



# Course guide

## 240743 - 240743 - System Dynamics

Last modified: 16/05/2023

**Unit in charge:** Barcelona School of Industrial Engineering  
**Teaching unit:** 707 - ESII - Department of Automatic Control.

**Degree:** BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGIES AND ECONOMIC ANALYSIS (Syllabus 2018).  
(Compulsory subject).

**Academic year:** 2023    **ECTS Credits:** 4.5    **Languages:** English

### LECTURER

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**Coordinating lecturer:** Serra Prat, Maria

**Others:** Giralt Ludevid, Xavier  
Serra Prat, Maria

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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#### Transversal:

04 COE. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.

05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.

07 AAT. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.

03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

### TEACHING METHODOLOGY

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#### THEORY CLASSES:

The theory classes consist in the presentation of the theory concepts and the resolution of related problems. The problems of the document "System Dynamic. Problems" by P. Caminal et al. are solved in the classroom.

Apart from the problems solved in the classroom, students are encouraged to do the problems of the following books:

-Caminal et al. Problemes d'Examen de Dinàmica de Sistemes. Atenea, 2009

-J. Ayza, L. Basañez, R. Casanellas, J. Riera: Problemes de Regulació Automàtica. CPDA-ETSEIB, 1996

#### PRACTICE CLASSES

The practical classes are focused on the design and implementation of controllers for the position and velocity control of a DC motor. These sessions, which are compulsory, are done in the laboratory.

### LEARNING OBJECTIVES OF THE SUBJECT

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#### General objective

- To provide the students with the concept of dynamic system, applicable to all the fields of engineering, and the concept of signal as the variable of this system evolving over time.

#### Specific Objectives

- To provide tools for the dynamic systems analysis in the time and frequency domains
- To present different methodologies for the study of the dynamic systems stability
- To present the basic concepts of continuous-time control systems
- To design controllers that improve the operation specifications of the dynamic systems



## STUDY LOAD

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Type	Hours	Percentage
Self study	67,5	60.00
Hours small group	7,5	6.67
Hours large group	37,5	33.33

**Total learning time:** 112.5 h

## CONTENTS

### System Dynamics

#### Description:

1. INTRODUCTION
  - 1.1. Object and scope of the course
  - 1.2. Basic definitions and examples of dynamic systems
  
2. SYSTEMS MODELING AND TRANSFER FUNCTION
  - 2.1. Elementary signals
  - 2.2. External representation
  - 2.3. Transfer function of linear systems
  - 2.4. Characteristic equation
  - 2.5. Poles and zeros, canonical gain and canonical form
  - 2.6. Delays
  - 2.7. Block schemes and block algebra
  - 2.8. Systems with multiple inputs and outputs
  - 2.9. Examples of models of physical systems.
  
3. TIME RESPONSE
  - 3.1. Impulse response of first and second order systems
  - 3.2. Step response of first and second order systems
  - 3.3. Stability
  - 3.4. Necessary and sufficient condition of stability
  - 3.5. Routh's theorem
  - 3.6. Stationary error
  
4. DESIGN OF CONTROLLERS IN THE TIME DOMAIN
  - 4.1. Basic control actions: proportional, integral and derivative control
  - 4.2. Design of PID controllers
  
5. FREQUENCY RESPONSE
  - 5.1. Isochronous transfer function
  - 5.2. Bode diagram
  - 5.3. Frequency response of the basic elements
  - 5.4. Asymptotic Bode diagram of a generic transfer function
  - 5.5. Polar diagram
  
6. STABILITY IN THE FREQUENCY DOMAIN
  - 6.1. Nyquist stability criterion
  - 6.2. Gain margin and phase margin.
  
7. DESIGN OF CONTROLLERS IN THE FREQUENCY DOMAIN
  - 7.1. Design of lead compensators
  - 7.2. Design of lag compensators

#### Specific objectives:

- To provide tools for the dynamic systems analysis in the time and frequency domains
- To present different methodologies for the study of the dynamic systems stability
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#### Related activities:

There are four 2-hour sessions (L1, L2, L3, EXAM) and one 2-hour session of autonomous learning in the Informatic Classroom (IC). The laboratory is in 2nd plant of the H building of the ETSEIB School.

The content of practical work is as follows:

IC. Introduction to Matlab and its Control Toolbox. It must be carried out in one of the Informatic Classrooms of the school as autonomous work.



- L1. Identification and modeling of an experimental DC electric motor. Analysis of open loop and closed loop behaviour.  
L2. Experimental study of the behavior of the controlled DC electric motor, both for speed and position control.  
L3. Design and implementation of a PID controller.  
EXAM. In this session the students will be evaluated of their practical work during sessions IC, L1, L2 and L3.

**Full-or-part-time:** 112h 30m

Theory classes: 37h 30m

Laboratory classes: 8h

Self study : 67h

## GRADING SYSTEM

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### ORDINARY EVALUATION:

There are four evaluations during the course:

- Partial Exam. It is an exam done approximately at the middle of the course, consisting of conceptual questions and one problem. The exam subject includes chapters 1 to 4. For the problem resolution, students can have a personal double sided DIN A4 with formulas, the table of Laplace Transforms and one calculator. The mark of this exam is  $N_{pe}$ .
- Two deliverables. They are exercises done at home. The mark of this tests is  $N_t$ .
- Practical mark. It is the mark of the reports corresponding to the three practical sessions. The mark of this part is  $N_{pre}$ .
- Final Exam. It is an exam of all the course matter, consisting of conceptual questions and some problems. For the problems resolution, a personal double sided DIN A4 with formulas, the table of Laplace Transforms and one calculator are permitted. Students are asked to provide semi-logarithmic paper. The mark of this test is  $N_{fe}$ .

The final mark,  $N_f$ , is calculated as follows:

$$N_f = 0,5N_{fe} + 0,275N_{pe} + 0,1N_t + 0,125N_{pre}$$

### EXTRAORDINARY EVALUATION:

The students that have failed the subject ( $N_f$ )

The extraordinary exam consists of conceptual questions and some problems. For the problems resolution, a personal double sided DIN A4 with formulas, the table of Laplace Transforms and one calculator are permitted. Students are asked to provide semi-logarithmic paper. The mark of this test is  $N_{ee}$ .

For the students presented to the extraordinary exam, the final mark,  $N_f$ , is calculated as follows:

$$N_f = 0,875N_{ee} + 0,125N_{pre}$$

## EXAMINATION RULES.

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In all the written exams, for the problems resolution part, a personal double sided DIN A4 with formulas, the table of Laplace Transforms and one calculator are permitted.

In the practical exam, students are asked to bring all the notes they have taken during the realisation of the practical sessions.

## BIBLIOGRAPHY

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### Basic:

- ESAII teachers. System Dynamics : Practical Sessions Guide. Atenea, 2020.
- Dorf, R.C. Bishop, R.H. Modern Control Systems [on line]. 13th edition. Essex: Prentice Hall, 2017 [Consultation: 29/06/2020]. Available on: <https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5185883>. ISBN 9781292152974.
- Caminal P. et al. System Dynamics : Problems. Atenea, 2020.
- ESAII teachers. System Dynamics : Matlab Session Guide. Atenea, 2020.
- Ogata, K.O. Modern Control Engineering. 5th ed. Boston: Prentice Hall, 2010. ISBN 9780137133376.

### Complementary:

- Luenberger D.G.. Introduction to Dynamic Systems. New York: John Wiley and Sons, 1979. ISBN 0471025941.
- Villà, R. System Dynamics : Guidance on practical works software. Atenea, 2020.
- Ayza, J. ; L. Basañez ; R. Casanellas ; J. Riera. Problemes de Regulació Automàtica. Barcelona: CPDA-ETSEIB, 1996.



- Caminal, P. Problemes d'Examen de Dinàmica de Sistemes. Atenea, 2009.
- Villà, R. Dinàmica de Sistemes [on line]. Barcelona: ETSEIB. ESII, 2017 [Consultation: 11/05/2020]. Available on: <http://esaii.upc.edu/people/rvilla>.
- Caminal, P. et al. Conceptual Questions on System Dynamics [on line]. Barcelona: ETSEIB. ESII, 2020 [Consultation: 11/05/2020]. Available on: <https://atenea.upc.edu/login/index.php>.