Servo & Control

Prof. Jamie Paik
Alihan Bakir
Reconfigurable Robotics Laboratory
EPFL, Switzerland

Topics

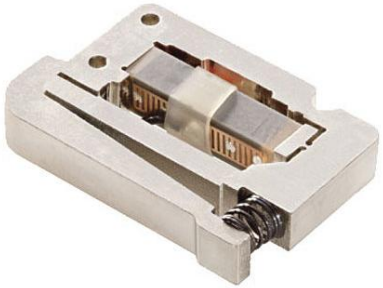
- Actuation systems
- Servo motors
  - Principle
  - Send data
- Control loop
- Servo control demo

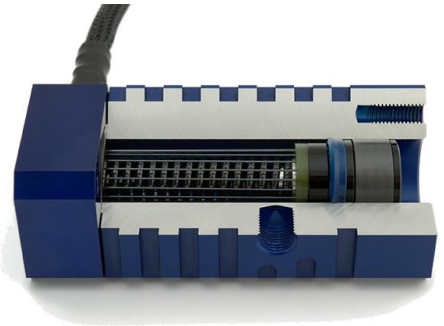
Actuation systems

- Combustion
- Hydraulics
- Pneumatics
- Electric
- Thermal

Types of electric actuators

- Electric motors
- Solenoids
- Piezoelectric
- Shape memory alloys

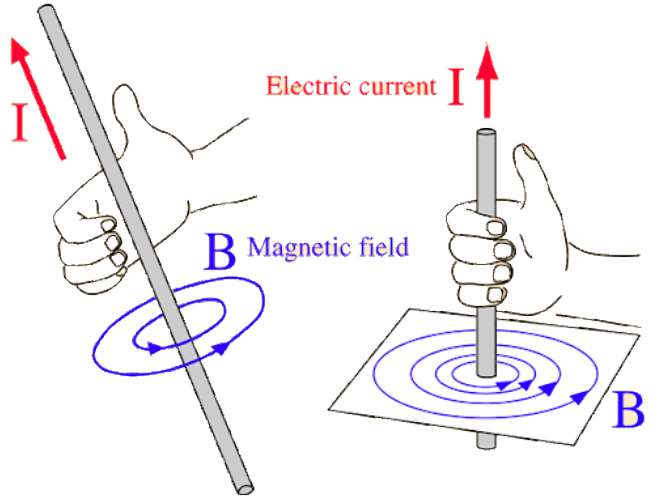


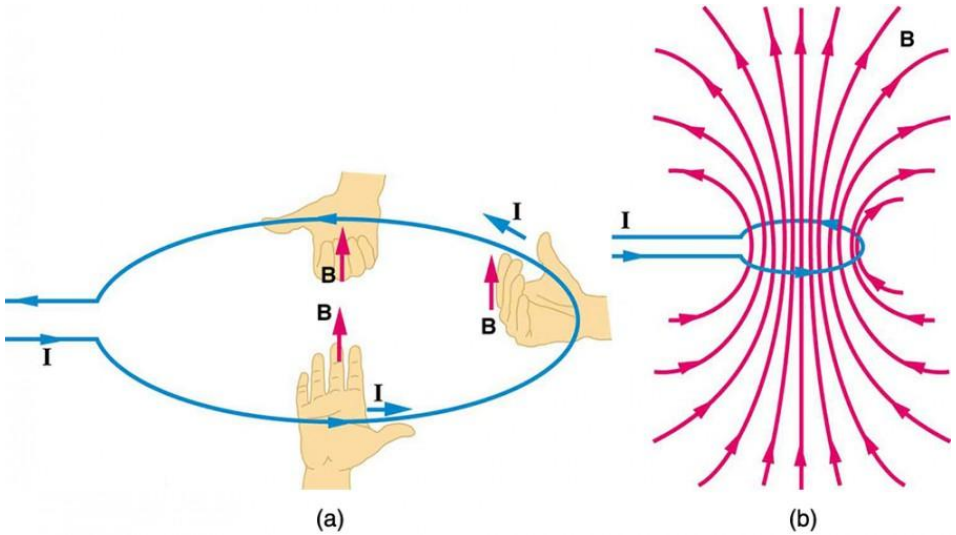


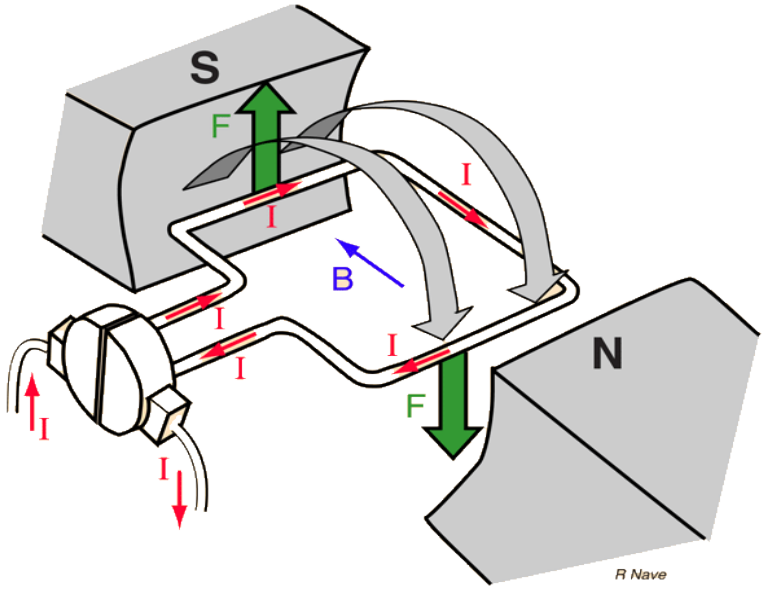
Types of electric motors

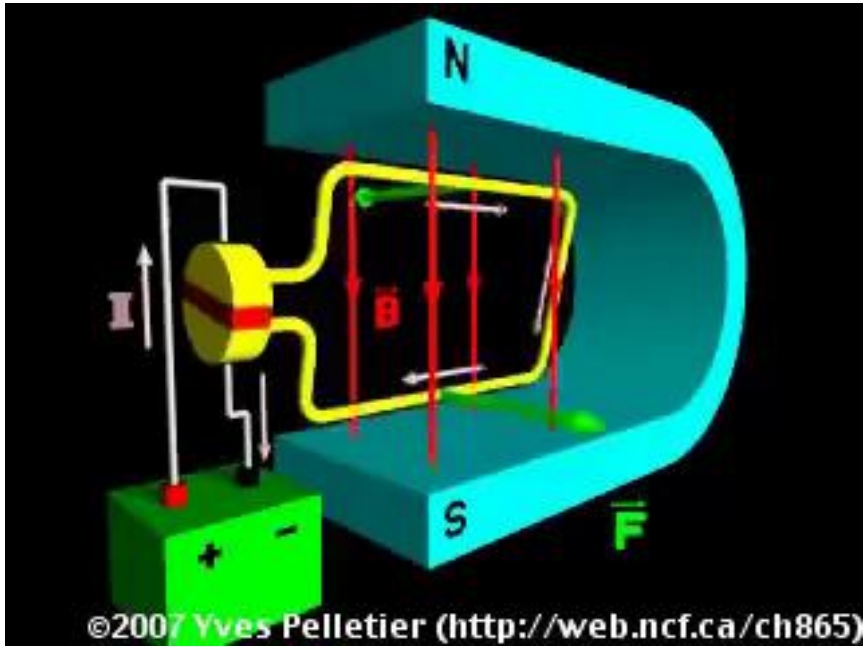
- Brushed DC motors
- Brushless DC motors
- Stepper motors
- Servomotors
- AC induction motors
- AC synchronous motors
- Universal motors

DC motor concept



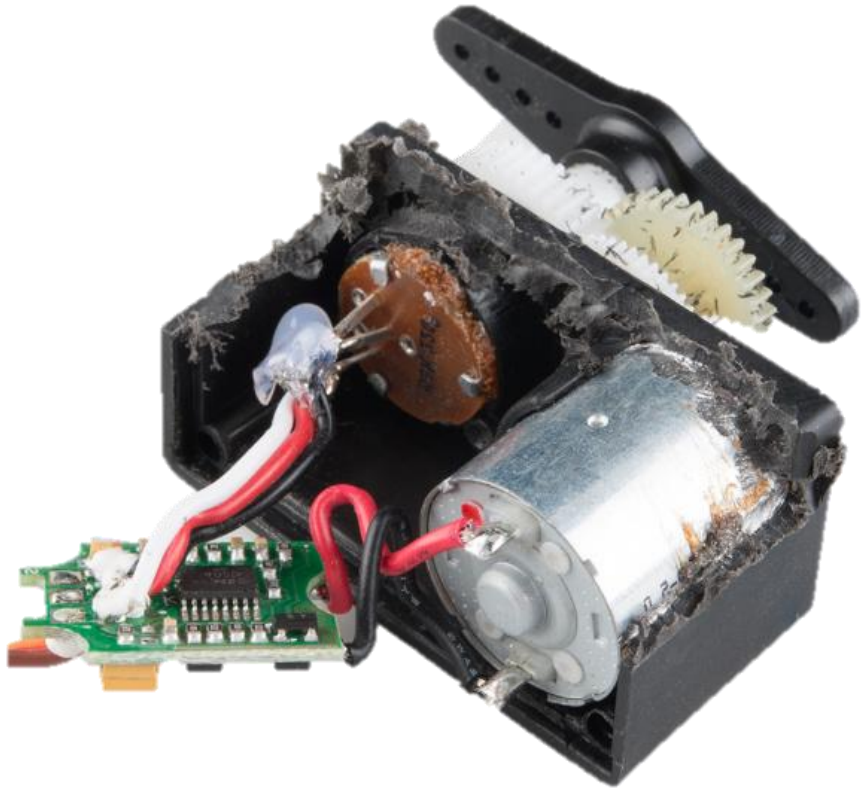






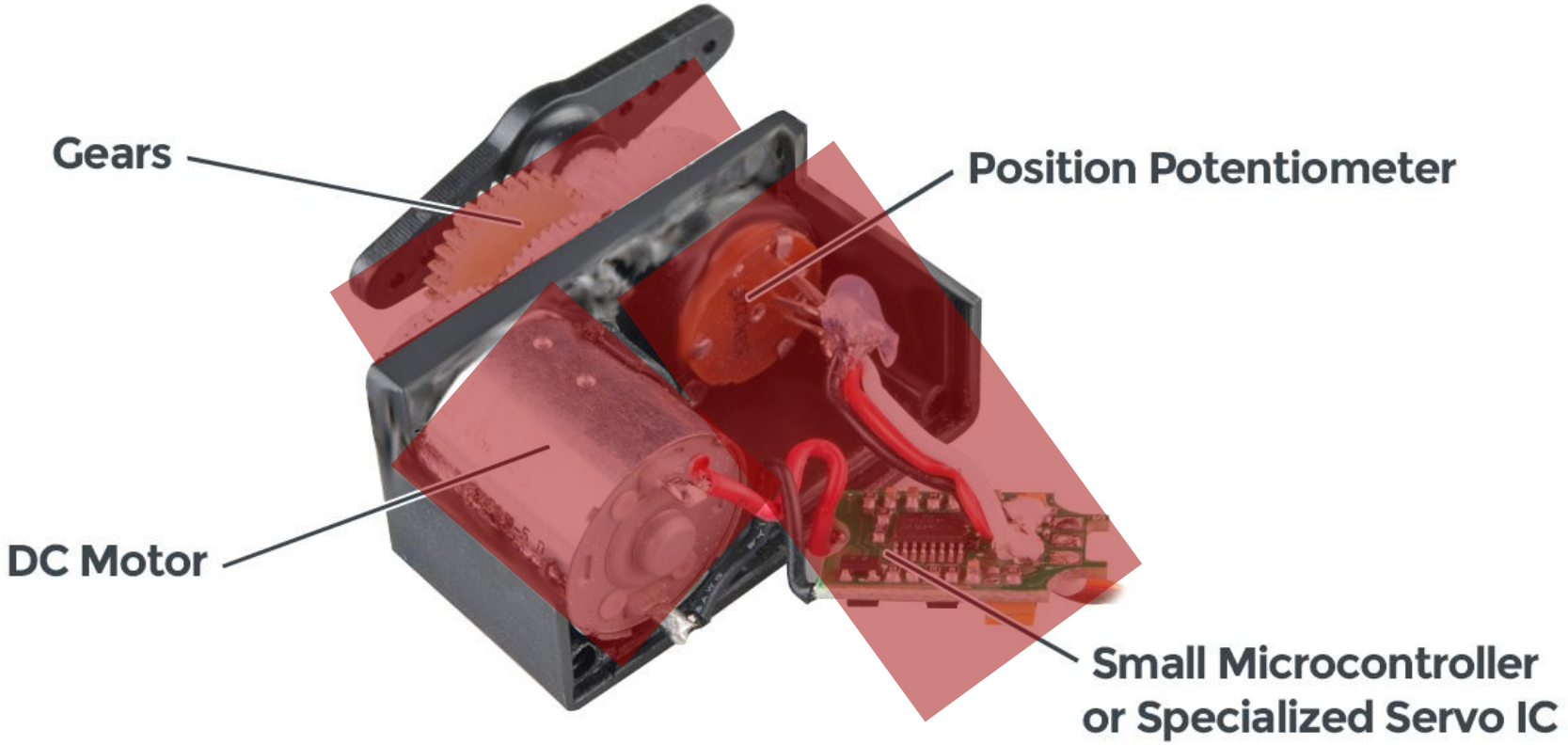
Servomotors

- DC motor with integrated **position/speed** control
- 3 main components:
  - DC motor
  - Gear box
  - Sensor and control circuit



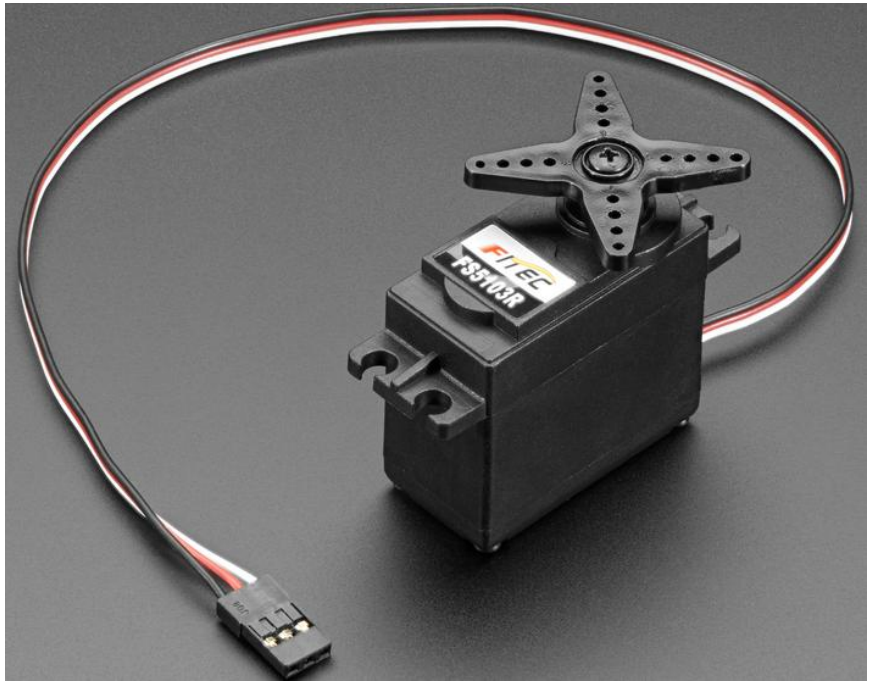
Servomotors

- 3 main components



Servomotors

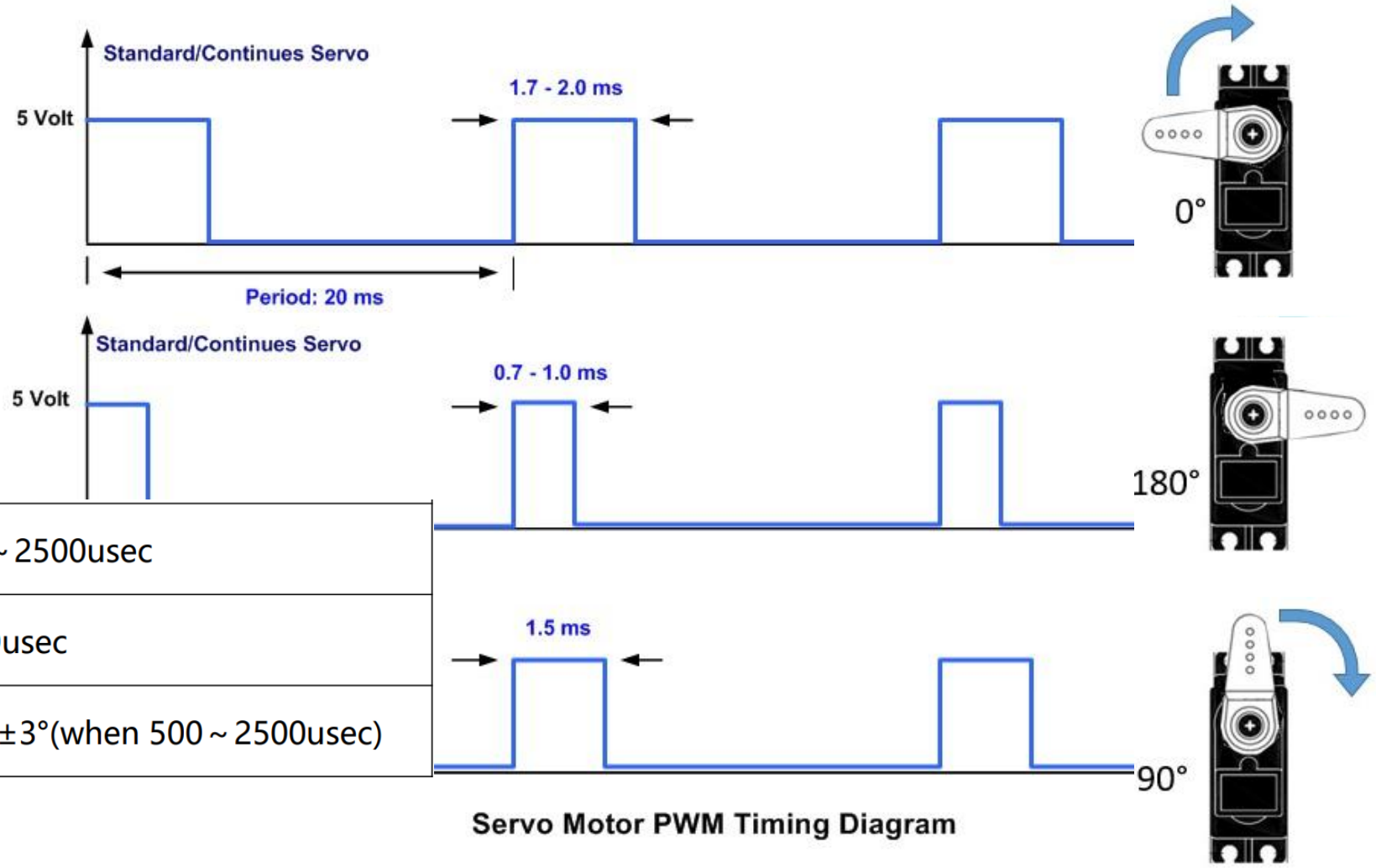
- Many different shapes and specs
  - Continuous rotation
    - Speed controlled
  - Limited rotation
    - Position controlled
- Torque: 20kg = 20kg.cm
- Rotation: 180, 270, cont. etc.
- PWM: 50Hz



Servomotors

- Limited rotation
  - Position controlled
- Check datasheet
  - 0-180
  - 0-270

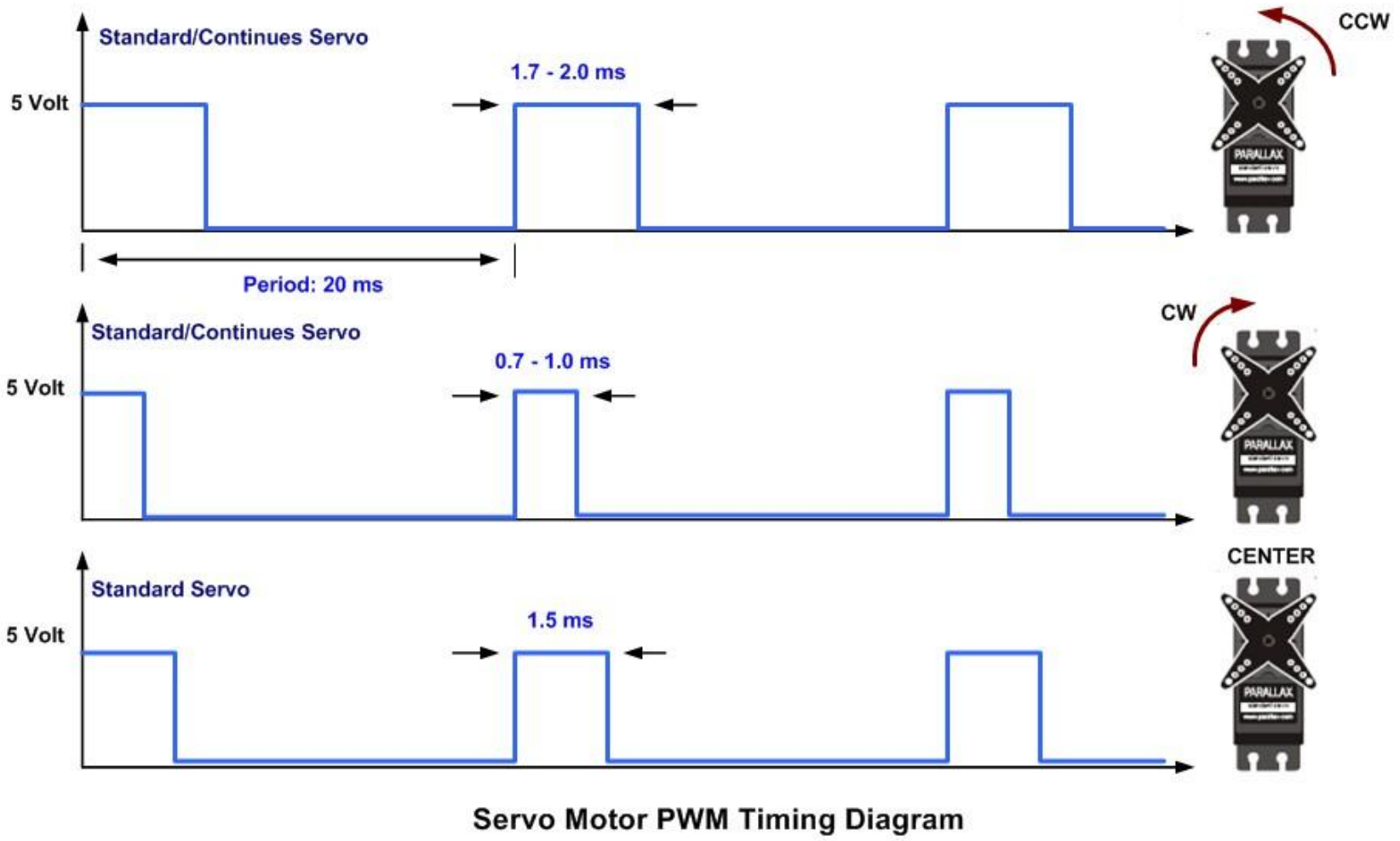
Pulse Width Range	500 ~ 2500usec
Neutral Position	1500usec
Running Degree	270°±3°(when 500 ~ 2500usec)



Servo Motor PWM Timing Diagram

Servomotors

- Continuous rotation
  - Speed controlled



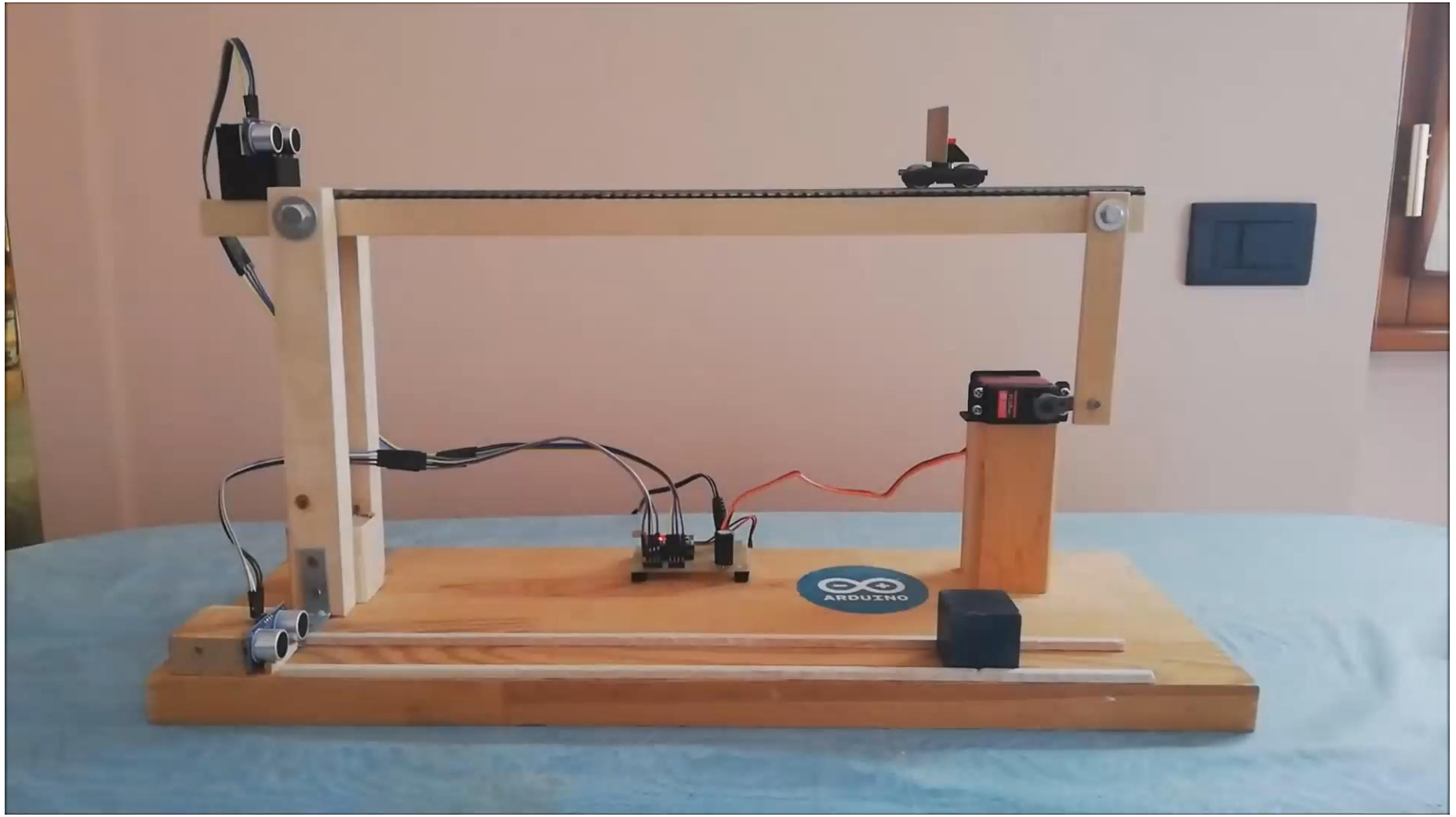
Servo Motor PWM Timing Diagram

Control

- How do servos control speed/position?
  - PID loop
- What is a PID loop?
  - A feedback control loop

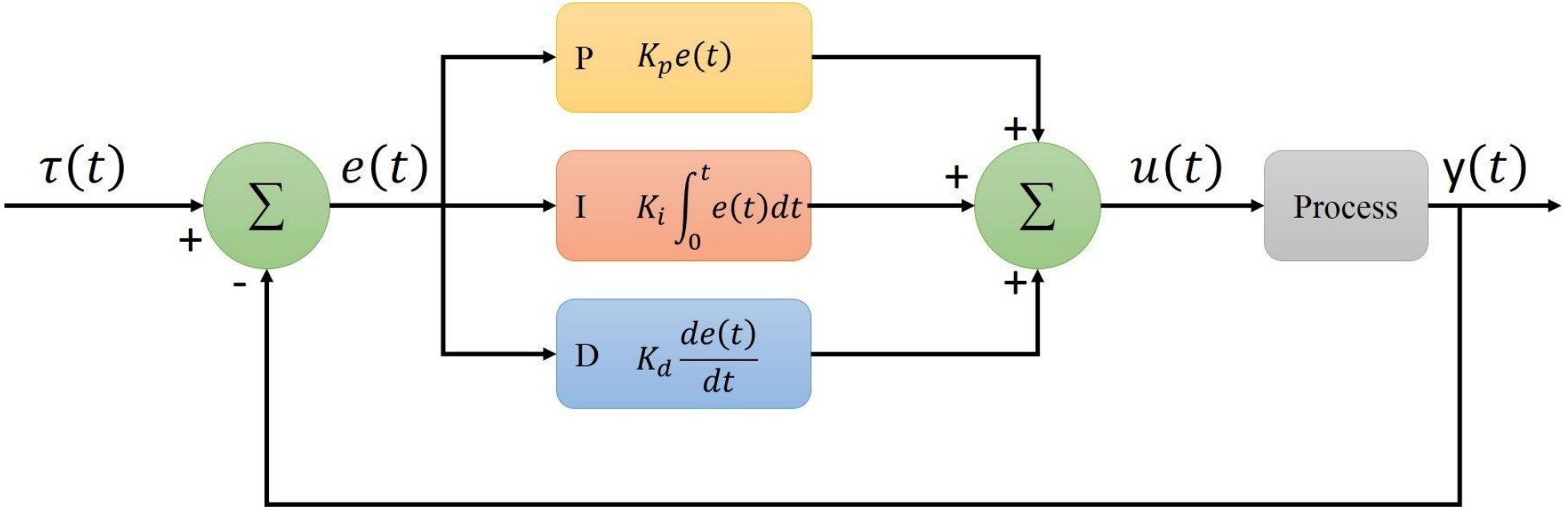
- Where else?
  - Temperature – apartment, office, fridge, AC
  - Position – car steering, RC plane flaps, drones
  - Flow, pressure etc.
  - Speed – Conveyor belts, electric cars

Control



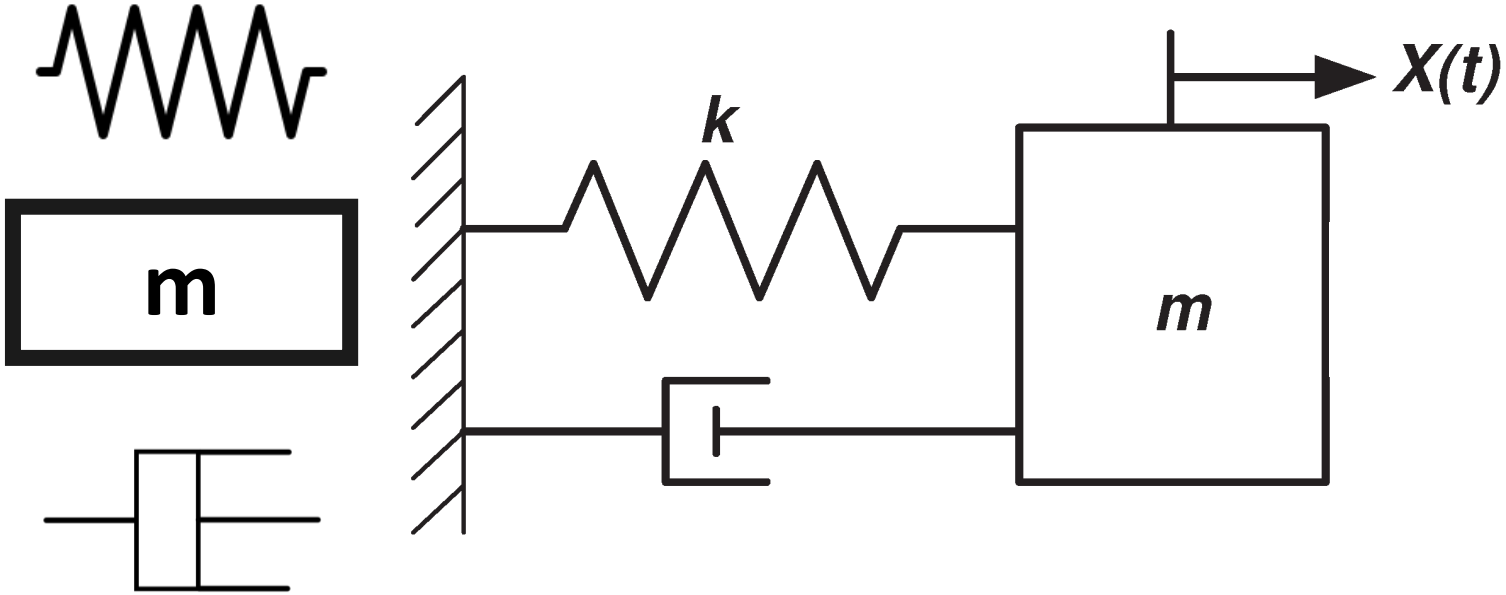
Control

- P responds to **current error**
- I responds to accumulation of **past errors**
- D responds to **future errors** (current rate)



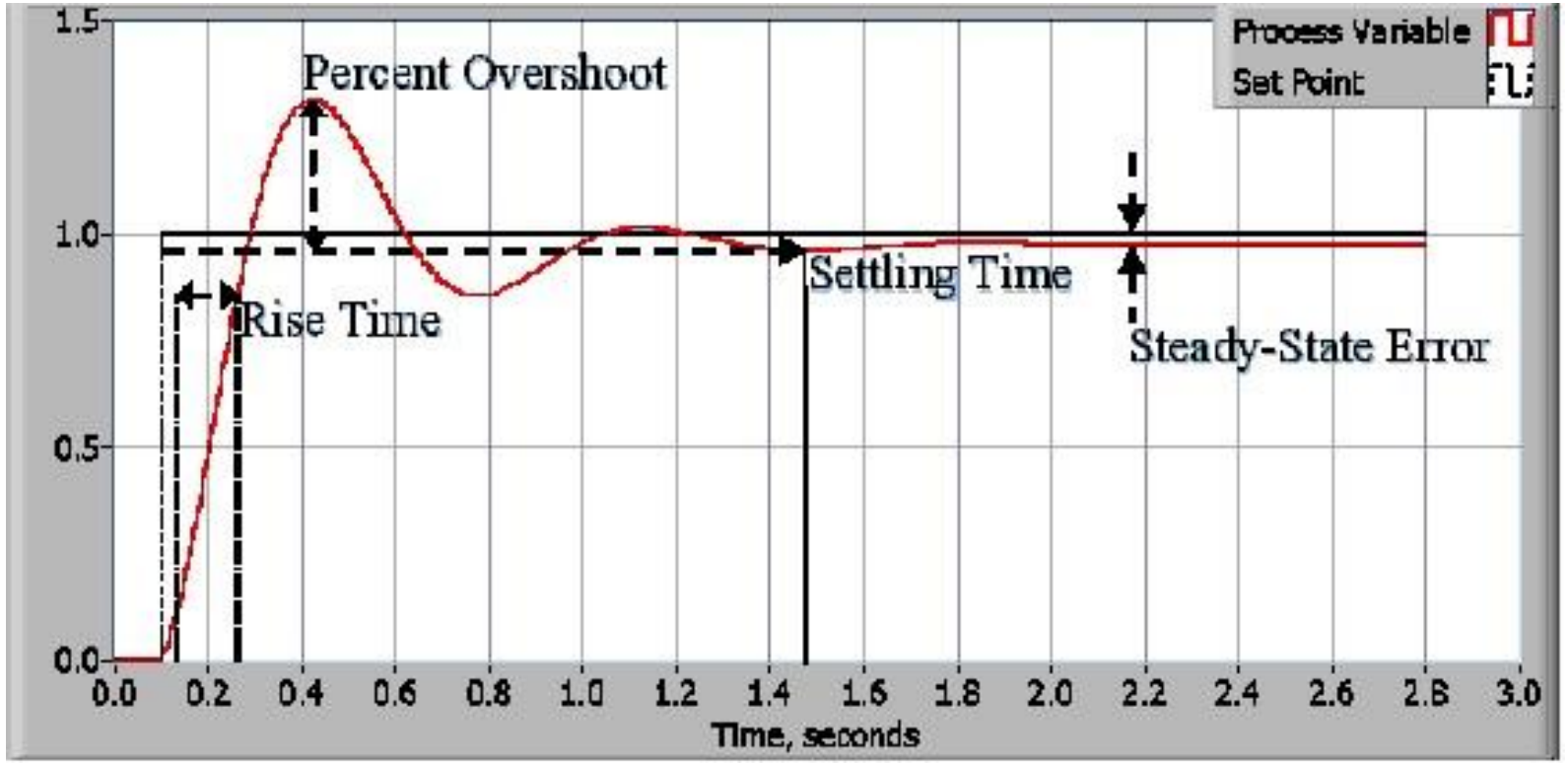
Control

- Proportional (P) term
  - $K_p * error$
- Integral (I) term
  - $K_i * \int error\ dt$
- Derivative (D) term
  - $K_d * \frac{\partial error}{\partial t}$



Control

- How to determine the performance of your system?
- Step response



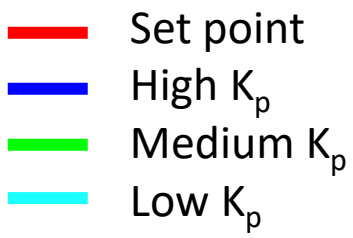
Control

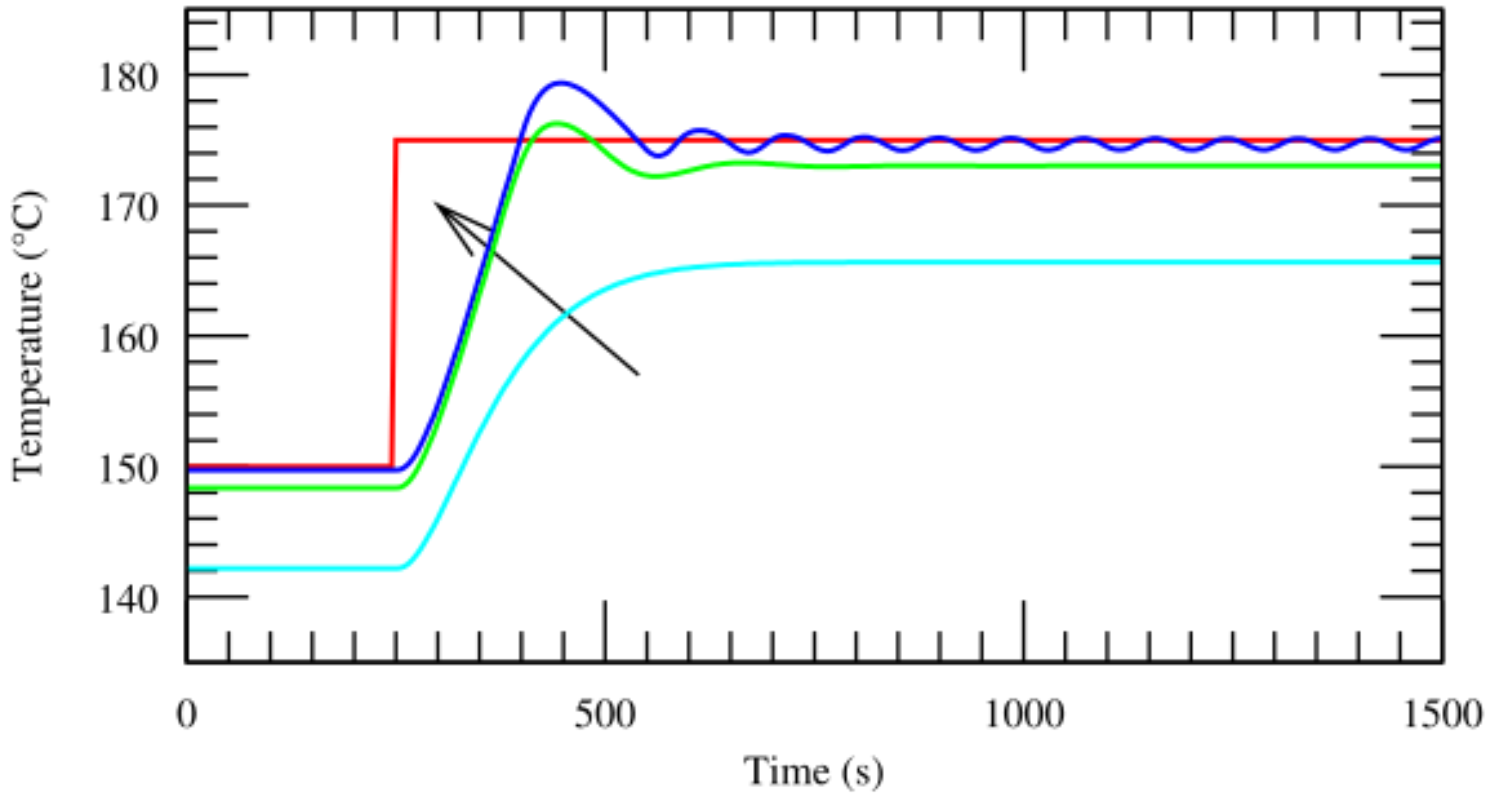
- What actually P term does to a system?

Proportional to error!

Decrease: Rise time, Settling time,
Steady-state error

Increase: Overshoot





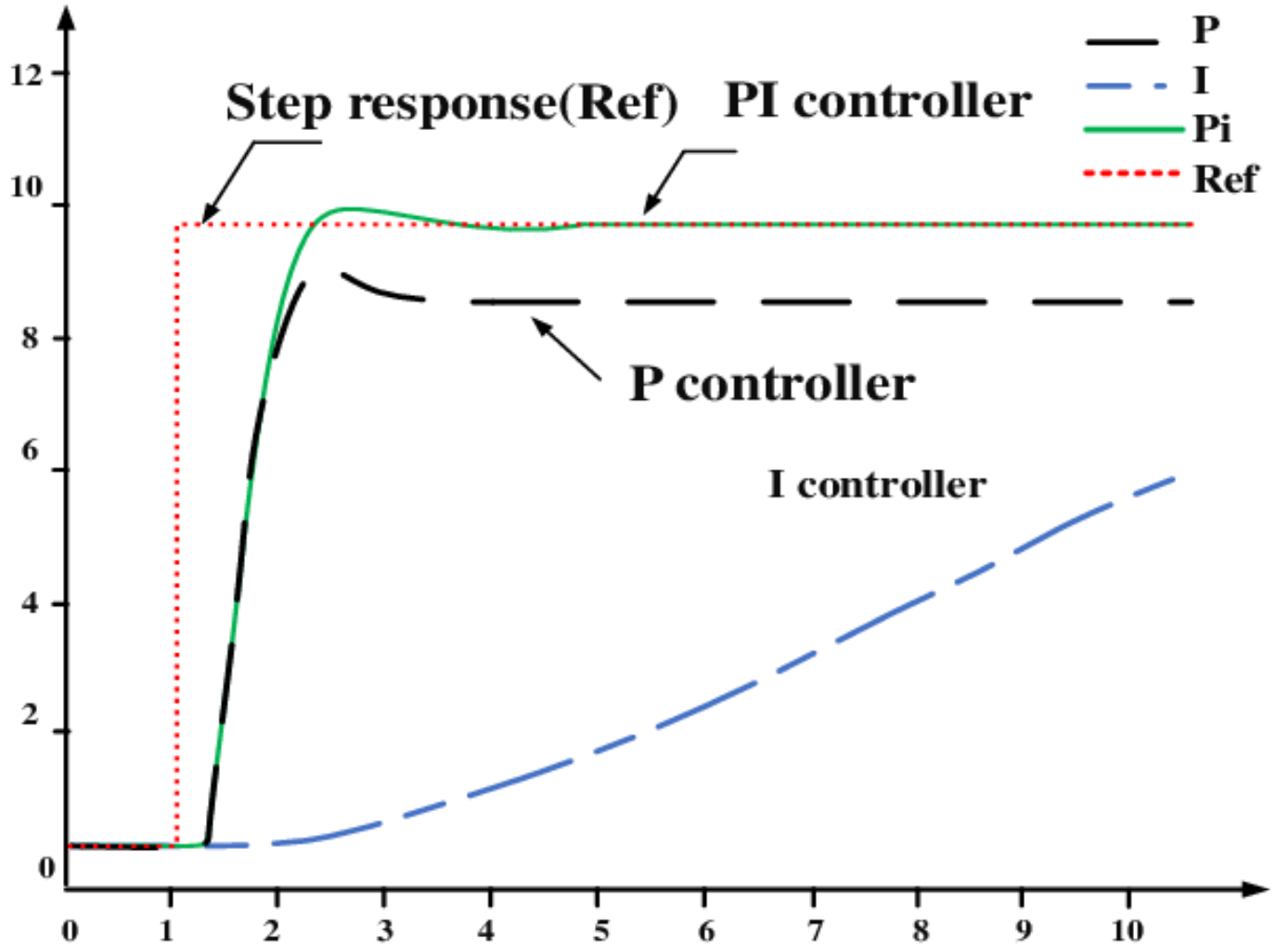
Control

- I term?

Decrease error accumulation!

Decrease: steady-state error

Increase: Overshoot, Settling time



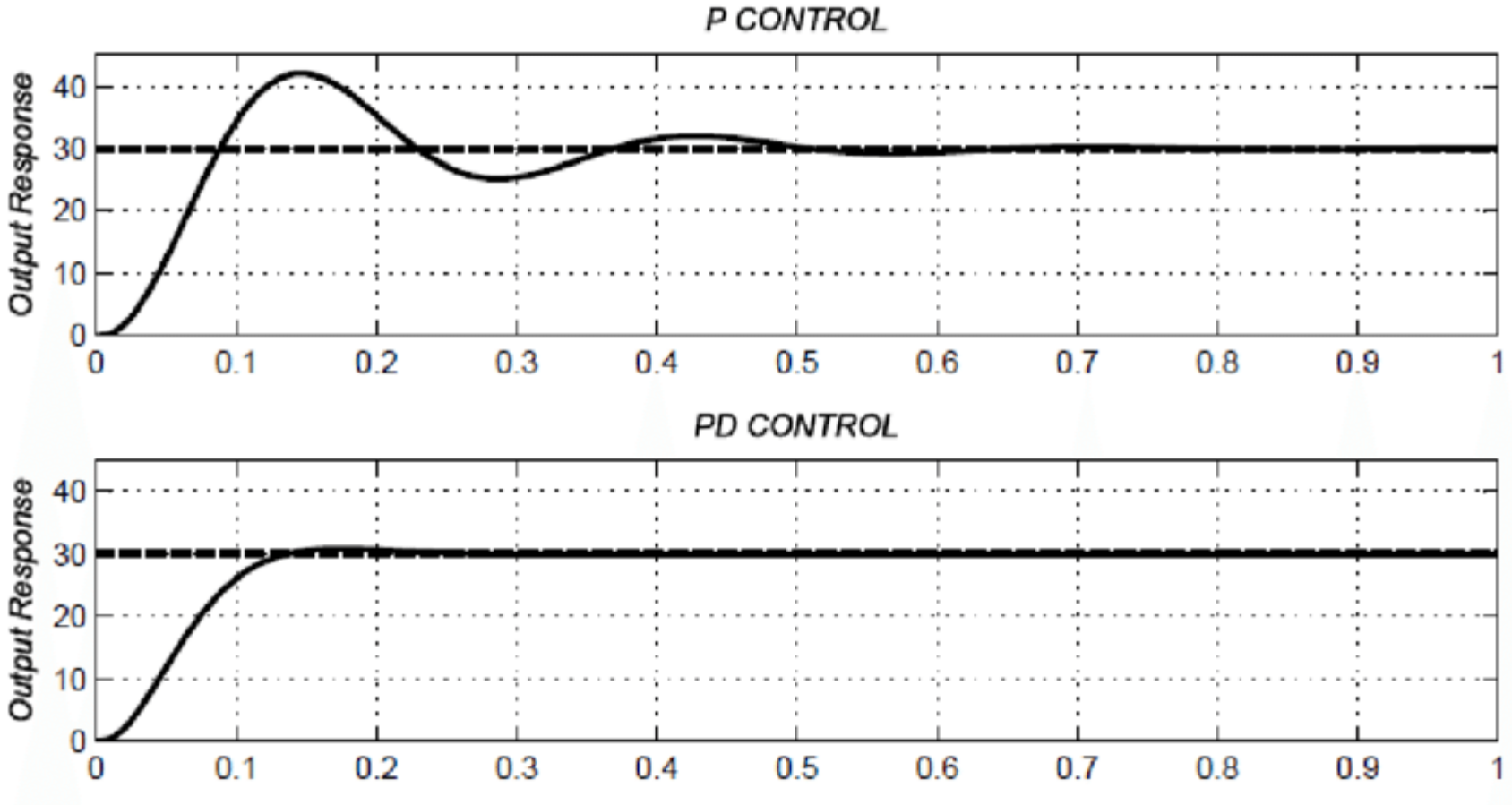
Control

- D term?

Decrease overshoot!

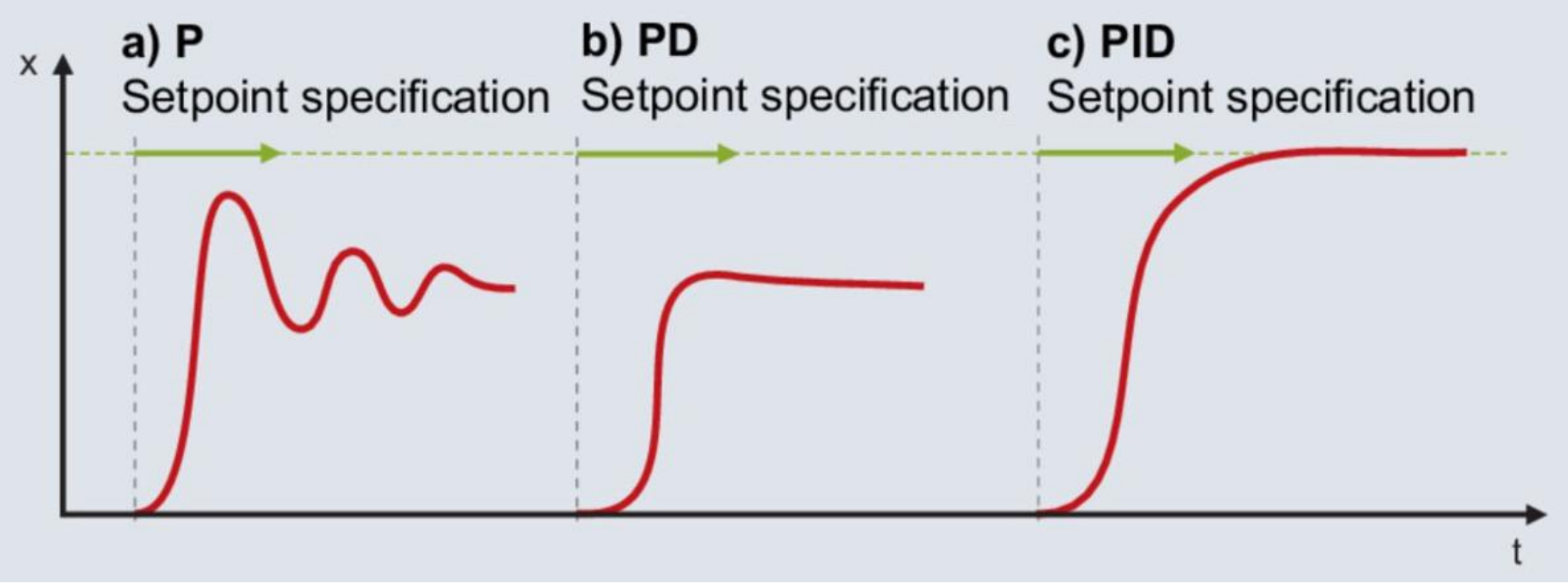
Decrease: Overshoot,

Settling time



Control

- In short:



Control

- Proportional (P) term
  - $K_p * error$
- Integral (I) term
  - $K_i * \int error\ dt$
- Derivative (D) term
  - $K_d * \frac{\partial error}{\partial t}$

Numerically →

- Proportional (P) term
  - $K_p * error$
- Integral (I) term
  - $K_i * \sum(error * \Delta t)$
- Derivative (D) term
  - $K_d * \frac{\Delta error}{\Delta t}$

- Error = Reference – Measured
- Challenge? – Discrete

- Check Youtube
- Ask ChatGPT
- Come to the office hour tomorrow

- Demo!