Introduction to the transient response

Contents map

developed content units	**taxonomy levels**
transitorio	u1, e1
sovraelongazione	u1, e1
sottoelongazione	u1, e1
tempo di salita	u1, e1
tempo di assestamento	u1, e1

prerequisite content units	**taxonomy levels**
sistema LTI	u1, e1
funzione di trasferimento	u1, e1

Main ILO of sub-module "Introduction to the transient response"

Explain the purpose of transient response analysis in the context of LTI systems with step inputs

Describe what overshoot and undershoot values are, and how one may find them from given system response data

Describe what dominant pole approximation means, in the context of simplifying transient analysis of higher-order systems

Roadmap

- introduzione di alcuni parametri importanti per caratterizzare la risposta di un sistema

Cosa studiamo ora?

Come rispondere alla domanda:

cosa succede quando $u(t)$ *cambia?*

Semplificazione importante

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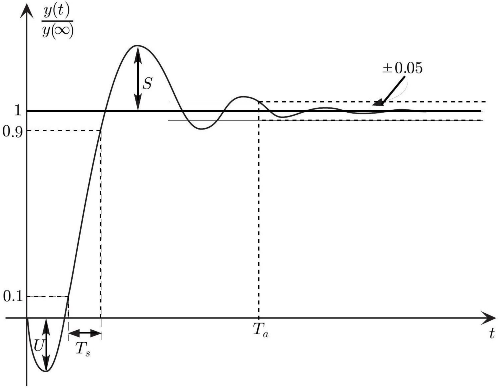
> analizzare il transitorio =
> molto piu' complesso di analizzare la risposta a regime

in questo corso: solo caso di ingresso a gradino

Prossime slides = serie di concetti ausiliari utili a caratterizzare il transitorio

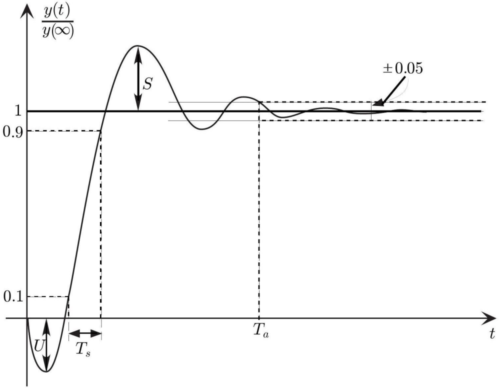
Concetto 1: sovraelongazione

$$S = \frac{y_{\max}}{y(\infty)} - 1$$



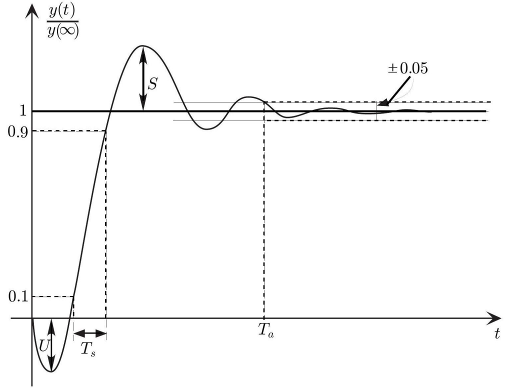
Concetto 2: sottoelongazione

$$U = \frac{y_{\min}}{y(\infty)}$$



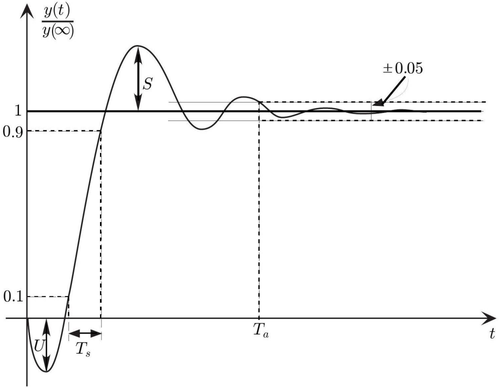
Concetto 3: tempo di assestamento

$T_a =$ tempo tra l' entrare la prima volta in, e poi restarci sempre, nella fascia $y(\infty)[1-0.05, 1$



Concetto 4: tempo di salita

$T_s =$ tempo per passare la prima volta da $0.1y(\infty)$ alla prima volta a $0.9y(\infty)$



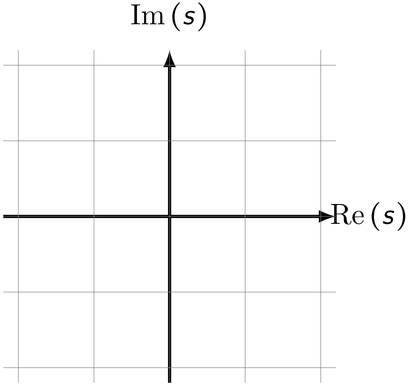
Sono parametri semplici da trovare?

- per sistemi del primo e del secondo ordine privi di zeri, si
- in generale, no (ma si puo' fare un'analisi approssimata basata sui poli dominanti)

Considerazione sull'approssimazione ai poli dominanti

in un sistema BIBO stabile $y_f(t)$ raggiunge il suo regime quando i modi asintoticamente stabili sono virtualmente esauriti. Situazioni piu' comuni:

- il polo piu' vicino all'asse immaginario e' semplice e reale
- i poli piu' vicini all'asse immaginario sono semplici e complessi coniugati



Analisi del transitorio in questo corso

Solo questa situazione:

- sistemi LTI
- risposta al gradino
- approssimazione ai poli dominanti

Summarizing

Explain the purpose of transient response analysis in the context of LTI systems with step inputs

Describe what overshoot and undershoot values are, and how one may find them from given system response data

Describe what dominant pole approximation means, in the context of simplifying transient analysis of higher-order systems

Most important python code for this sub-module

Control systems library

- `control.step_response()`
- `control.step_info()`

Self-assessment material

Question 1

What does the overshoot (S) in a system's transient response represent?

Potential answers:

I: The time taken for the system to reach its final value
II: The maximum percentage by which the output exceeds its final value
III: The difference between the rise time and settling time
IV: The damping ratio of the system
V: I do not know

Question 2

How is the rise time (T_s) defined in the context of transient response analysis?

Potential answers:

I: The time taken to go from 5% to 95% of the final value
II: The time when the output first reaches its maximum value
III: The time taken to go from 10% to 90% of the final value for the first time
IV: The time difference between the first and second peak of the response
V: I do not know

Question 3

What does undershoot (U) measure in a system's transient response?

Potential answers:

I: The time when the response first drops below the final value
II: The minimum value of the output relative to its final value
III: The difference between the first peak and first trough of the response
IV: The ratio of imaginary to real parts of the dominant poles
V: I do not know

Question 4

What is the settling time (T_a) in transient response analysis?

Potential answers:

I: The time when the output first reaches its final value
II: The time difference between the input change and output response
III: The time after which the output remains within 5% of its final value
IV: The time taken for all oscillations to completely die out
V: I do not know

Question 5

Why is the dominant pole approximation useful in transient response analysis?

Potential answers:

I: It eliminates the need to consider system zeros

II: It makes all systems behave like first-order systems

III: It simplifies analysis by focusing on poles closest to the imaginary axis

IV: It allows ignoring the steady-state response completely

V: I do not know

Recap of module "Introduction to the transient response"

- Transient response analysis is significantly more complex than steady-state analysis, focusing on how output evolves before reaching asymptotic value
- In this course, transient analysis is limited to step input responses
- Key parameters to characterize transient response include:
  - Overshoot ($S = \frac{y_{max}}{y(\infty)} - 1$)
  - Undershoot ($U = \frac{y_{min}}{y(\infty)}$)
  - Settling time (T_a): time to permanently enter and stay within $y(\infty)[1 - 0.05, 1 + 0.05]$
  - Rise time (T_s): time to first transition from $0.1y(\infty)$ to $0.9y(\infty)$
- These parameters are easy to calculate for first and second-order systems without zeros, but generally difficult otherwise
- Dominant pole approximation is used: poles closest to the imaginary axis have the most significant influence on transient behavior

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