Universidad Rey Juan Carlos

TEACHING GUIDE

Discrete Time Systems

GRADO EN INGENIERÍA BIOMÉDICA (INGLÉS) (1º y 2º curso)

ACADEMIC YEAR 2026-27

Q2803011B UNIVERSIDAD REY JUAN CARLOS
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I.-Subject Identification	
Type	OBLIGATORIA
Teaching period	2 course, 2Q semester
Nº of credits	6
Language in wich the subject is taught	English

II.-Presentation

Discrete Time Systems delves into the modelling (description) and analysis of signals and discrete systems both in the time domain and in the frequency domain, with an emphasis on biomedical signals. It focuses on understanding the relationship between signals and continuous systems and their discrete counterparts, both in the time domain (sampling, sub-sampling and overlapping), and in the frequency domain (introducing the Discrete Fourier Transform, which enables the calculation of transformed signals by digital processors). The final part of the subject is dedicated to presenting a new transform for signals and discrete systems—the Z transform—, as well as its application to the design of discrete filters.

The contents of this subject are fundamental for modelling, analysing and solving a large part of the problems that appear in the field of Engineering—such as information transmission through channels, coding and processing of audio-visual information, analysis of biomedical signals, etc.—and are a fundamental basis for later subjects.

Prerequisites:

•Having passed *Linear Systems and Application to Circuits* (in the first semester of the second year).

•Having acquired the knowledge and competences in other subjects in the first and second years (first semester), specifically:

1. Analysis and signal processing tools for continuous systems: 1. Leveraging properties of signals and systems, specially linear, time-invariant systems; 2. Working out convolutions in continuous time; 3. Finding the Fourier Series Representation (FSR) and the Fourier Transform (FT) for continuous signals; 4. Knowing the properties of the DSR and TF of continuous signals.
2. Fundamentals of calculus: 1. Working our geometric series and integrals; 2. Polynomial factorization and continuous fraction expansion of polynomial quotients in the complex domain.
3. Fundamentals of algebra: 1. Working with vector spaces and their bases, and orthogonality between vectors; 2. Working with and representing functions of one complex variable; 3. Knowing how to represent additions or subtractions of complex exponentials as sinusoids.

Therefore, **we recommend that students who have not passed those subjects where these concepts are studied do not enroll in Discrete Time Systems**.

To ensure success in acquiring the competences and learning outcomes in the subject (see below) teaching will proceed using different formative and evaluation activities.

Formative activities will include: 1) lectures concerning theory for each unit; 2) Time-synchronous classes about solving some of the problems in the handouts for each unit; 3) lab sessions using the adequate SW, e.g. Matlab and/or Julia; 5) the use of Fora to exchange remarks, problem solutions and doubts for each unit; and 5) individual/group tutoring sessions.

Assessment may include of: 1) two written tests (partial and final); 2) synchronous (immediate) test or hand-in of a notebook for each lab session using AV (the details will be explained by the lecturer during subject unrolling); 3) attendance to and taking part in class, active participation in fora---e.g. by solving doubts for classmates, proposing new projects beyond those of the handouts, supplying pieces of news or information about the subject, etc.

III.-Learning outcomes

CON06. Know and understand the principles of signals and biomedical systems in discrete time.

HAB08. Analyze and control dynamic biomedical systems in both continuous and discrete time, both linear and non-linear.

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- Key for degrees not adapted to RD 822/21: **CB** - basic competences, **CG** - generic competences, **CE** - specific competences, **CT** - transversal competences.
- Key for degrees adapted to RD 822/21: **CON** - knowledge, **COM** - competences, **HAB** - skills.

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IV.-Contents

IV.A.-Syllabus

Topic 1: Discrete-time Signals and Systems in the Time Domain
- Discrete-time Signals.
- Discrete-time Systems.
- Discrete-time System properties.
- Discrete-time convolution sum.

Topic 2: Discrete-time Signals and Systems in the Frequency Domain
- The discrete-time Fourier Series Representation for signals: definition, properties, Fourier series and Linear Time-Invariant (LTI) systems.
- The discrete-time Fourier transform for signals: definition, properties, frequency response of LTI systems.

Topic 3: Sampling
- Sampling of continuous signals: sampling theorem; continuous-time signal reconstruction through interpolation.
- Discrete-time processing of continuous signals.
- Discrete-time signal sampling: decimation and interpolation.

Topic 4: Discrete Fourier Transform: frequency sampling
- Definition: the DFT as the sampling of the Fourier Transform.
- Properties.
- Circular convolution: definition, relationship with the DFT, relationship with convolution sum.

Topic 5: The z-Transform
- Definition and Region-of-Convergence (ROC).
- Properties.
- Pole-and-zero diagram.
- Analysis of discrete-time systems described by difference equations.
- Block diagrams.

Topic 6: Introduction to the design of discrete filters
- Fundamentals of digital filtering.
- Design of FIR filters.
- Overview of IIR filter design.

IV.B.-Training activities

Type	Title
Theoretical sessions	Q&A session on theoretical material previously studied autonomously.
Other activities	Preparatory autonomous study of materials in a flipped classroom model.
Experimental and/or technological laboratories	Data programming training sessions.
Resolution of exercises, problems, case studies	Problem-solving sessions used as training for written exams.
Group work	Biological signals data-analysis programming projects.
Group work	Filter design and programming projects.
Realización de Pruebas	1 formative assessment, 1 + 1 habilitative assessment (ordinary + extraordinary calls)

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Academic tutorials	Collective or individual, whether at the request of students or professors.

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V.-Student workload	
Theoretical sessions	12
Resolution of exercises, problems, case studies, etc.	20
Practical sessions in experimental, technological and clinical laboratories, fieldwork, etc.	26
Tests and/or exams	2
Academic tutorials	4
Related activities: conferences, seminars, etc.	44
Preparation of theoretical sessions and self-study	18
Preparation of practical tasks, exercises, case studies, projects, etc.	46
Preparation for tests and/or exams	8
Total student workload	180

VI.-Methodology and academic programme

Type	Period	Content
Theoretical sessions	Week 1 to Week 13	Special emphasis on difficult and/or crucial concepts.
Resolution of exercises, problems, case studies	Week 1 to Week 13	Training for Problem-Based learning to be assessed on written tests.
Experimental and/or technological laboratories	Week 1 to Week 13	Signal processing laboratory exercises with open SW tools.
Active methodologies or innovative teaching	Week 1 to Week 9	Inverted Classroom.
Tests and/or exams	Week 8 to Week 10	2h formative assessment written test.
Tests and/or exams	Week 14 to Week 19	3h habilitative assessment as per the official exam dates for the ordinary and extraordinary calls.
Academic tutorials	Week 1 to Week 19	Individual or collective per the students' or the professor's request.
Active methodologies or innovative teaching	Week 10 to Week 14	Cooperative, Collaborative, Project-Based Learning on a challenge on signal processing of biological data.

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VII.-Assessment methods

The general assessment method is continuous as established in the *Regulation for the Assessment of Learning Outcomes* of Rey Juan Carlos University.
All the assessment systems established in the degree report must be employed, except for those that have a minimum weight of 0%, which can be used by professors in the academic years they consider relevant. Each assessment system may be applied through one or more assessment activities, consistent with the system. No assessment activity can exceed individually 60% of the overall grade for the subject.
The sum of non re-evaluable activities cannot exceed 40% of the overall grade for the subject and, in general, should not have an established minimum grade (except for practical activities in which, strictly speaking, the conditions of the ordinary call cannot be reproduced in the extraordinary call).
Those students who do not manage to pass the subject in the ordinary call, or do not attend this first call, may attend the extraordinary call only for failed re-evaluable assessment activities.
The distribution and characteristics of the assessment activities are described below.

VII.A.-Description and weight of the assessment activities

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Continuous ordinary assessment:

The distribution and characteristics of the assessment tests are those described below. Only in exceptional case and for special reasons may the teacher add changes to the Guide. These changes will require the prior consultation with the Subject Head and the prior and explicit authorisation of the Degree Programme Coordinator, who will notify the Vice-Rector's office in charge of Academic Affairs of the modifications made. In any case, the changes proposed must take into account the stipulations of the verified report. In order for these changes to take effect, they must be duly communicated at the start of the course to the students using Aula Virtual.

Ordinary Evaluation Summary Table and Checklist

Assessment System	Assessment Activity	Re-assessable in Extraordinary Call?	Weight	Minimal Grade	Contents	Dates
SE02 (written tests)	Mid-term	Yes	20%	No	U1, U2 and U3	Weeks 8-10
SE=2 (written tests)	Final	Yes	50%	4.0	All Syllabus	Ordinary Call
SE05	Solving SW enabled practical cases	No	30%	No	Filtering and Signal processing on computers	Weeks 1-14

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•To pass the course students will have to obtain a grade above 4.0/10.0 in the ***Final test*** and an aggregate grade above
•5.0/10.0
•The aggregate mark is: grade = 0.2Partial Test + 0.4Lab Score + 0.4Final Test
•If the ***final test*** grade is less than 4.0 you may not pass the subject in the ordinary call, regardless what the average is. In such case, the official public grade will be as specified in the Evaluation Reglament.
•If a student does not turn up for **all** of the previous assessment tasks the final mark will be ***NO PRESENTADO***
•Class attendance is compulsory (unless you obtain an academic exemption). In order for attendance to be acknowledged it may be controlled (a roll-call or signature form, etc.) and only **three** misses will be allowed.
•Students with academic exemption from class must refer to the Evaluation Reglament regarding non-reassessable activities.

Extraordinary assessment

Students who do not manage to pass the ordinary assessment, or who did not attend any of the tests, will be subject to completion of an extraordinary assessment to verify their acquisition of the skills established in the guide, only for activities that are re-assessable.

Extraordinady assessment check list

•In the extraordinary call, only the ***Partial test*** and ***Final test*** grades may be subject to re-assessment, and only **if they were not passed**. They will both be re-assessed in the date and time designated by the university for extraordinary assessment. The extraordinary call aggregate grade formula is the same as in the ordinary call.
•To pass the course in the extraordinary call students will have to obtain a grade above 4.0/10.0 in the ***Final test*** and an aggregate grade above 5.0/10.0 with the same weighting scheme as in the ordinary call.
•If the ***extraordinary test*** grade is less than 4.0 you may not pass the subject, regardless of what the average is. In such case, the official public grade will be as specified in the Evaluation Reglament.

Advance evaluation call:
For the September advance evaluation call, students will be required to sit for a written exam on the whole subject for a grade of 6.0/10 points, and a lab-theory exam for a grade of 4.0/10.0 points. Minimum grade for passing each is 5.0/10.

Final clarifications

- Professors may require the **defense of any of the assessment tests either written or orally (tests, labs or others)** if deemed necessary. The result of such defense may results in ratifying the assessment grade or a completely new assessment. Not turning up for the defense will result in a grade of 1.0/10 in the assessment being defended.
- Note that no assessment grades will be saved for later courses, nor will any previous courses' assessments be taken into consideration for the present course's assessment grades. Specifically, this applies to the Advance Evaluation during September.

VII.B. Assessment of students with academic exemption from class attendance

Having Academic Exemption from Class Attendance (DAAC) does not imply that students are automatically exempt from participating in the continuous assessment activities or in the training activities of compulsory attendance as established in the teaching guide. Once the exemption has been granted, students must contact the subject's teaching staff, who will propose the adaptations he/she may consider relevant, as long as they guarantee the acquisition and adequate assessment of the learning goals established. Students must maintain adequate communication with the teaching staff so that they may provide information on the dates for training and assessment activities, if these are not established in the programme and available for students at the time of achieving the exemption.
Subject with possibility of academic exemption: Yes.

VII.C. Review of assessment activities

In accordance with the Regulation for the Assessment of Learning Outcomes of Rey Juan Carlos University.

VII.D.-Students with a disability or special educational needs

In order to guarantee equal opportunities, non-discrimination, universal accessibility and academic success, students with disabilities or especial education needs may request curricular adaptations to follow their studies. These adaptations will be provided by the Unit of Attention to People with Disabilities of Rey Juan Carlos University, in accordance with the regulation which regulates the service for the Attention of People with Disabilities at the University. This Unit will issue a report for curricular adaptations, so that students with disabilities or special education needs must contact the service (at e-mail discapacidad.programa@urjc.es) in order to provide relevant information for different educational alternatives.

VII.E.-Academic behaviour, academic integrity and honesty

Rey Juan Carlos University is fully committed to the highest standards of academic integrity and honesty, so studying at the URJC means assuming and subscribing to the values of integrity and academic honesty set out in the University's Ethical Code. To support this process, the University has Rey Juan Carlos University's Academic Conduct Regulation as well as different tools (anti-plagiarism, supervision...) that offer a collective guarantee for the full development of these essential values.

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VIII.-Teaching resources and materials
Basic bibliography
Hwei P. Hsu, "Signals and Systems", Schaum's Outlines, McGraw-Hill, 1995. This basic text covers strictly and exactly what you need for this subject. Nothing is missing, nothing can be left out. It has a wealth of problems too.
Consultation bibliography
Monson H. Hayes. "Digital Signal Processing, 2nd Edition " Schaums Outlines, McGraw-Hill, 2011. This book can be used to train on further problems.
Alan V. Oppenheim and Ronald W. Schafer, "Discrete-Time Signal Processing", 3rd Ed. 2009. This book has an extensive coverage of all matters in the course. Perhaps a bit too verbose.
Edward W. Kamen, Bonnie S. Heck. "Fundamentos de señales y sistemas usando la Web y MATLAB". Pearson education.
B. P. Lathi, "Signal Processing and Linear Systems ", Oxford University Press, 2nd Ed. 2004 This is an alternative to Oppenheim's text, following the same pattern of explanation, verbosity and depth.

IX.-Professors	
Name and surname	FRANCISCO JOSÉ VALVERDE ALBACETE
E-mail address	francisco.valverde@urjc.es
Department	Teoría de la Señal y Comunicaciones y Sistemas Telemáticos y Computación
Campus	Fuenlabrada
Category	Titular de Universidad
Academic degree	Doctor
Person responsible for the subject	Yes
Tutorial timetable	Para consultar las tutorias póngase en contacto con el/la profesor/a a través de correo electrónico
Number of quinquennia	3
Number of sexennia	3
No. of positive evaluations by Docentia	1
Name and surname	VÍCTOR MANUEL TENORIO GÓMEZ
E-mail address	victor.tenorio@urjc.es
Department	Teoría de la Señal y Comunicaciones y Sistemas Telemáticos y Computación
Campus	Fuenlabrada
Category	Profesor/a Ayudante Doctor/a

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Academic degree	Doctor
Person responsible for the subject	No
Tutorial timetable	Para consultar las tutorias póngase en contacto con el/la profesor/a a través de correo electrónico
Number of quinquennia	0
Number of sexennia	0
No. of positive evaluations by Docentia	1

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