COURSE DATA

Data Subject	
Code	34943
Name	Digital control
Cycle	Grade
ECTS Credits	6.0
Academic year	2022 - 2023

Study (s)

Degree	Center	Acad. year	Period
1404 - Degree in Industrial Electronic Engineering	School of Engineering	3	Second term

Subject-matter

Degree	Subject-matter	Character
1404 - Degree in Industrial Electronic Engineering	18 - Industrial automation and control	Obligatory

Coordination

Name	Department
ESPI HUERTA, JOSE MIGUEL	242 - Electronic Engineering

SUMMARY

This is an obligatory subject taught during the second semester, third curse of the Industrial Electronics Engineering degree. The total academic charge is 6 ECTS. The estimated amount of work for the student is around 150 hours during the semester, from which 60 are classroom hours and 90 are homework. The “Control Digital” subject is part of the matter “Automatización y Control Industrial”.

“Automation” is a wide concept that aims to solve tasks (in our case industrial tasks) in an “automatic” way, i.e., without the need for humans playing an active role on them, neither making decisions (which task to do) nor in the task realization itself.

Often in an automated installation, it is necessary to perform “regulation” of a given variable of a sub-process, or of the main process itself. That is, it may be necessary to take control of a given physical variable (a distance, temperature, rotational speed, etc.). To do so it is necessary to practise a feedback control of this variable, in which the command signal (order) is compared with the variable to be controlled (obtained using sensors), and the process is driven automatically until both variables are matched. To ensure a smooth, fast and accurate tracking of the command signal, it is necessary to perform

“compensation” calculations to determine, at any time, the amount of energy (or intensity) to be applied to the process. If these calculations are not well designed, stability problems may occur, and the transient response of the controlled variable can be unacceptable or even unstable. The goal of this subject is to present the stability problems related with digital feedback control, and teach how to design a digital control to satisfy a given static (precision) and dynamical (transient) specifications. This is an essential knowledge for any automation engineer involved in industrial process control, or any electronic engineer involved in electronic equipment design.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

The previous basic knowledge, needed to follow the subject, is that introduced in the Mathematics subjects (especially the complex variable) and Physics (particularly Newtons laws) during first course, and that taught in the course "Dinámica y Control"(especially transfer function, frequency response and block diagrams). We recommend background on instrumentation, and analog and digital electronics.

OUTCOMES

1404 - Degree in Industrial Electronic Engineering

- CG3 - Knowledge of basic and technological subjects that allows students to learn new methods and theories and provides them with versatility to adapt to new situations.
- CG4 - Ability to solve problems with initiative, decision-making skills, creativity and critical reasoning and to communicate and transmit knowledge, abilities and skills in the field of industrial engineering (with specific industrial electronics technology).
- CG6 - Ability to deal with specifications, regulations and mandatory standards.
- CE7 - Knowledge and capacity for systems modeling and simulation.
- CE8 - Knowledge of automatic regulation and control techniques and their application in industrial automation.
- CE11 - Ability to design control and automatic industrial systems.

LEARNING OUTCOMES

The learning result after taking the course "Digital Control" is summarized in the following capacities:

• Select the sampling frequency of digital control for each application (CG4, CG6, CE11).

• Obtain the discrete model of the continuous process to be controlled (CG3, CE7).

• Analyze the stability of a digital control system, and determine its robustness in terms of the stability margins (CG6, CE8, CE11).

• Select the appropriate compensation structure, and design it based on closed-loop specifications (CG4, CG6).

• Implement the digital compensator giving its difference equations, and program them into a controller device (CG4, CE11).

• Tune discrete PID compensators using either empirical techniques (CG4, CG6, CE8, CE11).

DESCRIPTION OF CONTENTS

1. Introduction to Digital Control

- Introduction: Objective, structure and operation of a digital control.
- Discrete signals: The ideal sampler. The Z transform and its properties. Basic discrete signals. Initial and final value theorems.
- Discrete systems: Finite difference equations. Causality. Transfer function in Z.
- Solution of the difference equations: impulse response and step response.
- Stability of discrete systems.
- Frequency response. Sampling theorem. Bode diagram.

2. Discretization of Continuous Systems

- Introduction.
- Model of the A/D conversion.
- Integer encoding and floating point encoding.
- Model of the D/A conversion. DACs and PWM outputs.
- Representation by means of a block diagram. Practical examples.
- Modeling by experimental methods.
- Model of the zero-order hold (ZOH).
- Equivalent discrete system: Discretization of continuous systems by ZOH method. Cases and practical examples.

3. Analysis of Discrete Feedback Systems

- Introduction.
- Steady-state analysis: Controllable range. Tracking error. Unitary errors. Practical examples.
- Relationship between transient response and poles in Z. Design of poles in the Z plane.
- Analysis of absolute stability: Direct method. Jury's stability criterion. Practical examples.
- Relative stability analysis: Nyquist stability criterion. Tustin transformation. Drawing of the asymptotic Bode of the open-loop system. Phase and gain margins. Sampling period design criteria. Practical examples.

- The discrete Root Locus: The angle and magnitude conditions. Drawing rules. Practical examples.

4. Discrete Compensators

- Introduction.
- PID compensators: P, I (Forward Euler, Backward Euler and Trapezoidal), D, PD, PI and PID compensators. Transfer functions in Z and in the Tustin domain. PI - PID comparison. Standard parallel implementation.
- Other compensators: Lead compensator, lag compensator and PI+pole compensator. Direct and parallel implementations. Examples.

5. Frequency-Based Design of Discrete Compensators

- Introduction.
- Timers and PWM modules in microcontrollers: Setting the sampling period. PWM configuration.
- Asymptotic frequency design of PI compensators. Anti-windup limitation. Practical examples. Microcontroller control programming.
- Asymptotic frequency design of PID compensators. Practical examples. Programming.
- Analytical frequency design of PI compensators. Practical examples. Programming.
- Analytical frequency design of PI+pole and lead compensators. Cancellation method. Maximum phase method. Practical examples. Programming.

6. Compensators Design Using Root-Locus Methods

- Introduction. Dominant poles design expressions.
- Design strategies on the root locus. Plant cases: first-order, overdamped second-order, underdamped second-order, and integral second-order systems.
- Design of PI compensators in the root locus. Practical examples. Microcontroller control programming.
- Design of PI+pole compensators in the root locus. Practical examples. Programming.
- Design of PID compensators in the root locus. Practical examples. Programming.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	30,00	100
Laboratory practices	20,00	100
Classroom practices	10,00	100
Development of group work	15,00	0
Study and independent work	40,00	0
Readings supplementary material	5,00	0
Preparing lectures	5,00	0
Preparation of practical classes and problem	25,00	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

THEORY CLASSES.

The theory classes will be taught masterfully. After the introduction of new content, its application will be illustrated with practical examples (CG3, CG6, CG23, CE7, CE8, CE11). Afterwards, the teacher will be able to propose a related problem as homework (CG3, CG4, CG6, CG23, CE7, CE8, CE11), which will be solved in the following problems class.

PROBLEMS CLASSES.

During the problems classes, the teacher will solve example problems and all the problems proposed to the students as homework.

LABORATORY CLASSES.

They are taught in the ETSE’s lab facilities, which are equipped with specific electronic equipment and computers. Students will be organized in groups of 2 or 3. There will be a descriptive guide of each practice.

EVALUATION

In the first call the student will be able to choose between two evaluation modalities: continuous evaluation or evaluation by final exam. In the second call the student will always be evaluated by the final exam modality. Both evaluation modalities are detailed below.

a) CONTINUOUS EVALUATION:

- Evaluation of the theory-problems part:

Two partial exams will be held: the first in the middle of the semester, and the second on the day set by the center for the first-call exam. Students who pass the first part will only have to take the contents of the second part of the subject in the second partial exam, and their Theory-Problems grade (*grade_theorpro*) will be obtained as the arithmetic mean of both parts. Students who fail the first part will have to take the entire subject in the second partial exam, obtaining *grade_theorpro* directly from that exam.

- Evaluation of the laboratory part:

The continuous evaluation of the laboratory practices will be carried out and the *grade_pract* (out of 10) will be obtained as the arithmetic mean of all of them.

A laboratory exam will be carried out, which, if passed, determines the *grade_test* (out of 10). Otherwise *grade_test* = 0.

The final lab grade will be calculated as:

grade_lab = 0.7**grade_pract* + 0.3**grade_test*.

b) Evaluation by FINAL EXAM:

A final theory-problem exam and a laboratory exam will be held on the date set by the center, obtaining the *grade_theorpro* and *grade_lab* directly from these exams. To be able to take advantage of this modality in the first call, the student must indicate it to the laboratory professor at the beginning of the classes, to avoid being evaluated by him continuously, and will not have to take the first partial exam of theory-problems.

Regardless of the evaluation modality chosen, a minimum of 5 (out of 10) will be necessary both in theory-problems (*grade_theorpro*) and in laboratory (*grade_lab*) to pass. In that case, the final grade for the course will be obtained as follows:

Final_grade = (2**grade_theorpro* + *grade_lab*)/3.

Otherwise: *Final_grade* = min(*grade_theorpro*, *grade_lab*).

In any case, the evaluation system will be governed by the provisions of the Regulation of Evaluation and Qualification of the University of Valencia for Degrees and Masters.

REFERENCES

Basic

- b1: Digital Control Engineering. M. Sami Fadali; Antonio Visioli. Ed. Elsevier, Academic Press. ISBN: 978-0-12-374498-2.
  http://proquest.safaribooksonline.com/9780123744982?uicode=valencia
- b2: Microcontroller Based Applied Digital Control. Dogan Ibrahim. Ed. John Wiley & Sons. ISBN: 978-0-470-86335-0. ISBN (e-book): 0-470863-35-8.
  http://proquest.safaribooksonline.com/9780470863350
- b3: Sistemas de Control en Tiempo Discreto. Katsuhiko Ogata. Ed. Prentice-Hall. ISBN: 9789688805398.
- b4: Digital Control. Kannan Moudgalya. Ed. Wiley-Interscience. ISBN: 0-470031-43-3.
  http://proquest.safaribooksonline.com/9780470031438?uicode=valencia

Additional

- c1: Ingenieria de Control Moderna. Katsuhiko Ogata. Ed. Pearson. ISBN: 9788483226605. ISBN (e-book): 9788483229552.
  http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=1259
- c2: Control de Sistemas Dinámicos con Realimentación. Gene F. Franklin. Ed. Addison-Wesley Iberoamericana. ISBN: 0-201-64421-5.