

Program	59EC – Communications Electronic Engineering B. Eng.
	59SC – Telecommunications Systems Engineering B. Eng.
	59SO – Sound and Image Engineering B.Eng.
	59TL – Telematics Engineering B. Eng.

Course code and name				
Code	595000025, 595000324, 595000124, 595000224			
Name	Digital Signal Processing			
Semester	S3 [(September-January)] & S4 [(February-June)]			

Credits and contact hours					
ECTS Credits	4,5				
Contact hours	45				

Coordinator's name	Díaz Martín, César [cesar.diazm@upm.es]
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	S	pecific	course	infor	mation
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Tuition language Spanish

Description of course content

Some of the main deterministic digital signal processing techniques are introduced so this course could be a continuation of "Signals and Systems" and a detailing in discrete time signals and systems. There are three parts:

- 1) Sampling and digital processing of continuous signals. This topic shows the block diagram used to sample a continuous signal for processing on a digital microprocessor, it is reviewed the sampling theorem, discussed how to design a discrete system to be equivalent to a continuous system (and vice versa); the quantization noise that appears in real continuous-discrete converters is analyzed; finally there is an introduction to multirate processing (that is, changing the sample rate within the digital domain).
- 2) Discrete Fourier Transform (DFT). This topic presents one of the main tools currently used in signal processing systems: the discrete Fourier transform (DFT). The DFT allows calculating the Fourier transform of a discrete sequence in a microprocessor easily and quickly (through its fast version, the FFT). The DFT is defined, its relationship with the Fourier transform and series expansion is discussed, and two of the main applications of the DFT are presented: spectral analysis and filtering.
- 3) Design of frequency-selective filters. This topic provides design mechanisms for one of the most common types of filters in practice: frequency-selective filters. Focusing on the low-pass filters, some methods are provided for designing finite impulse response (FIR) filters and infinite impulse response (IIR) filters. Finally, some of the main structures used for the building of filters in practice (both in



hardware and software).

In addition to these three topics, the course has a laboratory (5 simulation sessions carried out with Matlab) which reviews the main concepts of each topic.

List of topics to be covered

- 1. Digital processing of continuous signals
 - 1.1. Introduction
 - 1.2. Continuous signal sampling
 - 1.3. Discrete-time processing of continuous signals
 - 1.4. Continuous-time processing of discrete signals
 - 1.5. Changing the sampling rate
- 2. The discrete Fourier transform (DFT)
 - 2.1. Introduction
 - 2.2. DFT: Definition, calculation, relationships and properties
 - 2.3. Introduction to spectral analysis using DFT
 - 2.4. Filtering signals using the DFT
- 3. Filter design
 - 3.1. Introduction
 - 3.2. FIR filter design
 - 3.3. IIR filter design
 - 3.4. Comparison between design methods and filter types
 - 3.5. Structures for the implementation of digital filters

Prerequisites or co-requisites

- Calculus I
- Lineal Algebra
- Calculus II
- Signals and Systems

Course category in the program

R (required)

□ E (elective)

(elective courses may not be offered every year)

Specific goals for the course Specific outcomes of instruction RA126 – To apply the DFT to the linear convolution with a long sequence. RA102 – To perform the convolution of signals. RA105 – To make an analysis on frequency of discrete time signals. RA115 – To link continuous time systems and systems of discrete time in the time domain. RA101 – To perform basic operations with signals and functions. RA108 - Ability to characterize LTI systems of discrete time in the time domain (response to the impulse and linear difference equation with constant coefficient) and processed domains (frequency and function of system response). RA114 – To link time continuous signals and time discrete time-domain signals. RA129 – To describe the characteristics of the spectral estimation of sequences

- with the spectrum of the continuous-time signal where they come.
- RA136 To describe the basic methods for the design of FIR filters.
- RA143 To characterize and describe mathematically IIR filters.
- RA145 To design IIR filters using the bilinear transformation method.



- RA155 To apply the rational change of the sample rate to the solution of problems.
- RA156 To handle mathematical tools of analysis and design for discrete time systems.
- RA150 To represent the flowchart of digital filters in their basic forms.
- RA107 To calculate the signal spectrum ideally sampled.
- RA153 To determine the parameters of an interpolator.
- RA106 To characterize mathematically the operation of sampling of continuous-time signals.
- RA100 Analysis and characterization of discrete time signals.
- RA112 Ability to describe the block diagram of a digital signal processing system in real time enumerating the significant parameters of each block.
- RA128 To describe the properties of DFT in the spectral analysis of sequences.
- RA134 To differentiate the types of digital filters according to the characteristics of their impulse response: FIR and IIR filters.
- RA119 To define the discrete Fourier transform (DFT).
- RA124 To connect the linear and the circular convolutions.
- RA141 To design the FIR filters through the windowing method.
- RA113 To connect the time continuous signals and time discrete signals in the time domain.
- RA125 To link the linear convolution with the DFT.
- RA135 To describe the basic methods to design FIR filters.
- RA137 To describe linear-phase FIR filters.
- RA138 To differentiate the types of linear-phase FIR filters.
- RA139 To describe the characteristics of the different linear-phase FIR filters.
- RA142 To describe the principles of frequency sampling-based FIR filter design and to link it with DFT.
- RA144 To design IIR filters through the impulse-invariant transformation.
- RA154 To determine the parameters of a decimator.
- RA116 To connect the continuous time systems and the discrete time systems in the frequency domain.
- RA120 To connect the DFT with some other transforms: Fourier transform, Fourier series.
- RA121 To determine the circular convolution of the sequences.
- RA127 To apply DFT in the spectral analysis of sequences.
- RA132 To define what is a digital filter.
- RA122 To connect the circular convolution with DFT.
- RA133 To describe the utilities of a digital filter.
- RA146 To describe the differences, advantages and disadvantages, and selection criteria for the design method of a digital filter.
- RA152 To set out the solution for the problems of change of the sampling rate.
- RA103 To determine the connection between the different ways of characterizing LTI systems.
- RA98 To characterize and analyze the discrete time LTI systems and signals in the frequency and transform domains.
- RA111 To characterize the different types of systems according to their frequency discrimination.
- RA123 To describe, develop and apply the linear convolution methods for the



long sequences.

• RA96 - To characterize and analyze mathematically the discrete and continuous time LTI systems and signals in the time domain.

Further reading and supplementary materials

- James F. Kurose, Keith W. Ross. Computer Networking: A Top-Down Approach Pearson Addison Wesley, 2012.
- Douglas E. Comer Internetworking with TCP/IP Volume One. Prentice Hall, 2013.
- Andrew S. Tanenbaum, David J. Wetherall Computer Networks. Pearson Education International, 2010.
- William Stallings Data and Computer Communications. Prentice-Hall International, 2007.
- The Internet Engineering Task Force (IETF) Request For Comments (RFC): <u>https://www.ietf.org/rfc.html</u>
- Moodle.