ΗΜΥ 631
ΘΕΩΡΙΑ ΣΥΣΤΗΜΑΤΩΝ

Ακαδημαϊκό έτος 2015-16
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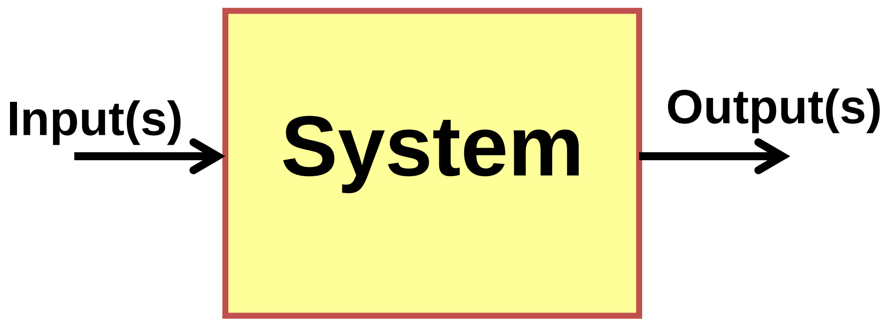
System Theory

I. Introduction

System Theory: Definitions



- A **System** is an aggregation or assemblage of things so combined by nature or man as to form an integral and complex whole.
- A **System** is the mathematical description of a relationship between externally supplied quantities (inputs) and the dependent quantities (outputs) that result from the action or effect on those external quantities.

Signals and Systems – what’s the difference?

System Theory is the study of the interactions and behavior of the system components when subjected to certain conditions or inputs.

Aspects of System Theory

- **Multi-disciplinary** (electrical engineering; mechanical engr; chemical engr; civil and environmental engr; biology; economics; sociology; etc)
- **Mathematically rigorous**
- **Provides a common language for scientists and engineers**
- **Modeling; Prediction; Monitoring; Control**
- **Optimization**

Monitoring and Control Applications

- Distributed Autonomous Vehicles
- Power and Energy Systems
- Chemical and Petrochemical Engineering Processes
- Biological and Biomedical Engineering Applications
- Environmental Monitoring and Control Applications
- Transportation Systems
- Smart Buildings
- Water Distributions Networks
- Military and Security Applications
- many more …..

Mathematical Modelling

a) First principles of physics (chemistry, biology, economics, etc.)

b) System identification using real data

c) Combination of first principles and system identification

→ Why do we need a mathematical model?

→ Why do we need a *design model* (simplified mathematical model)?

Everything Should Be Made as Simple as Possible, But Not Simpler – A. Einstein

→ What are the limitations of mathematical modelling?

Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful. – George E. Box

Mathematical Modelling

- Differential/dynamic systems vs algebraic systems
  - Systems with memory – the outputs depend not only on the inputs but also on the initial conditions
- Linear vs nonlinear models
- Continuous-time vs discrete-time models
- Time invariant vs time-varying systems
- Causal vs non-causal (anticipatory) systems

Mathematical Modelling – the 3 domains

$$u \longrightarrow \boxed{H(s)} \longrightarrow y$$

s-plane (Laplace transform)
Transfer Functions

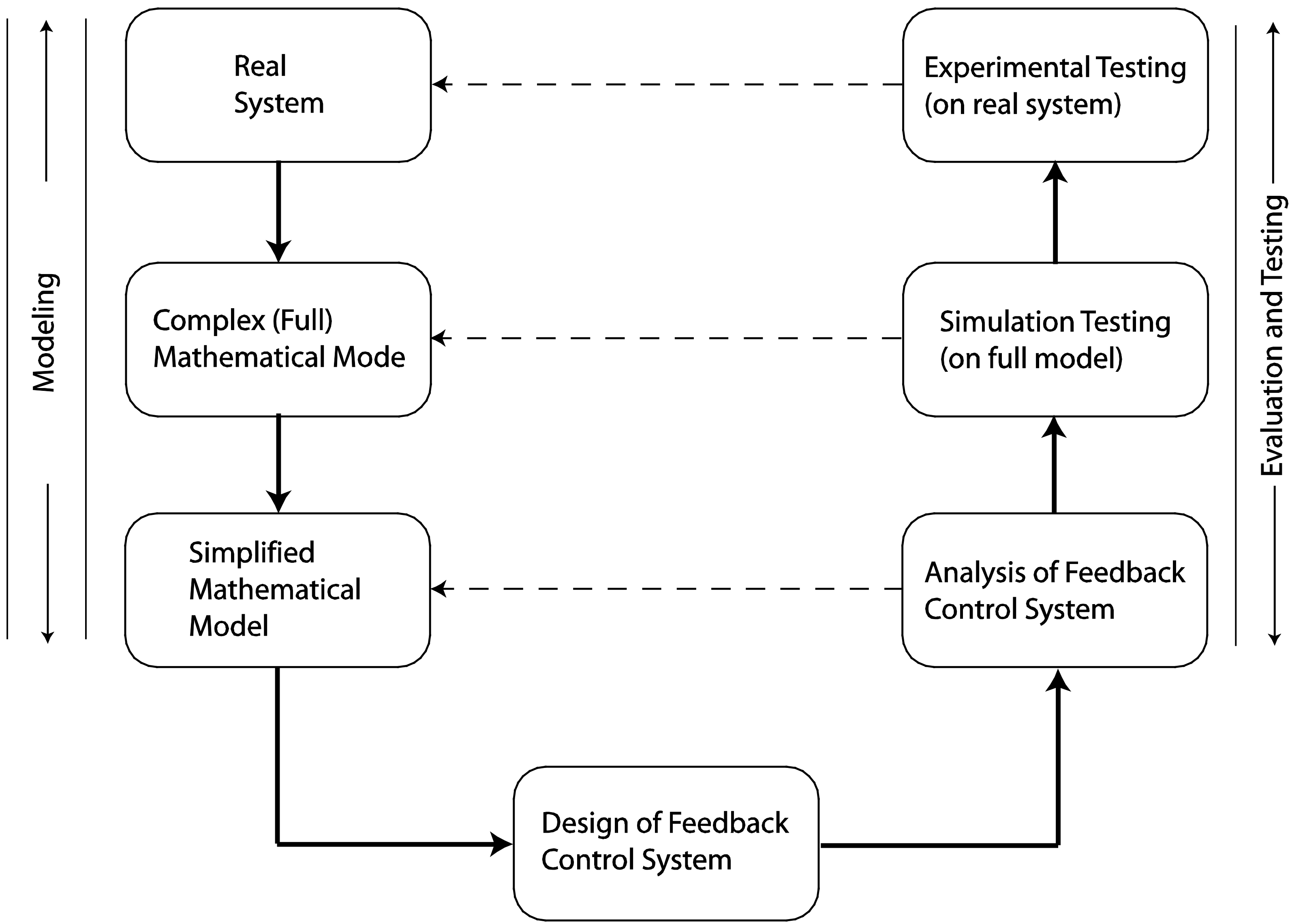
$$u \longrightarrow \boxed{\begin{array}{c} \left|H(j\omega)\right| \\ \angle H(j\omega) \end{array}} \longrightarrow y$$

Frequency Response
Bode diagrams

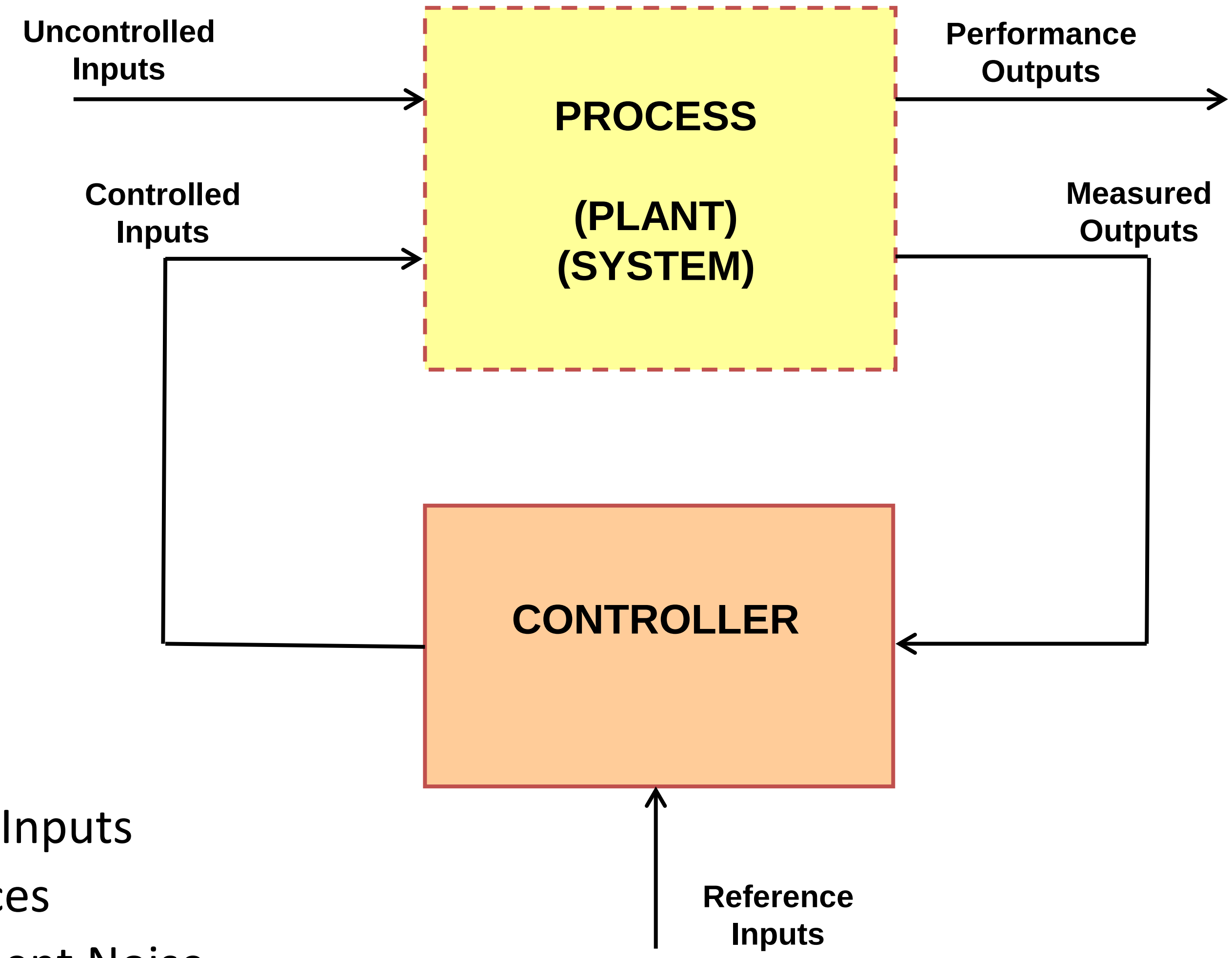
$$u \longrightarrow \boxed{\begin{array}{l} \dot{x} = Ax + Bu \\ y = Cx + Du \end{array}} \longrightarrow y$$

State-Space (time domain)
Differential Equations

Modelling, Feedback Control Design and Evaluation



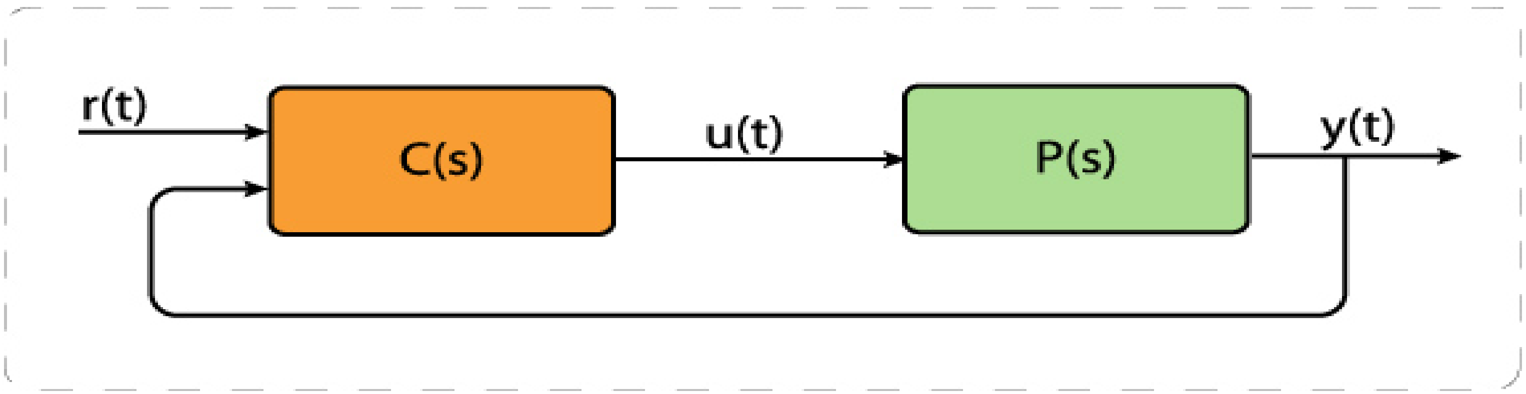
General Control Formulation



Key Issues:

- Sensors
- Actuators
- Reference Inputs
- Disturbances
- Measurement Noise
- ***Feedback***

General Control Formulation



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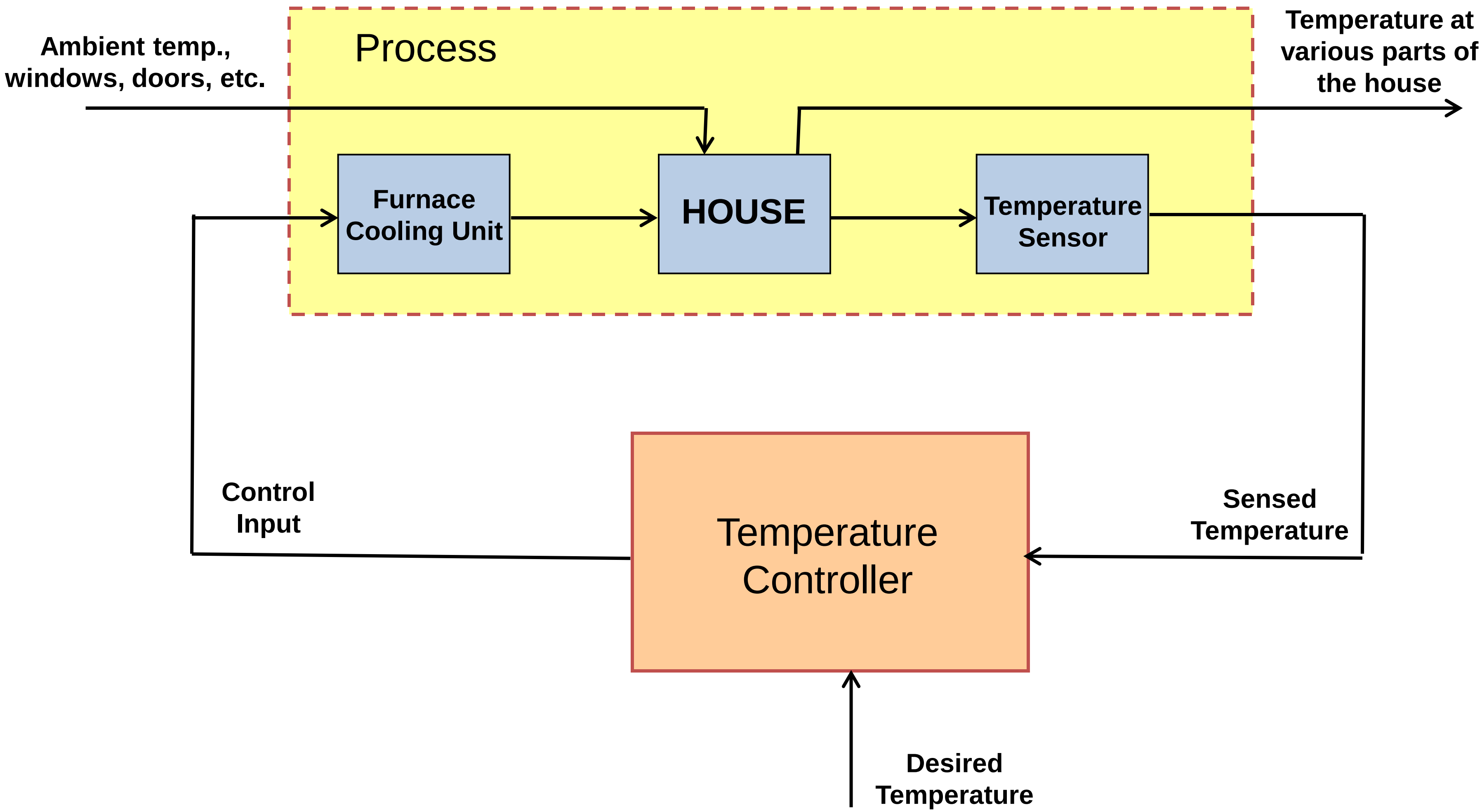
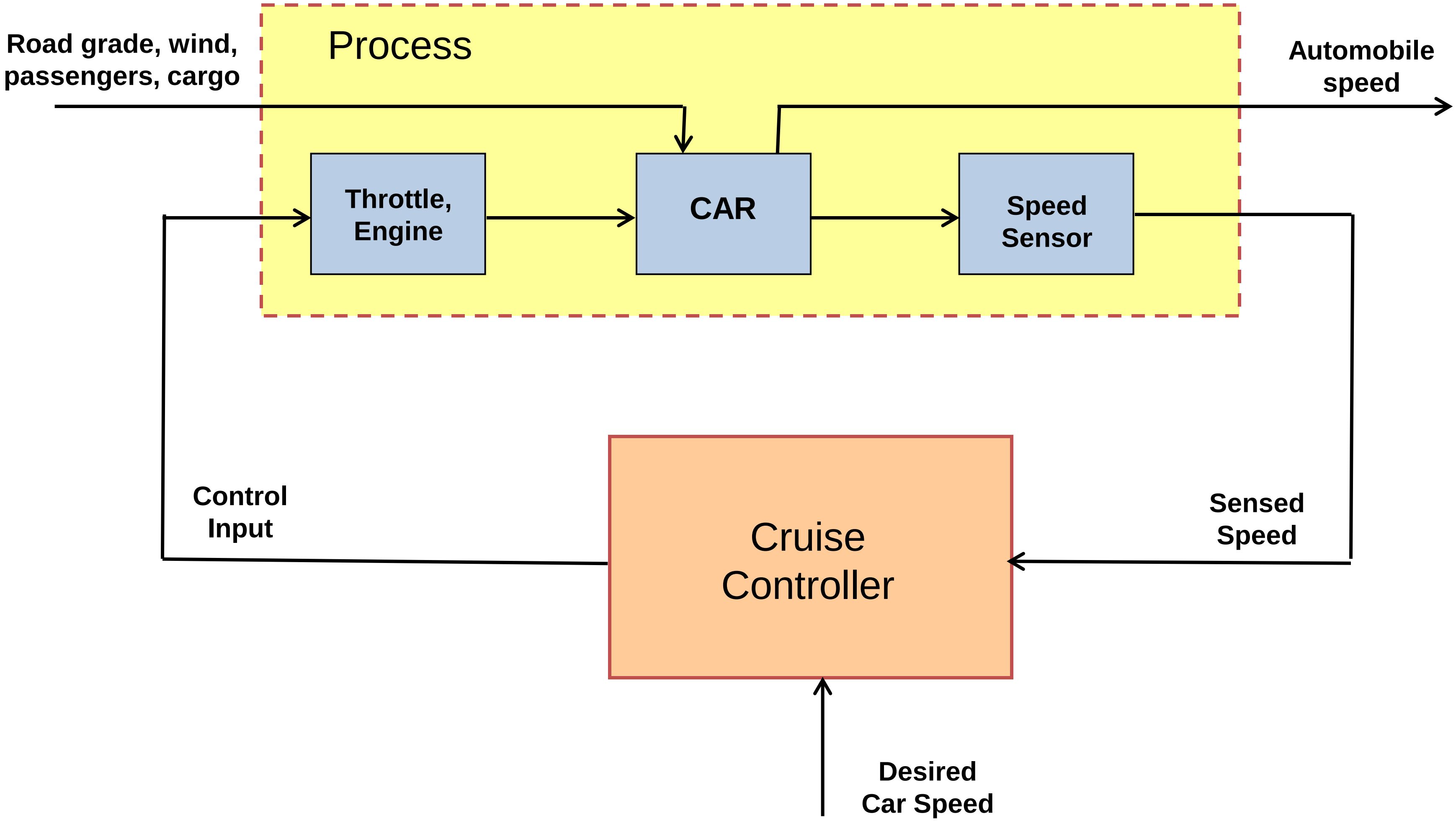
Simple Example of Automation: Temperature Control

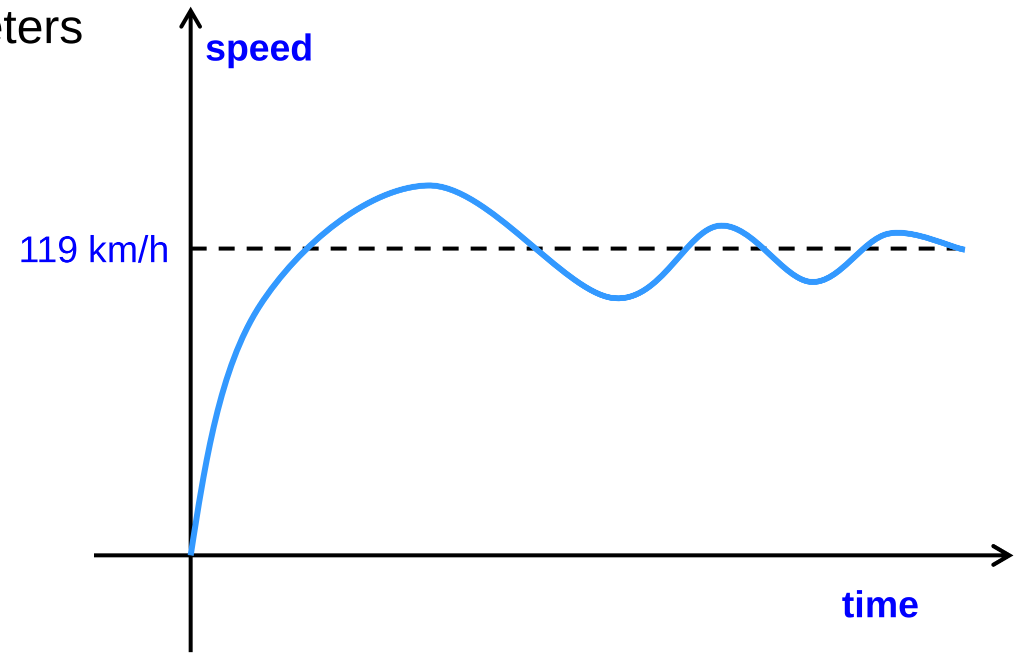


Simple Example of Automation: Cruise Control



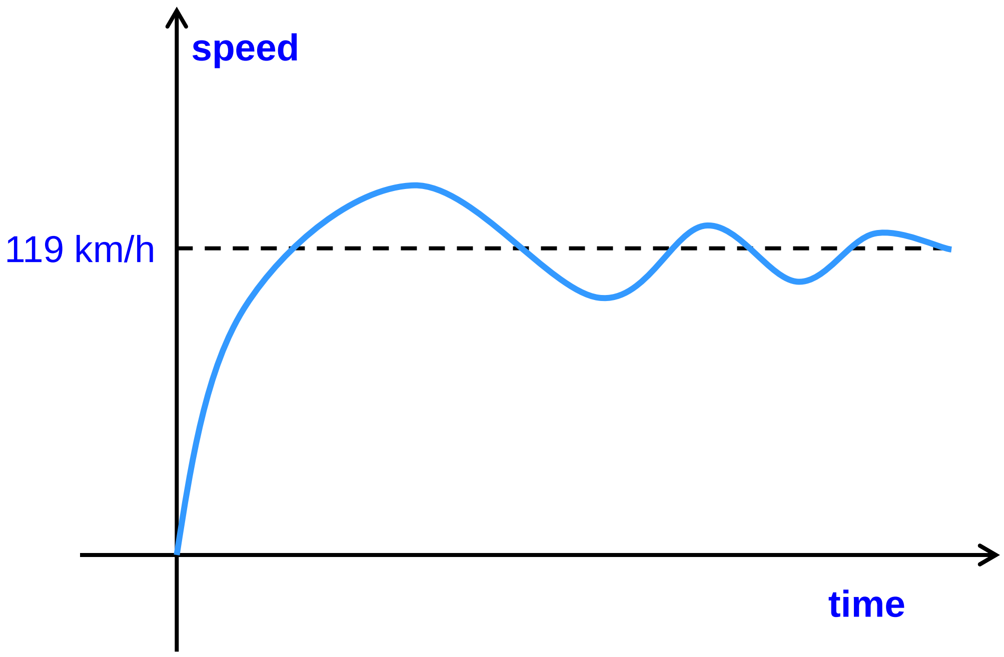
Design Objectives: **Technical**

- Tracking (regulation)
- Disturbance rejection
- Insensitivity to plant parameters
- Stability
- Rise-time
- Overshoot
- Settling time
- Steady-state error



Design Objectives: **Engineering Goals**

- Cost
- Computational complexity
- Reliability
- Adaptability, maintainability, expandability
- Effect on the environment
- Politics



Key Technological Trends

- Internet of Things
- Big Data
- Cyber-Physical Systems
- Distributed Information Processing
- Cooperation/coordination between controllers
- System of Systems
- Autonomous mobile systems