

## Course guide

# 280725 - 280725 - Advanced Control of Marine Systems

**Last modified:** 27/05/2024

**Unit in charge:** Barcelona School of Nautical Studies  
**Teaching unit:** 707 - ESAII - Department of Automatic Control.

**Degree:** MASTER'S DEGREE IN THE MANAGEMENT AND OPERATION OF MARINE ENERGY FACILITIES (Syllabus 2016). (Compulsory subject).

**Academic year:** 2024    **ECTS Credits:** 5.0    **Languages:** Catalan

### LECTURER

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**Coordinating lecturer:** ROSA M. FERNANDEZ CANTI

**Others:** Primer quadrimestre:  
ROSA M. FERNANDEZ CANTI - MGOIE

### PRIOR SKILLS

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It is recommended to have knowledge of physics (Newton's second law, analogies, linear circuits), mathematics (Laplace transform, complex variable theory, Taylor series) and computers (matlab).

### REQUIREMENTS

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Basic course on automatic regulation

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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**Specific:**

CE7-MGOIEM. Capacitat per conèixer, entendre i utilitzar els principis de control avançat de processos d'operació, manteniment i reparació

**General:**

CG1-MGOIEM. Conocimientos suficientes en materias básicas y tecnológicas, que le capaciten para el desarrollo de nuevos métodos y procedimientos

CG2-MGOIEM. (ENG) Capacidad para resolver problemas complejos y tomar decisiones con responsabilidad sobre bases científicas y tecnológicas en el ámbito de su especialidad

CG5-MGOIEM. (ENG) Capacidad de integración de sistemas marítimos complejos y de traducción en soluciones viables

CG11-MGOIEM. Capacitat per realitzar tasques d'investigació, desenvolupament i innovació en l'àmbit de la seva especialitat

**Transversal:**

CT2. SUSTAINABILITY AND SOCIAL COMMITMENT: Being aware of and understanding the complexity of the economic and social phenomena typical of a welfare society, and being able to relate social welfare to globalisation and sustainability and to use technique, technology, economics and sustainability in a balanced and compatible manner.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

CT1. ENTREPRENEURSHIP AND INNOVATION: Knowing and understanding the organization of a company and the sciences that govern the activity; be able to understand the business rules and relationships between planning, industrial and commercial strategies, quality and profit.

**Basic:**

CB7. That the students can apply their knowledge and ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their study area.

CB9. That students can communicate their conclusions and the knowledge and Latest rationale underpinning to specialists and non Specialty clearly and unambiguously.

CB10. Students must possess the learning skills that enable them continue studying in a way that will be largely self-directed or autonomous.

## TEACHING METHODOLOGY

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Weekly work (weekly delivery of tasks via Atenea)

Receive, understand and synthesize knowledge.

Define and solve problems by hand and with the help of the computer.

During the course each student will develop an individual work ("control system draft project"), in which he or she will apply the concepts presented in the lectures. This work consists in the design of a control system for a marine application chosen by each student and it will be delivered in 5 phases. At the end of the course, the students will have to present their projects.

## LEARNING OBJECTIVES OF THE SUBJECT

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Given different systems of the ship and/or marine facilities,

1. Know how to get models of their dynamic behavior that allow the subsequent design of control systems.
2. Know how to pose realistic specifications (stability, bandwidth, precision, implementability, cost).
3. Given the model and specifications, design and instrument a one-loop feedback control system, and know how to choose the control law.
4. Know how to design the controller by different methods (polynomial, empirical, graphical) by hand and using the computer, and know how to discretize it.
5. Understand the concept of optimal control, being able to choose reasonable behavior indexes and know to design the corresponding controllers.
6. Know how to design state space controllers for both pole placement and optimization.
7. Know how to analyze the behavior of the analogic and digital control system using the computer.

The STCW competences associated to this course are:

A-III/2 - 3. Operation, surveillance, performance, assessment and maintaining safety of propulsion plant and auxiliary machinery, including the KUPs: A-III/2 - 3.4 Functions and mechanism of automatic control for main engine, and A-III/2 - 3.5 Functions and mechanism of automatic control for auxiliary machinery.

A-III/2 - 5. Manage operation of electrical and electronic control equipment, including the KUPs: A-III/2 - 5.1 Marine electrotechnology, electronics, power electronics, automatic control engineering and safety devices, A-III/2 - 5.2 Design features and system configurations of automatic control equipment and safety devices, A-III/2 - 5.3 Design features and system configurations of operational control equipment for electrical motors, and A-III/2 - 5.5 Features of hydraulic and pneumatic control equipment.

## STUDY LOAD

Type	Hours	Percentage
Hours large group	45,0	100.00

**Total learning time:** 45 h

## CONTENTS

### Topic 0. Introduction to the control of marine systems. Matlab and Simulink

**Description:**

Several examples of control systems applied to marine systems are presented.  
The Matlab/Simulink simulation tool is also presented

**Related activities:**

Phase I of SCP: Control problem formulation

**Full-or-part-time:** 6h 30m

Theory classes: 6h 30m

### Topic 1. Models and instrumentation (A-III/2 - 3.4, A-III/2 - 3.5)

**Description:**

- 1.1 Transfer function
- 1.2 ime response (1st and 2nd order)
- 1.3 Block diagrams
- 1.4 Frequency response
- 1.5 Instrumentation of control loops

**Related activities:**

Phase II of SCP: Instrumentation selection and component medelling

**Full-or-part-time:** 20h

Theory classes: 20h

### Topic 2. Feedback and closed loop control systems

**Description:**

- 2.1 Feedback Theory
- 2.2 Effects and limitations

**Full-or-part-time:** 16h

Theory classes: 16h

### Topic 3. Analysis of stability and behavior (A-III/2 - 5.1, A-III/2 - 5.5)

**Description:**

- 3.1 Evans Root Locus
- 3.2 Error constants
- 3.3 Routh-Hurwitz criterion

**Related activities:**

Phase III of ASC: Specifications and analysis of a proportional controller

**Full-or-part-time:** 13h

Theory classes: 13h

### Topic 4. Design of controllers I (A-III/2 - 5.2, A-III/2 - 5.3)

**Description:**

- 4.1 Formulation of specifications
- 4.2 Direct synthesis of controllers
- 4.3 PID regulator
- 4.4 Empirical methods: Ziegler-Nichols
- 4.5 Graphical methods (I): Evans
- 4.6 Controller optimization. ISE, ITAE
- 4.7 Graphical methods (II): Lead-lag

**Related activities:**

Phase IV of SCP: Controller design

**Full-or-part-time:** 35h 30m

Theory classes: 35h 30m

### Topic 5. Digital implementation of controllers

**Description:**

- 5.1 Digital control systems. Sampling selection
- 5.2 Z transform. Time and frequency response
- 5.3 Discretization methods
- 5.4 Design of digital controllers. Dead beat, Kalman and Dahlin

**Related activities:**

Phase V of SCP: Controller discretization and implementation

**Full-or-part-time:** 9h

Theory classes: 9h

## Topic 6. Design of controllers II

### Description:

- 6.1 Description in the state space
- 6.2 Conversions
- 6.3 Controllability and observability
- 6.4 Modal control
- 6.5 LQG stochastic optimal control
- 6.6 Robust control
- 6.7 Adaptive control

**Full-or-part-time:** 25h

Theory classes: 25h

## GRADING SYSTEM

The final grade is the weighted sum of the partial marks as follows:

$$N_{\text{final}} = 0.4 \times N_{\text{asc}} + 0.3 \times N_{\text{parcial}} + 0.15 \times N_{\text{ex}} + 0.15 \times N_{\text{pr}}$$

$N_{\text{final}}$ : Final grade of the course

$N_{\text{asc}}$ : Mark of the control system project

$N_{\text{parcial}}$ : Mark of the mid-term test

$N_{\text{ex}}$ : Mark of the weekly exercises

$N_{\text{pr}}$ : Mark of the practices with matlab/simulink

## EXAMINATION RULES.

If not done any of the continuous assessment activities or laboratory practices, this will be considered as non-rated (and its value is 0).

The delay in the deliveries (practice reports, proposed exercises, and phases of the control project will be penalized (each day of delay will take a point to the activity mark).

Students who do not deliver the control system project will be graded as "not presented" in the subject.

## BIBLIOGRAPHY

### Basic:

- Kuo, B.C. Sistemas de control automático. México: Prentice Hall Hispanoamericana, 1996. ISBN 9688807230.
- García de Jalón, J.; Rodríguez, J. Ignacio. Aprende Matlab 7.0 como si estuviera en primero [on line]. Madrid: Universidad Politécnica de Madrid. Escuela Técnica Superior de Ingenieros Industriales, 2005 [Consultation: 14/07/2021]. Available on: <http://ocw.uniovi.es/file.php/146/T4MaterClase/MATLAB/matlab70primero.pdf>.
- Ogata, Katsuhiko. Ingeniería de control moderna [on line]. 5a ed. Madrid: Pearson Educación, 2010 [Consultation: 01/09/2022]. Available on: [https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB\\_BooksVis?cod\\_primaria=1000187&codigo\\_libro=1259](https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=1259). ISBN 9788483226605.
- Phillips, Charles L; Chakraborty, Aranya; Nagle, H. Troy. Digital control system analysis & design [on line]. Fourth edition. Boston: Pearson Prentice Hall, 2015 [Consultation: 01/09/2022]. Available on: <https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=5174338>. ISBN 9781292061887.

### Complementary:

- Jackson, Leslie.; Boyd, G. Instrumentation and control systems. 5th ed. London: Adlard Coles Nautical, 2013. ISBN 9781408175590.
- Embleton, William. Reed's engineering knowledge instruments & control systems for deck officers. 5th ed. Surrey, UK: Thomas Reed, 1995. ISBN 0901281158.



- Jackson, L.; Russell, P.A.; Morton, T.D. General engineering knowledge for marine engineers. London: Bloomsbury, 2013. ISBN 9781408175965.

## RESOURCES

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### Other resources:

Course notes, theoretical videos, practices and exercises in Atenea