Course of
"Automatic Control Systems"
2022/23

PID controller: Ziegler and Nichols tuning methods

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Ziegler-Nichols tuning methods

- The **Ziegler–Nichols tuning method** is a heuristic method of tuning a PID controller.

- Controller tuning is the process of determining the controller parameters which produce the desired output.

- It allows the optimization of a closed loop performance and minimizes the error between the variable of the process and its set point.

- The Ziegler-Nichols methods are trial and error method often used when the mathematical model of the system is not available

- The Ziegler-Nichols methods can be used for both **closed** and **open loop systems**

Ziegler-Nichols closed loop method

- The Ziegler-Nichols closed loop method is a simple method of tuning PID controllers by means of a number of tests carried out on the control system in closed loop with the PID controller

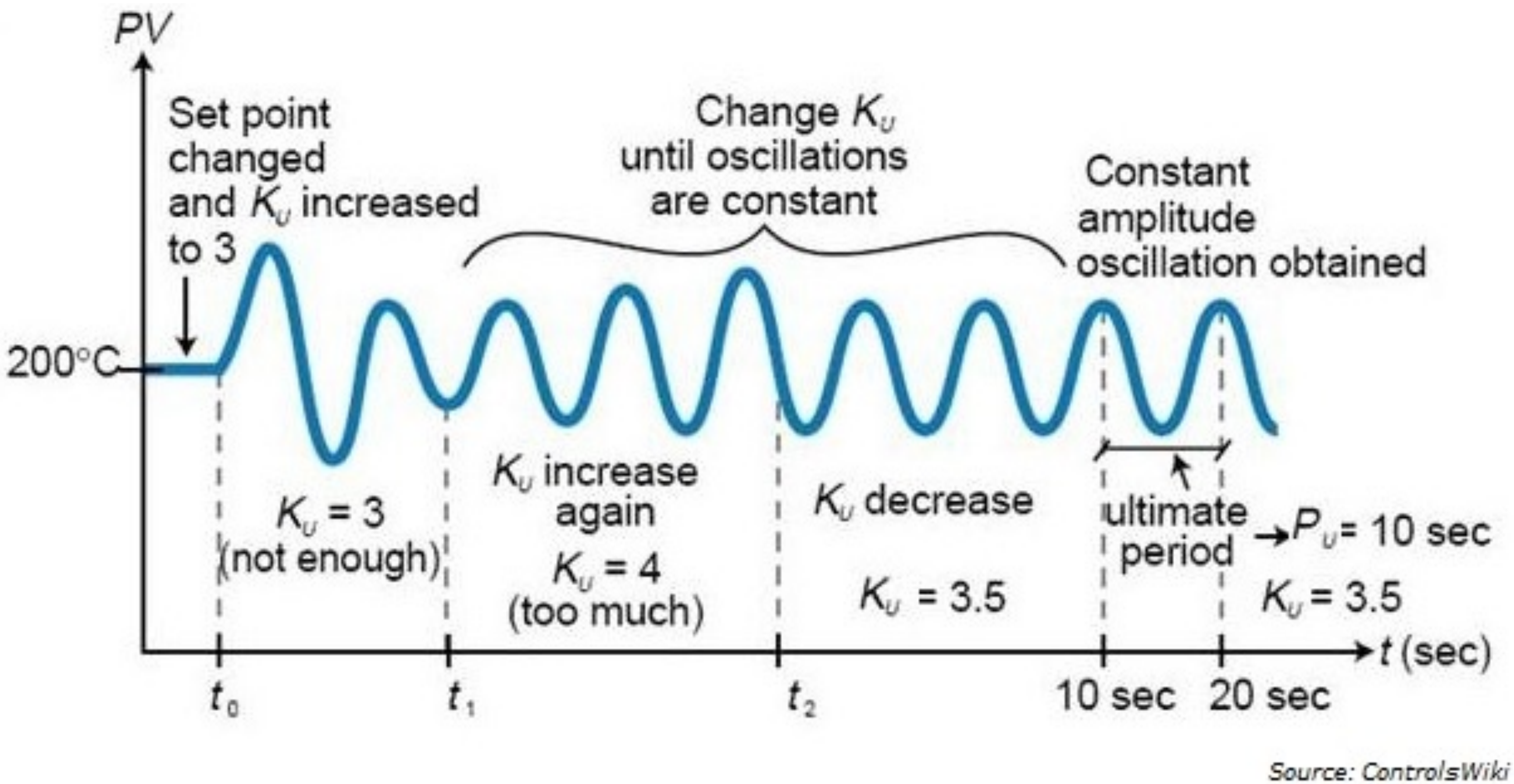
- It can be used only with regularly stable systems: closed loop systems moving toward the instability when the proportional gain increases

- Let us define **ultimate gain $\bar{K}_P$** the proportional gain which gives stable and consistent oscillations for closed loop systems

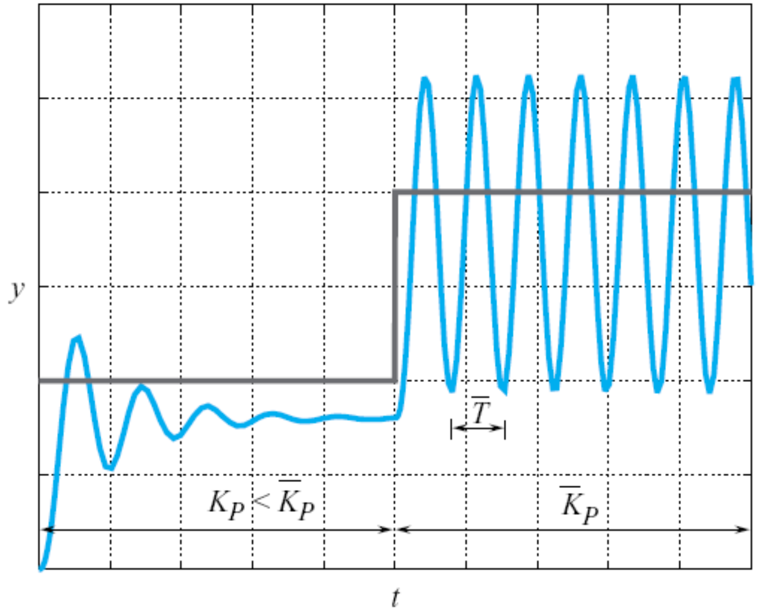
- $\bar{K}_P$ is found experimentally by starting from a small value of K_P and adjusting upwards until consistent oscillations are obtained. The integral and derivative actions are set to zero.

- Another important value associated with the ultimate gain $\bar{K}_P$ is **the ultimate period $\bar{T}$**. The ultimate period is the time required to complete one full oscillation while the system is at steady state

Ziegler-Nichols closed loop method



- The parameters, $\overline{K}_P$ and $\overline{T}$ are used to find the loop-tuning constants of the controllers (P, PI, or PID)

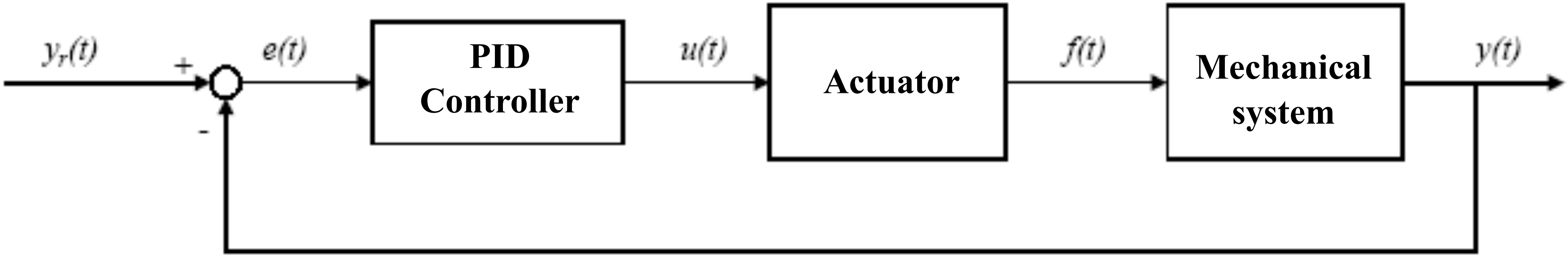


	K_P	T_I	T_D
P	$0.5\bar{K}_P$		
PI	$0.45\bar{K}_P$	$0.8\bar{T}$	
PID	$0.6\bar{K}_P$	$0.5\bar{T}$	$0.125\bar{T}$

Ziegler-Nichols closed loop method: example

- Let us design a
  - Proportional (P) controller
  - Proportional-Integral (PI) controller
  - a Proportional-Integral-Derivative (PID) controller

for the closed loop system



- The mechanical systems is a mass-friction-damper system

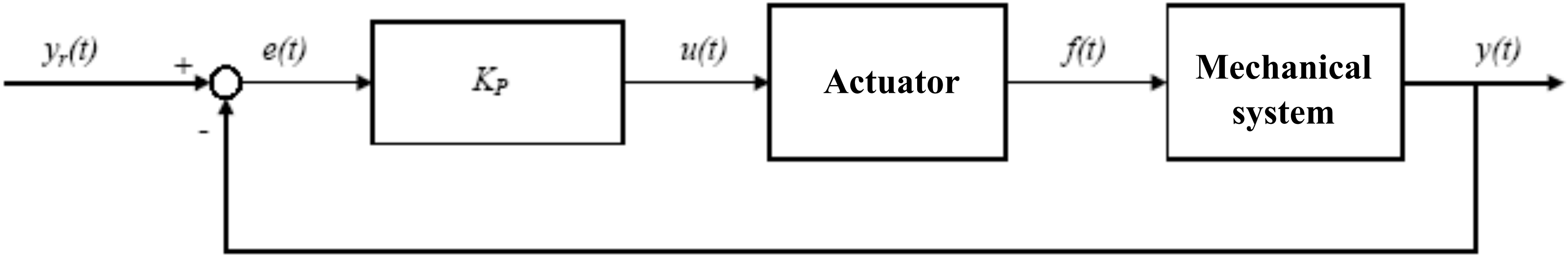
$$m\ddot{y}(t)+b\dot{y}(t)+ky(t)=u(t)$$

with $m = 1$ Kg, $k = 25$ N/m, $b = 20$ Ns/m .

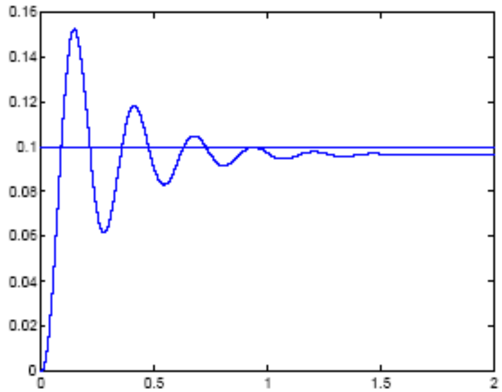
- The actuator is modelled with a first order system in the form

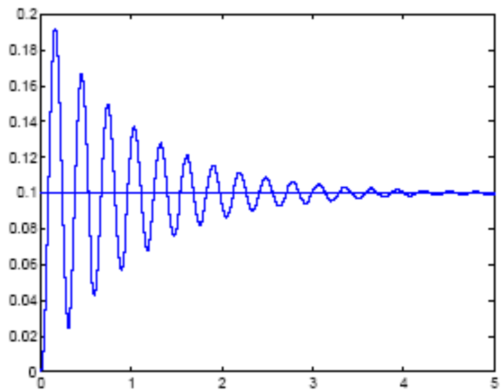
$$\dot{f}(t)+50f(t)=50u(t)$$

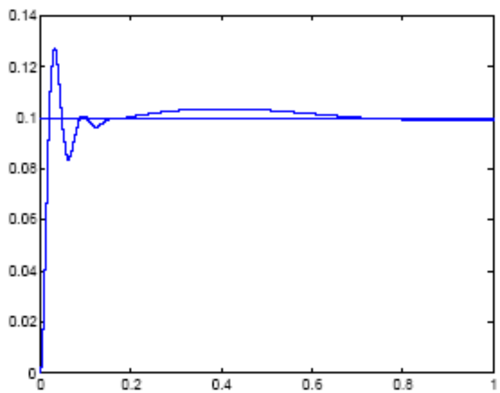
- The P, PI and PID controllers have been tuned with the Ziegler-Nichols closed loop method



Ziegler-Nichols closed loop method: example Performance







P-controller

- No-null steady state error
- Overshoot $s \cong 15\%$

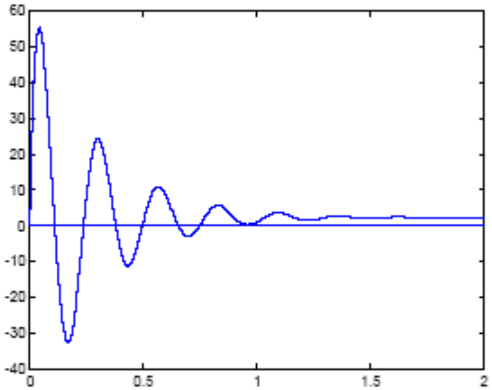
PI-controller

- Null steady state error
- Overshoot $s \cong 20\%$ with a slow oscillating response

PID-controller

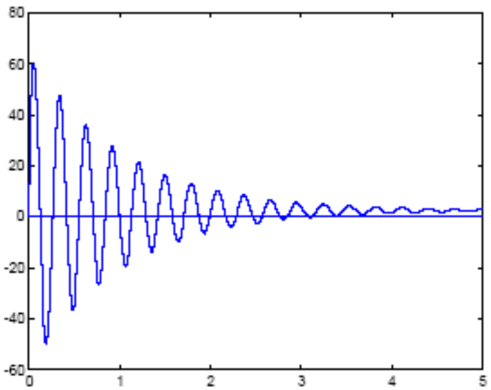
- Null steady state error
- Overshoot $s \cong 13\%$ with fast response

Ziegler-Nichols closed loop method: example
Control signal



P-controller

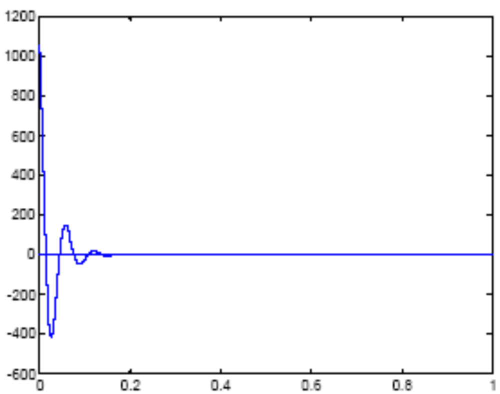
- Control input peak =60
- Slow oscillations



PI-controller

- Control input peak =60
- Fast oscillations

TUNING REFINEMENT IS NECESSARY



PID-controller

- **Control input peak =1200**
- NO oscillations

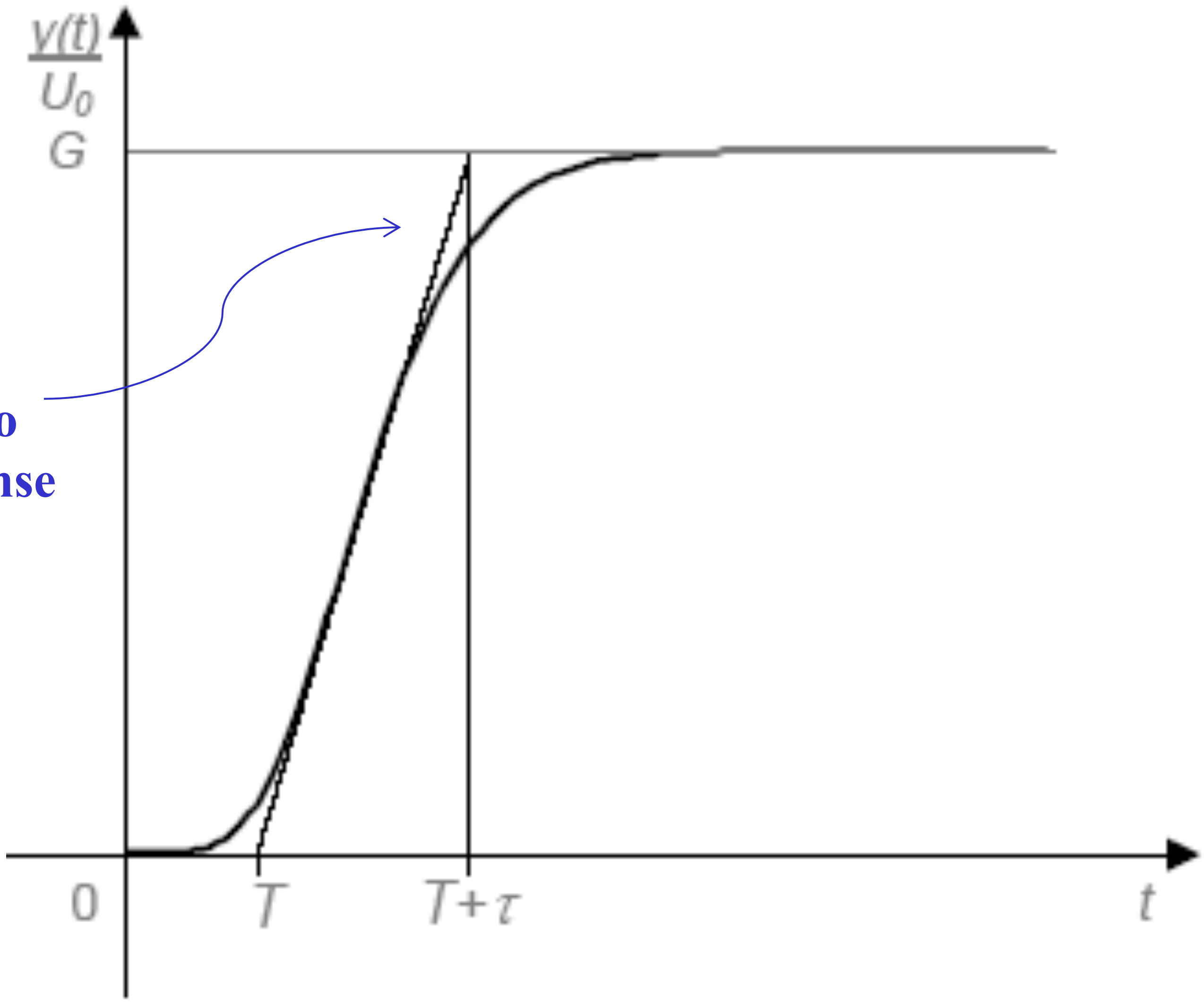
Ziegler-Nichols open loop method

- The Ziegler-Nichols open-loop method is also referred to as a process reaction method, because it tests the open-loop reaction of the process to a change in the control variable output.

- The Ziegler-Nichols open loop method can be applied on processes whose step response doesn't oscillate.

- To use the Ziegler-Nichols open-loop tuning method, you must perform the following steps:
  - Evaluate the open loop unitary step response of the process
  - From the process reaction curve, determine
    - **the transportation lag or dead time *T***,
    - **the equivalent time constant τ**
    - **the steady state value *G*** of the a step response

Ziegler-Nichols open loop method



Line tangent to the step response at the point of inflection

Ziegler-Nichols open loop method

Dead time T: time interval defined by the intersection of the line tangent to the step response at the point of inflection and the time-axis

Equivalent time constant τ: Time interval from T to the intersection of the line tangent to the step response at the point of inflection and the line indicating the steady-state value G

Ziegler-Nichols open loop method

- The parameters, T, τ and G are used to find the loop-tuning constants of the controllers (P, PI, or PID)

	K_P	T_I	T_D
P	$\frac{\tau}{TG}$		
PI	$\frac{0.9\tau}{TG}$	$3T$	
PID	$\frac{1.2\tau}{TG}$	$2T$	$0.5T$