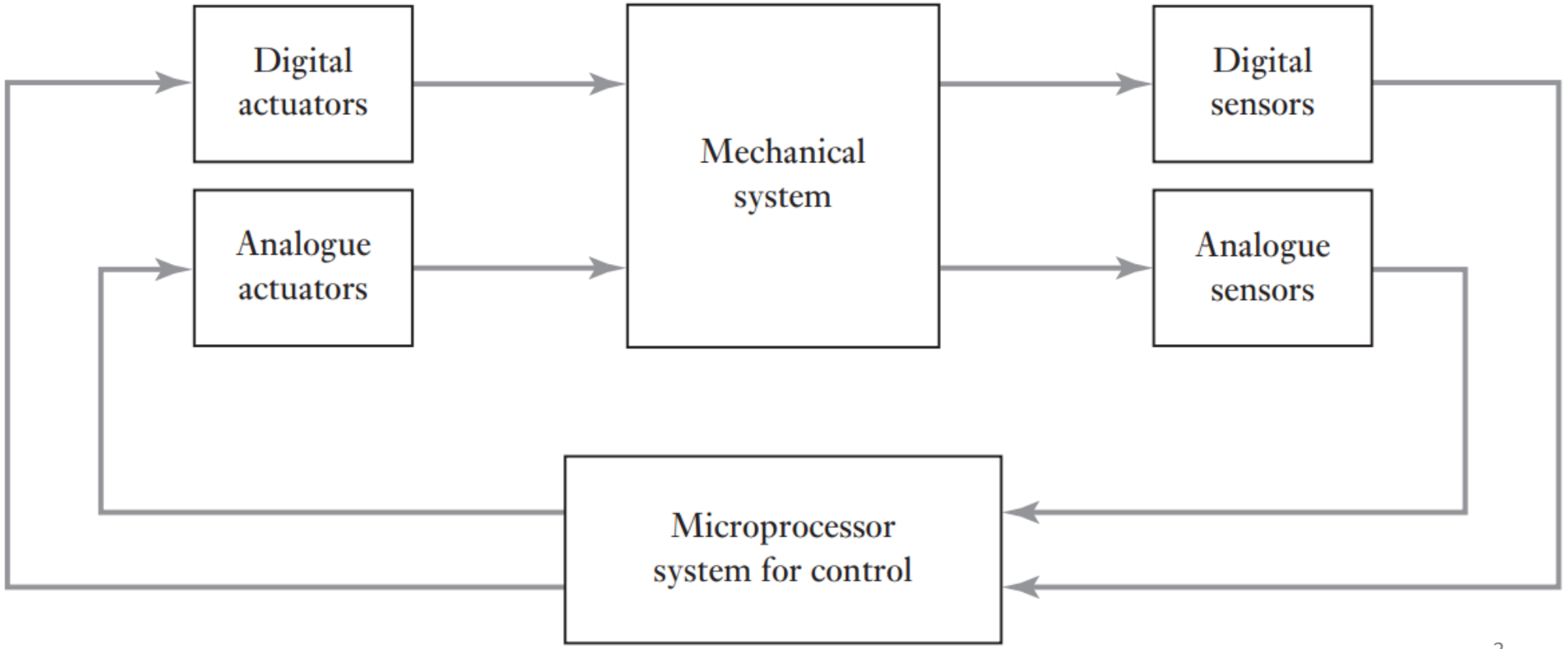
1. Mechatronics

Mechatronics is a field of engineering that *combines mechanical engineering, electronics, computer science, and control engineering* to design and create smart machines and systems.

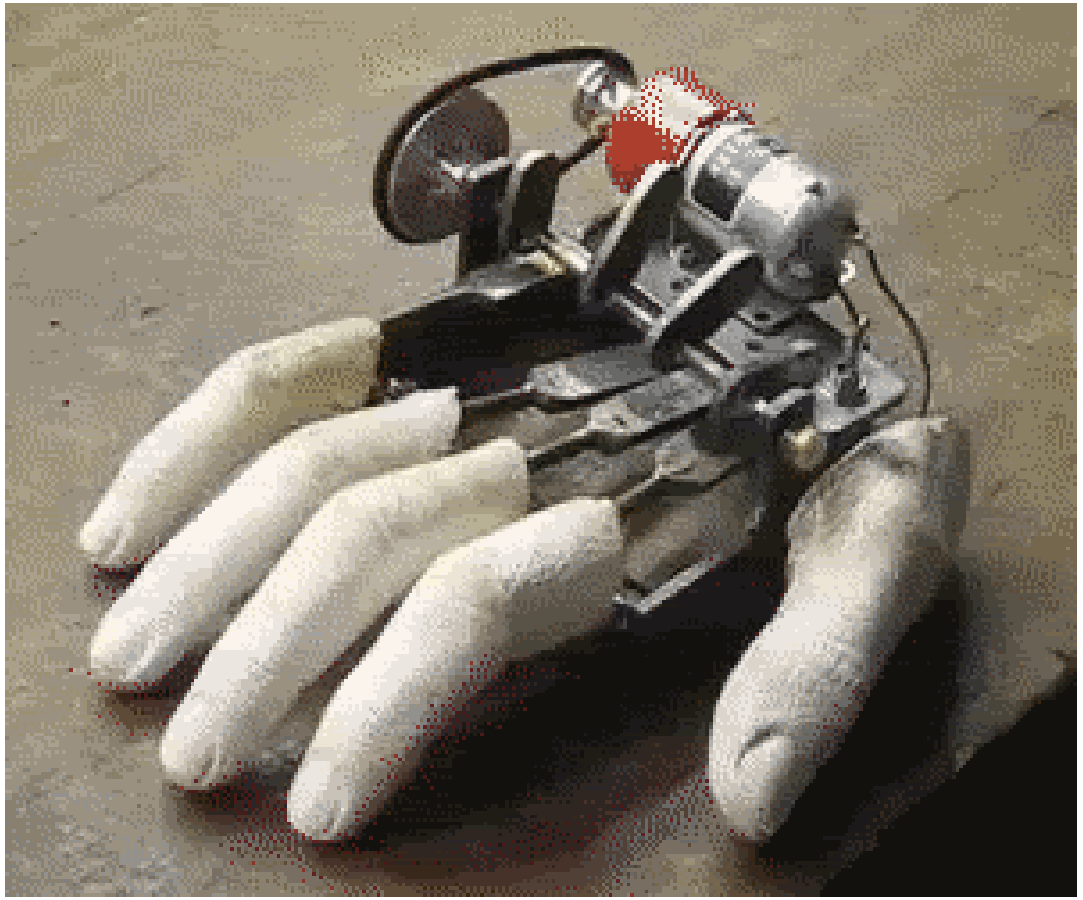
2. Basic elements of a mechatronic system

Mechatronics brings *sensors and measurement systems*, *drive and actuation systems*, and *microprocessor systems* together with the analysis of the *behavior of systems* and *control systems*.



2.1 Actuators

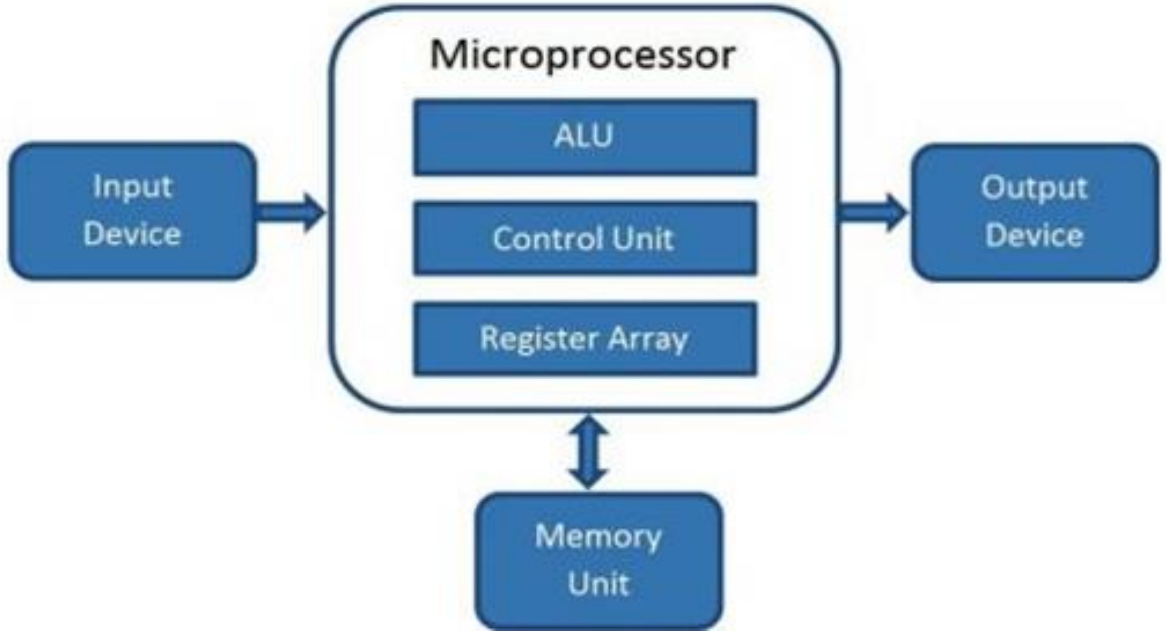
used as mechanisms *to introduce motion*, or to clamp an object so as *to prevent motion*.



2.2 Microprocessor

A microprocessor is the "brain" of a computer that *performs calculations* and *executes instructions* to carry out tasks.

It is a central processing unit (CPU) that *handles the logic for computing* but *needs external components* like memory and input/output interfaces to function.

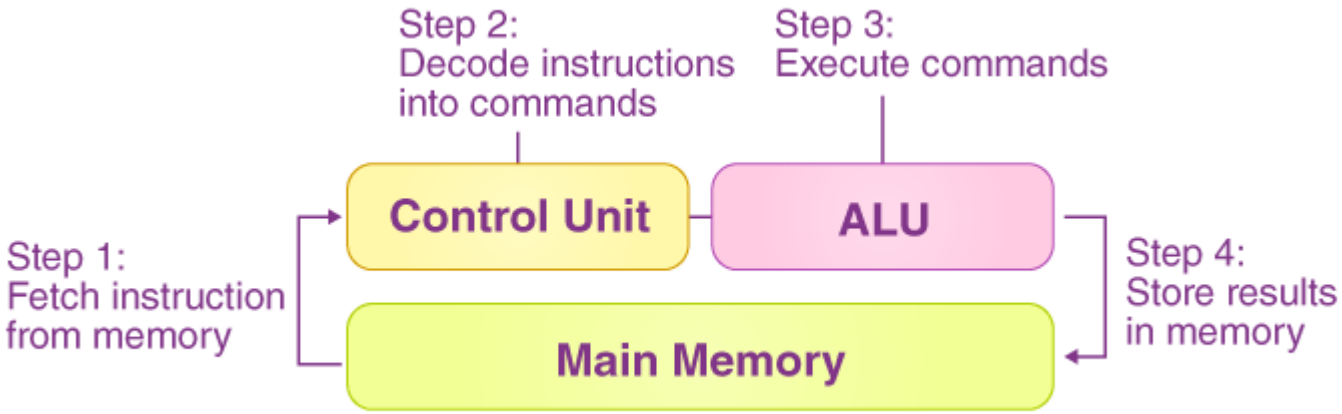


2.2.1 Control Unit (CU)

CU acts like a *manager* in a computer.

CU *receives orders from RAM* in the form of *instruction* and decode (break) that instruction down *into specific commands* for other components inside computer system.

It *directs* the data flow and the operation of the ALU.

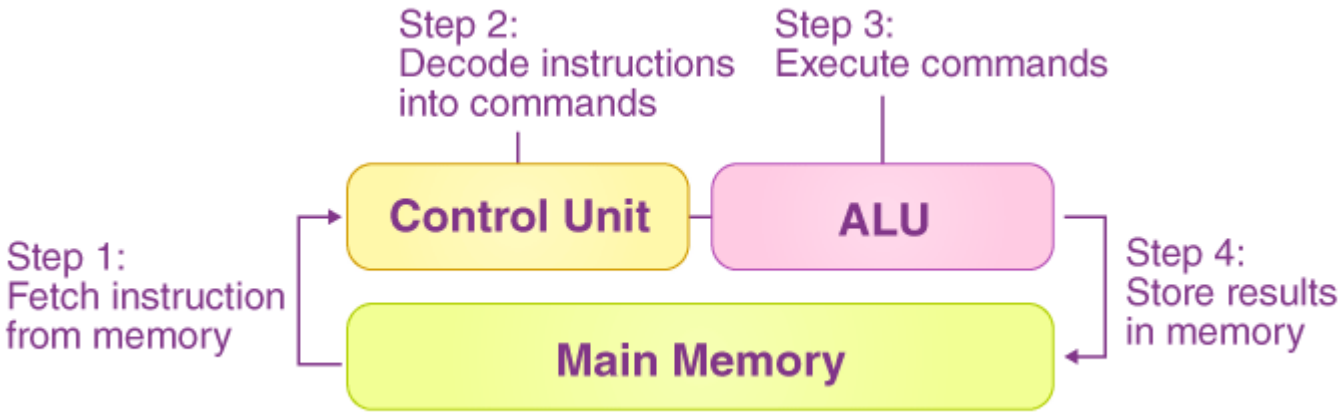


2.2.2 Arithmetic/Logic Unit (ALU)

ALU does all *mathematical operations* (arithmetic) (+/-/compare) and *logical (AND/OR) calculations*.

Some computers have *two ALUs* to process *two calculations simultaneously*. That is called *dual core technology*.

ALUs contain several *special storage units* called *registers*.



2.2.3 Register

Register is a *small, very fast storage area* inside CPU.

It is used to *store intermediate values* from calculations or instructions that is *needed again immediately*.

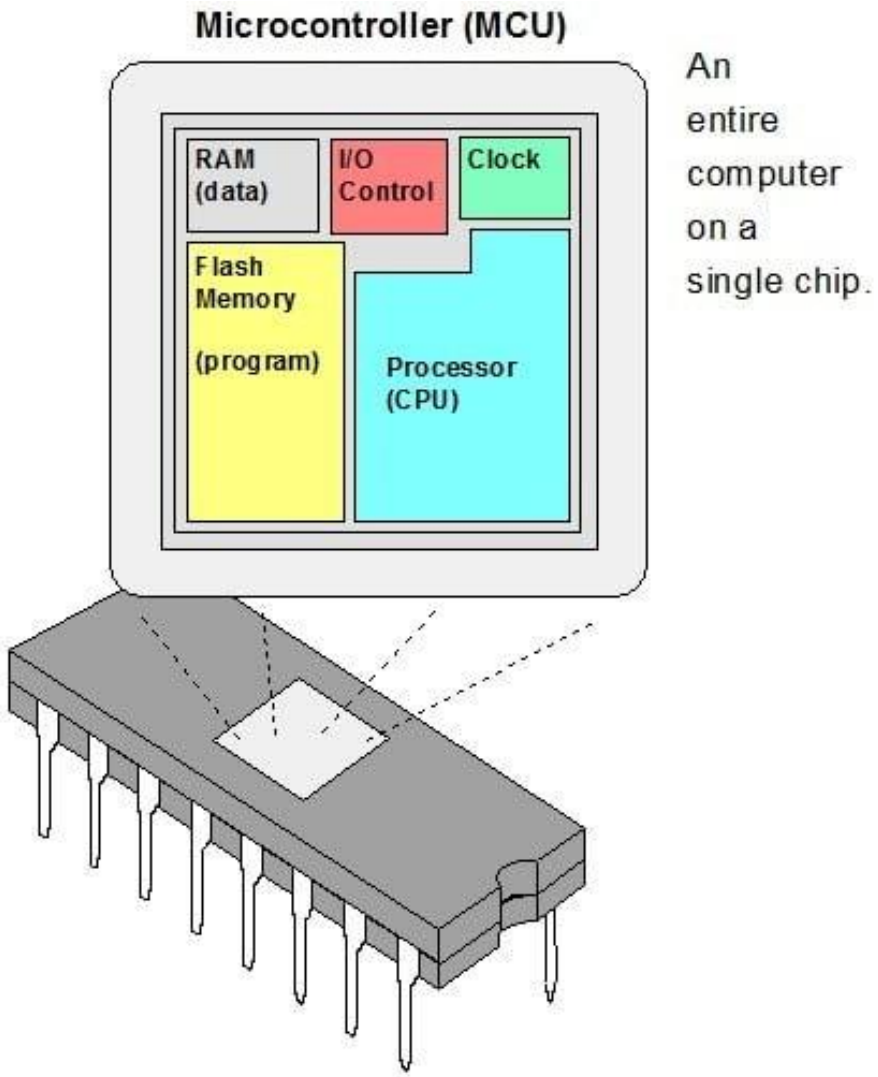
For instance, when a ALU is commanded to calculate A*(B+C), ALU needs to calculate B+C first, then ALU need to store the result for a moment and use the result to multiply A.

It is *faster for ALU to access register* than store the data in memory units.

Microcontroller

A microcontroller is like a small, self-contained computer on *a single chip* that includes a microprocessor, memory, and input/output interfaces all in one.

It is *designed to control specific tasks* within devices like appliances, cars, and gadgets.



Embedded systems

microprocessor-based system that is *designed to control a range of functions* and is *not designed to be programmed* by the end user in the same way that a computer is.

Home Appliances: Microwave ovens, washing machines, and refrigerators.

Consumer Electronics: Smartphones, digital cameras, and smart TVs.

Medical Devices: Pacemakers, insulin pumps, and medical imaging equipment.

Industrial Machines: CNC machines, industrial robots, and process control systems.

Communication Devices: Routers, modems, and network switches.

Examples of Embedded Systems









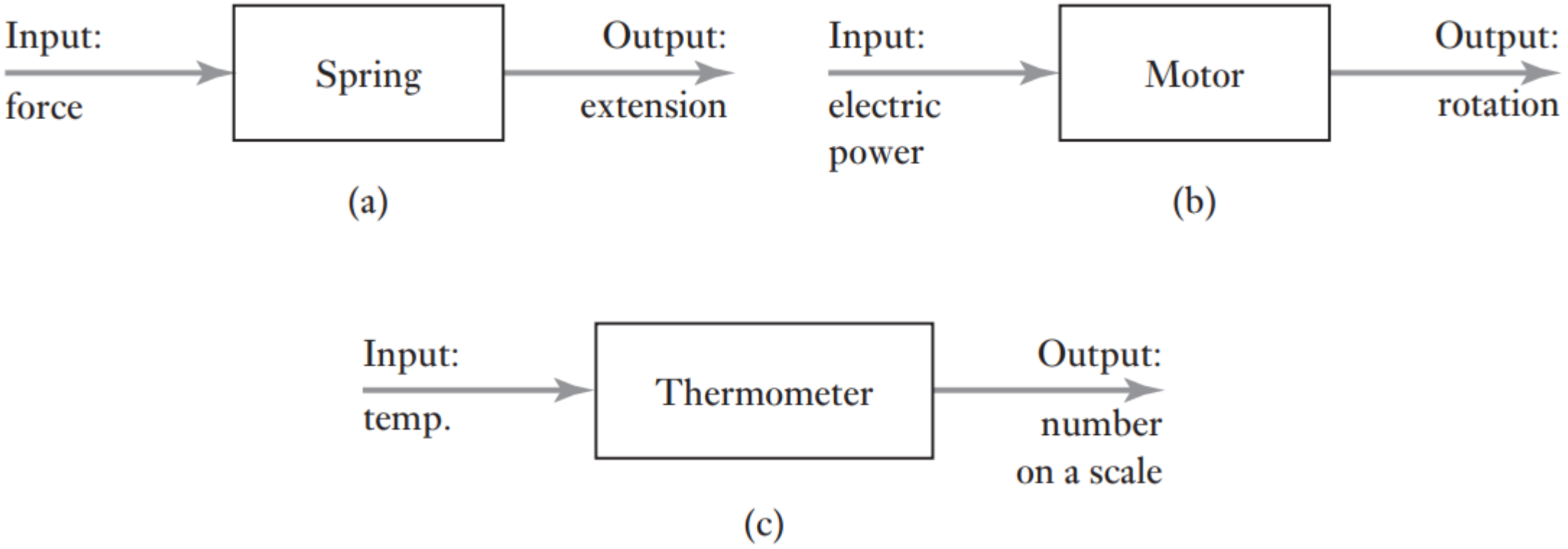






2.3 System

A system can be thought of as a box or block diagram which has an *input and an output* and where we are concerned not with what goes on inside the box, but with only the *relationship between the output and the input*.



2.3.1 System Modelling

represent the *behavior of a real system* by *mathematical equations*, such equations representing the *relationship between the inputs and outputs* from the system.

Consider a spring as a system with an input force (F) and an output extension (x).

When we *apply a force to the spring*, it *extends or compresses* in response.

To model the relationship between the input force and the output extension,

$$F = kx$$

where:

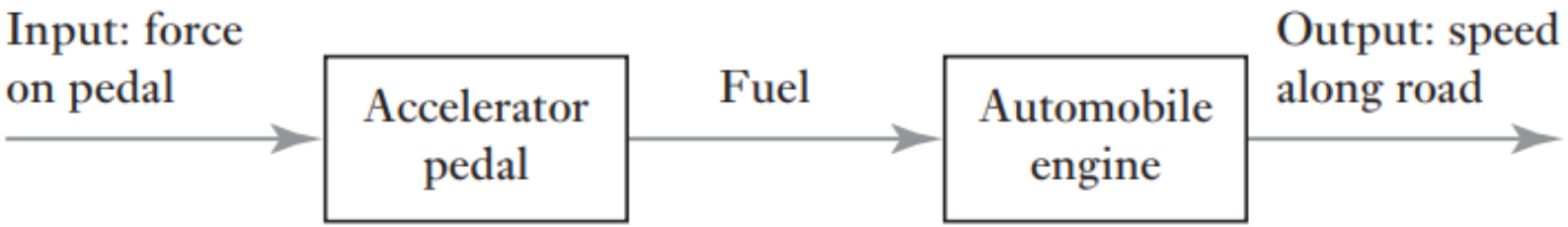
F is the applied force (input).
x is the resulting extension or compression (output).
k is the spring constant, a measure of the spring's stiffness.

A *higher spring stiffness* indicates *greater resistance* to compression or stretching by an external force.

2.3.2 Connected System

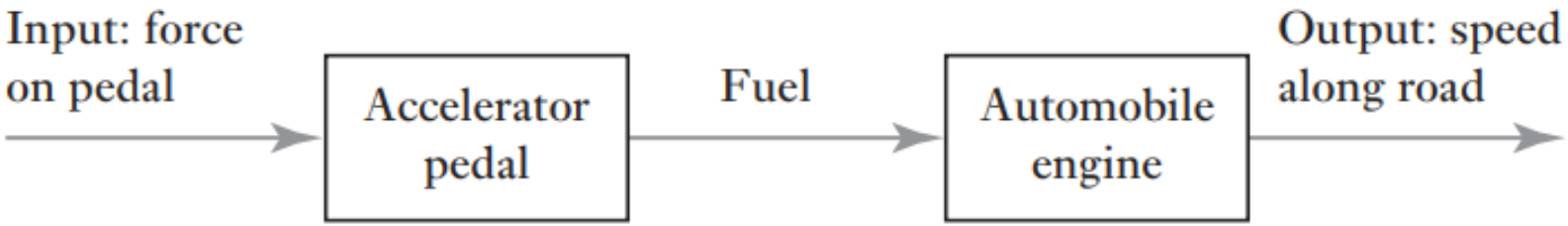
A *series of interconnected blocks* or components, where each block serves a specific function or purpose.

These blocks are connected in a way that allows the *output from one block to become the input to the next block*, forming a chain of interconnected components.



Accelerator Pedal Block:

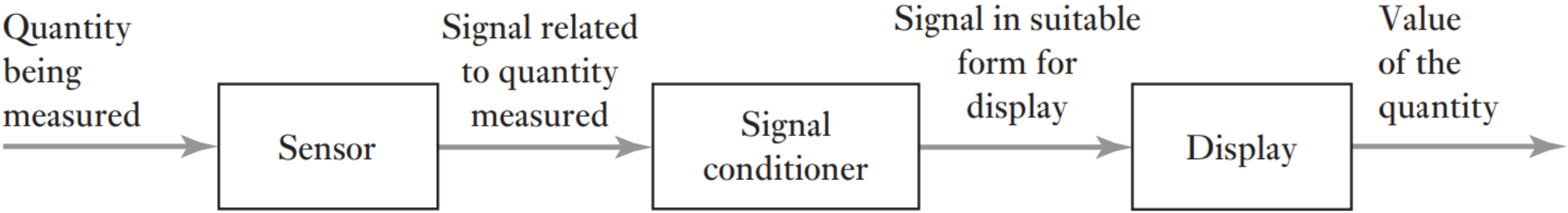
receives an input force applied by the driver's foot. *It controls an output*, which is the *amount of fuel* supplied to the engine.



Engine System Block:

receives the input of fuel and *controls the output*, which is the *speed of the vehicle* along the road.

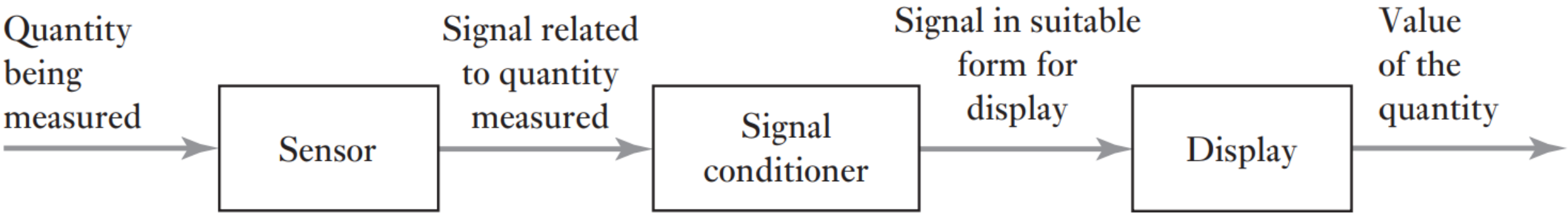
2.4 Measurement System Components



2.4.1 Sensor:

A sensor is a device that *responds to a physical quantity*, such as temperature, by *producing an output signal* related to that quantity.

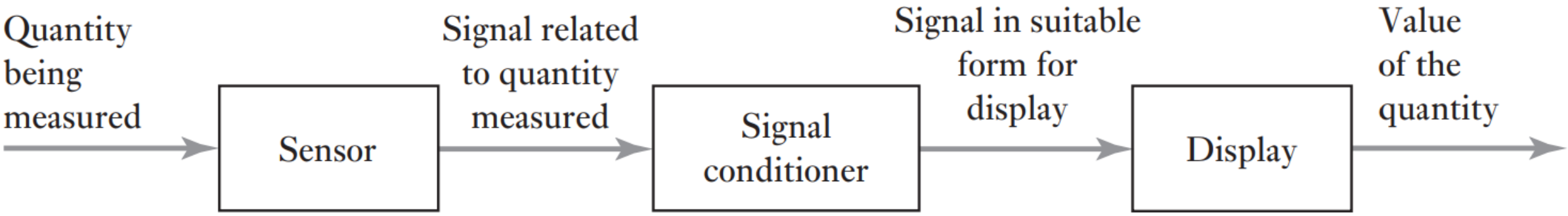
Example: A *thermocouple* is a temperature sensor. When subjected to a *temperature change*, it generates an *electromotive force (e.m.f.) as an output*, which is proportional to the temperature.



2.4.2 Signal Conditioner:

The signal conditioner takes the *raw signal from the sensor* and processes it to *make it suitable for further use*, such as display or control.

Example: In the case of a thermocouple, the *e.m.f. generated is typically small*. An *amplifier* can be used as the signal conditioner to *increase the signal's amplitude*, making it more usable for further processing.

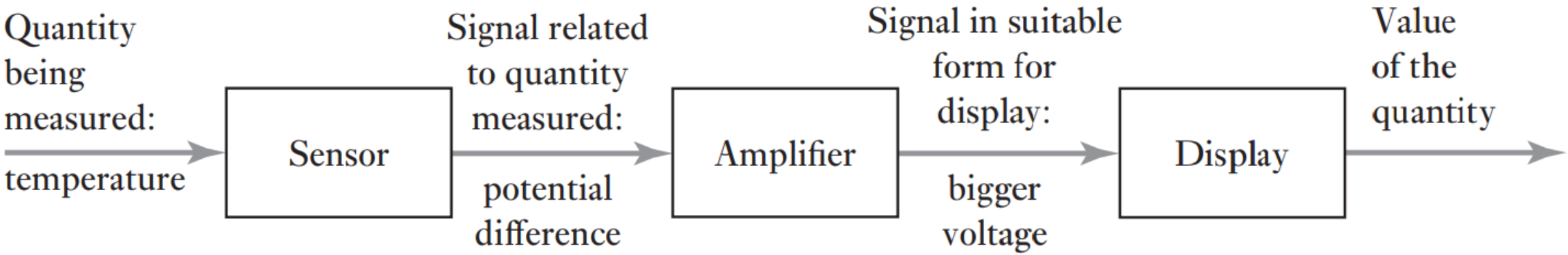


2.4.3 Display System:

The display system *presents the processed signal* in a format that can be *easily interpreted by the user*.

Example: A digital thermometer takes the conditioned signal and displays the temperature measurement. This display could be in the *form of a digital readout*, making it *easy for users to read* the temperature value.

A digital thermometer system



2.5 Control System

A control system can be thought of as a system used to *manage and regulate the behavior* of other devices or systems.

Control a Variable to a Specific Value:

Example: *Central heating system*.
Purpose: To maintain the room temperature at a *set value*.

Control the Sequence of Events:

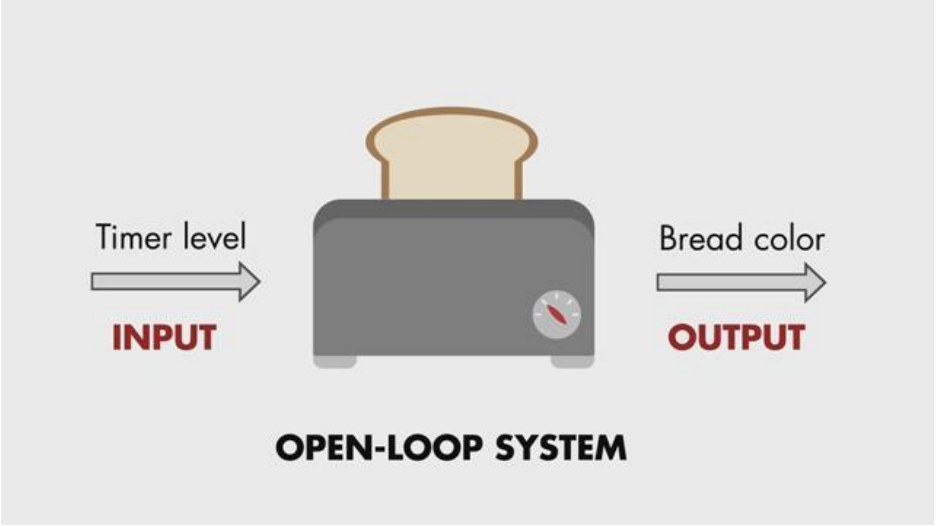
Example: *Washing machine*.
Purpose: To follow a *specific washing cycle* based on the settings, ensuring clothes are washed in a particular order (e.g., soak, wash, spin).

Control Whether an Event Occurs or Not:

Example: *Safety lock* on a machine.
Purpose: To ensure the *machine cannot operate* until a *safety guard is in place*, preventing accidents.

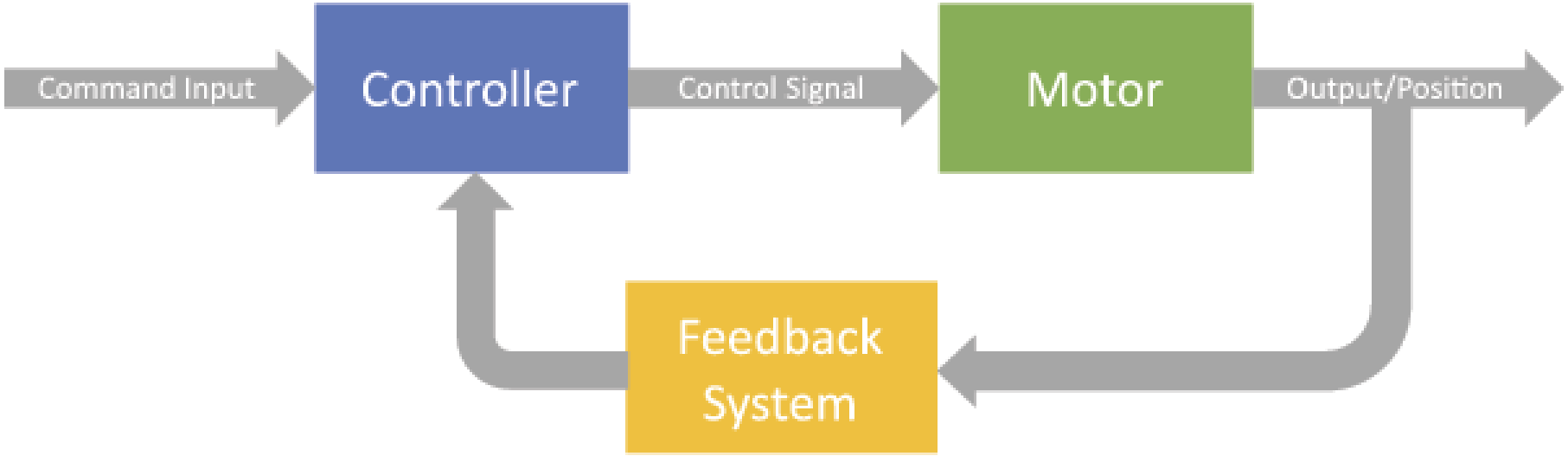
2.5.1 Open-Loop Control

the control *action is determined* solely by the *initial setup or input*, *without considering the system's actual output* or the *need for correction*.



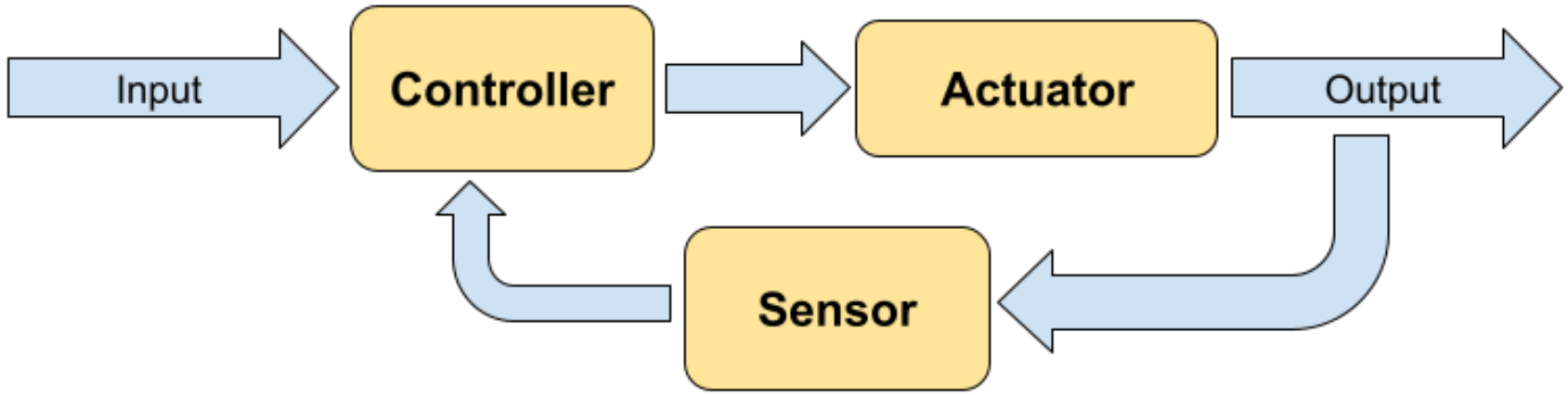
Open Loop System

Closed Loop System



2.5.2 Closed-Loop (Feedback) Control

It involves *comparing the actual output* (feedback) of the system *with the desired output* and *adjusting the system's actions* accordingly.



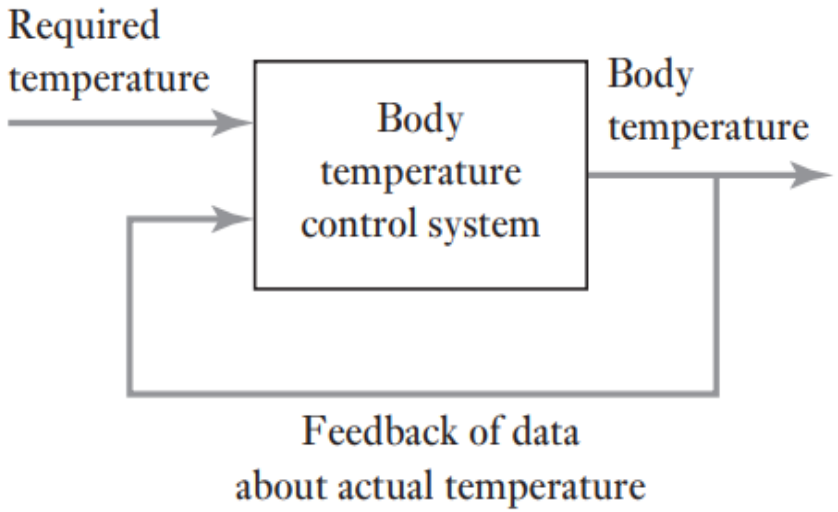
Practical Example of closed-loop / feedback control system

Sensors:

The *body has sensors* that *continuously monitor its temperature*.

Comparison:

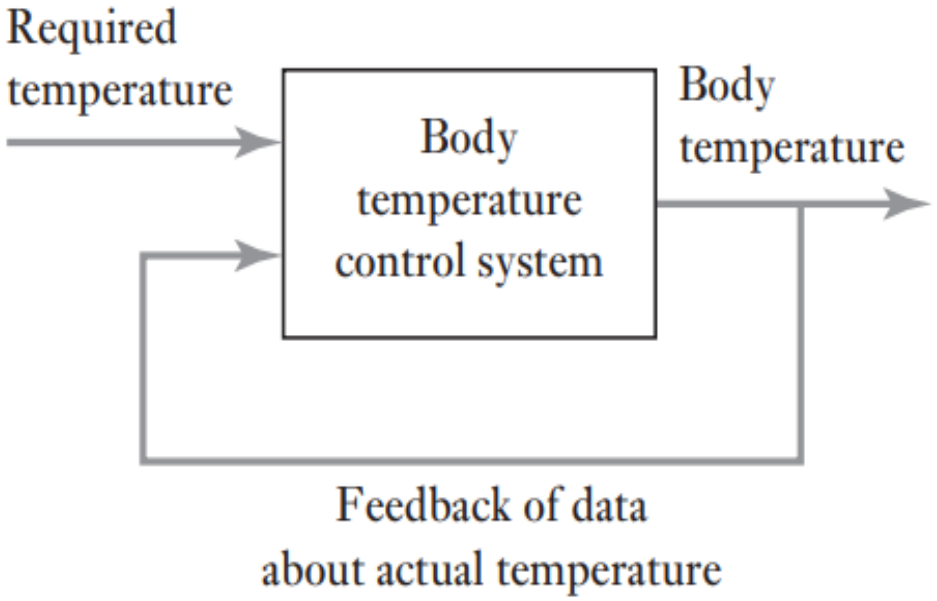
The *sensed temperature is compared* to the desired or *"normal" temperature*.



Response:

If the *sensed* temperature *deviates from the normal range*, the body responds:

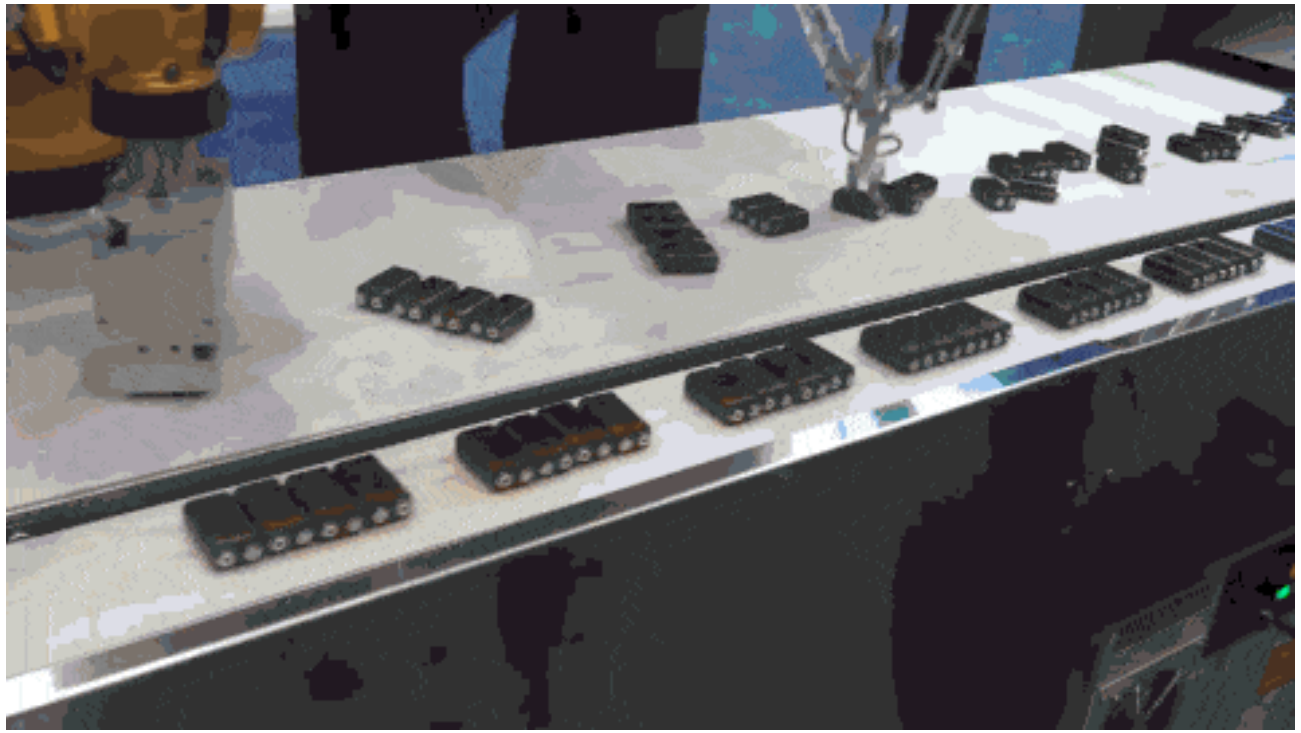
- ❑ If the temperature is too high, the body *initiates sweating to cool down*.
- ❑ If the temperature is too low, the body *initiates shivering to generate heat*.



3. Examples of mechatronic systems

Robots:

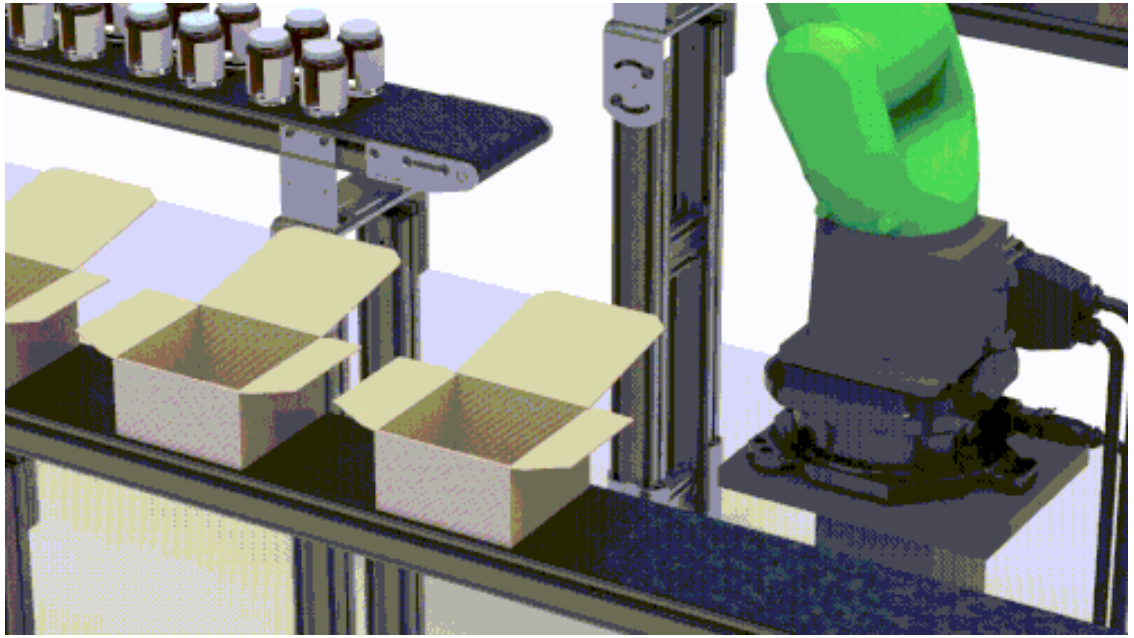
Industrial robots used in manufacturing for assembly, welding, painting, and packaging tasks.



assembly

welding

painting



packaging tasks

Automated Guided Vehicles (AGVs):

Self-driving vehicles used in warehouses and factories to transport goods.

Drones:

Unmanned aerial vehicles (UAV) used for surveillance, photography, and delivery services.

surveillance, photography

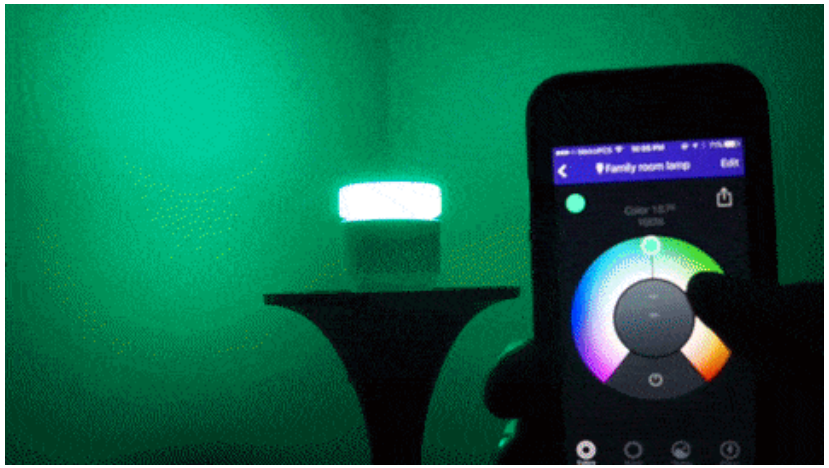
delivery services

Smart Home Devices:

Appliances like robotic vacuum cleaners, smart thermostats, and automated lighting systems.

robotic vacuum cleaners

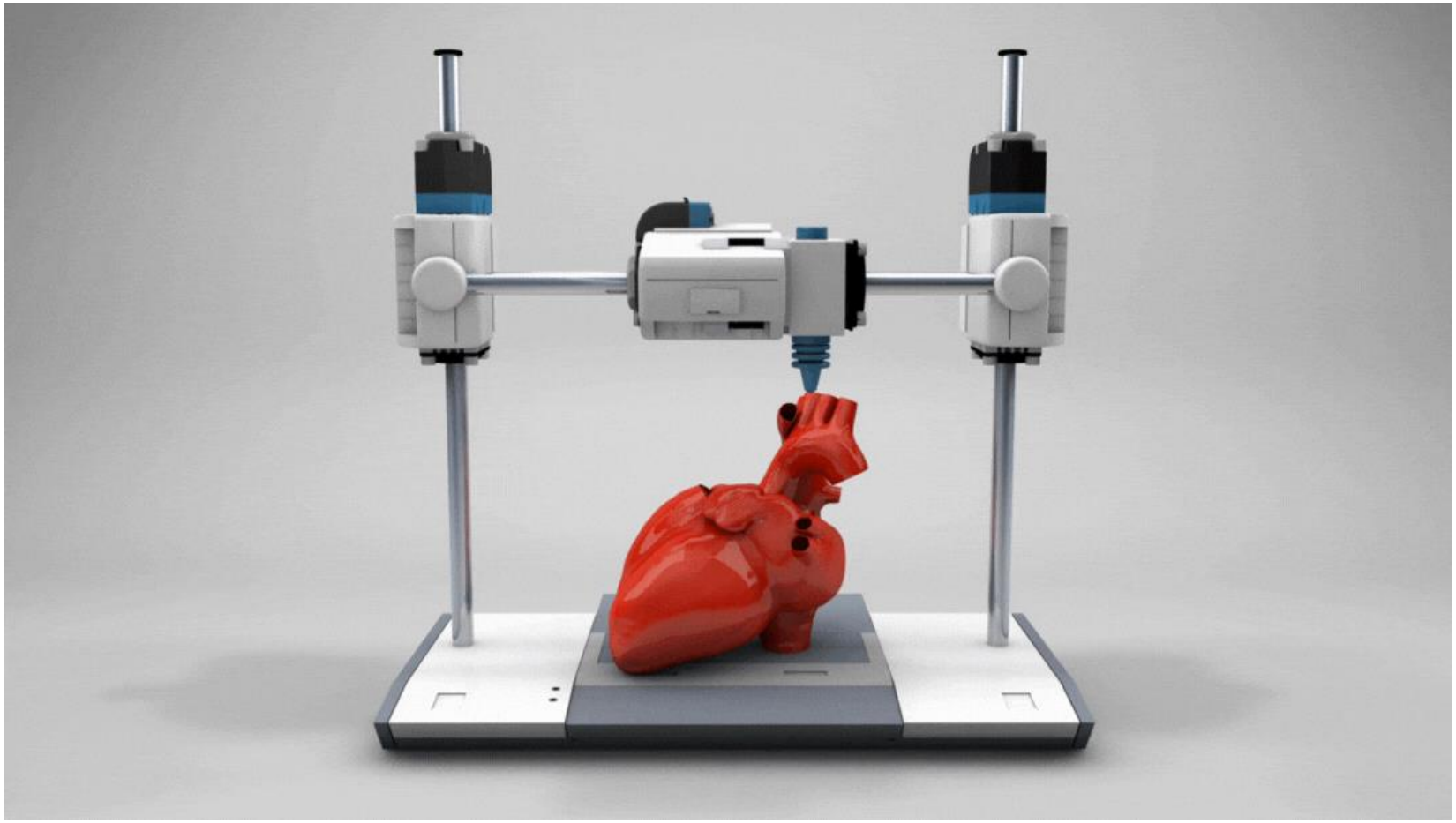
smart thermostats



automated lighting systems

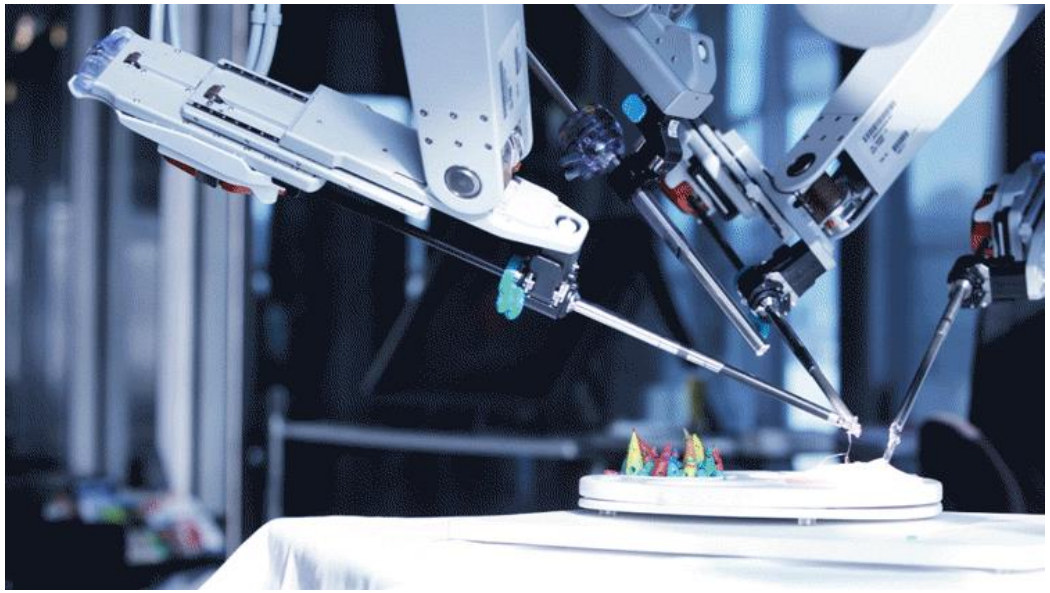
3D Printers:

Machines that *create objects layer by layer* using digital models.



Medical Devices:

Automated surgical instruments, robotic prosthetics, and advanced imaging systems.



Automated surgical instruments

robotic prosthetics

advanced imaging systems

Consumer Electronics:

Devices like smartphones, smartwatches, and gaming consoles with integrated sensors and actuators.

CNC Machines:

Computer Numerical Control machines used for precise manufacturing and machining tasks.

CNC Milling

CNC Lathe