

Introduction to Control Systems

Introduction to Control Systems

(A concise, easy-to-read guide for students and engineers)

1. What Is a Control System?

Aspect	Description
Definition	A set of devices or algorithms that manages, directs, or regulates the behavior of other devices or processes to achieve a desired performance.
Goal	Maintain a system variable (temperature, speed, position, etc.) at a prescribed value (the setpoint) despite disturbances or changes in the environment.
Typical Elements	Sensor ? Controller ? Actuator ? Plant (the process being controlled).

2. Classification of Control Systems

Category	Key Characteristics	Examples
Open Loop	No feedback; action is predetermined.	Toaster timer, sprinkler system without rain sensor.
Closed Loop (Feedback)	Output is measured and compared with the setpoint; correction is applied automatically.	Cruise control, temperature regulator, robotic arm.
Linear vs. Non-Linear	Linear: superposition holds; Non-linear: behavior changes with magnitude.	Linear: small-signal amplifier; Non-linear: pneumatic valve with dead zone.
Time-Invariant vs. Time-Varying	Parameters constant vs. changing with time.	Time-invariant: most industrial controllers; Time-varying: adaptive flight control.
Continuous-Time vs. Discrete-Time	Signals vary continuously or at sampled instants.	Continuous: analog PID; Discrete: digital microcontroller controller.

3. Core Components

Introduction to Control Systems

1. Plant (Process)

- The physical system to be controlled (motor, chemical reactor, aircraft).

2. Sensor (Measurement)

- Converts the plant output into a usable signal (voltage, digital count).
- Important specs: accuracy, bandwidth, resolution, noise.

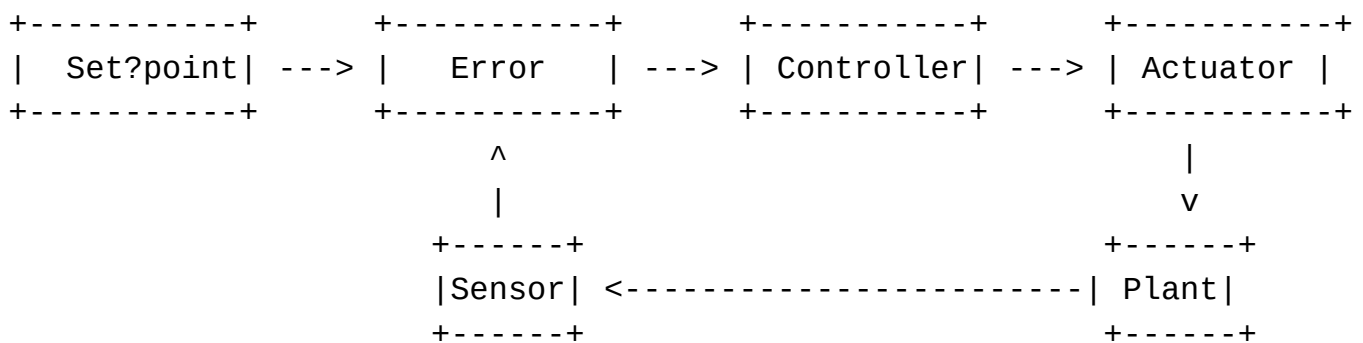
3. Controller

- Computes the control effort based on the error (setpoint – measured value).
- Common forms: **PID**, state feedback, optimal, adaptive, fuzzy, neural.

4. Actuator

- Executes the control command (valve, motor, heater).
- Must have sufficient bandwidth and authority to influence the plant.

4. Basic Control Loop Diagram



- **Error** = Setpoint – Measured output
- The loop repeats continuously (or at a fixed sampling period).

5. Fundamental Concepts

Concept	Meaning	Typical Use
Transfer Function	Ratio $G(s)=\frac{Y(s)}{U(s)}$ in the Laplace domain for linear time-invariant (LTI) systems.	Analyzing stability, frequency response.
Block Diagram	Visual representation of signal flow and interconnections.	System modeling, design simplification.
Stability	Ability of the system to return to equilibrium after a disturbance.	Determined via poles of $G(s)$, Routh-Hurwitz, Nyquist.

Introduction to Control Systems

Concept	Meaning	Typical Use
Steady?	Difference between setpoint and output after	
State Error	transients vanish	