Universidad de Alcalá

TEACHING GUIDE

Digital Signal Processing

Degree in
Telecommunication Technologies Engineering (GITT)
Telecommunication Systems Engineering (GIST)

Universidad de Alcalá

Academic Year 2021/2022

3rd Year - 1st Semester (GITT+GIST)

Approved by the School Board on July 6, 2021

TEACHING GUIDE

Course Name:	**Digital Signal Processing**
Code:	**350024 (GITT+GIST)**
Degree in:	**Telecommunication Technologies Engineering (GITT)** **Telecommunication Systems Engineering (GIST)**
Department and area:	**Teoría de la Señal y Comunicaciones** **Signal Theory and Communications**
Type:	**Compulsory (GITT+GIST)**
ECTS Credits:	**6.0**
Year and semester:	**3rd Year - 1st Semester (GITT+GIST)**
Teachers:	To be defined
Tutoring schedule:	To be determined on the first class.
Language:	Spanish/English friendly

1. COURSE SUMMARY

The general objective of Digital Signal Processing is the study of mathematical tools needed to process discrete time signals. The major content of the subject is focussed on discrete-time linear and time invariant systems, although linear systems which do not hold the invariance property are also considered because of their importance in communications as well as in audio and image coding.

Knowledge and skills to be acquired by the student are described in section 5.2.

To improve the subject applicability, a high balance between theoretical and laboratory contents has been achieved. At the same time, a practical approach closer to the real system implementation is followed. For this purpose, a set of practical sessions are programmed to enable the theoretical content validation by students, and also to let them carry out simulations and to analyze digital systems in real environments. At the end of the subject, students should have acquired a good knowledge about the different stages of a digital system and they should have developed the skills in the usage of the different tools.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following generic skills, which are defined in the Section 3 of the Annex to the Orden CIN/352/2009:

en_TR2 - Knowledge of basic subjects and technologies that enables to learn new methods and technologies, as well as to provide versatility that allows adaptation to new situations.

en_TR3 - Aptitude to solve problems with initiative, decision making, creativity, and to communicate and to transmit knowledge, skills and workmanship, comprising the ethical and professional responsibility of the activity of the Technical Engineer of Telecommunication.

Professional Skills

This course contributes to acquire the following professional skills, which are defined in the Section 5 of the Annex to the Orden CIN/352/2009:

en_CST1 - Ability to build, operate and manage telecommunications networks, services, processes and applications, understood as systems for capturing, transporting, representing, processing, storing, managing and presenting multimedia information, from the point of view of transmission systems .

en_CST2 - Ability to apply the techniques on which telecommunication networks, services and applications are based, both in fixed and mobile environments, personal, local or at a great distance, with different bandwidths, including telephony, broadcasting, television and data, from the point of view of transmission systems.

en_CST6 - Ability to analyze, encode, process and transmit multimedia information using analog and digital signal processing techniques.

Learning Outcomes

After succeeding in this subject the students will be able to:

RA1. To understand the relationship between the discrete-time and continuous-time domains by means of the signal sampling.

RA2. To understand the basic blocs of multirate systems and their combination with filters to design filter banks. To know the 2-channel filter bank architecture to implement the wavelet transform. To apply the previous structures to multimedia processing.

RA3. To identify the characteristics, properties, and applications of inverse, all-pass, minimum phase, and linear phase systems.

RA4. To design and apply digital filters to multimedia signals.

RA5. To understand and apply the DFT as a tool to characterize signals in the frequency domain.

RA6. To understand how to apply the DCT to audio and image compression.

RA7. To understand and apply spectral estimation methods to stocastic signals. To know the parametric models for spectral estimation and its application to speech compression.

RA8. To justify the different steps followed in application of concepts and problems resolution related to digital signal processing and its application to multimedia signals.

3. CONTENTS

Contents Blocks	Total number of hours
Presentation	1 hour of classroom session
Unit 1. Sampling and signal reconstruction 1.1 Transform domains 1.2 C/D converter 1.3. D/C converter 1.4. Discrete-time processing of continuous-time signals 1.5 Practical considerations	6 hours of classroom sessions
Unit 2. Multirate systems 2.1 Introduction 2.2 Upsampling and downsapling 2.3 Sampling frequency conversion 2.4 Introduction to filter banks 2.5 Implementation of the discrete wavelet transform 2.6 Applications to audio and image signal processing.	7 hours of classroom sessions
Unit 3. Types of systems 3.1 Inverse systems 3.2 All-pass systems 3.3 Minimum-phase systems 3.4 Linear-phase systems	4 hours of classroom sessions
Unit 4. Analysis and design of digital filters 4.1 Introduction 4.2 Filter specification 4.3 Relation with analog systems 4.4 FIR filter design 4.5 IIR filter design 4.6 Application to audio and image signal processing	10 hours of classroom sessions

Unit 5. The discrete Fourier transform 5.1 The discrete Fourier transform (DFT) 5.2 Properties of the DFT 5.3 The discrete cosine transform (DCT) 5.4 Bidimensional transforms 5.5 Applications to audio ans image signal processing	10 hours of classroom sessions
Unit 6: Spectral analysis 6.1 Application of the DFT to signal processing 6.2 Power spectral density 6.3 Non parametric estimation 6.4 Stocastic models 6.5 Application to audio coding.	6 hours of classroom sessions

Contents Blocks of Laboratory	Total number of hours
Practice 1. Discrete-time signals and systems	2 hours of classroom session
Practice 2. The discrete Fourier transform	2 hours of classroom session
Practice 3. Filter design (I)	2 hours of classroom session
Practice 4. Filter design (II)	2 hours of classroom session
Practice 5. Multirate digital signal processing	2 hours of classroom session
Practice 6. Spectral estimation of signals	2 hours of classroom session

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	58 hours (56 hours on-site +2 exams hours)
Number of hours of student work:	92
Total hours	150

4.2. Methodological strategies, teaching materials and resources

The methodology differs depending on the scenario: theoretical sessions in large group, problem resolution in small groups, and laboratory sessions, also in small groups.

Large group sessions in the classroom:

The main concepts of the subject are presented in the theoretical session in large groups. The objective is to introduce the basic ideas in a guided and reflexive way. To promote reflexion and make the master class more dynamic, short examples of applications will be proposed to be solved by the students. These examples along with the discussion generates the appropriate conditions for critical learning. Thus, the learning process begins under these bases to significantly increase with laboratory and class problems.

Problem sessions in small groups

The purpose of these sessions is to create a suitable atmosphere for participating and apply the theoretical concepts as well as encouraging the capacity of analysis and synthesis. The student must interpret the problems, recognize the implicit or explicit concept, be able to handle the tools for resolution, and analyze the results from a critical standpoint. The teacher will solve basic problems and will propose the students to solve problems individually to test their knowledge and taking feedback to improve their comprehension. Participation will be promoted through several strategies such discussions, set of questions, quiz, etc. Special attention must be paid to the analysis and resolution of problems to leanr how to solve problem from different perspectives and also checking its consistency.

In these sessions, the teacher will observe the student activity to determine the level of learning attained and the difficulties found as a means to adapt the explanations to the degree of understanding. The continuous assessment tests will be carried out during these sessions in order to achieve a formative evaluation.

Information and Communication Technologies will be used during the course to support the formative activities: Internet, forums, wikis, email, available material in Aula Virtual, etc.

Laboratory sessions

Laboratory sessions in small groups are the third learning scenario. The students will work individually to write the algorithms where the theoretical concepts to solve problems are applied using a computer and a programming platform such as Matlab. A script with the objectives and the characteristics of the algorithms will be provided.

Before every session, the student has to prepare the work starting by the theoretical fundamentals. In the lab, the student will write the algorithms and will analyze the results from a critical standpoint to infer convenient conclusions. This work is carried out under the teacher supervision who will provide advice to the student to let him think from a creative and reflexive view.

During the session, the teacher can make a set of questions to each student to check how the problem is faced and with the aim to make an oral assessment, follow up and suggestions. Finally, the student will deliver the solution (algorithms and result analysis) through Aula Virtual. The report must summarize the conclusions arisen from the implementation.

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Regulations for the Regulation of Teaching Learning Processes, NRPEA, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Regulations for the Evaluation of Apprenticeships (approved by the Governing Council on March 24, 2011 and modified in the Board of Directors). Government of May 5, 2016) as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

Ordinary Call

Continuous Assessment:

This assessment will consist of:

- Laboratory practices carried out during the semester with the result of the corresponding interviews and reports.
- Intermediate assessment tests programmed throughout the course.
- Final exam

Final assessment:

In the case, the evaluation will consist of a single final exam.

Extraordinary Call

The procedure will be the same as that described for the final assessment of the ordinary call. For the laboratory part of the subject, students under the continuous assessment will be allowed to choose between been assessed during the final exam by filling out the corresponding part, or to preserve the mark obtained during the continuous assessment.

5.2. EVALUATION

EVALUATION CRITERIA

The assessment criteria measure the level in which the competences have been acquired by the student. For that purpose, the following are defined:

CE1. The student understands the existing relation between the discrete and continuous-time domains by means of the signal sampling.

CE2. The student understands the basic blocs of multirate systems and their combination with filters to design filter banks. The student knows the 2-channels filter bank architecture to implement the wavelet transform. He is able to apply the previous structures to multimedia processing.

CE3. The student shows knowledge on the different systems and their properties: inverse, all-pass, minimum phase, and linear phase systems.

CE4: The student shows capacity to design and apply digital filters to multimedia signals.

CE5: The student understands and applies the DFT as a tool to characterize signals in the frequency domain.

CE6: The student understands how to apply the DCT to audio and image compression.

CE7: The student understands and applies spectral estimation methods to stocastic signals. The student knows the parametric models for spectral estimation and its application to speech compression.

CE8: The student is able to justify the different steps followed in application of concepts and problems resolution related to digital signal processing and its application to multimedia signals.

GRADING TOOLS

This section summarizes the grading tools that will be followed for the assessment

1. **Intermediate assessment test (PEI)**: It consists of a problem solving exam. The contents of tests, as well as the dates, will be informed during the first several weeks of the course.
2. **Laboratory practices (LAB)** carried out on-site with computer tools. The following material will be

taken into account: personal interviews to students, delivered report with algorithms, results, and conclusions.

3. **Laboratory Test (PL)**: It will be carried out by those students choosing the final assessment or during the final call test. An individual written exam regarding the resolution of laboratory problems similar to those achieved throughout the course will be performed in this test. In the extraordinary call, the student will be allowed to preserve the mark obtained in LAB.
4. **Final exam test (PEF)**: Individual written test with theoretical and/or practical problems related to every units of the subject.

GRADING CRITERIA

Ordinary call. Continuous assessment

In the ordinary call-continuous assessment the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CST1,CST2,CST6,TR2, TR3	RA1-RA8	CE1-CE7	PEI1	35%
			LAB	25%
		CE1-CE8	PEI2	40%

Laboratory practices are mandatory to overcome the course during continuous assessment, because is the practical part according to article 6.4 of N.P.R.

During continuous assessment, the mark "Non-Presented" will be assigned to students who had not carried out any PEI, or had failed to attend 60% or more of the theoretical sessions, problems or laboratory practices.

A student either surpassing the attendance rate or having delivered the works mentioned in the previous paragraph, independently of his/her attendance to the final exam, he/she will not be eligible for a qualification of "Non-Presented".

Ordinary call. Final assessment

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CST1,CST2,CST6,TR2, TR3	RA1-RA8	CE1-CE8	PEF	75%
			PL	25%

Extraordinary call

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CST1,CST2,CST6,TR2, TR3	RA1-RA8	CE1-CE8	PEF	75%
			PL	25%

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- M. Blanco Velasco, F. Cruz Roldán, R. Jiménez Martínez, J. Sáez Landete, Tratamiento digital de señales. Problemas y ejercicios resueltos, Universidad de Alcalá, 2017.
- M. Blanco Velasco, F. Cruz Roldán, R. Jiménez Martínez, J. Sáez Landete, Tratamiento digital de señales, Universidad de Alcalá, 2013.
- M. Blanco Velasco, F. Cruz Roldán, R. Jiménez Martínez, J. Sáez Landete, Prácticas de laboratorio de tratamiento digital de señales, Univesidad de Alcalá, 2010.
- P. S. R Diniz, E. A. B. da Silva, S. L. Netto, Digital Signal Processing. System Analysis and Design. 2nd Edition. Cambridge, 1011.
- A. V. Oppenheim, R. W. Shafer, J. R. Buck, Discrete-time Signal Processing-3rd Ed., Prentice Hall Signal Processing Series, 2010.
- J. G. Proakis and D. G. Manolakis, Digital Signal Processing. Principles, Algoritms and Applications, Prentice-Hall, 2007
- P. P. Vaidyanathan, Multirate Systems and Filter Banks. Englewood Cliffs, N.J.: Prentice Hall, 1993.

6.2. Additional Bibliography

- M. H. Hayes, Statistical Digital Signal Processing and Modeling, John Wiley & Sons, 1996.
- S. K. Mitra, Digital Signal Processing. A Computer Based Approach-3rd Edition, Mc-Graw-Hill, 2006.
- H. S. Malvar, Signal Processing with Lapped Transforms, Artech House, Norwood, MA, 1992.
- K. R. Rao and P. Yip, Discrete Cosine Transforms, Academic Press, New York, 1990.

Disclosure Note

The University of Alcalá guarantees to its students that, if due to health requirements the competent authorities do not allow the total or partial attendance of the teaching activities, the teaching plans will achieve their objectives through a teaching-learning and evaluation methodology in online format, which will return to the face-to-face mode as soon as these impediments cease.