



IDENTIFYING DATA

Digital Signal Processing

Subject	Digital Signal Processing			
Code	V05G306V01205			
Study programme	Grado en Ingeniería de Tecnologías de Telecomunicación			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	2nd	1st
Teaching language	English			
Department				
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General description Digital signal processing is nowadays a feature of most everyday communications and entertainment devices. The aim of this course is to equip students with a mathematical grounding in general signal and systems analysis. In subsequent course subjects, this knowledge will be applied to specific applications of signals and systems, including audio, image, video and voice signals.

Objectives cover the following areas:

- Managing signals and systems mathematically and visually, including learning and applying their properties.
- Studying the different domains for signal and systems analysis: time domain, frequency domain and Z domain.
- Learning how to transfer a problem in one domain to a domain in which it is easier to solve.
- Mastering the concept of filter frequency response and learning to interpret the system function.
- Understanding the relationship between the poles and zeros of the system function and the frequency response.
- Acquiring basic notions of filter design in the Z domain.
- Managing specific digital signal processing software.
- Applying the above knowledge to simple and practical laboratory examples.

English Friendly subject: International students may request from the teachers:

- a) resources and bibliographic references in English,
- b) tutoring sessions in English,
- c) exams and assessments in English.

Training and Learning Results

Code	
B3	CG3: The knowledge of basic subjects and technologies that enables the student to learn new methods and technologies, as well as to give him great versatility to confront and adapt to new situations
B4	CG4: The ability to solve problems with initiative, to make creative decisions and to communicate and transmit knowledge and skills, understanding the ethical and professional responsibility of the Technical Telecommunication Engineer activity.
C48	(CE48/T16) The knowledge of the appropriate techniques to develop and exploit signal processing subsystems.
C49	(CE49/T17) The ability to analyze digital signal processing schemes.
D2	CT2 Understanding Engineering within a framework of sustainable development.
D3	CT3 Awareness of the need for long-life training and continuous quality improvement, showing a flexible, open and ethical attitude toward different opinions and situations, particularly on non-discrimination based on sex, race or religion, as well as respect for fundamental rights, accessibility, etc.

Expected results from this subject

Expected results from this subject	Training and Learning Results
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Managing specific software for digital signal processing	B3	C48	D3
Applying mathematical knowledge for signal filtering	B4	C49	D2
Mastering filtering operations in frequency domain.	B4	C49	D2
Learning mathematical issues for understanding the processes of sampling and windowing of analog signals.	B3	C48	D3
Analysis of simple processing systems.	B4	C49	D2

Contents

Topic	
Subject 1. Introduction	Concept of signal and system. Mathematical representation
Subject 2. Sinusoids	Sinusoidal signals: Frequency, amplitude and phase. Complex exponentials and phasors. Phasor addition rule.
Subject 3. Spectrum representation	Spectrum of a sum of sinusoids. Mathematical expression and graphical plot. Fourier Series analysis of periodic signals.
Subject 4. Introduction to Sampling and Aliasing	Sampling and digital frequency. Analog frequency vs discrete frequency. Aliasing. The sampling theorem.
Subject 5. FIR Filters	Introduction to discrete-time systems. Difference equation. Filter Coefficients. Block Diagrams. Causality, linearity and time-invariance. LTI systems and convolution. FIR frequency response. Cascaded LTI systems.
Subject 6. Frequency response of FIR filters	Sinusoidal response of FIR systems. Frequency response. Properties. Graphical representation.
Subject 7. Z Transform	Definition and properties. Linear-phase filters.
Subject 8. IIR Filters	Difference equation. Filter Coefficients. Block Diagrams. Impulse response. Relation between the position of poles and zeros of the system function and the frequency response.
Subject 9. Continuous-Time Signals and Systems	Introduction to continuous-time systems. The unit impulse. The unit step. Time delaying. Linearity and time-invariance. Convolution
Subject 10. Continuous-Time Fourier Transform	Definition. Basic pairs. Properties
Subject 11. Sampling and Reconstruction in the Frequency Domain	The sampling theorem in the frequency domain
Project 1. A/D and D/A Conversion	Digitalisation of Continuous-Time Signals. Aliasing.
Project 2. Digital Filters	Digital filters in the time and frequency domains.

Planning

	Class hours	Hours outside the classroom	Total hours
Introductory activities	1	0	1
Lecturing	32	37	69
Laboratory practical	10	20	30
Problem solving	14	28	42
Discussion Forum	0	2	2
Objective questions exam	1.5	0	1.5
Problem and/or exercise solving	4.5	0	4.5

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Introductory activities	Course presentation: programme, reading materials, teaching methodology and assessment system
Lecturing	Instructor presentation of the main concepts of each subject. During the 5 minutes before the lecture, a student will summarize the main concepts presented in the previous session. Students will participate by answering questions during the explanation and by doing exercises. Student will work alone afterwards on the concepts studied in class and on expanding this content using the guidelines provided for each subject. Identification of doubts that need to be resolved in personalized tutorials. Through this methodology the competencies C48, B3, and D3 are developed.
Laboratory practical	Application of Matlab functions and commands for digital signal processing to solve practical exercises. Identification of doubts that need to be resolved in personalized tutorials. Software to be used: MatLab. Through this methodology the competencies C49, B4 and D2 are developed.

Problem solving Problems and exercises formulated according to the content of the lectures and the guidelines for each subject.
 Students solve problems and exercises prior to the class in which one or several students explain the solution on the board.
 Identification of doubts that need to be resolved in personalized tutorials.

Through this methodology the competencies C49, B4 and D2 are developed.

Discussion Forum The website for the course is included in the MooVi platform (<https://moovi.uvigo.gal/>). Subscription to this platform, including a photograph, is mandatory. The website provides all the information related to the course. It also publishes continuous assessment grades and runs forums for students to exchange ideas and discuss doubts.

Through this methodology the competencies C48, C49, B3, B4, D2 and D3 are developed.

Personalized assistance

Methodologies	Description
Lecturing	Students will have the opportunity to attend one-on-one tutorials at specific times established by lecturers for this purpose at the beginning of the academic year and published on the subject's page, on MooVi (https://moovi.uvigo.gal/), within the "Teaching staff and tutorials" section. These tutorials are aimed at resolving student doubts and providing guidance regarding: □ The content of the lectures and approaches to study. □ Laboratory projects and the software used. □ Problems and exercises proposed and solved in the classroom as well as other problems and exercises arising during the course. Online tutorials will be available too by appointment.
Laboratory practical	The same as in the previous section.
Problem solving	The same as in the previous section.

Assessment

	Description	Qualification	Training and Learning Results		
Objective questions exam	These tests are a requirement to pass the subject. See details in the "Other comments and second call" section.	0	B3	C48 C49	D3
Problem and/or exercise solving	These tests are a requirement to pass the subject. See details in the "Other comments and second call" section.	100	B3 B4	C48 C49	D2 D3

Other comments on the Evaluation

ASSESSMENT PROCEDURE:

A. Overview

The acquired skills are assessed by a series of tests grouped into two parts, with different requirements:

1. **Lab assessment.**
2. **Problems assessment.**

To pass the course it is necessary to pass all two parts.

- For each part one or more tests are performed to obtain an independent grade on each.
- There are tests for the two parts both in continuous assessment and in global assessment.
- A pass grade in any part is valid for the entire academic year.
- The final grade for Lab assessment is a numerical mark between 0 and 10. A student needs a grade greater than or equal to 5 to pass the Lab. Moreover, if the Lab exams are carried out during the classes period and the Lab grade for that period is greater than 7, the Lab grade will increase the Course mark (see details below).
- The final grade for the Problem assessment is a numerical mark between 0 and 10.
- The **Course mark** is obtained as follows (for both continuous and global assessment):
 - If you have passed all two parts and your continuous assessment Lab grade (the one obtained during the classes period) is not greater than 7:
 - Course mark=Problems assessment grade.
 - If you have passed all two parts and your continuous assessment Lab grade is greater than 7:

- Course mark=minimum [10 , Problems assessment grade + [(Continuous Assessment Lab grade-7)/3]
- If you have not passed any of the two parts:
 - Course mark=minimum [Problems assessment grade, Lab grade]
- In case the student has more than one mark for any part, the highest one will be used.

It is also important to note that:

- The course can be passed with full marks from continuous assessment, with no need to sit the final exam.
- Students who have done continuous assessment and have failed any part, in the final exam, only have to sit the part they failed (Lab or Problems).
- Students who sit any of the tests corresponding to Problem assessment will obtain a mark that will be listed in the academic records.

The following sections explain in detail how each part is graded.

B. Details of the assessment procedure

B1. Lab assessment

- Its goal is to determine whether the student has acquired all the knowledge and/or skills corresponding to the laboratory practice, emphasizing the use of MatLab for digital signal processing.
- Content to be assessed: content of the lab manuals and related theory content.
- Type of test: The test consists of a combination of multiple-choice questions and short questions. Students may use MatLab, lab manuals with personal notes, and text book. Students may not use a calculator for this test.
- The final grade for Lab assessment is a numerical mark between 0 and 10. A student needs a grade greater than or equal to 5 to pass the Lab. If the continuous assessment Lab grade is greater than 7 (not a Lab grade obtained in a final exam), the Lab grade will increase the Course mark.
- Assessment method:
 - **Ordinary exam:** Students will have two nonexclusive ways to pass the Lab part.
 1. Two tests in the lab room during the class period (continuous assessment)
 - The test consists of a series of questions at the end of each Lab assignment. The practice that is completed and all the previous ones are evaluated.
 - The tests will be graded between 0 and 10. The lab grade will be obtained as the weighed average of the grades of both practices, being the weights the 40% and the 60% for practices 1 and 2 respectively. The student will pass this part if he/she gets a weighed average greater than or equal to 5. It is compulsory to sit the two tests.
 - The schedule of the tests will be approved in the Comisión Académica de Grado (CAG) and it will be announced on the subject web site at the beginning of the lecture period.
 1. A final exam (global assessment). The pass mark for this test is 5 out of 10.
 - **Extraordinary exam or end-of-program exam:** A final exam (global assessment). The pass mark for this test is 5 out of 10.
- Remarks:
 - Once the Lab part has been passed, the Lab grade will be valid for the entire academic year.

B2. Problems assessment

- Its goal is to determine whether the student has acquired all the knowledge and/or skills corresponding to the course and knows how to apply them to solve problems.
- Content to be assessed: as specified in the guidelines document for each topic (available on the subject web) in the section "Content to be assessed". MatLab knowledge is not assessed.
- Type of test: A problem solving test. Students are not allowed to use books or notes. The use of calculators may be granted on an exam basis.

- It will be graded between 0 and 10. The pass mark is 5.
- Assessment method:
 - **Ordinary exam:** Students will have two nonexclusive ways to pass the Problems part.
 1. Three problem solving tests in the classroom during the class period (continuous assessment). Each test will be graded between 0 and 10 and it is mandatory to sit the three tests.
 - The mark will be obtained as : $w1 * \text{Test1Mark} + w2 * \text{Test2Mark} + w3 * \text{Test3Mark}$
 - The weight $w1$ will be 0.25 if the mark of the first test is higher than or equal to 3 out of 10. Otherwise $w1$ will be 0.
 - The weight $w2$ will be 0.35 if the mark of the second test is higher than or equal to 3 out of 10. Otherwise $w2$ will be 0.
 - The weight $w3$ will be 0.40 if the mark of the third test is higher than or equal to 3 out of 10. Otherwise $w3$ will be 0.
 - Test1: Units 1 to 4. Test2: Units 1 to 7. Test3: Units 1 to 11.
 - The schedule of the tests will be approved in the Comisión Académica de Grado (CAG) and it will be announced on the subject web site at the beginning of the lecture period.
 2. A final exam (global assessment). The pass mark for this test is 5 out of 10.
 - **Extraordinary exam or end-of-program exam:** A final exam (global assessment). The pass mark for this test is 5 out of 10.
- Remarks:
 - Once the Problems part has been passed, the Problems grade will be valid for the entire academic year.
 - A student who has passed the Problems part in the Ordinary exam through the continuous assessment method is allowed to sit the final exam of the Ordinary exam to try to get a better mark.
 - A student who has passed the Problems part in the Ordinary exam is NOT allowed to sit the Problems Part of the final exam of the Extraordinary exam.

C. Other comments

- After the end of the course students will have a single grade of the subject in their academic record:
 - After the Ordinary exam their corresponding grade is registered. If this grade is greater than or equal to 5, it will be the student final grade
 - If a student who has not passed the subject in the Ordinary exam, gets a better grade in the Extraordinary exam, this new grade will be the one that will be included in his academic record. If it is not better the academic record will stay unchanged. In any of these cases, this grade becomes the final grade.
- Continuous assessment tests may not be rescheduled.
- Lab or Problems grades are only valid for the current academic year.
- The use of books, notes or electronic devices such as phones or computers is not permitted in any test or exam. Mobile phones must be turned off and out of reach of the student. If calculator use is permitted, the calculator must be a conventional scientific calculator. Therefore, calculators that allow formulas to be saved or that have libraries that automatically perform operations with complex numbers, calculation of roots, etc. are not allowed under no circumstances.
- Plagiarism is regarded as serious dishonest behavior. If any form of plagiarism is detected in any of the tests or exams, the final grade will be FAIL (0), and the incident will be reported to the corresponding academic authorities for prosecution.
- Throughout the course, during the celebration of the lectures, the teachers of the subject will eventually propose activities or exercises in which students can be rewarded with up to 1 point out of 10. If they receive it, this bonus will be added to the final grade that the students have obtained following the assessment methods previously described.
- English Friendly subject: International students may request from the teachers: a) materials and bibliographic references in English, b) tutoring sessions in English, c) exams and assessments in English.

Basic Bibliography

J.H. McClellan y R.W. Schafer, R, **Signal Processing First**, Pearson Prentice Hall,

Complementary Bibliography

A. Quarteroni y F. Saleri, **Cálculo científico con Matlab y Octave**, Springer,

M. J. Roberts, **Señales y Sistemas**, McGraw Hill,

A.V. Oppenheim y R.W. Schafer, **Tratamiento de señales en tiempo discreto**, Prentice Hall,

Recommendations

Subjects that it is recommended to have taken before

Physics: Analysis of Linear Circuits/V05G301V01108

Mathematics: Linear algebra/V05G301V01102

Mathematics: Calculus 1/V05G301V01101

Mathematics: Calculus 2/V05G301V01106
