How to write the final Lab Report

Control Laboratory

Instructor: Francesco Ticozzi

Ok, so you have to do some writing…

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- **I will try to give some suggestions that apply to scientific/technical writing, and to the presentation of results;**
- **Key aspects to consider - ask yourself before writing:**
- **Do I know what I want to ~~write~~ communicate?**
  What is the essential message to be delivered?

  Identify clearly what are the results, and what is needed to support them;
  Design? Idea? Method? Algorithm? Theorem?
  How has it been obtained?
- **Who is the intended readership?**

  It should influence your style of writing;
  The background determines what can be considered known;

What about this report

- **What is the essential message to be delivered?**

  There is a list of **tasks** in the assignments:
  Some require to build models,
  some to design controllers;
  some to run simulations;
  etc

  Recurring theme: comparison of simulations with real systems performance;
  comparison of different designs for the same problem;
  Show some critical analysis of the results.

- **Who is the intended readership?**

  It should be written so that somebody who took (the theory part of) this course can understand;

Control Problem Essentials

System of interest

Model(s)

Desired performance

Chosen control architecture

Controller parameters

Simulation results validating the design

Real-world tests

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Laboratory Report X: Fancy Control of Exotic Systems

Name Lastname; email: {name.lastname}@unipd.it
Group: Y, Shift: Z, components: XYZ, WRT, MNO

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1 Introduction

1.1 Activity Goal

1.2 System and Model

2 Tasks, Methodologies and Results

2.1 Assigment #1

2.2 Assigment #2

...

A Appendix

A.1 Matlab code

A.2 Data sheet

A.3 Detailed calculations for PID design

Structure

- **Part 1: Introduction; Description of the system and its model; Include writer info, group, engine number, etc.**
  2 pages max.

- **Part 2: Methodologies and Results**
  Follow the structure of the assignments and address each point.
  18 pages max.

- **Part 3 Appendices**
  Things that are not essential, but potentially useful to have a better understanding and have more details.
  10 pages max.

Recommended: use LaTeX, character size 12.

First of all, **before** writing…

- **Carefully list the requested tasks to perform, and the extra ones:**
  Be sure to have all the data you need to address them;

  Clearly write and highlight if you tried something *non-standard*, and why;

  Use it as a "skeleton" for the sections of the main part of the report;

- **Before writing a section, organize the logic of the contents;**
  Leave lengthy derivations, data and so on for the appendix;
  Think how to organize the graphs you need to illustrate the results;

- **Before writing any sentence, know what you are going to write:**
  It helps to make sure you're writing an orderly, concise sentence;

- **Being honest is better:**
  List the difficulties you encountered in each point.
  They can help to show you understand the key aspects, and allow for interesting discussions.

Make an effort…

- **The LOGIC of what you do and write should be clear...**

  Rather than just describe "how" you did something, reflect on "why".

- Add comments and explanations to highlight the why,
  where needed and with moderation;

- **If you noticed a strange/interesting/unexpected response of the system, try to explain it with the theory you know;**
  Possibly, design an experiment that demonstrate that your hypothesis is reasonable/correct.

  Ex. If something is probably an effect of the nonlinearity - remove the NL in simulation.

- **Add a comment about it, and if needed data in the appendix.**

Description of the System and Its Model

- **Briefly recap the physical systems and its components (data sheets are better placed in the appendix);**

- **Highlight who the input and outputs are, and from which actuators and sensors are provided.**

- **A drawing or a picture with added descriptions is concise and immediate.**

- **Introduce the mathematical model of the system - no derivation needed. You need however to say which variables correspond to the inputs, outputs, disturbance, state, etc…**

- **It should be *just enough* for a person who has not followed the course to understand the physical system and its mathematical model!**

Description of Identification and Control Design

- **You are not writing a textbook!**
  It is important to specify the methods used and show the key formulas (not their derivations): you can refer to specific sections of the handouts for details**;**

- **Be concise, but do not forget key details:**
  It helps to try to imagine to be a reader, e.g. a non-expert person that assigned you the control task -
  is he/she in the position to reconstruct what has been done?

- **Please maintain a "scientific" style:**
  USE SHORT SENTENCES, subject-verb-object/complements.
  Avoid Italian (or other languages) sentence construction.
  Slang, inappropriate, lab jargon to be avoided
  ("the controller gives a nice kick");
  Avoid contractions e.g. "You're";
  Technical terms have precise meanings, avoid them out of context
  (e.g. identify)

Formulas and math notations

- **Try to maintain a notation that is consistent with the one seen in the course/typical ones:**

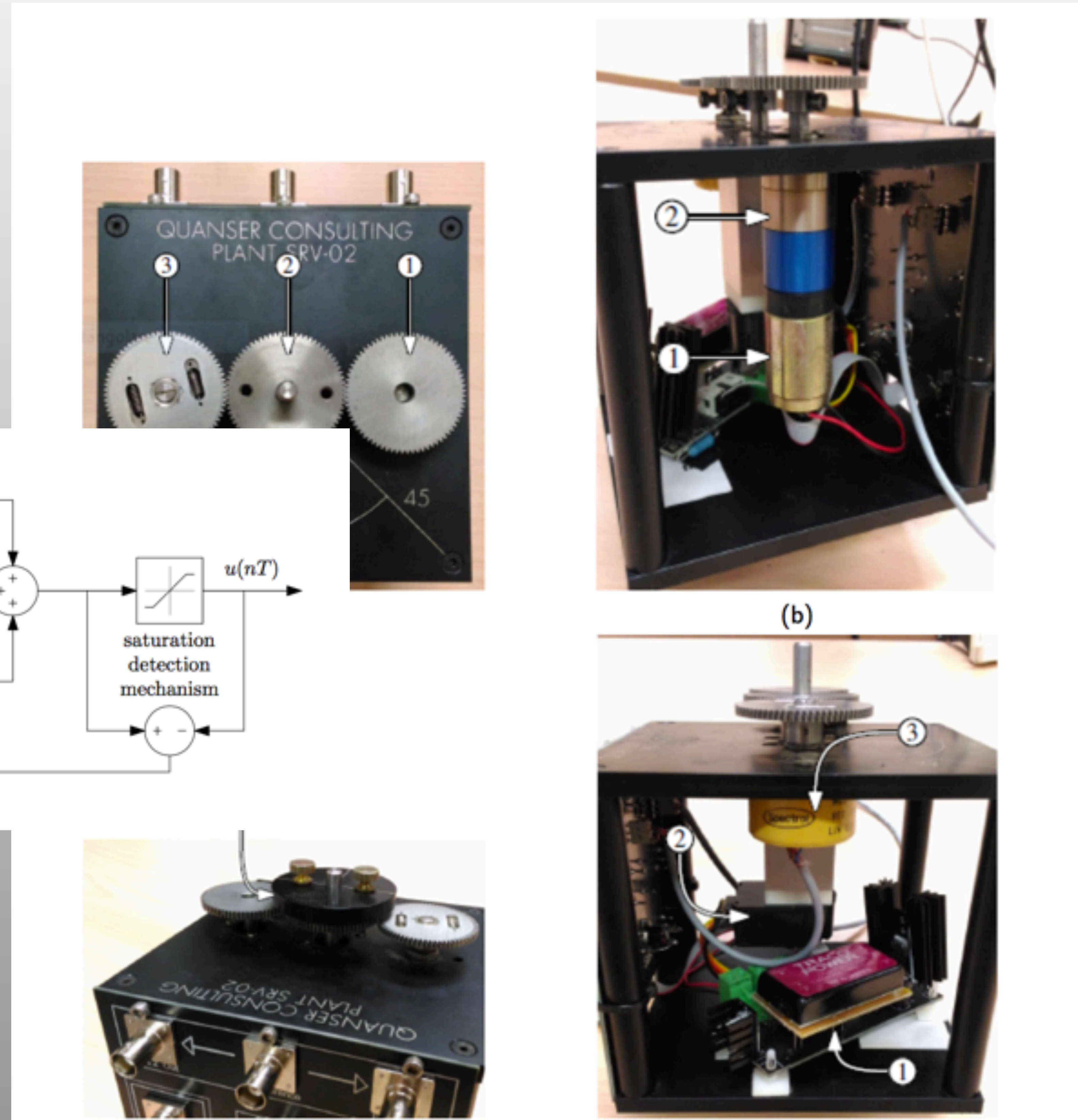
  In each field a “math convention” is developed, which allows for quick reading of the results.

- **Not all steps of a derivation are needed, but if non-standard it must be possible to reconstruct what you do;**

- **All symbols in a formula must have been defined somewhere;**

- **Measurements units are important !!!**

Figures



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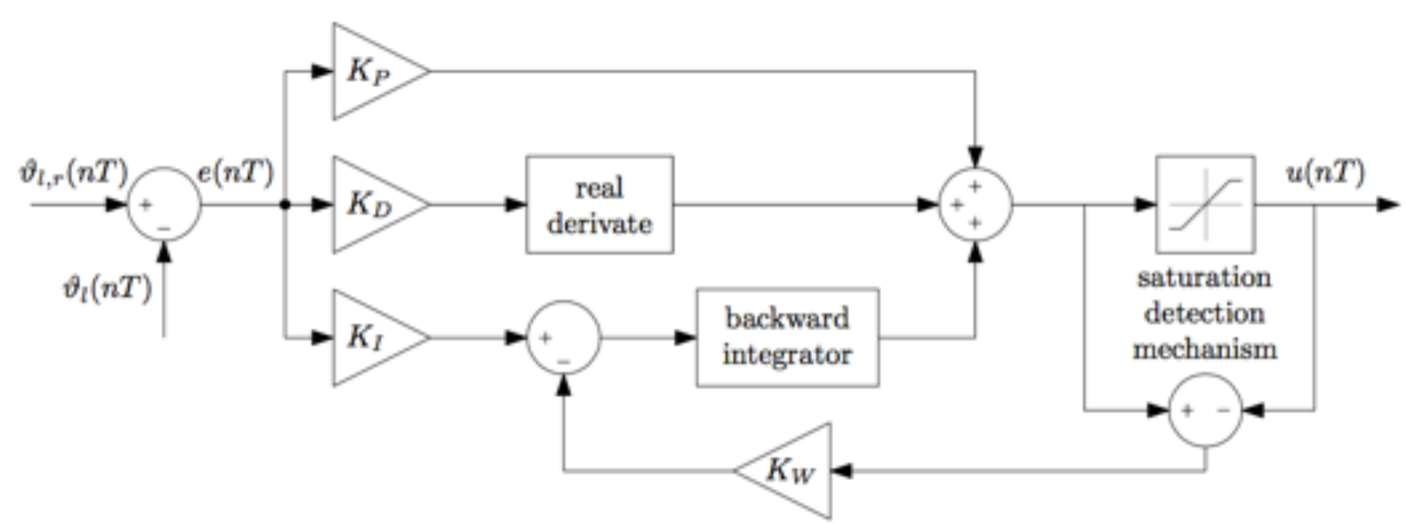
(b)
(c)
(d)



$\vartheta_{l,r}(nT)$
$e(nT)$
$\vartheta_l(nT)$
K_P
K_D
K_I
K_W
real derivate
backward integrator
saturation detection mechanism
$u(nT)$

Results

- **From the assignment, write the expected/needed results:**
  Example: **if you are requested to design a controller, a unit-step response graph is not enough. I want the structure and the numbers - gains, transfer function, block scheme, etc..**
  I should be able to build and run a simulation to verify your claims.

- **I suggest to present next to each other the same test for your model and the real-system/black-box one;**

- **Use tables to quickly compare performance indexes and similar:**

	SS nominal tracking		SS robust tracking	
	Numerical sim.	Experimental sim.	Numerical sim.	Experimental sim.
$t_{s,5\%}\,[s]\,(T_s = 1\,ms)$	0.0875	0.1246	0.1639	0.1561
$M_p\,[\%]\,(T_s = 1\,ms)$	0	5.2083	55.7554	42.0863
$e_{ss}\,[°]\,(T_s = 1\,ms)$	-0.4000	-1.8400	0	0
$t_{s,5\%}\,[s]\,(T_s = 10\,ms)$	0.0845	0.0929	0.1857	0.1861
$M_p\,[\%]\,(T_s = 10\,ms)$	0.7143	0	47.4820	34.8921
$e_{ss}\,[°]\,(T_s = 10\,ms)$	-0.4000	-0.7600	0	0
$t_{s,5\%}\,[s]\,(T_s = 50\,ms)$	4.6989	0.1018	0.6698	0.2922
$M_p\,[\%]\,(T_s = 50\,ms)$	16.7260	0	41.8773	44.3636
$e_{ss}\,[°]\,(T_s = 50\,ms)$	-3.1000	2.4800	0	0

		ideal continuous-time PID			
		$T_{s,5\%}$ [s]		M_p	
	simplified model	0.162		30.7	
		dicrete-time PID			
		T_1		T_2	
		$T_{s,5\%}$ [s]	M_p	$T_{s,5\%}$ [s]	M_p
Backward Euler	accurate model	0.228	28.7	0.237	46.3
	real plant	0.229	31.3	0.239	48.5
Forward Euler	accurate model	0.230	28.0	0.231	33.4
	real plant	0.234	29.9	0.232	36.2
Tustin's	accurate model	0.242	31.7	0.241	40.8
	real plant	0.242	33.6	0.243	43.4
Exact	accurate model	0.259	29.9	0.748	32.5
	real plant	0.256	32.0	0.747	33.1

Graphs/Figures

- **Readability is key; Graphs should be immediate, clear, with appropriate and evident x/y axis units; In step response graph highlight peaks, rise times, etc…**
- **Use more than one response per graph:** great to quickly compare responses of different controllers for the same task, and save space.
- **Caption with synthetic description helps the reader (e.g.** response of the closed-loop system to a 40 deg step, with a PID controller emulated with tustin and sample time T=0.1,0.01,0.001**);**
- **Where needed insert colors and different line styles for different data sets;**
- **If needed, add a subfigure with a “zoomed-in” version of an area of another figure (e.g. around the peak, resonance, etc);**
- **Keep into account it may get printed in B&W;**

Graphs

- **Readibility is key: Graphs should be immediate, clear, with appropriate**
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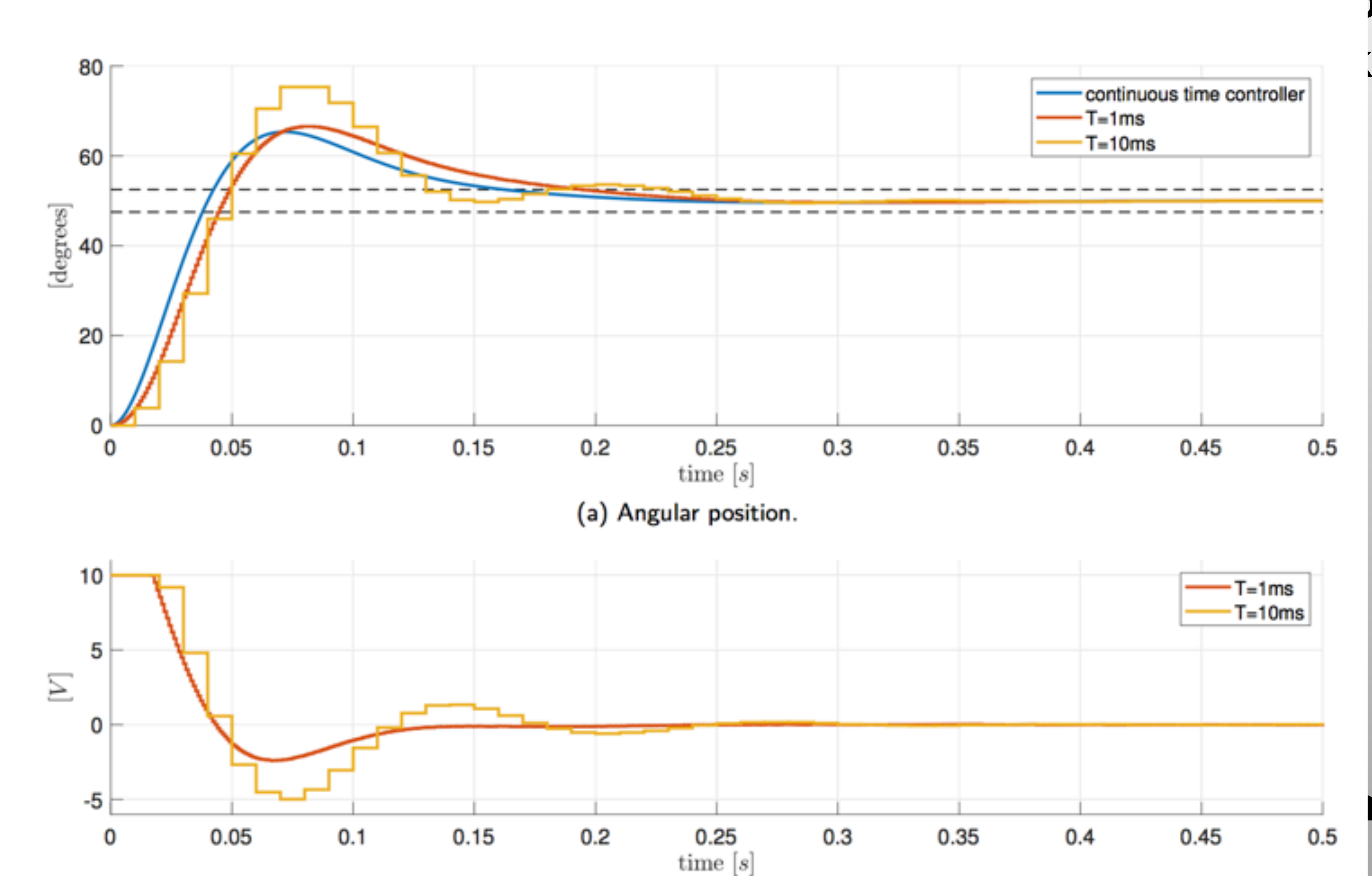

(a) Angular position.

(b) Driver input voltage.

- **Keep into account it may get printed in B&W;**

Simulink Schemes

- **Useful to understand what you implemented, but usually too complicated to be inserted in the main text - may be put into appendix, use simplified versions (block diagrams) in the text where needed;**

- **They can help understand anomalous behavior;**

- **All parameters used in the simulation/experiments should be present somewhere in the report;**

Appendices

- **Can be used to insert datasets, lengthy derivations, simulink schemes, etc etc**
- **There should not be any key piece of information to follow your work - that goes in the main text.**
- **Put there matlab code that is used to compute parameters.**