MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
Petro Mohyla Black Sea National University
Faculty of Computer Science
Computer Engineering Department

APPROVE
Vice-rector
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SYLLABUS OF THE DISCIPLINE
SIGNAL PROCESSING

Speciality 123 Computer Engineering
Higher Education Levels and Scientific Degrees – third (Doctor of Philosophy)

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1. DESCRIPTION OF THE DISCIPLINE

INDEX	CHARACTERISTIC OF THE DISCIPLINE
Discipline	Signal Processing
Branch	12 Information Technologies
Specialty	123 Computer Engineering
Educational program	Computer Engineering
Higher educational level	PhD
Status of the Discipline	Normative
Year of study	3
Year	2021-2022
Semester	6
The scope of the discipline	4 credits / 120 hours
Structure:	
– lectures	20
– seminars	20
– student's work	80
Language	English
Final control form	Final Test

2. PURPOSE AND TASKS OF THE DISCIPLINE

PURPOSE:

the formation of theoretical knowledge on the transformation and digital processing of signals and information on specific examples using the tools of the computer mathematics system (CMA) Maple to solve design problems in the field of computer engineering; formation of practical skills for the implementation of digital signal and information processing systems.

TASKS:

- familiarization with the main directions of research and development in the theory of digital processing of signals and information, as well as with software and hardware implementation of analysis and digital filtering of signals and information;
- formation of knowledge about concepts, models, methods, general principles, basic algorithms of analysis and means of digital processing of signals, images and information;
- formation of knowledge about methods of diagnosing systems based on experimental data and about the basics of spectral-correlation analysis of signals and information, as well as about methods of digital filtering;
- familiarization with the capabilities and means of SCM Maple for solving problems of modeling, analysis and processing of signals and information;

– acquiring practical skills in the use of COS algorithms and solving problems of digital filter design, process modeling, development, optimization and improvement of COS methods and tools in the field of computer engineering.

PREREQUISITES:

“Sensors And Transducers”, “System Programming”, “Probability theory and mathematical statistics”, “Computer architecture”

EXPECTED LEARNING OUTCOMES:

In accordance with the educational program "Computer Engineering", after studying the discipline, a student must acquire the following general and special competencies:

ZK03 Ability to work in an international context.

SK04 The ability to effectively apply methods of analysis, mathematical modeling, perform natural and mathematical experiments when conducting scientific research.

SK06 The ability to argue the choice of methods for solving specialized problems, critically evaluate the obtained results, justify and defend the decisions made.

According to the educational program "Computer Engineering", the normative content of the training of applicants in terms of learning outcomes should be as follows:

N1 Know and understand the scientific principles underlying the functioning of computer tools, systems and networks.

N2 Have skills in conducting experiments, collecting data and modeling in computer systems.

N6 To be able to apply knowledge to identify, formulate and solve technical problems of the specialty, using methods that are most suitable for achieving the set goals.

N16 Be able to evaluate the obtained results and justify the decisions made.

AS A RESULT OF STUDYING THE DISCIPLINE, THE STUDENT:

MUST KNOW:

– definition and classification of signals, features of data arrays with information;
– spectral representation and transformation of signals and information;
– basics of discretization and quantization of signals;
– methods of presentation and processing of analog and discrete signals, arrays of periodic, quasi-periodic and random data;
– basic algorithms of digital filtering, as well as structures of digital filters;
– basic methods and algorithms for designing digital filters;
– purpose and functions of libraries and extension packages of SCM Maple, intended for working with signals and information: Statistics, AudioTools, ImageTools, ExcelTools, SignalProcessing, DiscreteTransforms, Optimization;
– problems and actual tasks of digital processing of signals, information and prospects for further development, representation of real-time series and high-frequency data by triangular and trapezoidal fuzzy numbers, main mathematic operators and arithmetic operations in fuzzy data processing;

MUST BE ABLE TO:

– work with ADC and digitize analog signals;

– logically and consistently justify the choice of methods, means and methods of analysis and digital processing of signals and/or information in the time and frequency domain;

– operate with the capabilities of Maple SCM application packages and libraries for solving problems of analysis and digital processing of signals and information in the field of computer engineering;

– process signals and arrays of data obtained from experimental measurements;

– independent work on conclusions from the results of the TSO and generalization with further argumentation of proposals regarding prospects;

– analyze the effectiveness of various methods of processing signals and information in the form of data arrays for solving practical tasks.

– application of methods for investigations of the impact of aggregation and defuzzification algorithms to quality indices of fuzzy systems;

3. PROGRAM OF THE DISCIPLINE

#	Topic	Lectures	Seminars	Student's work
1.	Analysis and processing of one-dimensional signals	7	20	56
2.	Analysis and processing of two-dimensional signals (images)	3	10	24
	Total	**10**	**30**	**80**

4. CONTENT OF THE DISCIPLINE

4.1. LECTURES

# of the lecture	Topic/structure	Hours.
1	**Lecture 1.** Functional principle of classification of methods of medical and biological measurements. Methods of medical research. Digital signal processing. Digital processing of medical signals. Counting theorem.	1
2	**Lecture 2.** Statistical methods of analysis. Autocorrelation and cross-correlation analysis of signals. Spectral methods of signal analysis. Fourier transformations and their varieties. Parseval's theorem.	1

# of the lecture	Topic/structure	Hours.
3	**Lecture 3.** Laplace transform and transfer functions of devices. Amplitude-frequency characteristics and Nyquist diagrams.	1
4	**Lecture 4.** Signal filtering methods. Analog and digital frequency filters. Design principles of digital filters.	1
5	**Lecture 5.** Wavelets Methods of wavelet analysis, cleaning and compression of one-dimensional signals.	1
6	**Lecture 6.** ADC conversion, analysis, processing and DAC conversion of audio signals.	1
7	**Lecture 7.** Visualization of signals. Color mapping of brain bioelectric activity.	1
8	**Lecture 8.** Software packages for working with two-dimensional images. Image processing, construction of histograms.	1
9	**Lecture 9.** Two-dimensional wavelets: principles and methods of wavelet image analysis.	1
10	**Lecture 10.** Analytical processing and compression of medical images.	1
	Total	**10**

4.2. SEMINARS

# of the lesson	Topic / plan	Hours
1	**Task 1. Discretization and signal spectra.** Discretization of analog signals and Nyquist frequency. Fourier spectra of discretized and analog signals.	2
2	**Task 2. Digital voice processing.** Voice message recording, digital conversion and analysis. Voice message processing, filtering and playback.	4
3	**Task 3. Statistical analysis of signals.** Statistical analysis of electroneuromyograms (EHMG). Autocorrelation functions and spectral analysis.	2
4	**Task 4. Analysis of temporal changes in solar activity.** Fourier analysis of time sequences on the example of solar activity. Schwabe's eleven-year cycle.	4
5	**Task 5. Analog frequency filters and their modeling.** Analog frequency filters of the first order. Filters of the second and higher orders. Filters of special types.	2

# of the lesson	Topic / plan	Hours
6	**Task 6. Design and creation of a digital FIR filter.** Calculations and design of a digital filter with finite impulse response (FIR). Testing the FIR digital filter.	4
7	**Task 7. Wavelet analysis of one-dimensional signals.** Haar wavelets and their applications. Wavelet analysis of arterial blood pressure and pulse wave frequency. Cross-correlations of primary and purified signals.	2
8	**Task 8. Image processing.** Software for working with image files. Brightness histograms and convolutional masks.	4
9	**Task 9. Methods of wavelet analysis of images, part one.** Principles and methods of wavelet image analysis.	2
10	**Task 10. Methods of wavelet analysis of images, part two.** Wavelet analysis, cleaning and compression of your own photo.	4
	Total	**30**

4.3. TECHNICAL SUPPORT

Practices on the discipline are carried out in computer classes using Maplesoft Maple 2018

5. FINAL TEST

5.1. FINAL TEST QUESTIONS

1. Definition of concepts: signal, impulse, information.
2. Classification of signals.
3. Basic characteristics of signals.
4. Definition of concepts: harmonics, spectrum of amplitudes, spectrum of phases.
5. How is a decibel defined?
6. Static and dynamic forms of existence of information.
7. Information measures according to Hartley and Shannon.
8. Units of measurement of information.
9. Definition of the concept of "entropy" in Digital Signal Processing.
10. Transmission channel capacity.
11. What is statistical coding? Its advantages and disadvantages.
12. What determines the bandwidth of a noisy channel?
13. What determines the speed of information transmission for a channel with noise?
14. What is the maximum data transfer speed?
15. What is signal volume and how is it related to channel capacity?
16. What is the difference between continuous and discrete messages?
17. Types of messages and signals.
18. Transient processes in electric circuits.

19. Analog implementation of digital elements.
20. Parseval's theorem. Discrete and integral representations of signals.
21. Analog-digital and digital-analog conversion.
22. What signals are called discrete?
23. How to mathematically describe the discretization process: a) in the case of one-dimensional signals; b) in the case of two-dimensional signals?
24. How does the spectrum of a discrete signal change compared to the spectrum of an analog signal?
25. What conditions must be met in order for a discrete signal to be equivalent to the original analog signal?
26. Under what conditions do overlay distortions occur?
27. How to mathematically describe the process of restoring a continuous signal from its discrete readings?
28. Difference between interpolation and approximation processes.
29. What is the process of scalar quantization?
30. What is vector quantization?
31. What is the difference between uniform and uneven quantization?
32. What quantization is called optimal?
33. Under what conditions does uneven quantization have advantages over uniform quantization?
34. What is the difference between quantization and discretization?
35. Shannon-Nyquist-Kotelnikov theorem. Nyquist frequency.
36. What should be the sampling rate when converting a continuous message to a discrete one?
37. What is the difference between ideal and real systems? In what ways can real systems be improved?
38. Spectrum of a discrete signal.
39. Discrete noise.
40. What is called the basis of space?
41. Discrete Fourier transform (DFT).
42. According to what basis is expansion in the Fourier series performed?
43. Define the amplitude-frequency spectrum.
44. Define the phase-frequency spectrum.
45. Formulate the main properties of the DPF.
46. Formulate the main theorems of DPF.
47. Gibbs effect.
48. Welch's method.
49. Restoration of a continuous signal using DFT.
50. Signal amplification. Operational amplifiers and their main parameters.
51. Correlation and cross-correlation functions.
52. What is modulation and how are its methods classified?
53. Amplitude modulation.
54. What is the spectrum of amplitude modulation? What are its advantages and disadvantages?
55. Phase and frequency modulation.
56. What are frequency deviation and frequency modulation index?
57. What do frequency and phase modulation have in common?
58. What modulation methods are most often used in analog transmission systems and why?

59. Demodulation.
60. What filters are called digital?

5.2. Example of the Final test task

Final test paper #0

1. Correlation and cross-correlation functions.
2. What is the difference between ideal and real systems? In what ways can real systems be improved?
3. Under what conditions do overlay distortions occur?

6. Criteria for evaluating tasks

#	Task	Points
1.	Task 1	7
2.	Task 2	7
3.	Task 3	7
4.	Task 4	7
5.	Task 5	7
6.	Task 6	7
7.	Task 7	7
8.	Task 8	7
9.	Task 9	7
10.	Task 10	7
11.	Final test	30
	Total	**100**

6.1. Criteria for evaluating tasks to achieve the maximum number of points

Laboratory work

It is executed and completed by each student individually according to options. It is submitted in the form of two files: a report prepared in Maplesoft Maple and converted to pdf format. Both files are uploaded to Moodle by each student. In case of untimely performance, the total score for the work is reduced by 1 (unit). Each laboratory work contains individual tasks. The performance of each laboratory work is evaluated according to the criteria in the table below:

– development of the code and theoretical parts - a maximum of 2 points;

– performance of an individual task according to the option - a maximum of 2 points;

– defense of a prepared report on laboratory work in the form of answers to control questions and teacher's questions - a maximum of 2 points.

Maximum number of points – a PhD student with high quality independently performed the entire scope of work, answers all questions related to the work performed, and makes additional calculations, for example, using the methods of fuzzy data processing offered to him by the teacher. The teacher has no complaints about the software implementation and performance requirements.

70%-99% of the maximum number of points – a PhD student with sufficient quality independently completed all tasks, but in the process, he made some mistakes, which, after pointing to them by the teacher, corrected themselves. He answers some questions with a slight error. The additional calculations offered by the teacher make with some complexity. Not all work requirements are met.

40%-69% of the maximum number of points – a PhD student of average quality independently completed all tasks, but did not meet all the requirements for implementation. He answers the question with a slight error. The additional calculations offered by the teacher, for example, using fuzzy methods of decision making makes with insignificant errors. Not all requirements for the design of the work are met.

1% -39% of the maximum number of points – a PhD student performed all the work independently, but the quality of implementation is insufficient (errors in calculations, not all work requirements are met). The answers to the questions about the work are not entirely clear. There are errors in the answers.

0 points – a PhD student did not perform the entire amount of work, or performed with gross errors. He has problems with calculations by certain methods, does not know the theoretical material, the software implementation does not meet the requirements.

Final Test

Only those students who have accumulated at least 30 points for completing tasks during the semester are admitted to the Final Test. Otherwise, the student is considered absent from the course. The Final Test consist of 3 questions, the maximum points of each question is 10.

Points	Criteria
30	Completeness of the task; sequence of tasks; correct answers to basic and additional questions.
25–29	Independence and completeness of answers, occasional mistakes in solving problems
21–24	When answering additional questions from the lecturer, the student made mistakes
16–20	Lack of the answers on additional questions from the lecturer
11–15	The student made significant mistakes in answering the main questions, but solved additional problems of lower difficult
6–10	The student made significant mistakes in answering the main and additional questions
1–5	During the Final Test the student used the textbook, interfered with other students
0	Failure to perform the tasks, refusal to answer the questions.

7. REFERENCES

7.1. BASICS

1. Рибальченко М.О., Єгоров О.П., Зворикін В.Б. Цифрова обробка сигналів. Навчальний посібник. Дніпро: НМетАУ, 2018. 79 с.
2. Digital Signal Processing. Learn the fundamentals of digital signal processing theory and discover the myriad ways DSP makes everyday life more productive and fun : [сайт]. Режим доступу https://www.coursera.org/course/dsp.
3. Guo Y., Tsinghua University Tsinghua University Press, Qiu T. Signal Processing and Data Analysis. de Gruyter GmbH, Walter, 2018.

7.2. ADDITIONAL

4. Teaching Concepts with Maple. Examples & Applications. Support & Resources. Maple. url: https://www.maplesoft.com/teachingconcepts/.
5. Online Help. Online Product Help. Support & Resources. Maple. url: https://www.maplesoft.com/support/help/index.aspx.
6. Maplesoft Documentation Center. Maple. url: https://www.maplesoft.com/documentation_center/.
7. Veloni A., Miridakis N., Boukouvala E. Digital and Statistical Signal Processing. Taylor & Francis Group, 2018. 558 p.